EMBER

US Electricity 2025 Special Report

The US clean electricity transition continued as wind and solar generated more than coal for the first time. Electricity demand growth sped up and solar generation rose more quickly than gas to help meet it.

12 March 2025

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About

This report analyses full-year US Energy Information Administration's (EIA) electricity data which was published on 26th February to give an up-to-date view of the US electricity system and key developments in 2024.

Ember's US Data Explorer has the monthly state generation data freely accessible to empower others to do their own analysis.

Highlights

17%

Wind and solar combined produced a record 17% of US electricity in 2024, overtaking coal at 15% for the first time.

3%

The year-on-year increase in electricity demand – the fifth largest year-on-year increase this century.

64 TWh

The year-on-year increase in solar generation, larger than than the 59 TWh rise in gas generation.

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Clean electricity transition continued as demand rose

In 2024, wind and solar together generated more electricity than coal for the first time in the US, while solar rose more than gas to meet increased demand growth.

The United States' shift towards clean electricity continued in 2024, as wind and solar together rose to 17% of total electricity generation, surpassing coal, which dropped to an all-time low of 15%.

After nearly 14 years of stagnation, electricity demand is now firmly rising. It increased by 3%, marking the fifth-highest rise this century, partly as a rebound to a milder summer in 2023, when electricity demand fell by 1.3%. Rising demand drove an increase in gas generation, which grew three times more than the decline in coal, increasing power sector CO2 emissions.

However, solar generation met more of the rise in electricity demand and fall in coal than gas did. Solar (+64 TWh) added more generation than gas (+59 TWh) and together with wind (+32 TWh), contributed to the continued decline of coal (-22 TWh) and meeting high electricity demand growth (+128 TWh). It remained the fastest-growing source of electricity, with its generation rising by 27% in 2024, surpassing hydro generation for the time.

The expansion of solar and wind helped limit the increase in gas generation. Without solar and wind growth, gas would have needed to rise by 9%— more than double its actual increase (3.3%)— to meet rising demand and coal's small decline.

Although there was a slight rise in overall fossil generation and CO2 emissions (+0.7%), the rise in power demand was much faster than the rise in power sector emissions making per unit electricity the cleanest it has ever been.

Key takeaways

01 Wind and solar combined overtake coal for the first time ever

In 2024, wind and solar reached a record 17% (757 TWh) of US electricity, overtaking coal for the first time, which dropped to a historic low of 15% (653 TWh). Just six years ago, in 2018, coal was three times larger than the combined total of wind and solar. Solar generation boomed in 2024, rising by 27%, while wind rose by 7% and coal fell by 3.3%. Since the peak of US coal power in 2007, wind and solar have overtaken coal in 24 states, with Illinois the latest to join the ranks in 2024, following Arizona, Colorado, Florida and Maryland in 2023.

02 The rise of batteries unlocks record solar growth

California and Nevada both surpassed 30% annual share of solar in their electricity mix for the first time (32% and 30% respectively). California's battery growth was key to its solar success. It installed 20% more battery capacity than it did solar capacity, which helped it transfer a significant share of its daytime solar to the evening. Nationwide, solar made up 81% of all new annual capacity additions, with a record increase of 31 GW at utility scale, supported by a record 10 GW of battery – equivalent to 1 GW of battery for every 3 GW of solar. Texas installed more solar (7.4 GW) and battery capacity (3.9 GW) than even California. Yet the growth of solar was uneven – 28 states generated less than 5% of their electricity from solar in 2024, highlighting significant untapped potential – even before adding battery storage.

03 Gas and clean growth met rising electricity demand more than replacing coal

Gas generation rose by 3.3% (+59 TWh) in 2024, in line with the annual average rise of the previous ten years (+68 TWh), as its share of US electricity rose to a record 43%. However, unlike the previous decade, demand growth was the main driver of rising generation. 85% of the total growth in gas, solar and wind met rising electricity demand and 15% replaced the decline in coal generation. This resulted in the second smallest fall in coal generation since 2014. This is a significant shift from the previous ten years when 15% of gas, solar and wind growth met electricity demand growth and 85% met a fall in coal generation. States with the highest rise in gas generation were mostly those with the highest electricity demand growth. Virginia saw the biggest rise in gas generation. California saw the biggest fall in gas generation, as its clean generation grew even more than fast-rising electricity demand.

Since coal generation peaked in 2007, the US has made significant progress in its clean energy transition, leading to a 68% fall in coal and a 32% reduction in power sector emissions. However, the rise in electricity demand in 2024 slowed the decline of coal, as gas continued to grow. The small rise in fossil generation raises concerns that the historic era of falling power sector CO2 emissions is at risk of ending.

The country now faces a key challenge: ensuring its clean generation grows fast enough to meet rising demand. Unlike solar's booming growth, wind added the least capacity in ten years and there is very little other clean capacity under development.

The transformation of the US energy system hinges on two key trends: the expansion of clean electricity generation and the electrification of energy demand. In 2024, electrified vehicles made up 20% of all new car sales, with full electric vehicles comprising 9%. Heat pump sales rose to account for 57% of new space heating installations. Meanwhile, retail electricity prices increased by 3.0% in 2024, in line with economywide inflation; commercial prices rose 2.1% and industrial prices rose only 1.4%. Several major grid expansion projects were proposed in 2024 to enhance resilience as electricity demand rises and renewables grow. Together, these shifts can enhance efficiency, improve affordability and strengthen energy security.

Now, the next stage of the US electricity transition will be about meeting growing electricity demand. Clean power can fulfil this without raising bills, sacrificing security of supply or further relying on gas.

"As demand remained unchanged for years, solar, wind and gas together worked to replace coal, transforming the US electricity system. But now that electricity demand is rising fast, the battle is between solar and gas to meet this. And solar is winning - it added more generation than gas in 2024 and batteries will ensure that solar can grow cheaper and faster than gas."

Dave Jones
Chief Analyst, Ember

"Electricity demand is rising as new uses emerge across the U.S. economy, from data centers to transportation to heating. This makes the case for solar and wind today even stronger — they are not only fast to deploy and cheap but also help stabilize energy costs in the long run."

Daan Walter
Principal, Ember

Demand and supply changes in 2024

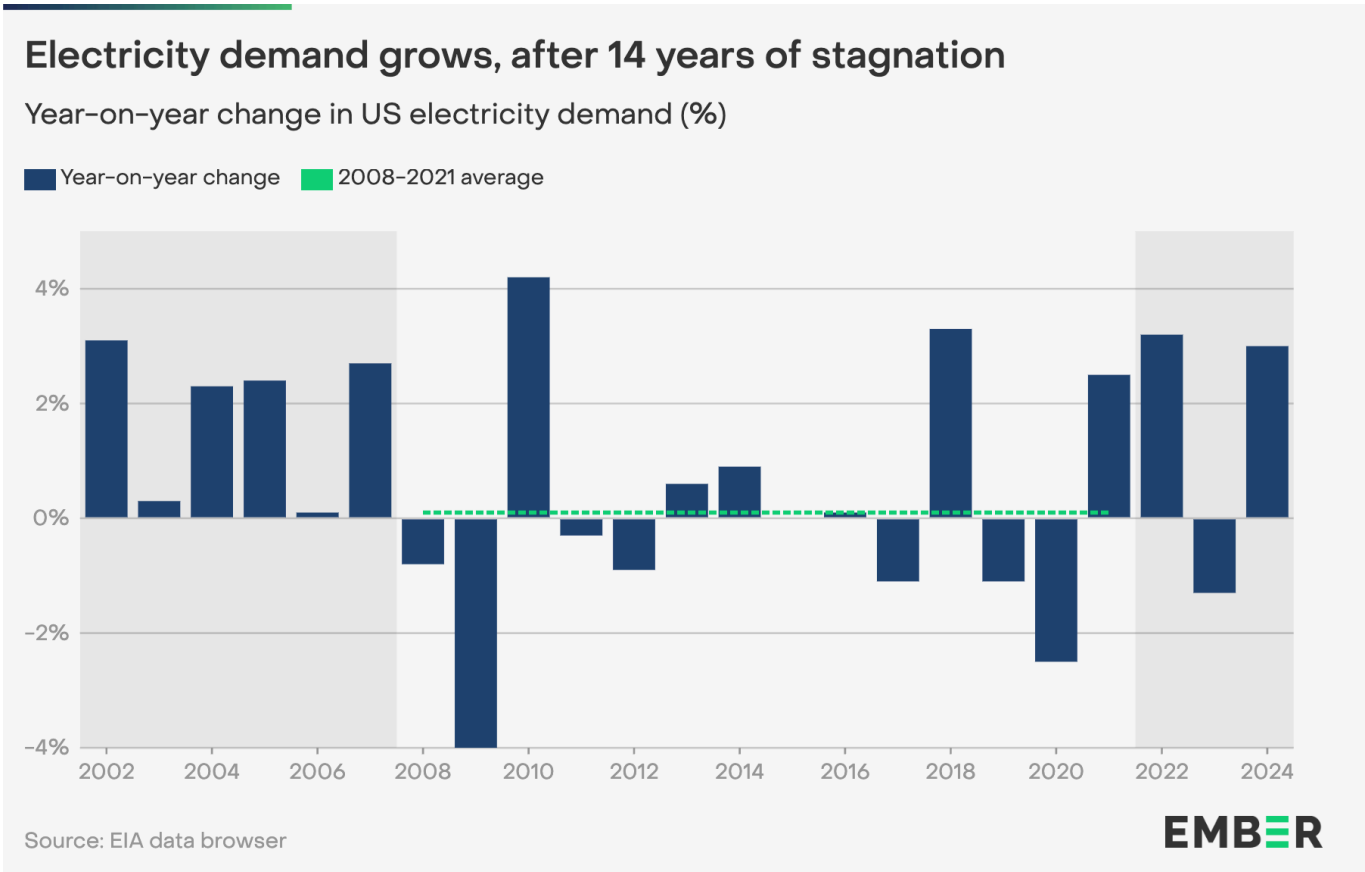
Electricity demand rose 3% in 2024 after years of stagnation. Solar, wind and gas all rose to meet the rise in demand and offset a small fall in coal generation.

Demand rising fast, but not yet surging

Electricity demand growth in the US had been near-stagnant for 14 years from 2008 to 2021 (averaging 0.1% per year). However, in 2024, it rose by 3.0% (+128 TWh), following a 1.3% fall in 2023. This marked the fifth highest level of demand growth this century.The country's GDP rose by 2.8% and the population by 1%, both not unusually high compared to the period of stagnant electricity demand, therefore the rise in demand cannot be fully attributed to these factors.

A much hotter summer in 2024 compared to a mild one in 2023, explains some of the increase. According to Ember's modelling, 25 TWh out of 128 TWh of the electricity demand rise in 2024 can be attributed to the difference in temperature compared to 2023. The analysis quantifies the extent to which higher or lower temperatures drive changes in monthly electricity use, isolating the impact of temperature variations from structural changes such as economic growth or increased electrification.

The modelling shows that a hotter summer added 35 TWh to air conditioning demand and milder winter months reduced heating demand by 10 TWh. An intense heatwave in June alone added 24 TWh (+8%) electricity demand compared to a relatively mild June the previous year. The biggest rises by state were Arizona (+20%), Utah (+22%) and Nevada (+23%) in June, most of which can be attributed to increased air conditioning. Overall, temperature-adjusted electricity demand in the country rose by an estimated 2.4% in 2024.



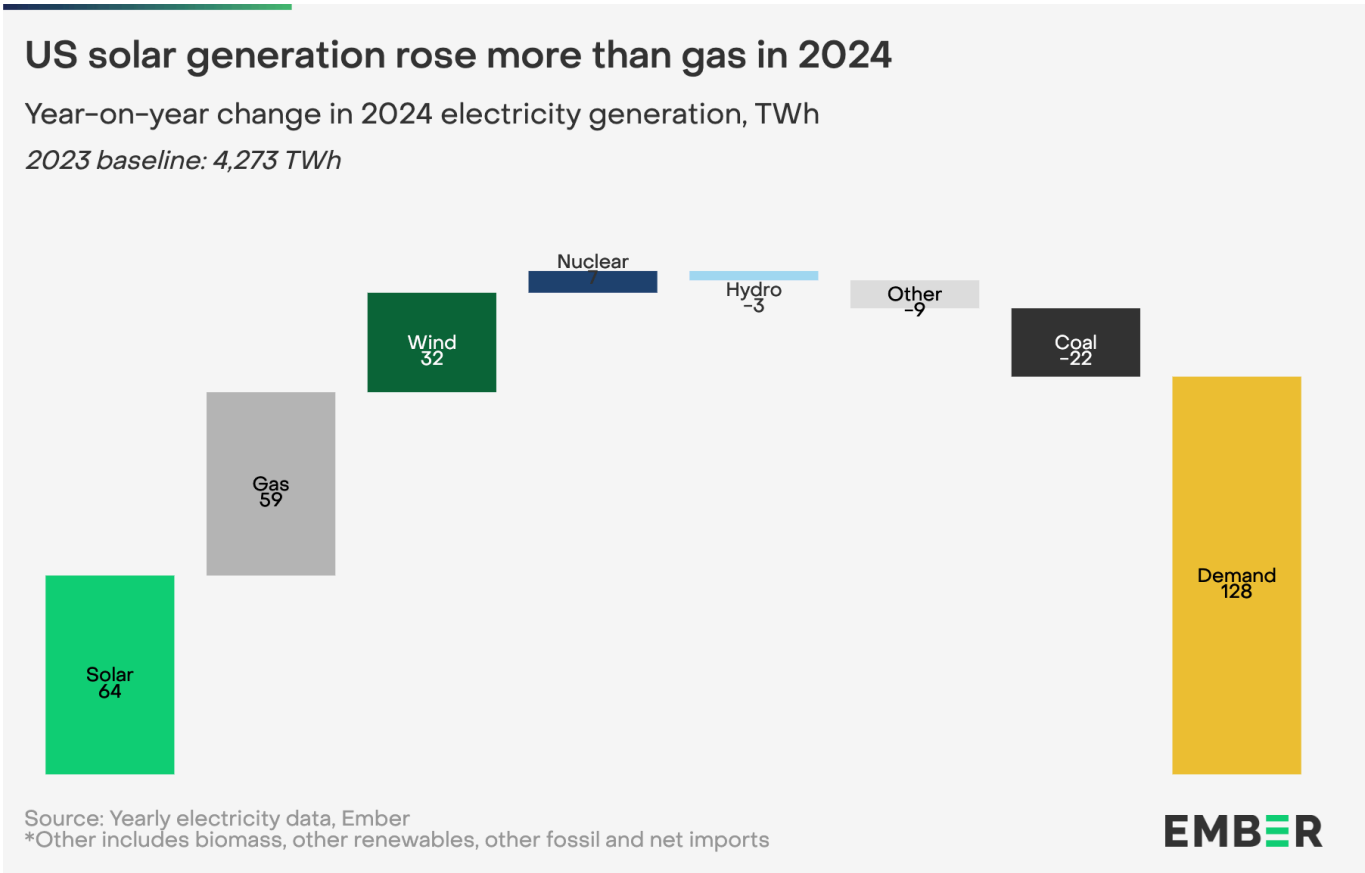
The impact of data centres is significant - but still uncertain. Electricity demand from data centres is estimated to have increased from 176 TWh in 2023 by between 8 TWh (+5%) and 55 TWh (+31%) in 2024, according to recent analysis by Lawrence Berkeley National Laboratory (LBNL). The means between 6% to 43% of the overall 2024 demand rise could be attributed to data centres. This large uncertainty range reflects how difficult it is to track data centre energy use.

Electricity demand from mining cryptocurrency is also rising. It grew by an estimated 16%, adding 7 TWh in 2024 and accounting for 5% of the total rise in demand. That's according to the latest December analysis by the LBNL. The bitcoin industry has been resisting disclosure, so estimates still contain a lot of uncertainty.

Just 3% (4 TWh out of 128 TWh) of the 2024 demand rise could be attributed to light duty electric vehicles. EIA data showed that demand from EVs grew to 11 TWh in 2024, making up just 0.25% of overall US electricity consumption.

Record solar led clean generation growth

Solar generation increased by a record 64 TWh, from 239 TWh in 2023 to 303 TWh in 2024, leading to a substantial increase in clean generation. Solar and wind together added 97 TWh to generation in 2024 compared to 2023, 64% more than gas (+59 TWh). The growth in all three sources met rising electricity demand while allowing coal to decline.



Solar

Solar generation increased by 27% (+64 TWh) in 2024, maintaining the strong growth trend seen in the past ten years. Overall, total solar generation reached 303 TWh, 7% of US total electricity generation and surpassed hydro generation (236 TWh) for the first time.

Of the 64 TWh increase in generation, the largest contribution was from Texas with 12 TWh, followed by 11 TWh from California, 5 TWh from Florida and 4 TWh from Arizona. 34 states saw increases of less than 1 TWh of solar generation.

Insight 2 provides an in-depth analysis of solar and battery growth.

Wind

Wind generation rose by a more modest 7% (+32 TWh) in 2024, however it still generated 50% more than solar, making up 10% of the US electricity mix. Of the rise in wind generation in 2024, about half was from newly installed capacity and the other half was from more favourable wind conditions which returned to average levels after very low wind speeds in 2023. Only 5.1 GW of wind capacity was installed in 2024 (5.0 GW onshore and 0.1 GW offshore), the lowest in ten years.

Of the 32 TWh increase, the largest contribution was from Texas with 5 TWh, followed by 3 TWh each from Kansas, Iowa, South Dakota and Illinois.

Nuclear, hydro and bioenergy

Nuclear generation rose 1% in 2024. The slight rise came with the commencement of operations of Vogtle unit 4 – unit 3 already began operations in 2023. The small rise didn't keep up with the overall electricity rise, so nuclear's share fell below 18% of US electricity generation, the lowest this century. In total, only 3 nuclear units have come online since 1998. Currently, there are no new commercial reactors under construction, although Palisades power plant is expected to restart in October 2025. No plants have been decommissioned since 2022.

Hydro generation fell 1% in 2024. Hydro generation fell to the lowest level since 2001 and was 10% less than the average of the last 20 years. The shortfall was mostly due to drought in the Columbia River basin, lasting into its second year, leading to low hydro levels in Washington, Oregon, Idaho and Montana.

Bioenergy generation fell (-1%) for the tenth year in a row, producing just 1% of US electricity generation.

Other sources: a small capacity geothermal plant (20 MW) began operations, while no new carbon capture plants were completed.

Fossil generation increased as gas rose almost three times more than coal fell

Fossil generation increased by 34 TWh (+1.3%) driven by a 59 TWh (+3.3%) increase in gas. This was partly offset by a smaller decline in coal, which fell by 22 TWh (-3.3%).

Coal

Coal generation fell 3.3% in 2024, marking the smallest year-on-year fall in the last ten years, except for the Covid rebound in 2021. The decline was driven by the closure of 4.5 GW of coal plants, equal to 2% of the remaining US coal fleet. It was the lowest rate of coal plant retirements since 2014. Of the 22 TWh fall, 6 TWh each came from Texas and Wyoming, 4 TWh from Florida and 3 TWh from Kansas.

Coal generation saw the largest falls in summer months, as solar replaced coal in the daytime hours. Gas was cheaper than coal in most places in most of the year, which led gas generation to replace coal.

Coal generation made up just 15% of US electricity generation in 2024.

Gas

Gas generation increased 3.3% in 2024 and remains by far the largest source of electricity in the US, accounting for 43% of the mix. The increase was driven by rising demand and cheaper running costs compared to coal.

Of the 59 TWh increase, the states with the largest rise were Virginia with 10 TWh, followed by Texas with 8 TWh and Ohio with 7 TWh. Gas generation fell in some states – California saw the biggest fall of 8 TWh.

Other fossil fuels

Other fossil generation, mainly oil, fell 9%, setting a new low. It now makes up just 0.7% of US electricity.

Imports

US net electricity imports fell by 5 TWh in 2024, to 14 TWh. This is the lowest import level since 2004. This was primarily driven by a reduction of imports from Canada due to poor hydro output, while flows from Mexico remained similar to 2023.

The US power sector in 2024

	2023 Electricity generation (TWh) **Share of generation (%)**	2024 Electricity generation (TWh) **Share of generation (%)**	Change 2023-2024 Generation (TWh) **Percentage change (%)**
Total clean	1740 TWh **40.9%**	1839 TWh **41.9%**	100 TWh **6% ▲**
- Solar	239 TWh **5.6%**	303 TWh **6.9%**	64 TWh **27% ▲**
- Wind	421 TWh **9.9%**	453 TWh **10.3%**	32 TWh **8% ▲**
- Hydro	239 TWh **5.6%**	236 TWh **5.4%**	-3 TWh **-1% ▼**
- Bioenergy	47 TWh **1.1%**	47 TWh **1.1%**	0 TWh **-1% ▼**
- Other renewables*	18 TWh **0.4%**	18 TWh **0.4%**	-1 TWh **-4% ▼**
Nuclear	775 TWh **18.2%**	782 TWh **17.8%**	7 TWh **1% ▲**
Total fossil	2514 TWh **59.1%**	2548 TWh **58.1%**	34 TWh **1% ▲**
- Coal	675 TWh **15.9%**	653 TWh **14.9%**	-22 TWh **-3% ▼**
- Gas	1806 TWh **42.5%**	1865 TWh **42.5%**	59 TWh **3% ▲**
- Other fossil**	33 TWh **0.8%**	30 TWh **0.7%**	-3 TWh **-8% ▼**
Net imports	19 TWh	14 TWh	-5 TWh
Electricity demand	4273 TWh	4401 TWh	128 TWh **3% ▲**

Source: Yearly electricity data, Ember
*'Other renewables' generation includes geothermal, tidal and wave generation. **'Other fossil' generation includes generation from oil and petroleum products, as well as manufactured gases and waste.

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Insight 1

Wind and solar overtake coal in historic US clean electricity landmark

For the first time, wind and solar produced more electricity than coal nationwide. Illinois just became the 24th state to make the crossover since the peak of US coal power in 2007.

In 2024, wind and solar hit a record 17% of US electricity, surpassing coal, which dropped to an all time low of 15%. The surge of renewables and gas has driven coal's rapid decline since its peak in 2007. Since then, wind and solar have overtaken coal in 24 states with half making the shift in just the last six years.

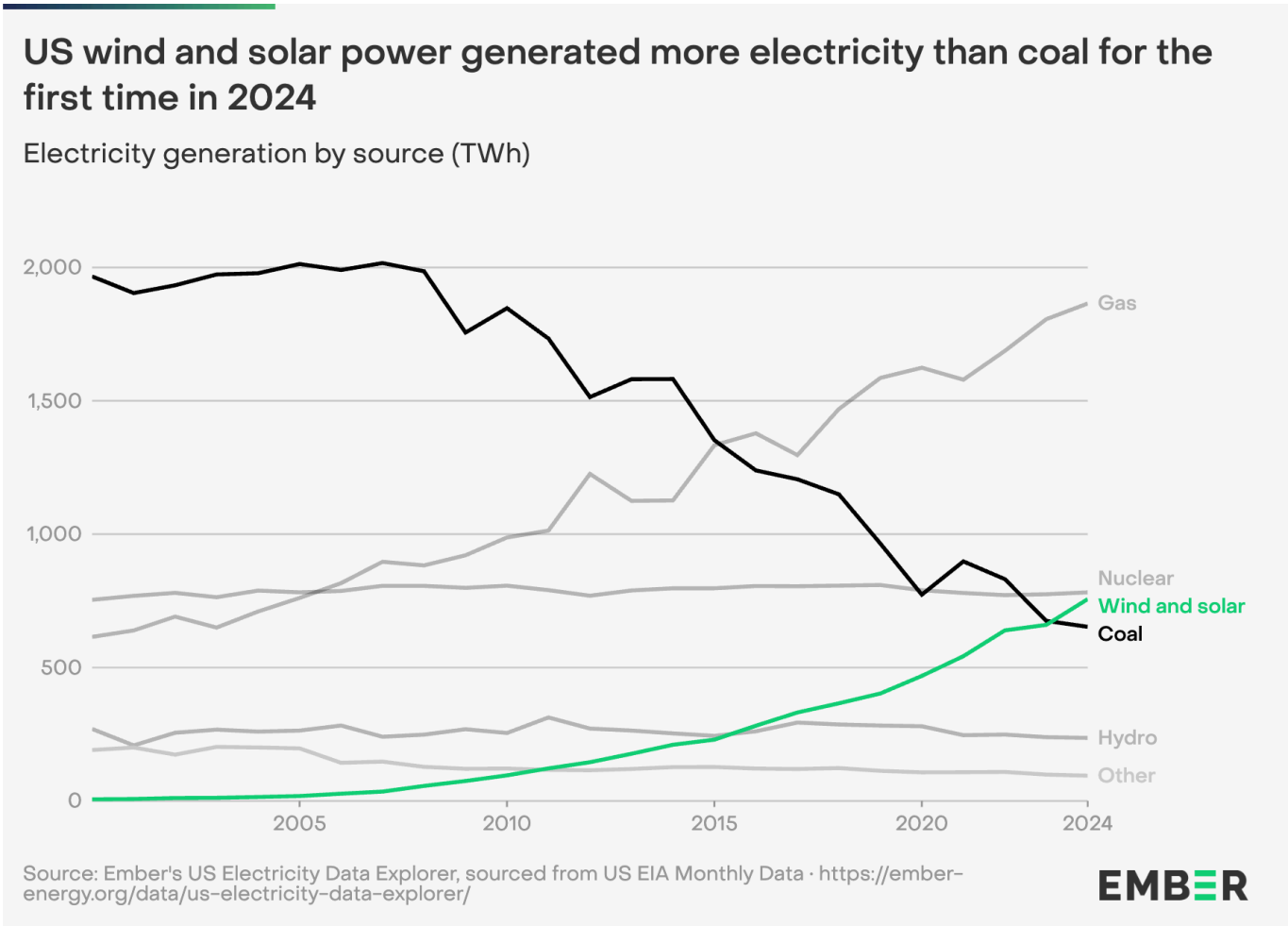
Wind and solar overtake coal nationwide

Last year marked a major milestone for US electricity generation. For the first time ever, wind and solar combined produced more electricity than coal.

In 2024, wind and solar produced a record 17% (757 TWh) of US electricity, marking a 15% (+97 TWh) increase from 2023 – enough to power 9.2 million additional homes. Meanwhile, coal generation decreased to its lowest level ever, making up just 15% of US electricity.

Coal's decline has been swift. Since its peak in 2007, coal generation has fallen by over two-thirds (-68%), displaced by gas, wind and solar. Gas generation more than doubled, increasing by 968 TWh. Wind and solar expanded twentyfold, together adding 722 TWh. In comparison, coal declined by 1,364 TWh.

The shift has been particularly fast in recent years. Just six years ago, in 2018, coal was three times larger than the combined total of wind and solar. Since then, coal has fallen by 43%, while the combined generation of wind and solar has doubled.



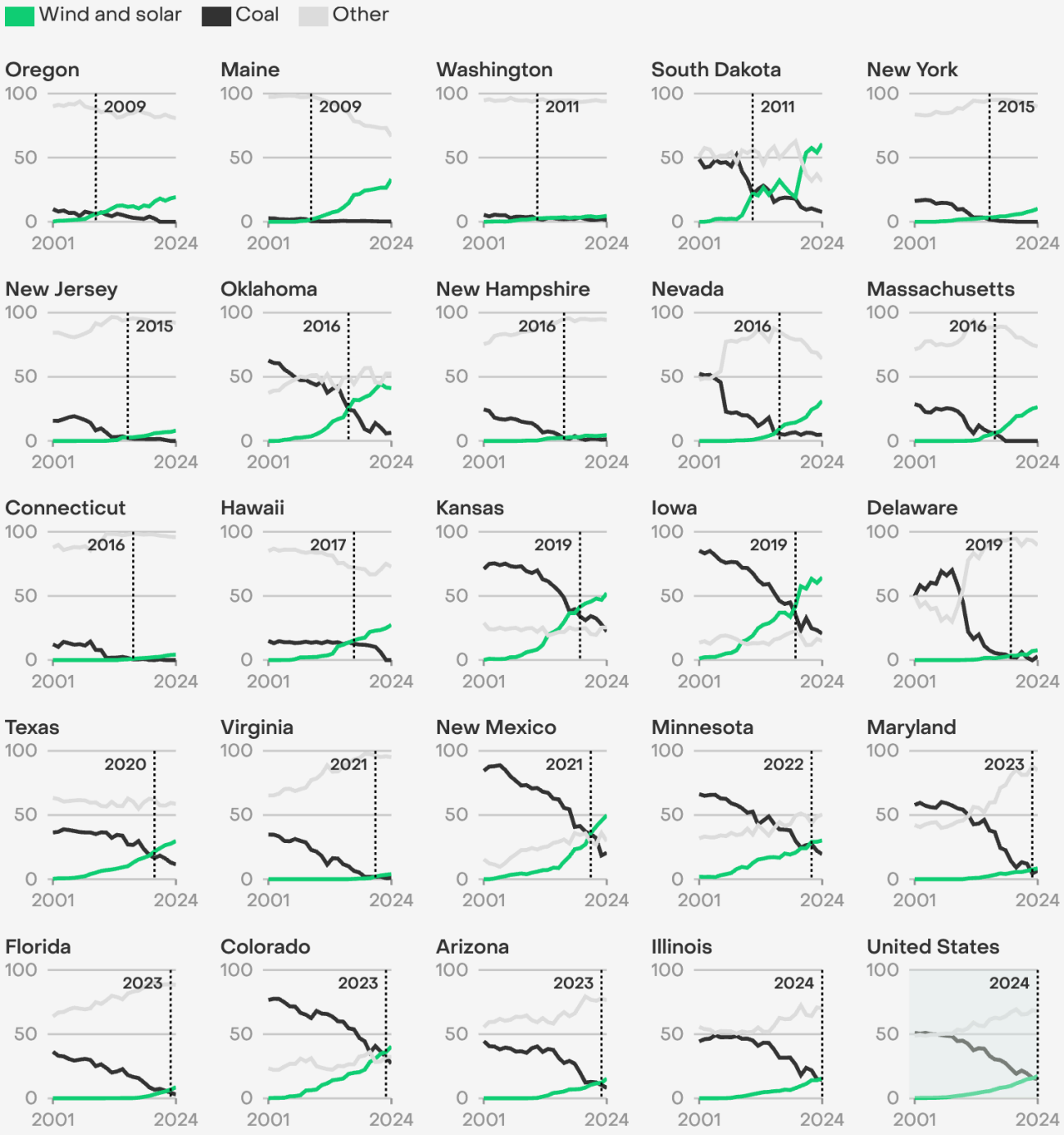
Wind and solar overtake coal in 24 states since 2007

Since coal's nationwide peak in 2007, wind and solar have surpassed it in 24 states– and the pace is accelerating. Half made the switch in just the last six years, with Illinois the latest to cross over in 2024, following Arizona, Colorado, Florida and Maryland in 2023.

Wind and solar have overtaken coal in 24 US states since national coal generation peaked in 2007

Share of electricity generation (%)

States ordered by the year that wind and solar overtook coal



Source: Yearly electricity data, Ember
Vermont never had coal Rhode Island, Idaho, and California had more wind and solar than coal before 2007

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In many of these 24 states, the rise of wind and solar has been substantial — 12 now generate over a quarter of their electricity from them. In Kansas, Iowa, New Mexico, South Dakota and Colorado, wind and solar combined have become the state's largest source of generation.

Meanwhile, 8 of the 24 states have a wind and solar share below 10% in their electricity mix, with gas playing a key role in their transition away from coal. In Delaware, Maryland, Virginia and Florida, coal generation declined mainly due to a shift from coal to gas. As a result, even a small rise in wind and solar was sufficient to surpass coal generation.

The shift away from coal has been primarily driven by market dynamics and availability of more cost-effective resources. The unit costs of wind and solar have reduced significantly and their quick installation makes them commercially attractive. In states like Kansas, Iowa and South Dakota, strong wind potential made wind the cheapest form of generation. In states like Texas and Florida, cheap gas also played a role.

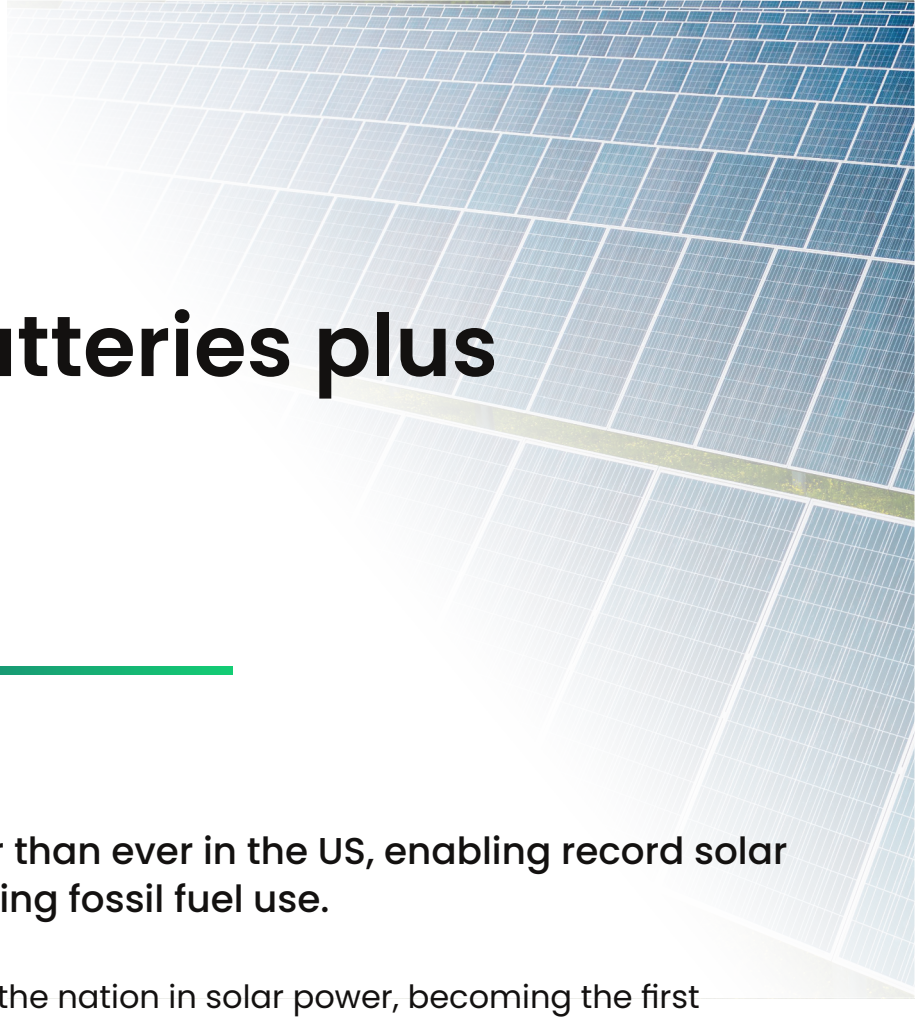
Some states have taken a more aggressive policy-driven approach to phase out coal. Both Illinois' 2021 Climate and Equitable Jobs Act and New Mexico's 2019 Energy Transition Act directly mandated the retirement of coal power plants.

Renewable and clean energy policies have also expanded rapidly, with many states – such as Vermont, Minnesota and Oregon – introducing Renewable Portfolio Standards (RPS) or clean energy targets, particularly in the last five years, which alongside incentives and tax credits, have supported rapid wind and solar growth.

The shift from coal to wind and solar has delivered cleaner electricity across most US states, even in those where wind and solar have not yet surpassed coal. The biggest reductions in carbon intensity have happened in states where wind and solar have replaced coal, rather than where coal has mostly been swapped for gas. But while this transition has made electricity cleaner, gas generation continues to rise, meeting growing electricity demand and slowing overall emissions reductions, as explored in Insight 4.

Insight 2

The rise of batteries plus solar



Batteries are scaling up faster than ever in the US, enabling record solar growth to continue and reducing fossil fuel use.

In 2024, California and Nevada led the nation in solar power, becoming the first states to surpass 30% annual solar share, with California hitting 32% and Nevada 31% – the highest shares of any state. But the transition is uneven – while some states are surging ahead, others are just beginning to see significant growth.

Batteries are essential for the rise of solar, allowing solar to meet growing demand and displacing gas and coal generation. Across the US, the growth of batteries is accelerating alongside solar, with 1 MW of storage being added for every 3 MW of solar added in 2024.

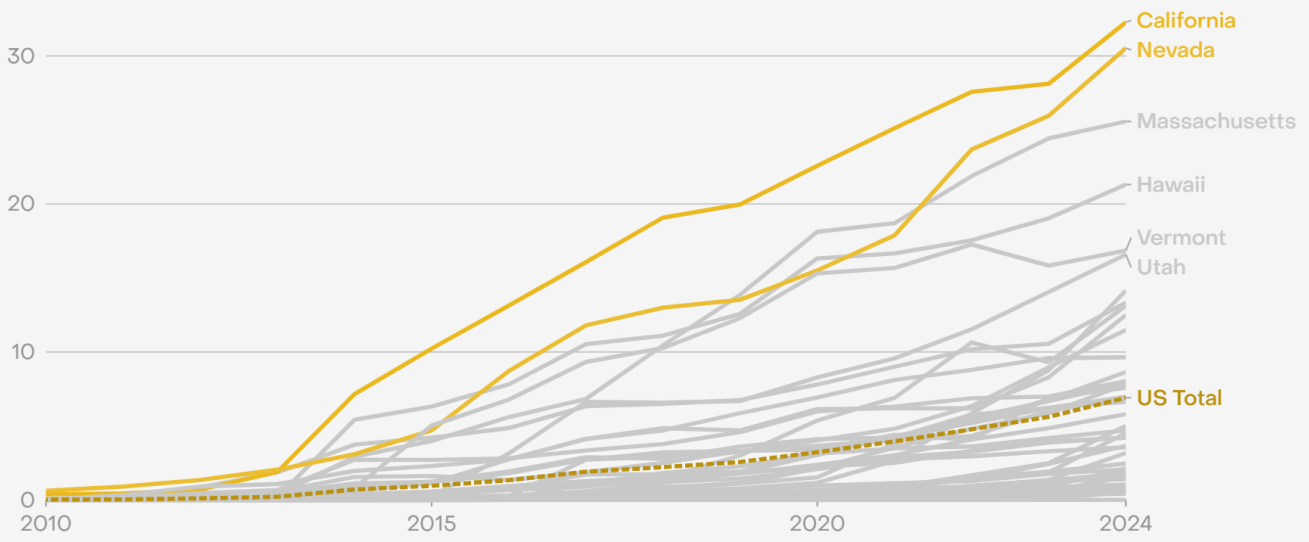
Solar reaches over 30% of electricity in two states for the first time ever

As of 2024, two states generate more than 30% of their annual electricity from solar for the first time ever. California generated 32%, up from 28% in 2023, while Nevada jumped from 26% to 31%. They now lead the nation alongside Massachusetts (26%, up 1 percentage point), Hawaii (21%, up 2% percentage points), and Vermont (17%, up 1 percentage point).

Despite these gains, solar remains a minor player in large parts of the rest of the country. While its share in the US electricity mix rose from 5.6% in 2023 to 6.9% in 2024, 28 states still generated less than 5% of their power from solar. In many of these states, solar is just beginning to emerge as a new source of generation growth. However, the pace of change can be rapid. In Maine, solar's share increased fivefold from less than 3% in 2021 to 14% in 2024. In Texas, the share of solar rose from less than 5% in 2022 to 8% by 2024. Texas surpassed California in utility-scale solar capacity in 2024, but solar made up a much smaller share of its electricity mix due its significantly higher power demand.

Two US states generate more than 30% of their electricity from solar. Just over a decade ago, the highest solar share for a US state was 2%

Share of electricity generation from solar (%)



Source: Yearly electricity data, Ember · US Electricity Data Explorer

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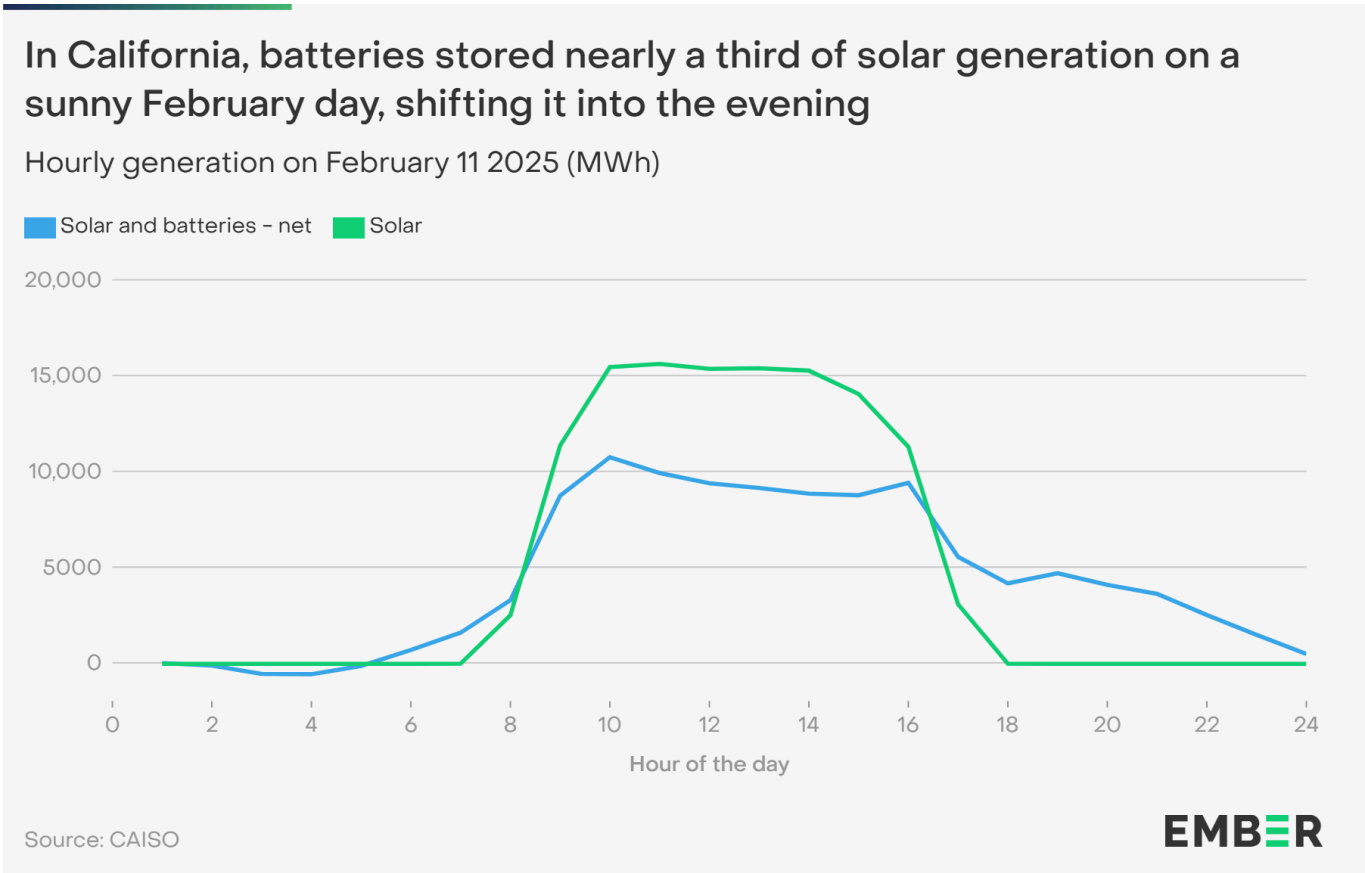
The rise of batteries will enable solar to continue growing

Batteries are a game changer for solar — they can store electricity during periods of high solar generation, typically midday, and make that power available to meet high demand during evening peaks or even overnight.

Nowhere is this more evident than in California, where a battery boom has propelled solar to a record 32% of electricity generation in 2024 – the highest in the US – while rapidly cutting gas use. In April 2024, California batteries made history, becoming the largest source of electricity on the grid during the evening hours for the first time. With batteries taking the lead, gas contribution to meeting evening peak demand fell to roughly half of what it was in April 2021.

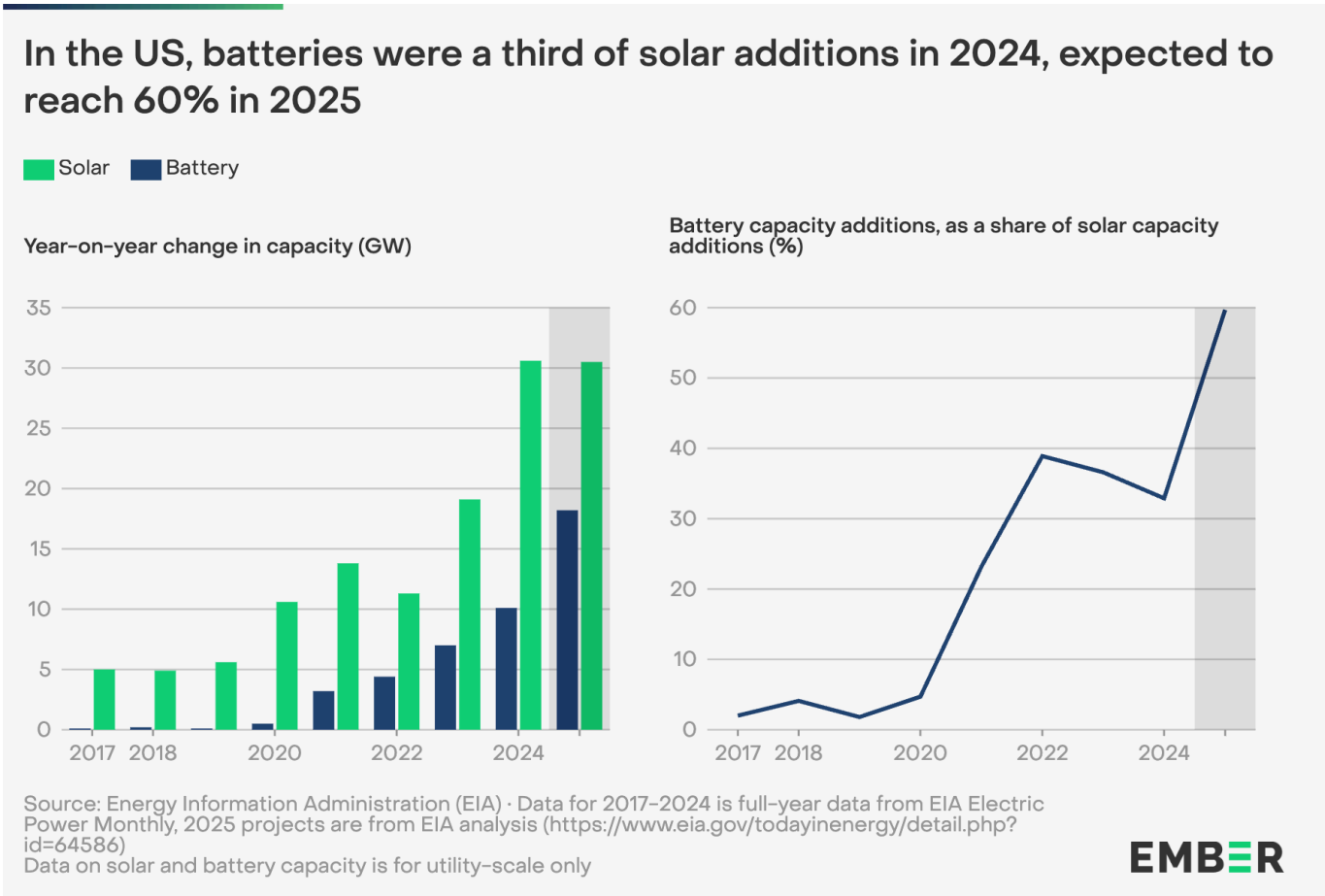


Without batteries, solar's share can grow only in the sunny hours. Once it saturates those hours, any further capacity growth would put stress on the grid and lead to large curtailment losses. Batteries are already storing a significant share of California's peak solar generation, shifting it to meet the evening demand. This also eases the stress on the grid at midday and helps reduce the occurrence and severity of negative prices. Looking at a relatively sunny day in February 2025, nearly a third (30%) of the daily solar generation was absorbed by batteries. Their rise will drive continued capacity growth and a higher share of generation, with California's example proving that batteries can unlock rapid solar expansion in other US states as well.

California has seen explosive battery growth, expanding nearly twentyfold from 0.6 GW in 2020 to 11.7 GW in 2024 – making up nearly half (45%) of total national utility battery capacity. The state installed more batteries than solar at utility-scale in 2024 – adding 3.8 GW of battery capacity compared to 2.5 GW of new solar.

Other states are racing to catch up. In 2024, Texas installed more new utility-scale battery capacity (3.9 GW) than California (3.8 GW), doubling its total from 3.6 GW in 2023 to 7.5 GW. The fast growth of batteries in Texas is underpinning soaring solar capacity growth, with 7.4 GW utility-scale solar added in 2024, nearly double the 2023 additions (3.7 GW). This means that Texas added 1 GW battery for nearly every 2 GW of solar added in 2024.

Arizona and Nevada also saw major growth, more than doubling their battery capacity. Arizona's battery capacity surged from 1 GW in 2023 to 2.1 GW in 2024, while Nevada's jumped from 0.6 GW to 1.1 GW. As more states scale up, batteries are rapidly reshaping the US grid, making way for greater solar growth.



On the national level, batteries are catching up to solar capacity additions. The US added a record 36 GW of new solar capacity in 2024, accounting for 81% of its total power capacity additions. Of this 36 GW, 31 GW was utility-scale solar, alongside 10 GW of utility-scale batteries – an 80% increase – bringing the ratio of new batteries to solar closer than ever. Overall, batteries made up a third of solar additions, with 1 GW battery added for every 3 GW of solar. This is expected to reach 60% in 2025 – 1 GW battery for every 1.7 GW solar.

More and more solar projects are co-located with batteries. Solar-plus-battery projects are already dominating US grid queues. In 2022, less than half (44%) of solar projects entering grid queues were planned to have a battery (590 projects) but in 2023, this rose to 75% (765 projects).

Insight 3

US gas and clean generation growth meets rising demand more than it replaces coal

The rise in gas, solar and wind generation in 2024 was predominantly used to meet electricity demand growth, whereas historically it had mostly replaced coal.

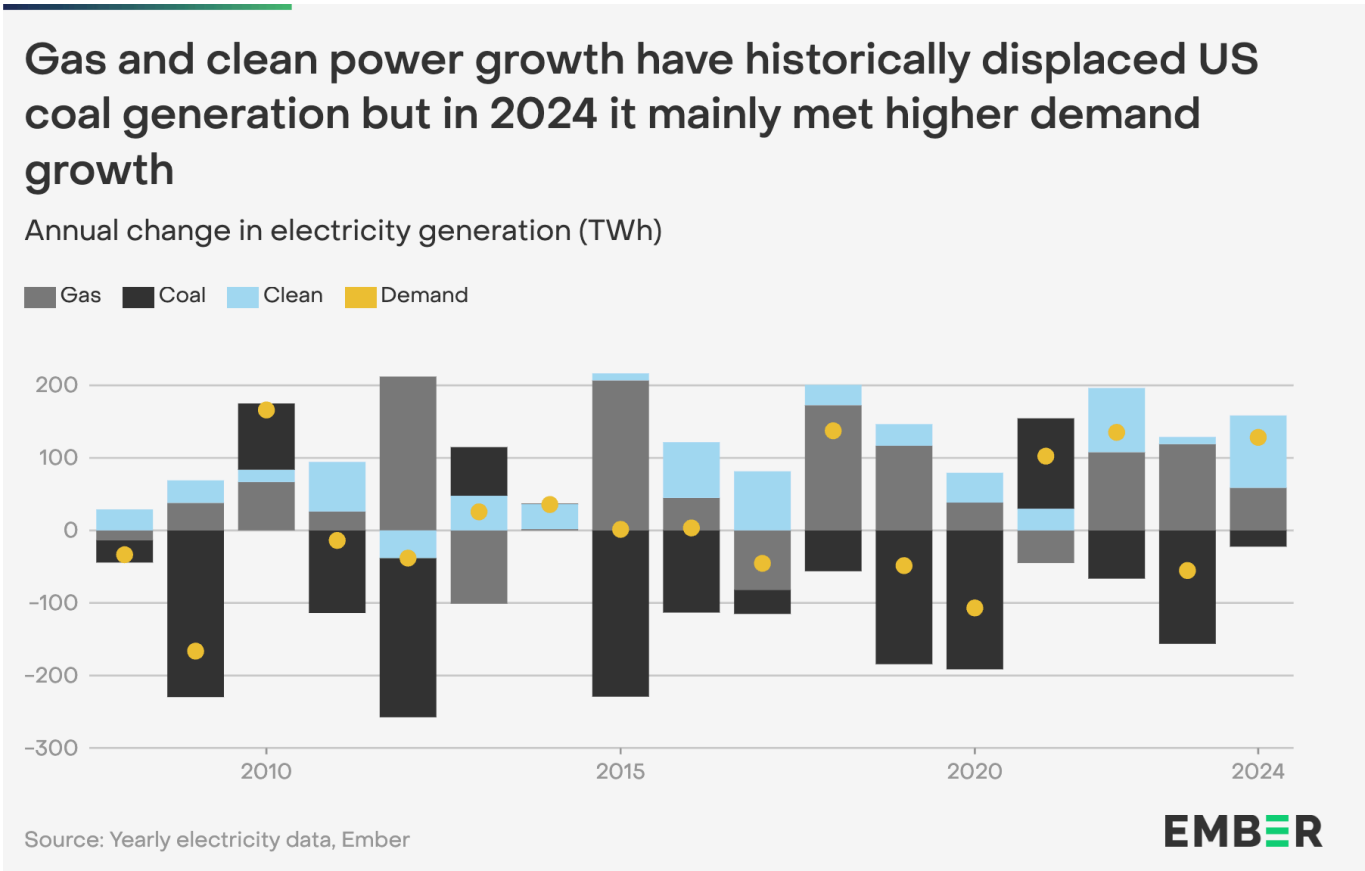
Gas generation rose 3.3% in 2024, similar to the average of the last ten years. However, the increase was mostly to meet electricity demand growth, which is a change from recent history, where gas increased to replace coal. Solar and wind growth slowed the growth of gas, which would have needed to grow by 9% to meet demand without them.

In 2024, states with the highest rise in gas generation also saw the highest electricity demand rise. Rising clean electricity generation slowed gas generation in many states. Only California and Georgia saw large enough growth in clean generation to create a significant fall in gas generation.

Gas and clean growth met rising electricity demand rather than replacing coal

US gas generation rose by 3.3% (+59 TWh) in 2024, a significant increase, though similar to the average growth of the previous ten years (+68 TWh).

What was different in 2024, is that the increase in gas, solar and wind was more to meet rising demand and less to replace coal. Demand rose by 128 TWh and coal fell by 22 TWh – the 150 TWh shortfall was met by gas, solar and wind. This also means that 85% of the total growth in gas, solar and wind met rising electricity demand and just 15% replaced coal generation, resulting in the second smallest fall in coal generation since 2014.



This is a significant shift from the previous ten years from 2013 to 2023 when only 15% of the increase in gas, wind and solar met electricity demand growth, while 85% met the fall in coal generation.

Solar and wind growth was critical to cushioning faster rises in gas generation last year. If gas alone had met the rise in electricity demand and fall in coal generation in 2024, it could have risen by 9%, more than twice as fast as it did.

Despite the rise in gas generation, its capacity increased by only 2 GW in 2024, the lowest level since 2000. By comparison, energy storage added a record 10 GW of new utility-scale capacity in 2024, marking a significant shift in investment from gas power plants to battery-backed renewables.

Gas rising with electricity demand is evident at a state level

The states with the biggest rises in gas generation in 2024 were those with the highest rise in electricity demand growth.

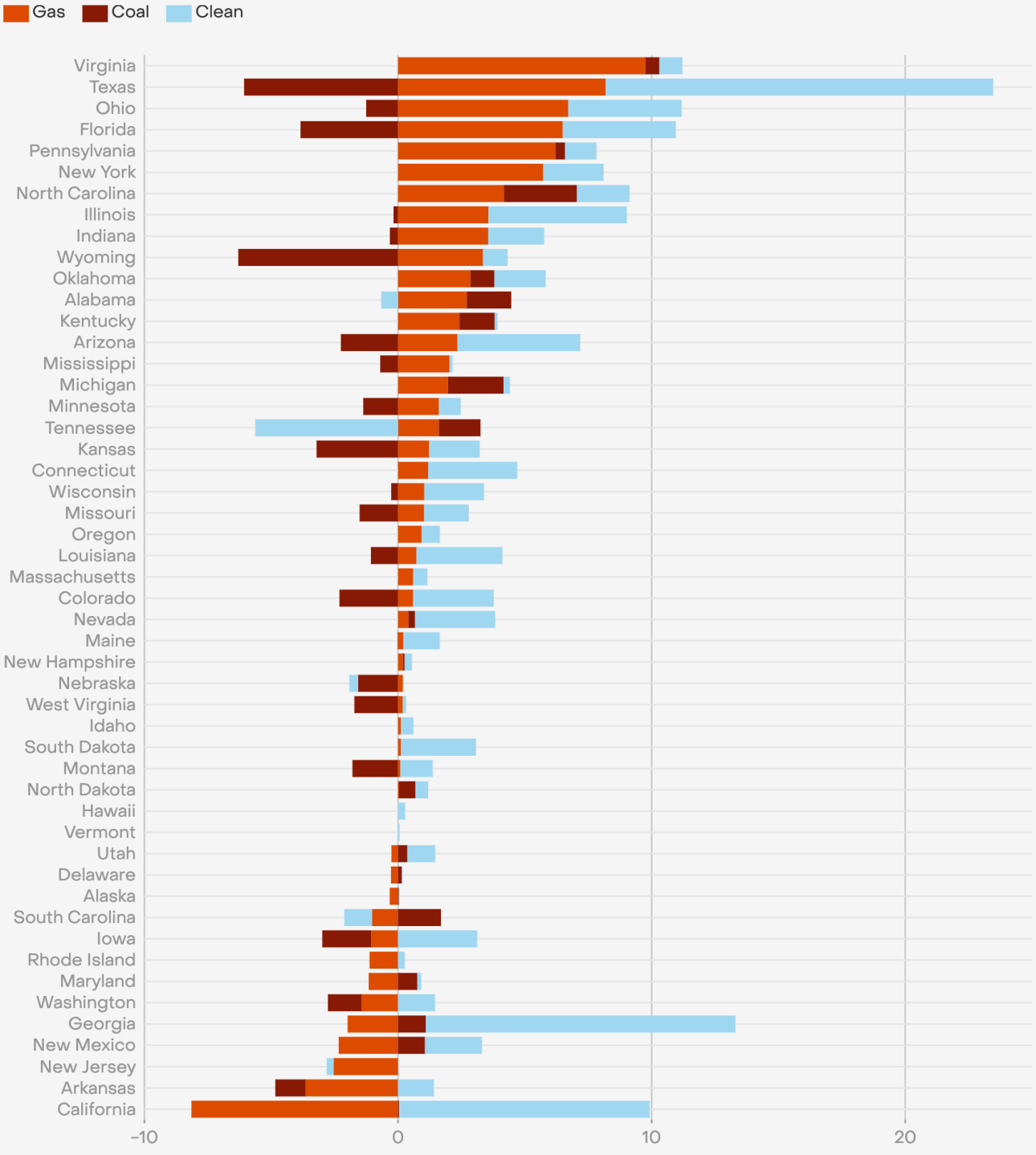
In the states with the highest rise in gas generation, electricity demand grew more than the decline in coal generation. Virginia saw the largest rise in gas generation (and coal generation even rose slightly). This establishes a clear – and perhaps obvious link that rising electricity demand is leading to rising gas generation.

32 states saw a rise in both gas generation and clean generation. In Virginia, gas made up 87% of the total increase in generation. In other states, clean sources played a bigger role and gas, a smaller role. In Texas, gas accounted for less than half (47%) of the total generation rise, and in Arizona, Connecticut and Colorado, it was only a third.

California saw the largest fall in gas generation as clean electricity rose more than electricity demand.

The states with the biggest rises in gas generation in 2024 were those with the biggest rise in overall electricity generation

Change in electricity generation in 2024, compared to 2023 (TWh)



Source: Yearly electricity data, Ember

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Insight 4

Rising demand pushes up emissions slightly, but electricity continues to get cleaner

The rise in power demand was much faster than the rise in power sector CO2 emissions - making each unit of electricity the cleanest it has likely ever been.

Maintaining the mature clean technologies of hydro and nuclear while rapidly adding newer ones, especially solar, was not sufficient to achieve a year-on-year reduction in carbon emissions. That's because fast-rising electricity demand necessitated extra gas generation.

Even though carbon emissions increased, carbon intensity (emission per unit of electricity) reached a record low of 384 gCO2/kWh in 2024 – mainly because clean generation grew faster than fossil and gas replaced coal, making US electricity cleaner.

Faster electricity demand growth halted the historic fall in US power emissions

US power sector emissions increased slightly in 2024, an interruption to the long-term fall since coal generation peaked in 2007.

US power CO2 emissions rose in 2024

The 0.7% rise in CO2 emissions in 2024 was relatively small compared to the increase in electricity demand (+3.0%), mainly because clean generation – predominantly solar and wind – helped meet a significant part of the increased demand.

While coal generation continued to fall, emissions rose due to increased gas generation, which not only replaced coal but also met most of the additional power demand growth.

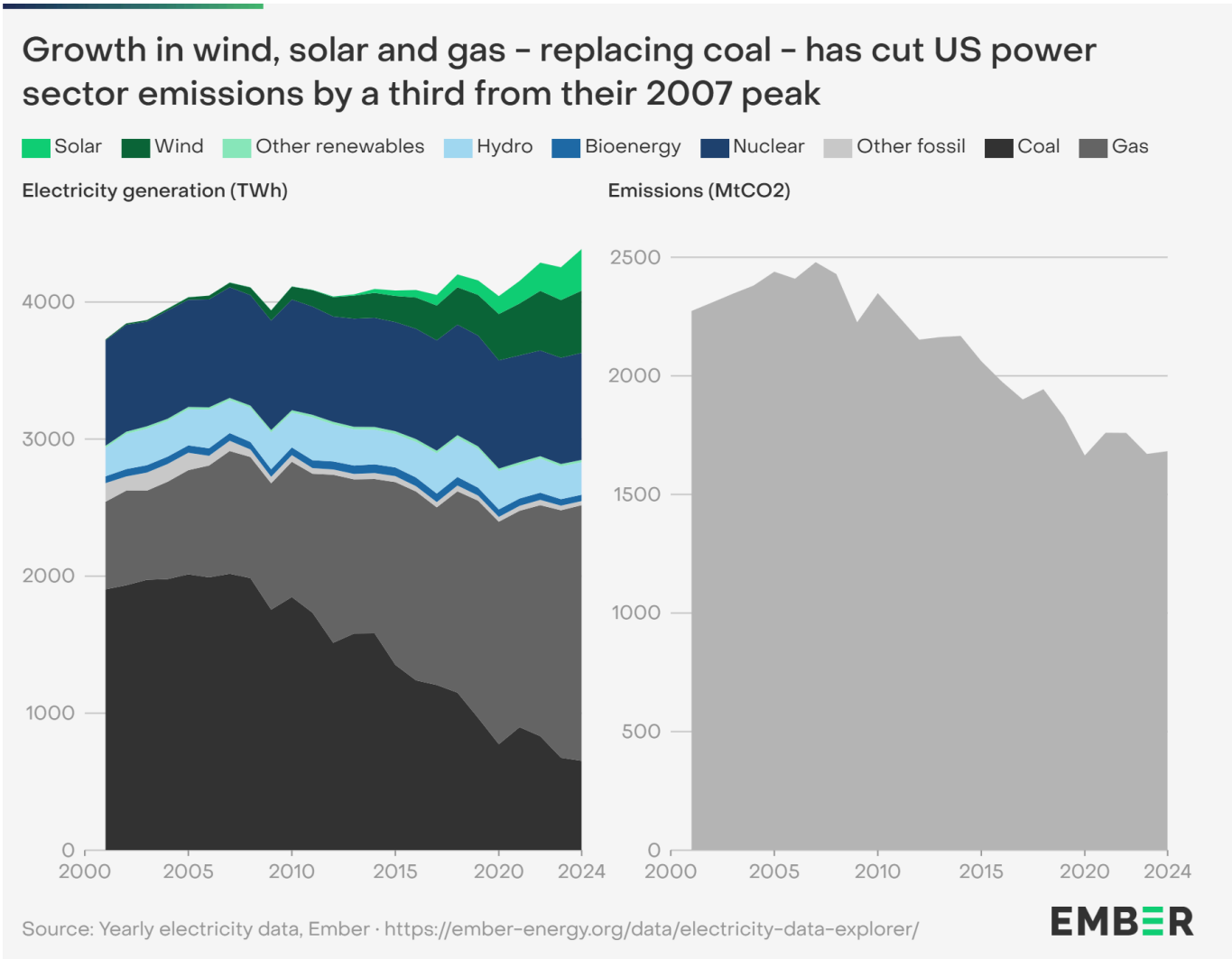
It rose three times more than the fall in coal, as discussed in Insight 3, leading to a 1.3% increase in overall fossil generation.

The rapid falls of CO2 emissions have stalled but not yet reversed

For nearly two decades, US power sector emissions have been in decline, falling by 2.3% per year on average since the peak of coal generation in 2007, resulting in a cumulative 33% fall by 2024.

The rise of wind and solar, along with the shift from coal to gas, was transformational, reducing coal's share in the electricity mix from 49% in 2007 to an all-time low of 15% in 2024. Meanwhile, mature clean technologies of hydro and nuclear maintained their share in the mix.

Even as demand grew, the US grid continued to get cleaner. The expansion of wind, solar and gas helped stabilize emissions in the face of rising consumption. The key question is whether these trends will continue as the economics and politics of power generation in the country continue to shift.



The last 17 years of progress means electricity got cleaner almost everywhere

Carbon intensity of power generation continued to fall – from 393 gCO2/kWh in 2023 to 384 gCO2/kWh in 2024. This is most likely the cleanest electricity in the US since the late 1800s when coal began to dominate.

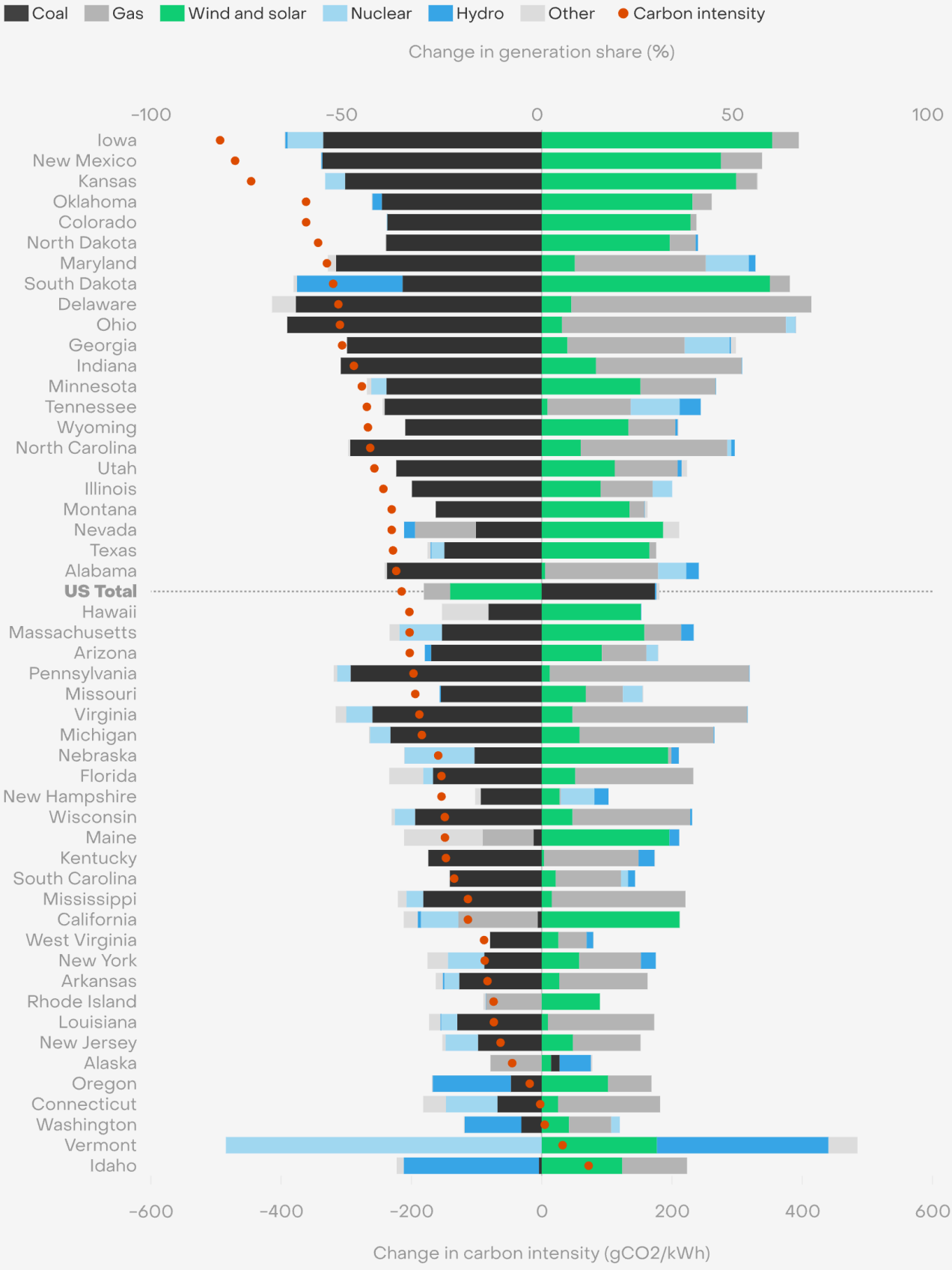
Since US coal generation peaked in 2007, the country's electricity has become substantially cleaner, falling from 598 gCO2/kWh in 2007 to 384 gCO2/kWh in 2024. Over that period, the combined generation of wind and solar, along with gas, increased substantially (by 722 TWh and 968 TWh, respectively), contributing to the fall in coal generation.

The biggest falls in carbon intensity between 2007 and today happened in states where increasing wind and solar were the biggest sources replacing coal, rather than gas. The five states with the largest falls in carbon intensity were Iowa, New Mexico, Kansas, Colorado, Oklahoma and North Dakota, which also saw large increases in wind and solar.

Meanwhile, Ohio and Delaware recorded the largest falls in coal share than any state but did not see their carbon intensity fall as steeply because most of the coal was replaced with gas.

The biggest falls in carbon intensity between 2007 and today happened in states where increase in wind and solar were the biggest factor replacing coal, rather than gas

Change to US states electricity generation, 2007-2024



Source: Yearly electricity data, Ember

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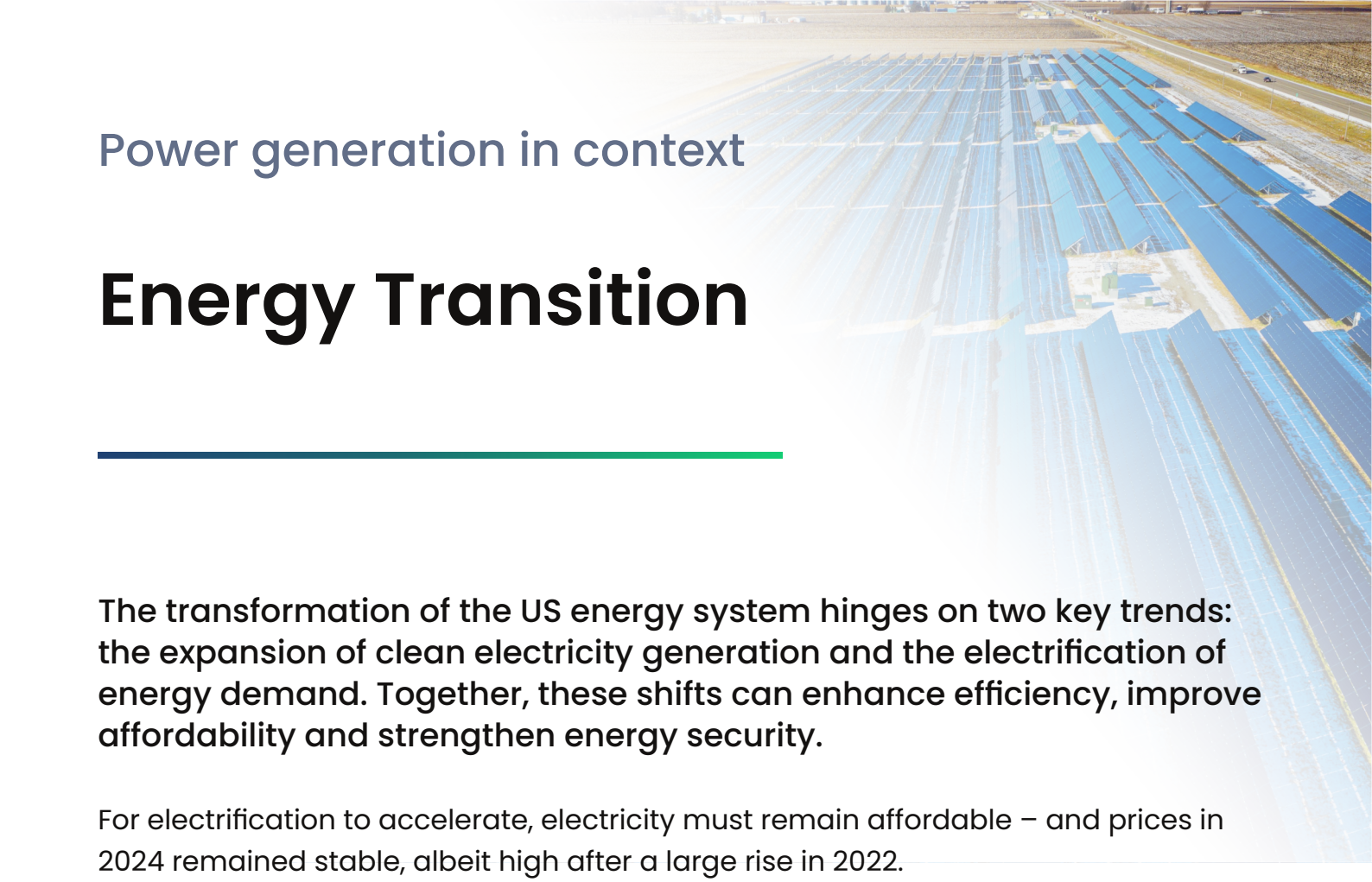


Energy Transition

The transformation of the US energy system hinges on two key trends: the expansion of clean electricity generation and the electrification of energy demand. Together, these shifts can enhance efficiency, improve affordability and strengthen energy security.

For electrification to accelerate, electricity must remain affordable – and prices in 2024 remained stable, albeit high after a large rise in 2022.

Sales of electrification technologies like electric vehicles and heat pumps continued their decade-long rise. While EVs made up one-fifth of total car sales, heat pumps accounted for 57% of new space heating installations in 2024.

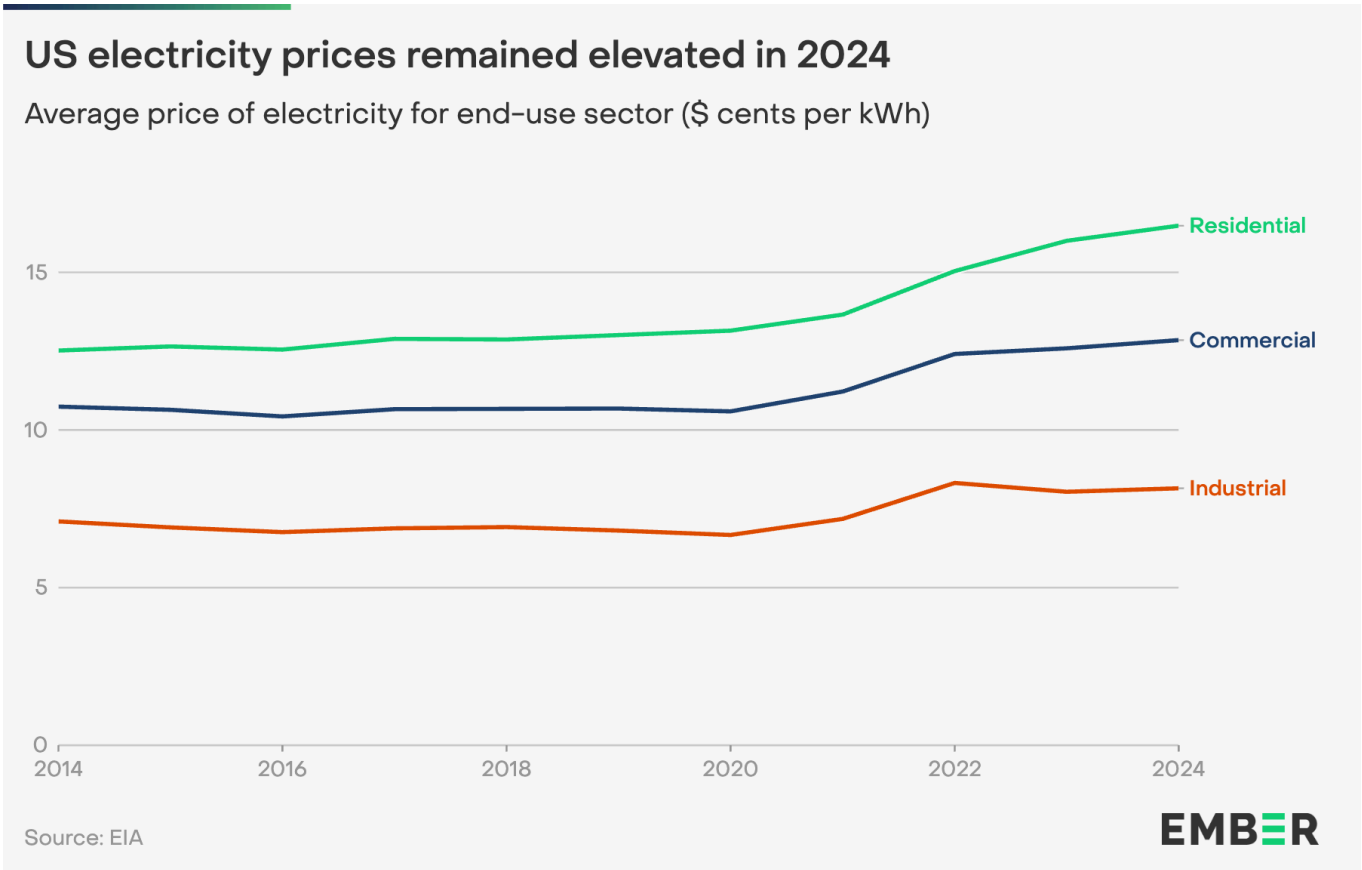
Grid modernisation is essential for maintaining supply security and presents a key infrastructure investment opportunity. As more renewables come online, a more interconnected grid and increased cross-border electricity trade could help stabilize prices, allowing high-cost regions to benefit from lower-cost power elsewhere. While intrastate electricity trade remains limited today, plans for greater grid integration are beginning to take shape.

Electricity prices remain steady

Affordable electricity is not only a key driver of economic growth but also a critical enabler of electrification.

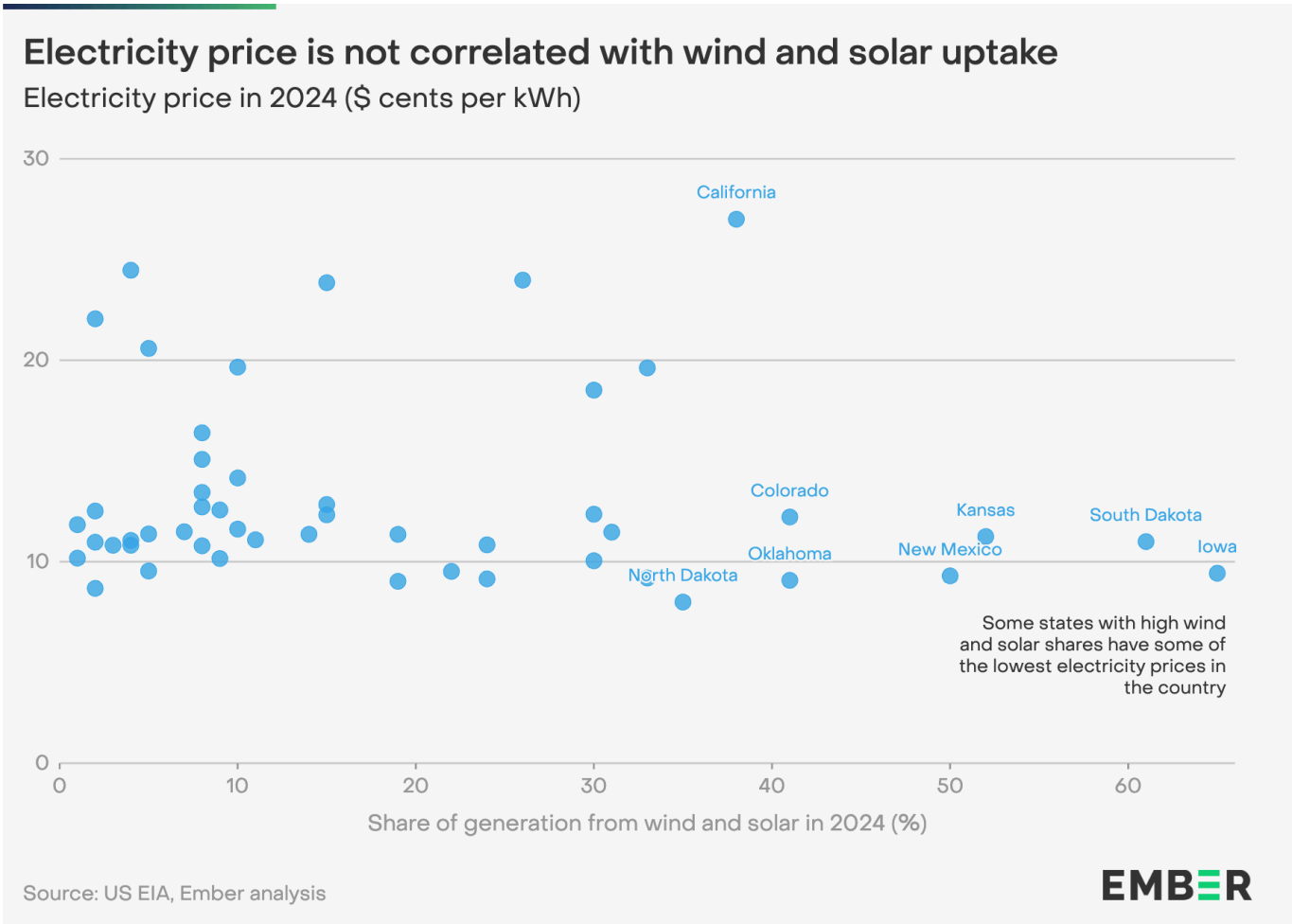
Wholesale prices were lower and less volatile in 2024 than the year before. This was mostly driven by low natural gas prices, increased generation from some lower cost renewable energy sources and new battery storage capacity.

Retail electricity prices increased by 3.0% in 2024, in line with economywide inflation, although commercial prices rose 2.1% and industrial prices rose only 1.4%. Prices have steadied after a 10% rise in 2022, triggered by a surge in fossil fuel prices following Russia's invasion of Ukraine, although they remain higher than pre-war levels.



There is no evident correlation between the share of electricity generated from wind and solar and overall electricity prices. However, some states with high wind and solar penetration – such as Iowa, South Dakota and Kansas – have some of the lowest electricity prices in the country.

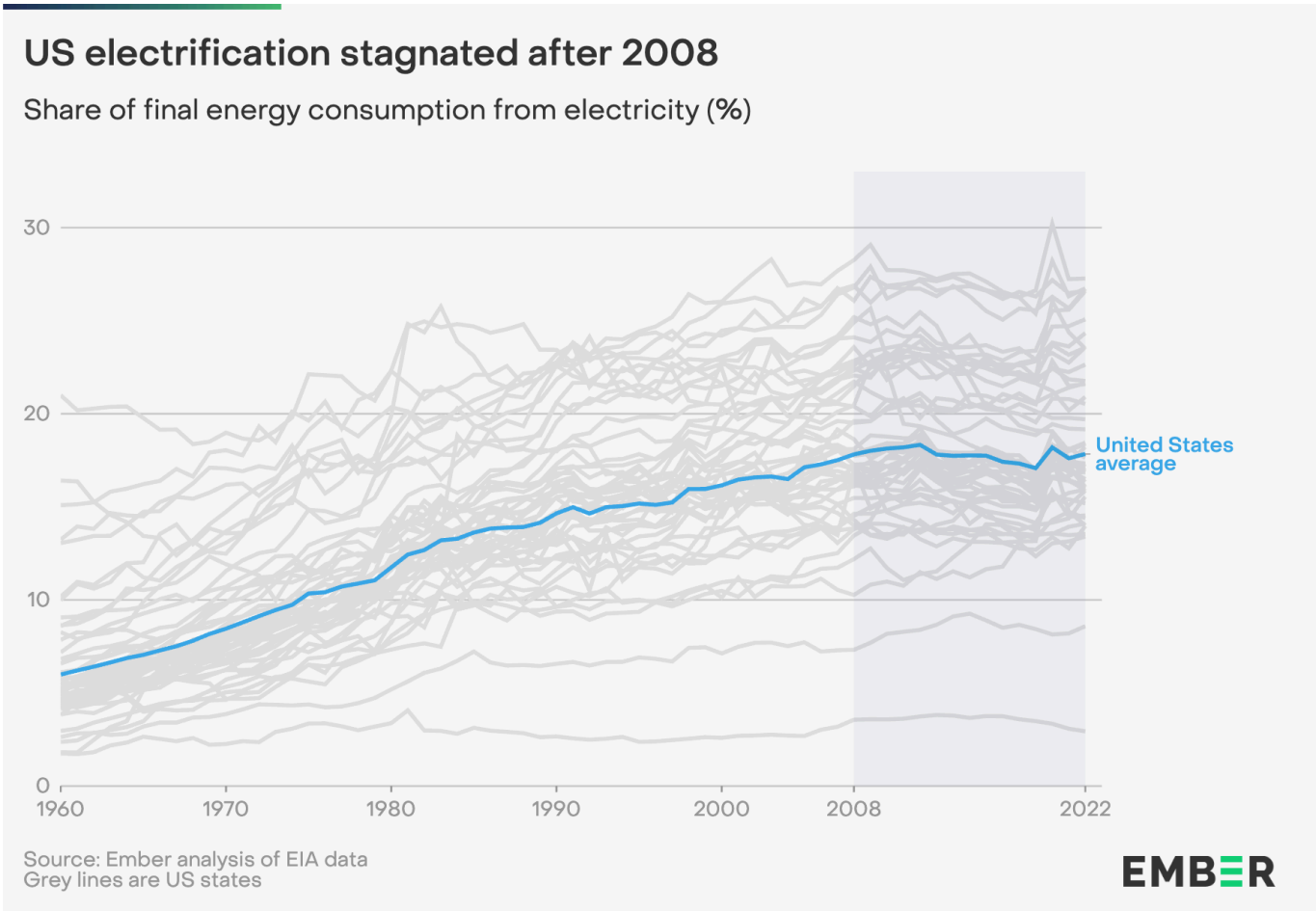
Conversely, higher electricity costs in states such as California and Massachusetts are influenced by factors including reliance on expensive imported fossil fuels, aging infrastructure and natural disaster damage. These elements play a more significant role in determining electricity prices than the level of wind and solar uptake.



Electrification has plateaued for a decade, but there are signs it will pick up again soon

Electricity currently accounts for approximately 18% of total energy demand in the United States. While the share of electricity in the energy mix grew steadily for much of the 20th century, the pace of electrification began to slow in the 1990s and has remained stagnant since 2008.

However, there are emerging signs that electrification is about to accelerate again. The rapid adoption of electric vehicles and heat pumps is expected to drive renewed growth in electricity's share of energy consumption.

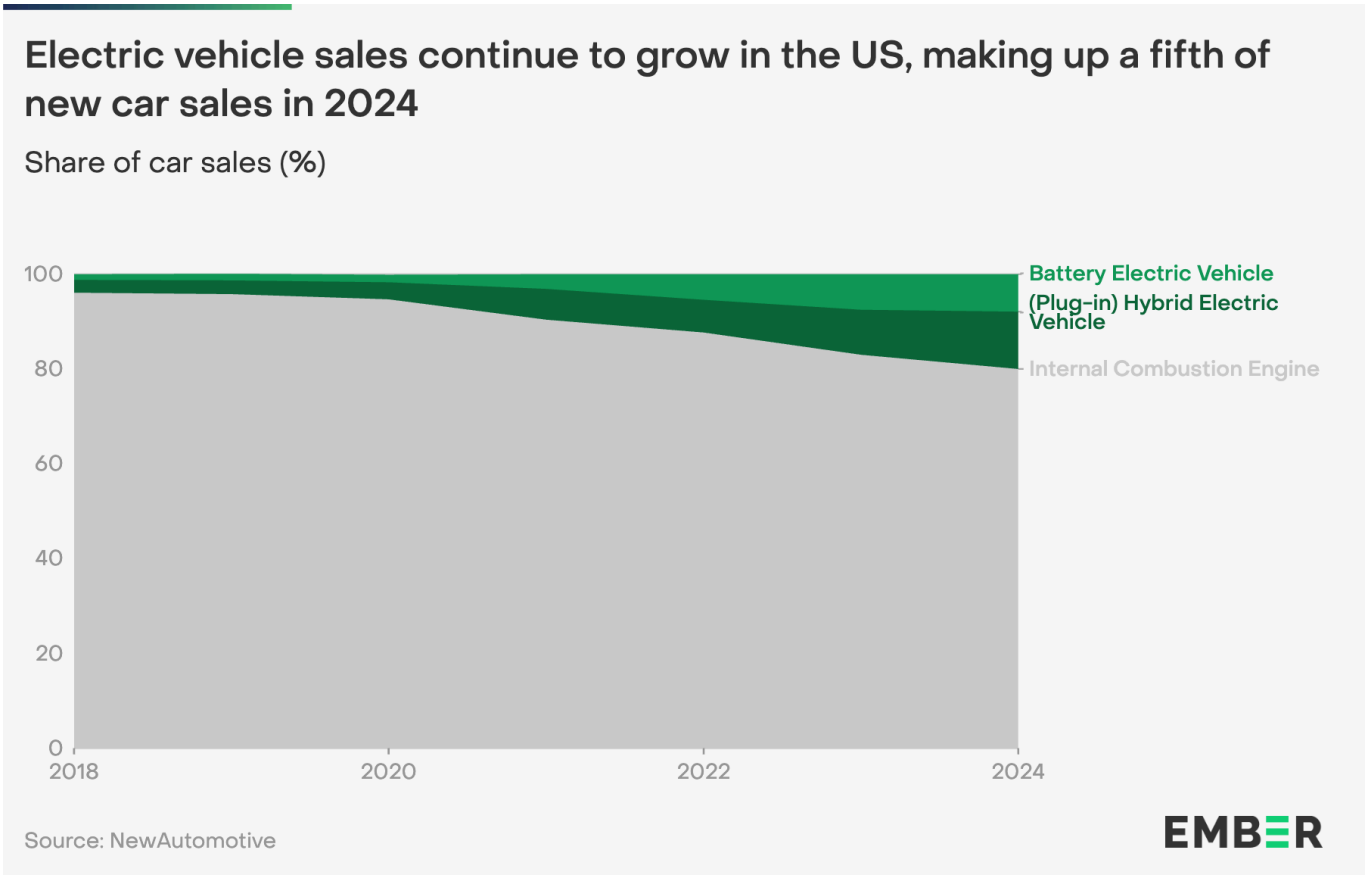


Electric vehicle sales continue to rise

Electric vehicle (EV) car sales in the United States are gaining momentum, setting the stage for a broader shift in road transport electrification. Sales translate into stock turnover, which leads to the electrification of passenger cars — and eventually the entire road transport sector. Road transport currently accounts for 23% of total energy consumption in the US, according to the EIA.

In 2024, electrified vehicles (xEVs) made up 20% of all new car sales, with battery electric vehicles (BEVs) comprising 9%. Sales of pure internal combustion engine (ICE) vehicles are declining since their peak over seven years ago and are continuing to fall as xEVs have absorbed virtually all of the post-COVID rebound in the auto market.

BEV sales growth slowed to 8% in 2024 after exceptionally rapid expansion from 2021 to 2023, when annual growth exceeded 50% per annum. Meanwhile, plug-ins and hybrid electric vehicles sales continued to rise sharply, growing by 31% in 2024.

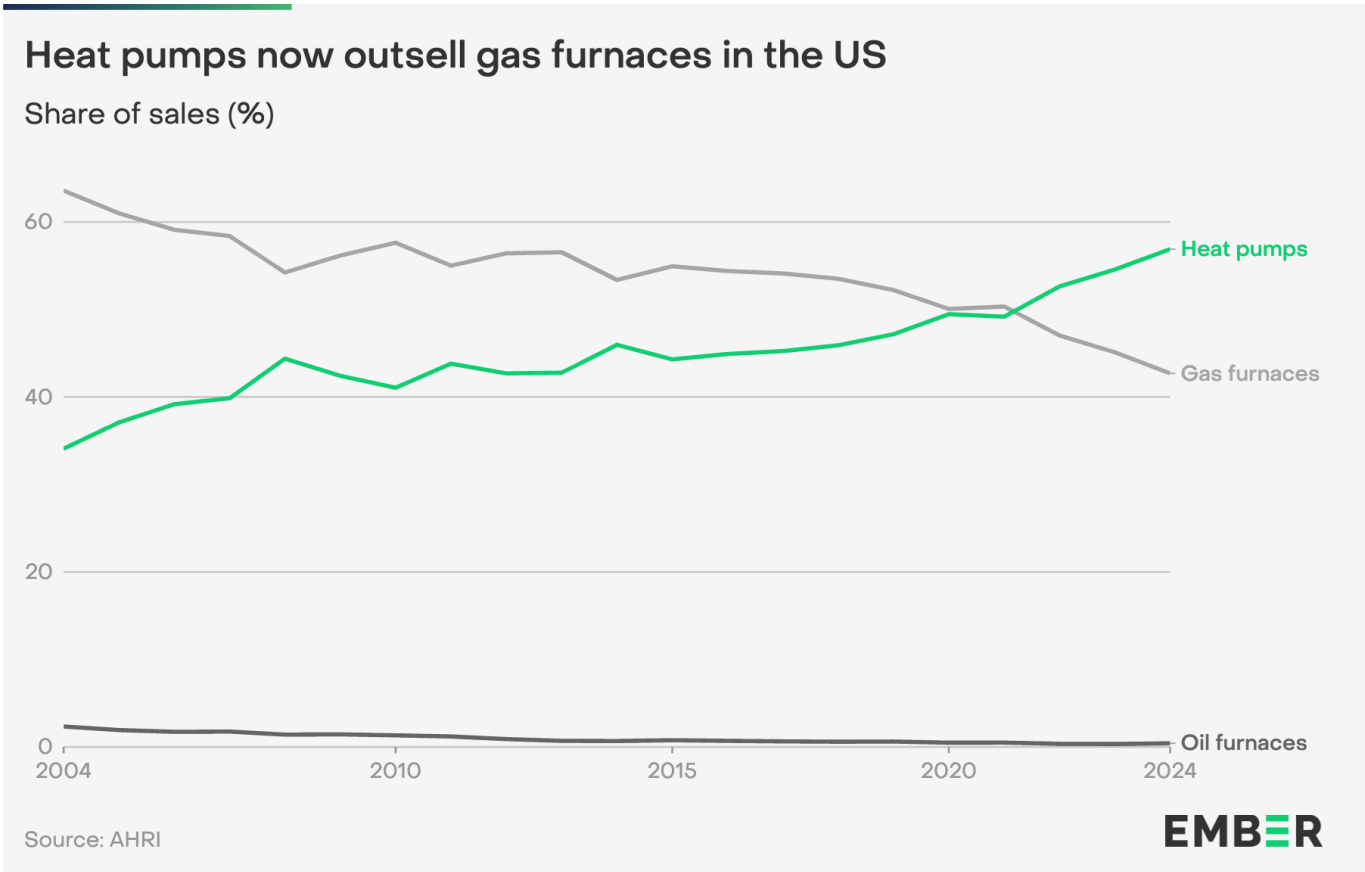


Heat pumps continue to outsell gas furnaces

Heat pump sales are rising rapidly, accelerating the electrification of low-temperature heating in buildings and industries, which together account for about 20% of total US energy demand according to NREL. As old systems are replaced, heat pumps are steadily displacing fossil-fuel-based heating, reshaping the U.S. heating market.

In 2021, heat pump sales overtook gas furnaces for the first time – a turning point in the transition away from fossil fuels. Gas furnace sales peaked that same year and have been in structural decline ever since. In 2024, heat pumps accounted for 57% of new space heating installations, growing by 2.3 percentage points from 2023.

This shift is the continuation of an upward trend for heat pumps that began in 2013. After over a decade of growth, heat pump sales continue to surge.



Electricity trade between states remains limited

The US electricity market is primarily composed of regional grids, with many states largely self-sufficient in their power generation. Despite the potential for interregional trade, electricity flows between states have remained relatively stable over the past few decades, with only a handful of states undergoing notable shifts. That will likely change in the coming years.

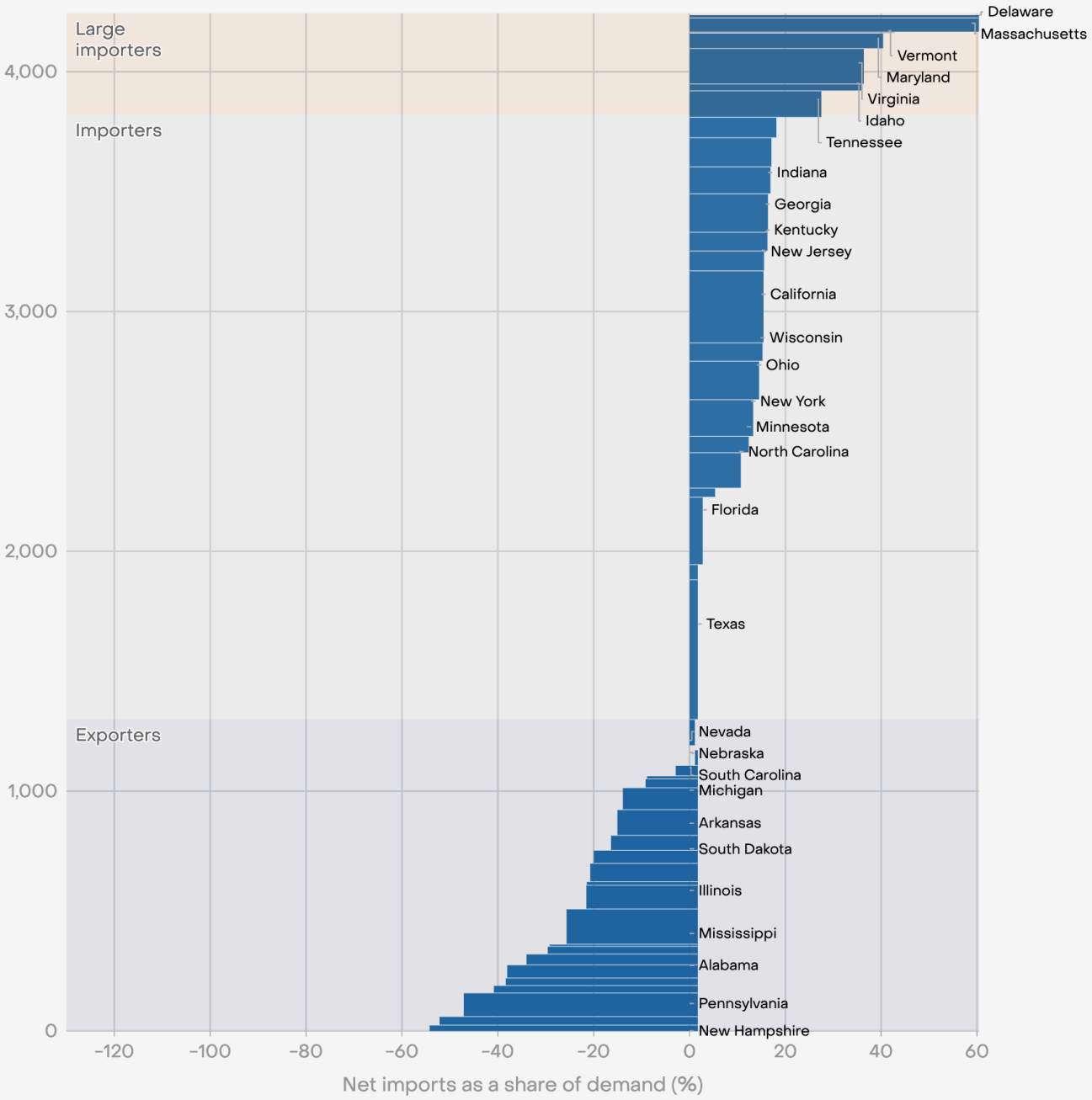
The latest data on interstate trade shows limited reliance on imports, with only seven states importing more than 20% of their electricity demand in 2023. Most of them had below-average wind and solar shares, including Delaware at the top (7.5% vs. 15.5% nationwide), followed by Maryland, Virginia and Tennessee. In contrast, states with high wind and solar have not relied much on imports to balance supply and demand, partly due to growing battery storage managing fluctuations in renewable generation.

There were 17 states exporting more than 20% of their demand, most with below-average wind and solar. New Hampshire, which had the highest exports relative to its demand also had less than 5% wind and solar. Since the 1990s, the rise of wind and solar has helped transform three states – Oklahoma, South Dakota, and Iowa – from net importers to net exporters.

Only eight US states imported more than a fifth of their electricity in 2023

Net imports as a share of demand (%)

Height of bars = total demand load (TWh)*



Source: EIA, Ember analysis
*Total supply needed to meet demand (i.e. including grid losses);
New Hampshire has been excluded from this graphic as its net exports are almost eight times larger than its demand load.

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Enhanced transmission links are essential to not only support the efficient integration of low-cost solar and wind, but to improve overall security of supply and resilience, especially in a world of rising electricity demand. The US grid is one of the oldest grids in the world, with more than half of its infrastructure over 20 years old, and has been experiencing rising outages. The ongoing grid transformation presents a substantial investment opportunity and the US has the potential to leapfrog from one of the oldest to one of the most modern grids globally. This transition could unlock numerous benefits, including higher efficiency, lower system costs and improved reliability.

Several major grid expansion projects were proposed in 2024 to modernize US transmission infrastructure and integrate more renewable energy. Key initiatives backed by the Department of Energy include the Aroostook, Cimarron Link, Southern Spirit and Southline projects, along with Nevada's Greenlink West and North lines. Collectively, these projects aim to improve grid reliability and unlock gigawatts of cheap renewable capacity to supply demand centers with elevated prices.

Methodology

US data on electricity generation, including generation, demand, net imports and capacity deployment is sourced from the US Energy Information Administration (EIA).

Generation from small-scale and distributed solar installations is included in both national and state level solar generation data. Small-scale solar data is reported by the EIA. National electricity demand values are the sum total of all generation sources (including small-scale solar) and net imports.

Ember compiles US state level data on generation as well as derived data on power emissions and emissions intensity which is used in this report. Emissions for the US total and states are calculated using the same methodology used in Ember's yearly electricity data.

Ember's electricity data, including the US total, is also accessible through Ember's Electricity data explorer. US state level data is also available in Ember's US electricity data explorer.

Acknowledgements

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Kostantsa Rangelova, Dave Jones, Daan Walter

Other contributors
Bryony Worthington, Nicolas Fulghum, Rashmi Mishra, Hannah Broadbent, Lauren Orso, Chris Rosslowe, Claire Kaelin

Cover image
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