

# New Energy Outlook 2018

BNEF's annual long-term economic analysis of the world's power sector out to 2050.



# NEO 2018 findings.

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# Setting the scene

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Focusing on the electricity system, the New Energy Outlook (NEO) combines the expertise of over 65 in-house country and technology-level specialists in 12 countries to provide a unique assessment of the economic drivers and tipping points that will shape the sector to 2050.

Since the 1970s, fossil fuels have commanded a consistent 60-70% share of the global power generation mix. We think this 50-year equilibrium is coming to an end, as cheap renewable energy and batteries fundamentally remake electricity systems around the world.

NEO 2018 sees **\$11.5 trillion** being invested globally in new power generation capacity between 2018 and 2050, with **\$8.4 trillion** of that going to wind and solar and a further **\$1.5 trillion** to other zero-carbon technologies such as hydro and nuclear.

Cheap renewable energy and batteries fundamentally reshape the electricity system, as we shift from two-thirds fossil fuels in 2017, to two-thirds renewable energy in 2050.

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## 50 by 50

By 2050, wind and solar technology provide almost 50% of total electricity globally – “50 by 50” – with hydro, nuclear and other renewables taking total zero-carbon electricity up to 71%.

By 2050, we expect only 29% of the electricity production worldwide to result from burning fossil fuels, down from 63% today.

This dramatic shift to “50 by 50” is being driven by cheap solar PV, cheap wind, and falling battery costs. The cost of an average PV plant falls by 71% by 2050. Wind energy is getting cheaper too, and we expect it to drop 58% by 2050. PV and wind are already cheaper than building new large-scale coal and gas plants. Batteries are also dropping dramatically in cost.

“We see \$548 billion being invested in battery capacity by 2050, two thirds of that at the grid level and one third installed behind-the-meter by households and businesses.

The arrival of cheap battery storage will mean that it becomes increasingly possible to finesse the delivery of electricity from wind and solar, so that these technologies can help meet demand even when the wind isn’t blowing and the sun isn’t shining.

The result will be renewables eating up more and more of the existing market for coal, gas and nuclear.”

- Seb Henbest, BNEF

## Highlights from the Outlook

**Coal is the biggest loser.** Coal will shrink to just 11% of global electricity generation by 2050, from 38% currently.

**Gas consumption for power generation remains flat out to 2050**, despite growing capacity. Gas plays a key role, however, in backing up renewables during extremes and wind and solar generation are at a minimum.

**Electric vehicles add around 3,461TWh of new electricity demand globally by 2050**, equal to 9% of total demand. About half of the necessary charging for EVs will be dynamic, taking advantage of times when electricity prices are low because of high renewables output.

## Methodology

What sets NEO apart is that we focus on technology that is driving change in markets and business models across the sector, such as solar PV, onshore and offshore wind and batteries.

In addition, we put special focus on changing electricity demand, electric vehicles, air-conditioning, and the growing role of consumers.

NEO includes our price forecasts for coal, oil and gas around the world, and assesses the impact of the energy transition on fossil fuel demand and



# Regional trends.

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**By 2050, renewables supply 87% of electricity in Europe, 55% in the U.S., 62% in China and 75% in India.**

As renewable penetration rises and existing large-scale plant retire, new flexibility becomes a top priority.

Dedicated flexible capacity grows almost six-fold, rising to 15% of the total power mix by 2050. Batteries make up around 44% of this and account for 70% of new build, along with demand response and peaker gas.

Investment in power generating capacity by region, 2018-2050 (\$ trillion, 2017 real)



Source: Bloomberg New Energy Finance

## Country highlights

### Europe

Europe shows that renewable energy can reach very high penetration at a low cost. By 2050, renewables make up 87% of the electricity mix, with wind and solar playing a dominant role.

Cheap renewables, flexible demand and batteries combine to shift the European power system away from fossil fuels and nuclear to one built around variable renewables and emissions-free energy.

### Germany

Germany sees rapid change to 2025 with coal and gas generation falling 29%, nuclear phased-out and renewables topping 70% of generation.

Battery deployment helps renewables reach higher penetration but, in the absence of policy intervention, cheap lignite is likely to remain in place.

By 2050, Germany is running on 74% wind and solar, and 84% renewables, but it has the highest emissions in Europe.

### U.K.

The U.K.'s plan to close its remaining coal-fired power stations by 2025 reduces the role of fossil fuels in generation to 12% by 2030.

At the same time, growth in high capacity factor offshore wind pushes renewables up to 73% of generation. By 2050, the U.K. has added 158GW of wind and solar, as well as 49GW of batteries and renewables provide 83% of generation.

### U.S.

The U.S. electricity system continues to replace aging coal and nuclear with cheaper gas and renewable resources, assuming there is no lasting federal policy intervention to prevent their retirement.

Coal and nuclear are pushed out by age and economics, such that by 2050 both nuclear and coal have almost disappeared from the electricity mix. We do not anticipate a U.S. nuclear renaissance with the current technology.

Batteries grow in significance from around 2030, supporting renewables penetration, which

reaches 55% in 2050. In that year, emissions are 58% lower than they are today.

## China

China sees peak coal generation and peak emissions in 2030, as the world's biggest electricity system reaches 39% renewables penetration with 23GW of batteries.

China will continue to be the largest market for wind and solar, which grow from 7% to 46% combined of total generation by 2050.

By that time China has 1.1TW of solar PV and 1TW of wind – equivalent to 21% of all the PV and a third of all the wind power installed globally.

## India

India has the cheapest new wind and solar anywhere in the world. This poses a profound challenge to the orthodoxy there that coal is forever king.

While we expect coal-fired electricity to continue to grow in India in the short to medium term, by 2050 wind and solar dominate, supported by

batteries and flexible gas. This pushes India's emissions 22% below what they are today.

## Japan

Japan's electricity system remains relatively coal-heavy for much of the next 33 years, even as strong renewables growth and nuclear restarts squeeze gas out of the mix.

By 2050, renewables account for almost three quarters of electricity generation, with PV supplying 43%, up from 6% today.

Negative demand growth and strong consumer uptake of small-scale PV and batteries make Japan one of the more decentralized power systems in the world, with 34% of installed capacity behind-the-meter.

## Australia

Australia's power system is on track to become one of the two most decentralized in the world, with consumer PV and behind-the-meter batteries making up 44% of all capacity.

This represents a dramatic turnaround from the

largely coal-fired system of today.

Wind, PV and batteries form the backbone of this new system, where coal has all but disappeared.

## South Korea

South Korea's generation mix shifts from 72% coal and nuclear in 2017 to 71% gas and renewables in 2050.

Utility-scale batteries and peaker gas plants become a crucial part of Korea's future power system, supporting growing offshore wind and PV, as the country's aging coal and nuclear plant retire.



# The role of renewable technologies.

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# Levelized costs of electricity.

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Coal and gas are facing a mounting threat to their position in the world's electricity generation mix, as a result of the spectacular reductions in cost not just for wind and solar technologies, but also for batteries – according to our latest report on the levelized costs of electricity, or LCOE, for all the leading technologies.

The report finds that fossil fuel power is facing an unprecedented challenge in all three roles it performs in the energy mix:

1. The supply of 'bulk generation'
2. The supply of 'dispatchable generation'
3. The provision of 'flexibility'

### In bulk generation

The threat comes from wind and solar photovoltaics, both of which have reduced their LCOEs further in the last year, thanks to falling capital costs, improving efficiency and the spread of competitive auctions around the world.

### In dispatchable power

The challenge to new coal and gas that provide dispatchable power (i.e., the ability to respond to

grid requests to ramp electricity generation up or down at any time of day) is coming from the pairing of battery storage with wind and solar, enabling the latter two 'variable' sources to smooth output, and if necessary, shift the timing of supply.

### In flexibility

Stand-alone batteries are increasingly cost-effective and are starting to compete on price with open-cycle gas plants, and with other options such as pumped hydro, for flexibility (i.e., the ability to switch on and off in response to grid electricity shortfalls and surpluses over periods of hours).

"Our team has looked closely at the impact of the 79% decrease seen in lithium-ion battery costs since 2010 on the economics of this storage technology in different parts of the electricity system. The conclusions are chilling for the fossil fuel sector." Elena Giannakopoulou, head of energy economics at BNEF.

Some existing coal and gas power stations, with sunk capital costs, will continue to have a role for

many years, doing a combination of bulk generation and balancing, as wind and solar penetration increase.

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**"The economic case for building new coal and gas capacity is crumbling, as batteries start to encroach on the flexibility and peaking revenues enjoyed by fossil fuel plants."**

BNEF calculates LCOEs for each technology, taking into account everything from equipment, construction and financing costs to operating and maintenance expenses and average running hours.

It found that in the first half of 2018, the benchmark global LCOE for onshore wind is \$55 per megawatt-hour, down 18% from the first six months of last year, while the equivalent for solar PV without tracking systems is \$70 per MWh, also down 18%. Offshore wind's LCOE is \$118 per MWh in 1H 2018, down 5%.

BNEF's analysis showed particularly low levelized costs of electricity for onshore wind in India, Brazil, Sweden and Australia, and particularly low levelized costs of electricity for photovoltaics in Chile, India, Australia and Jordan.

## India

Taking India as an example, BNEF is now showing benchmark LCOEs for onshore wind of just \$39 per MWh, down 46% on a year ago, and for solar PV at \$41, down 45%.

By comparison, coal comes in at \$68 per MWh, and combined-cycle gas at \$93.

Wind-plus-battery and solar-plus-battery systems in India have wide cost ranges, of \$34-208 per MWh and \$47-308 per MWh respectively, depending on project characteristics, but the center of those ranges is falling fast.

"Competitive auctions for new renewable energy capacity have forced developers, equipment providers and financiers to bear down on all the different costs of establishing wind and solar

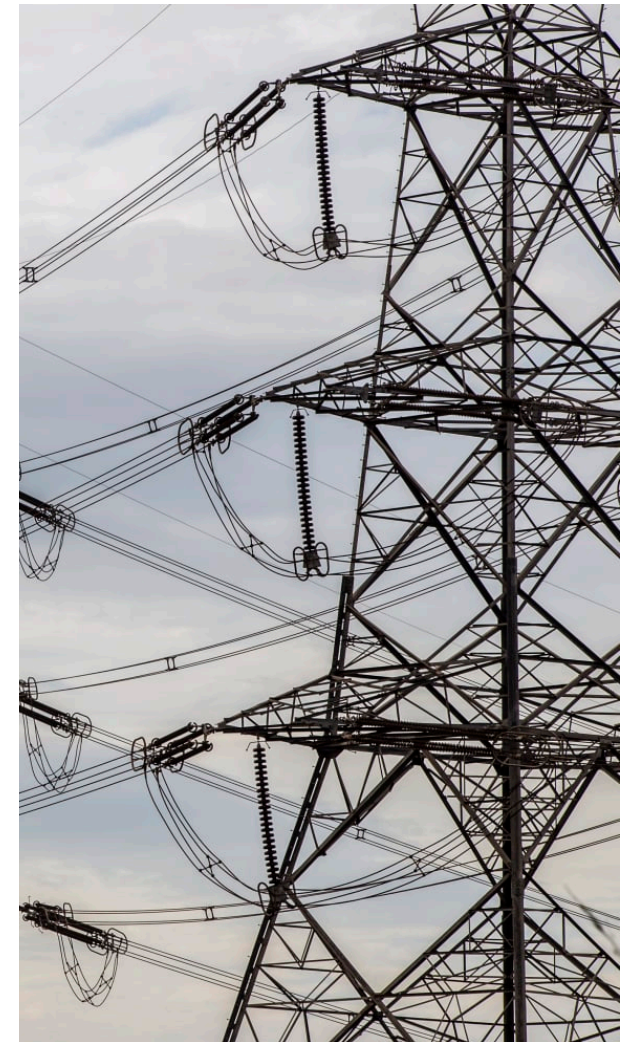
projects" said Seb Henbest, BNEF

"Thanks to this and to progressively more efficient technology, we are seeing record-low prices being set for wind and solar, and then those records being broken again and again on a regular basis. This is having a powerful effect - it is changing perceptions," he added.

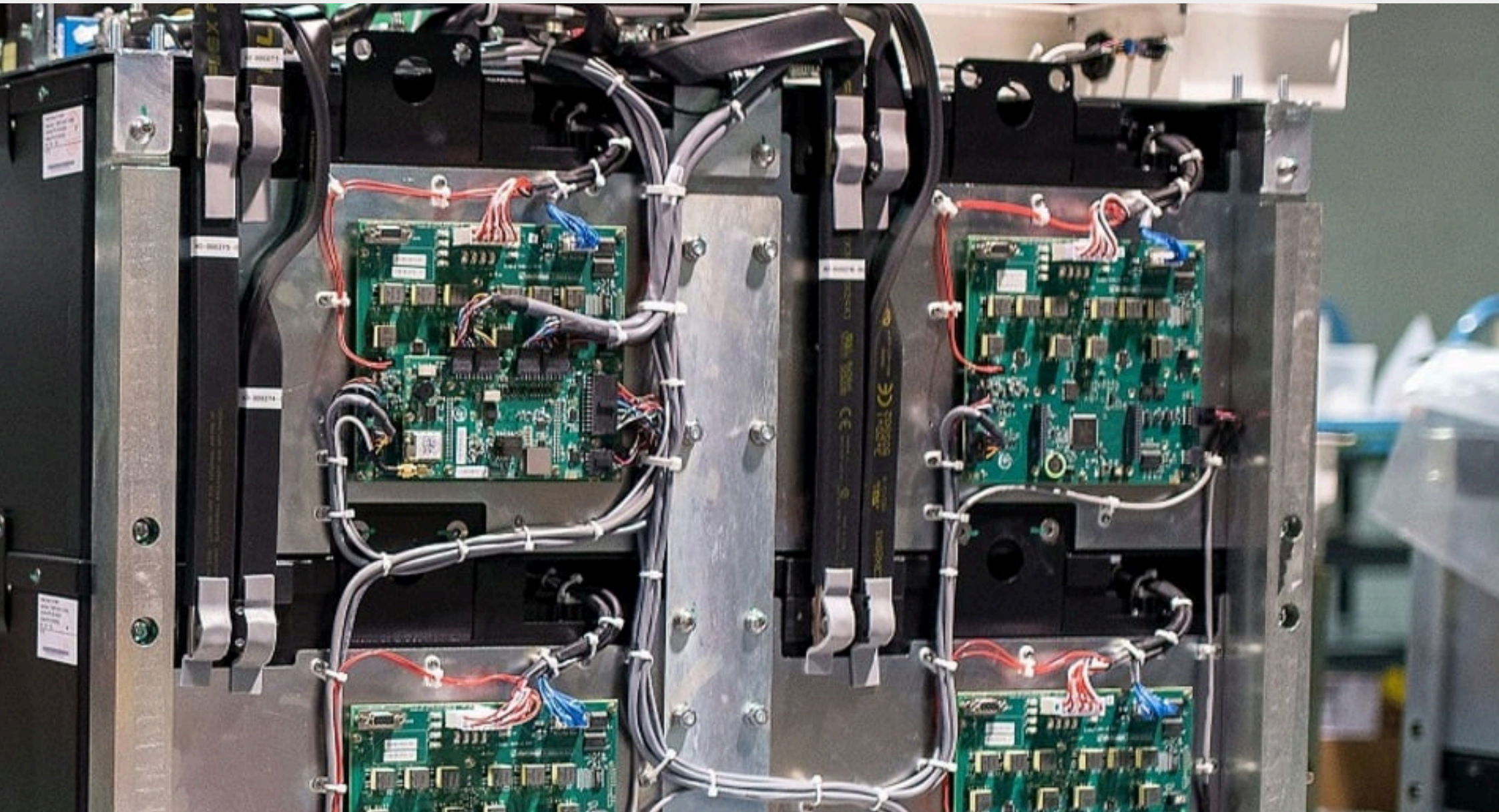
BNEF has been analyzing the numbers on LCOEs for the different technologies since 2009, based on its database of project financings and work by its analyst teams on the cost dynamics in different sectors. In that nine-year period, the global benchmark LCOE for solar PV without tracking has tumbled by 77%, and that for onshore wind by 38%.

LCOEs for older established sources, such as coal, gas, nuclear and large hydro, have seen only very modest reductions, at best, in that time - and in some countries, they have actually increased.

BNEF's lithium-ion battery price index shows a fall from \$1,000 per kWh in 2010 to \$209 per kWh in 2017.



# Batteries & their impact on the electricity sector.

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As PV and onshore wind emerge as the cheapest sources of bulk generation, flexibility becomes a top priority for power grids across the world.

In the meantime, the wide deployment of EVs drives the cost of batteries down.

Cheap batteries mean that wind and solar will increasingly be able to run when the wind isn't blowing and the sun isn't shining.

We expect 1,291GW of new battery capacity added to 2050, some 40% of which will be placed behind-the-meter.

**1,291GW** Battery capacity added globally between today and 2050

**\$70/kWh** Price of a battery pack for stationary applications by 2030

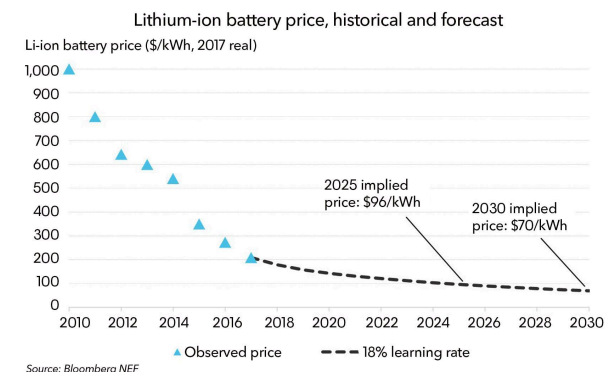
**40%** Share of behind-the-meter batteries globally in 2050 by MW

Source: Bloomberg NEF

## Global EV deployment drives down the cost of batteries

Battery prices are already down 79% in 2010, and we expect the ongoing build-out of battery manufacturing for electric vehicles to continue to drive down their prices for stationary applications, so that they reach \$70/kWh by 2030, 67% down from today.

This has profound implications for power grids across the world that are seeing the share of variable renewable penetration grow, making the need for flexibility a top priority.



## Cost competitive batteries mean that variable renewables will increasingly be able to run when the wind isn't blowing and the sun isn't shining

At present, flexibility is provided mainly by a combination of dedicated peaking plants, pumped hydro storage, interconnectors linking neighboring grid systems, and large-scale coal and gas plants that are capable of ramping up and down to meet changes in demand.

By 2030, the configuration of many systems is characterized by PV that meets daytime demand, and batteries that absorb excess generation and discharge at high value, low renewables times, particularly in the evening.

Renewables plus batteries operating together as virtual dispatchable units allow deeper renewables penetration and eat into the remaining market for coal, gas and nuclear.

**Asia Pacific** attracts 41% of the investment in batteries to 2050, with \$223 billion equally split between utility-scale and behind-the-meter storage.

**Europe** follows with \$168 billion, 77% of which goes to utility-scale batteries.

### Cheap renewables and the explosion of battery capacity are bad news for most thermal generators, but not all

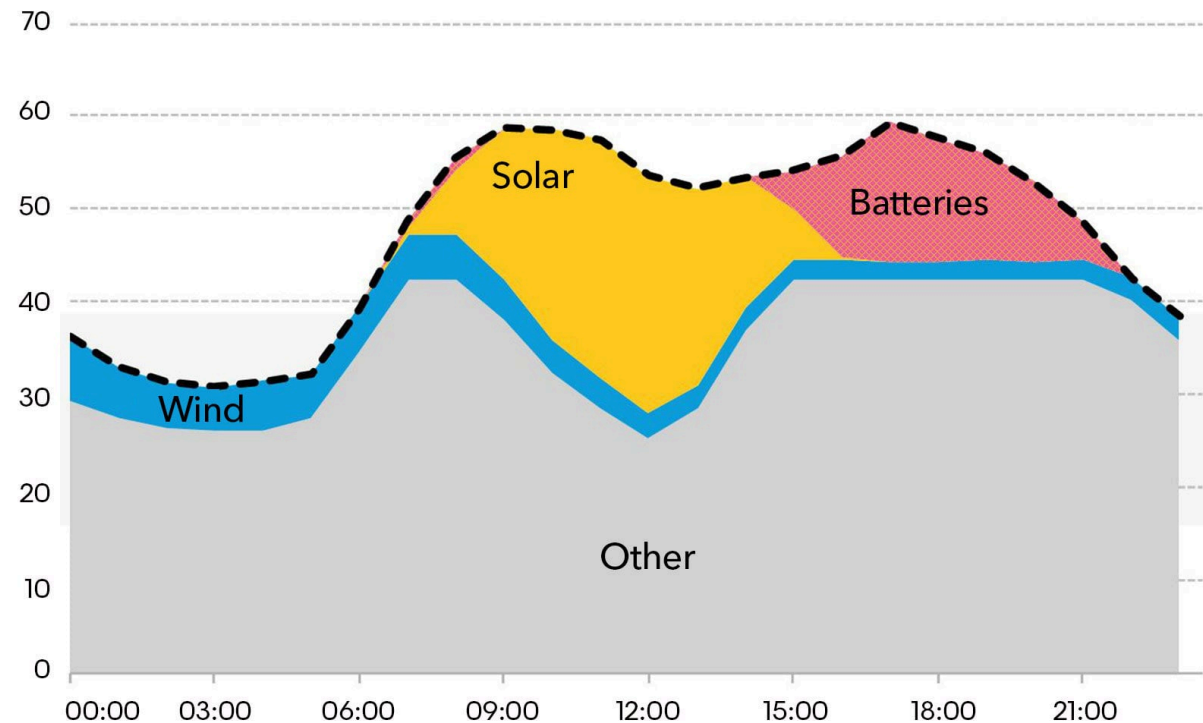
As thermal plants retire and variable renewables increase the variability on the supply side, new flexible capacity will be needed and there are limits to what renewables and batteries can do together.

Peaking gas emerges as a critical technology, to back up renewables during the extremes when wind and solar are at a minimum (sometimes this can be up to weeks at a time).

We expect peaker gas (i.e., open cycle gas turbines and gas reciprocating engines), to grow

## Cheap batteries can make solar and wind dispatchable

Intraday electricity generation (GW)



Source: Bloomberg NEF

by almost a factor of four by 2050, as a cheaper more nimble alternative to large-scale

CCGT (combined-cycle gas turbine) and coal-fired power plants running at low capacity factors.

# Electric vehicles & electricity demand.

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**Transportation becomes an increasingly important part of the electricity sector between now and 2050.**

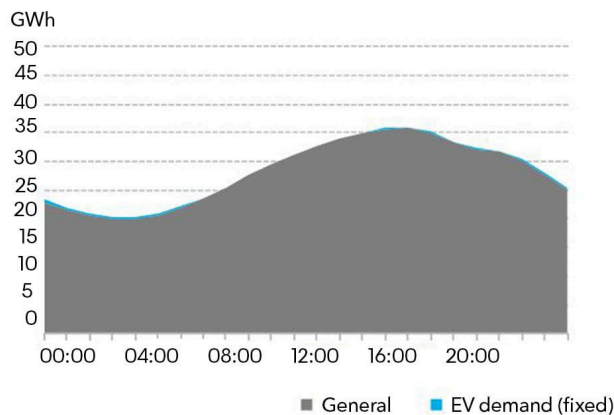
Our [Electric Vehicle Outlook](#) shows EVs (including light-duty vehicles and buses) growing from around 1.8% of global passenger vehicle sales today, to 55% of new sales by 2040.

This adds around 2,000TWh of new electricity demand globally by 2040 and 3,414TWh by 2050, when EVs account for 9% of all demand. In some countries, like Germany, this proportion is considerably higher, with EVs making up as much as 24% of total electricity demand by 2050.

Time-of-use tariffs and dynamic charging further support renewables integration: they allow vehicle owners to choose to charge during high-supply, low-cost periods, and so help to shift demand to periods when cheap renewables are running.

EVs don't just add to total electricity demand. As time-of-use electricity tariffs become increasingly available, we think more and more EV charging

California - Typical daily demand profile, summer day, 2017



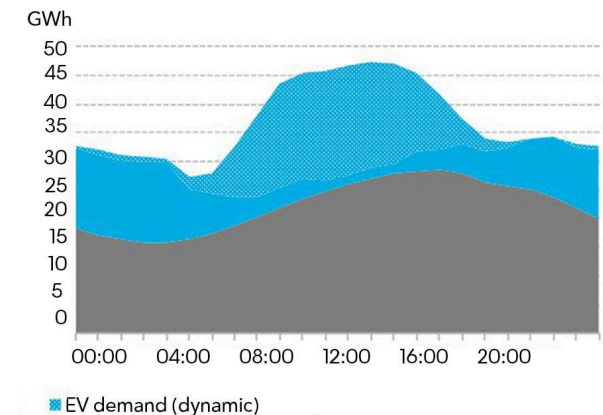
Source: Bloomberg NEF

will occur during times when cheap renewables are generating.

Already, more than 25 U.S. utilities have already introduced or are trialling EV-specific time-of-use rate structures, typically with a large difference between peak and off-peak prices.

In the longer term, the growth of PV is likely to push flexible demand towards midday in many markets. Whether EV owners are able to seek out low-cost charging in this way will depend on the

California - Typical daily demand profile, summer day, 2050



availability of public and workplace charging infrastructure.

We estimate that by 2050, some 50% of the EV fleet is able to be plugged in at all times when not on the road, charging from the grid via a time-of-use tariff whenever cheap renewables are running. That means that by 2050 we expect around 4% of electricity demand to move - much of it going to the middle of the day, coinciding with the solar maximum and supporting further build-out of PV capacity.

# Coal, gas, and impact on emissions.

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Since the 1970s, fossil fuels have commanded a consistent 60-70% share of the global power generation mix.

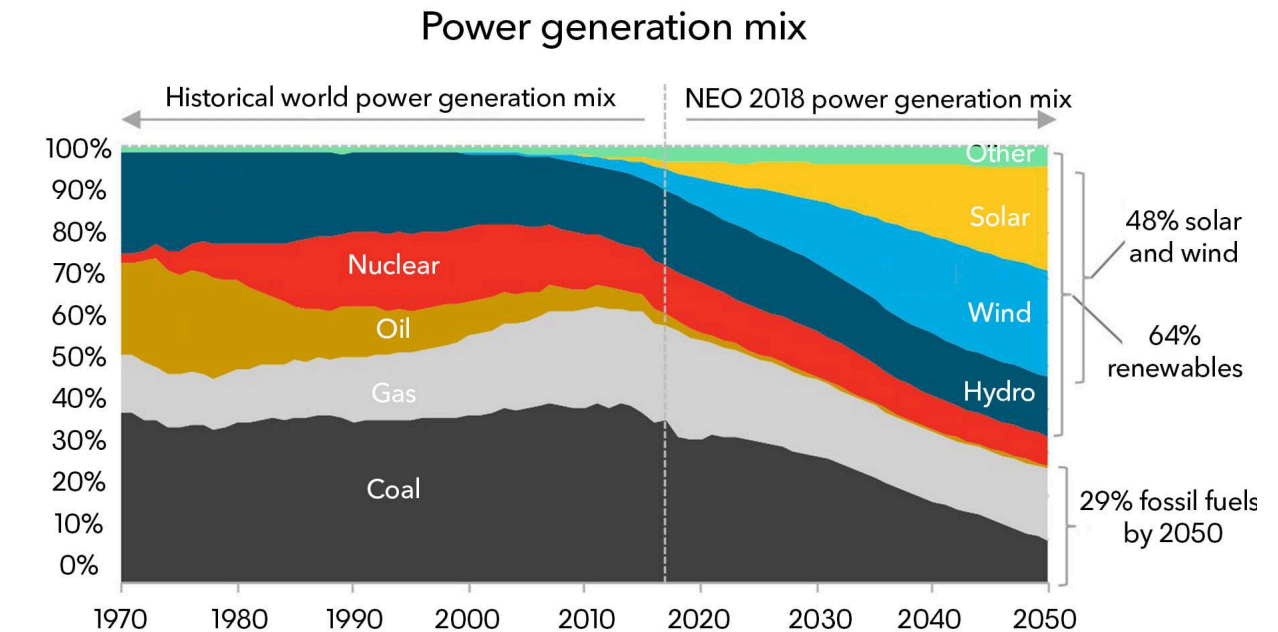
We think this 50-year equilibrium is coming to an end, as cheap renewable energy and batteries fundamentally remake electricity systems around the world.

**"By 2050, wind and solar technology provide 48% of total electricity - "50-by-50" - with hydro, nuclear and other renewables providing a further 23% of zero-carbon electricity."**

Seb Henbest, BNEF

### Coal is the biggest loser

Today coal makes up around 38% of global electricity generation, despite having already peaked in the U.S. and Europe, with China and India using coal for 66% and 79% of their electricity respectively.



Source: Bloomberg NEF, IEA.

However, as older plants retire and others get pushed out – first by an explosion of cheap wind and solar generation, then by cheap batteries – we think coal generation peaks globally in around 2027, before falling sharply to just 11% of world electricity by 2050.

### Gas consumption

Gas consumption for power generation increases only modestly out to 2050. Despite growing capacity in terms of megawatts, as more and more gas-fired facilities are either dedicated peakers or run at lower capacity factors helping to balance variable renewables, rather than run flat-out

around-the-clock. Gas use declines dramatically in Europe, grows in China and picks up materially in India beyond 2040.

The changes to the global generation mix cause power sector CO<sub>2</sub> emissions to peak in 2027 at 13.6 billion metric tons, then decline by 2% per year out to 2050. This most closely reflects the rise and fall of coal use in China and India. Emissions peak in China in 2030 and India in 2033.

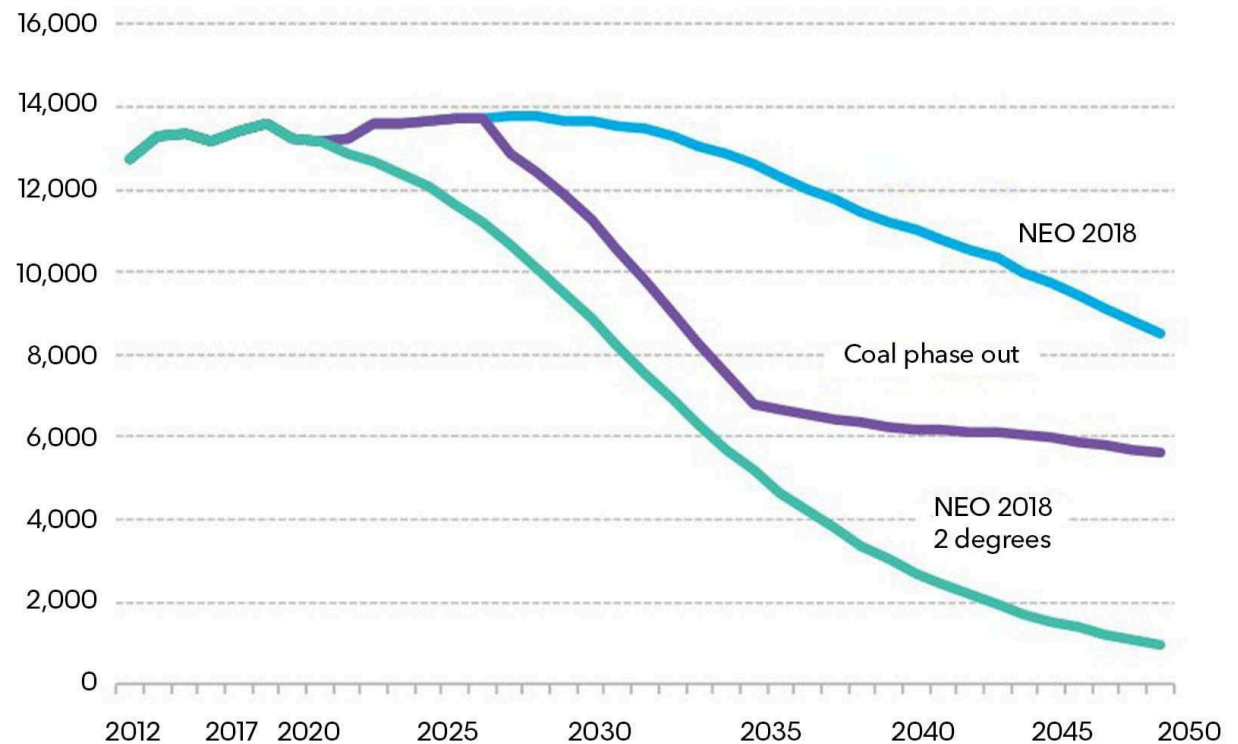
### How will we reach 2 degrees?

Getting rid of all coal-fired power still would not get us to 2 degrees. A forced phase-out of all coal-fired electricity worldwide by 2035 would lower emissions a further 54%.

That would also be good for gas and renewables, boosting the former by over 50%. Removing coal would also get us much closer to a 2-degree trajectory, the bad news is that it's not nearly close enough. To do that, we require new zero-carbon technologies that can decarbonize gas at scale or supplant its role in the system.

## Global power sector emissions under the different scenarios

Global power sector CO<sub>2</sub> emissions (MtCO<sub>2</sub>)



Source: Bloomberg NEF

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