ZERO-CARBON POWER IS A KEY MILESTONE ON THE ROUTE TO NET-ZERO

How the climate front-runners are discovering that zero-carbon electricity in the 2030s is key to meeting 2050 neutrality targets

EMBER

COAL TO CLEAN ENERGY POLICY

EMBER
COAL TO CLEAN ENERGY POLICY

Authors
Chris Rosslowe

Published date
April 2021

Disclaimer
The information in this report is complete and correct to the best of our knowledge, but if you spot an error, please email chris@ember-climate.org

Document design & layout by Wilf Lytton

Highlights

We analyse the latest energy scenarios informing UK and EU policy-making, and compare these with the announced US target for a zero-carbon electricity system by 2035. Commonalities offer insights into the actions required in the next 10-15 years to align with mid-century net-zero targets.

An 'unspoken consensus' is revealed between the UK, EU and US that clean electricity in the 2030s is crucial for net-zero by 2050.

A rapid end to coal-fired electricity can be seen across all scenarios, with major reductions before 2030.

Wind and solar become the dominant source of electricity from 2030 in the UK and EU, and the US could achieve the same.

Electricity generation from fossil gas declines in all regions in the next decade. A complete phase-out of unabated gas is recommended by 2035 in the UK and the same is implied by the US target.

Twenty-nine countries are committed to net-zero by 2050, including ten G20 members and over half of the OECD. However, these mid-century targets are not universally founded upon low carbon electricity in the next decade.

The stage is set for a high-ambition coalition on zero-carbon power by 2035 to emerge. Actions taken by this coalition could drive emissions reductions in the next decade, while adding integrity to net-zero targets.

Contents

Background to this briefing

Soon after taking office, President Biden issued an Executive Order on *Tackling the Climate Crisis at Home and Abroad*. This included one of the most eye-catching climate announcements from his administration yet: the promise of a "carbon pollution-free[1] electricity sector no later than 2035". This target is novel and seemingly world-leading among nations targeting net-zero. However, in this briefing we reveal the US isn't alone in aiming for a zero-carbon electricity system in the 2030s. Official analyses by the UK's Climate Change Committee (CCC) and the EU Commission (EU-COM) both point towards very low carbon electricity by 2035 or soon after. Like with the Biden announcement, the implications of these analyses are yet to be enshrined in law. However, they tell a common story that reaching net-zero emissions by 2050 requires a zero-carbon electricity system long before that date. The emergence of this pattern in official net-zero pathways is a consequence of the ever-improving economics and performance of renewable electricity. The idea that clean electricity can be a foundation for economy-wide decarbonisation is not new, but this could be the moment it enters mainstream thinking.

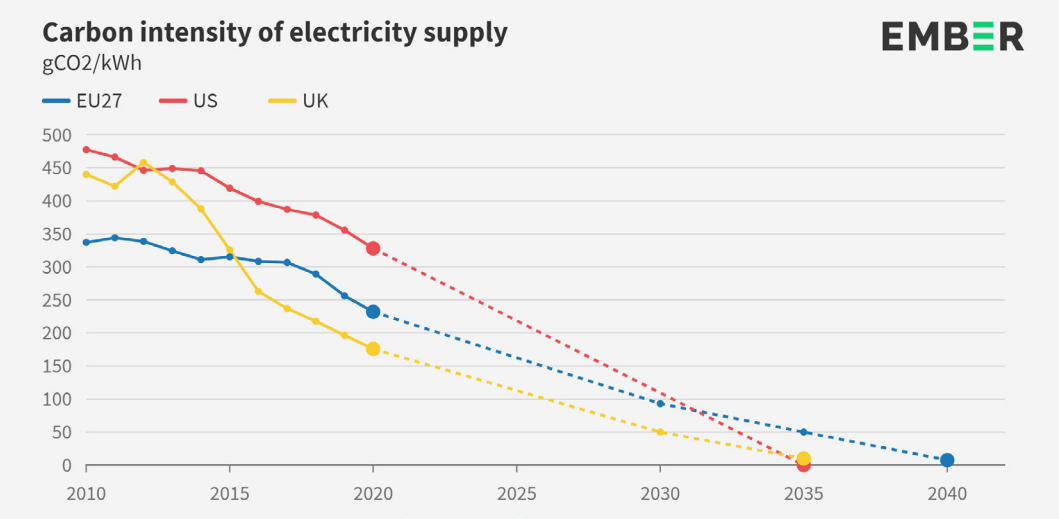
Recent years have seen a growing number of countries commit to net-zero by mid-century. On the eve of the US leader's summit, 29 countries (plus the EU) were committed to net-zero, including half of the OECD (21/37 members). While this is encouraging, anticipated emissions reductions in the next decade are not sufficient to remain on track to meet the Paris goals [1]. Key to getting the world on track will be phasing-out coal from global power systems, starting with OECD nations no later than 2030. The emerging consensus revealed by this briefing suggests the time could be right to extend a similar benchmark to all fossil fuels by 2035.

In this briefing we summarise energy scenarios by the European Commission (EU-COM) and UK Climate Change Committee (UK CCC). The scenarios considered serve to inform policy decisions, and do not reflect the specific intensions of the EU nor UK. However, the UK Government has accepted the carbon budget advice for 2030 and 2035 that is informed by the CCC analysis in question. Likewise, EU member states have agreed the 2030 climate target infomed by the scenarios in question. We compare these UK and EU scenarios to possible pathways the US might take to achieve zero-carbon power by 2035. Table 1 summarises the main scenarios informing our comparison. By highlighting common trends, we begin to piece together a blueprint for the near-term power sector interventions envisaged by climate leaders to achieve net-zero targets. We conclude with a brief assessment of power sector plans in other countries committed to net-zero by 2050, which reveals varying levels of clean power ambition in the next ten years, exposing a lack of credibility to mid-century goals.

1. The Executive Order doesn't define what qualifies as "carbon pollution-free". It is expected to include a wide range of technologies with zero or supposedly near-zero CO2 emissions, including bioenergy and fossil generation with carbon capture and storage.

FIGURE 1

Carbon intensity of electricity as indicated by official energy system analyses for the EU27 and UK, compared with the stated ambition for the US



The pathway for the UK sees the carbon intensity of electricity falling to 10gCO_2/kWh in 2035 and 2gCO_2/kWh in 2050. The pathway for the EU indicates an electricity supply with a carbon intensity of 40-60gCO_2/kWh in 2035, falling to 7-11gCO_2/kWh in 2050. The intensity of US electricity is shown as reaching 0g/kWh in 2035. This may however be higher, depending on what role is allowed for fossil CCS in the mix. Using the UC Berkeley 90% clean scenario as a guide, if the remaining 10% fossil generation were captured with a 90% capture efficiency, the intensity of the US grid in 2035 would be approx. 5gCO_2/kWh. If carbon capture were not applied, the political announcement would not be satisfied, and the resulting intensity would be approx 50gCO_2/kWh.

TABLE 1

Summary of scenarios forming the basis of UK-EU-US comparison in this briefing

UK

The 'Balanced pathway' by the UK Climate Change Committee - independent climate advisors to the UK government. This is one of several scenarios forming the evidence base for the sixth carbon budget advice to the UK Government. This advice constitutes the most detailed analysis available on how the UK can achieve the legally-binding carbon budget for the period 2033-37, as well as net zero by 2050. The UK Goverment is required by law to legislate on a sixth carbon budget before the end of June 2021, and recently announced it will accept the sixth carbon budget advice of the CCC and set an new emissions reduction target for 2035. It did not however agree to accept the recommendations in full. As a result, the Balanced pathway cannot be interpreted as an exact plan, but it is consistent with the legally-binding carbon emissions limits in 2030 and soon-to-be binding limit in 2035. In the words of the CCC, the Balanced pathway "*makes moderate assumptions on behavioural change and innovation and takes actions in the coming decade to develop multiple options for later roll-out*".

EU

The 'MIX' scenario presented by the European Commission as part of the impact assessment for raising the EU's 2030 greenhouse gas reduction target. This scenario, along with three other so-called 'policy scenarios', delivers -55% GHG emissions by 2030. The MIX scenario achieves these reductions by extending the scope of the ETS to buildings, road transport and intra-EU aviation and maritime navigation. It also models a 'medium' increase in ambition in renewables and energy efficiency policies.

US

While we await further details about how "carbon pollution-free power" by 2035 will be achieved, we consider a range of analyses and modelling exercises focused on net zero by 2050. One of the few studies to focus specifically on the 2035 target is the 2035 report by UC Berkeley (UCB), which presents a '90% clean' scenario, whereby 90% of electricity generation is provided by clean sources, i.e., sources not producing carbon emissions (a category in which the authors include bioenergy).

Comparing the plans

The electricity supplies in all three regions have been tending towards lower carbon intensity for several years (Figure 1). As things stand, the UK and EU have a head-start on the US, largely due to faster progress phasing out coal. However, looking ahead, such is the ambition of Biden's 2035 target that the US is set to make up ground quickly.

Here we summarise the key features of the available analyses and what we know about the stated UK, EU and US plans to eliminate carbon from power by the 2030s. This comparison is structured around three essential themes:

- Commitments to phase out existing fossil-fired generation, and implications for new capacity.
- Action to ramp up solar and wind, to both replace fossil-fired generation and meet growing demand.
- Strategies to secure clean firm power and flexibility options to back up a power supply dominated by variable renewables.

We ask: what do the UK, US and EU have in common and how do they differ across these three key themes?

1) Phasing-out fossils:

The available scenarios show that all three regions are united in a rapid end to coal-fired electricity, with large reductions coming before 2030. A reduction in unabated fossil gas is also a universal feature, with a 2035 phase-out recommended in the UK and the same target implied by the US announcement. The EU figures leave more room for unabated gas, with generation falling 10% between 2020 and 2030, and 63% by 2050.

Regarding new fossil generation capacity, both the UK-CCC and the UC Berkeley study for the US conclude there is little if any need for new capacities. The same cannot be concluded from the EU-COM scenario directly, however the common end-point of a very low carbon electricity by 2035 has a shared implication for new gas assets in the UK, US and EU. New gas assets will be required to operate with either low load factors or low carbon emissions well before the end of their economic lifetimes (typically 25 years).

In the table below we provide a summary of the consequences for coal and (fossil) gas-fired electricity. The details available for each region are expanded on below.

TABLE 2

The endgame for fossil-fired power generation

	UK	EU27	US (indicative)
Coal	Phase-out by 2024 (Government commitment, pending law)	Approx. 50TWh in 2030, or 2% of generation (an 84% reduction from 2020)	Phase-out before 2035, possibly as early as 2030 according to a synthesis of net-zero studies.
Fossil gas (without CCS)	Phase-out by 2035 (recommendation)	490TWh in 2030, or 15% of generation (a 10% reduction from 2020) 200TWh in 2050, or 3% of generation (a 63% reduction from 2020)	Phase-out by 2035 in order to deliver on the carbon-free electricity target.

Dates for the UK are taken from government announcements (coal) and the UK CCC Balanced Pathway. Data for the EU27 is retracted from policy scenarios in the EU-COM impact assessment for the new 2030 greenhouse gas target. Implications for the US follow an assumption that no unabated fossil generation will contribute to the mix after 2035. The conclusions are supported by various energy modelling studies, principally the Berkeley 90% clean scenario.

UK

- The UK has already largely phased out coal power, which rapidly declined from 40% to 2% of production between 2012 and 2020. The last remaining coal plants will close by 2024, a year earlier than initially planned.
- The CCC has advised the UK government to phase-out unabated fossil gas generation by 2035 (or retrofit it for CCS or hydrogen). In terms of capacity, they advise no new unabated gas capacity after 2030, and to ensure that everything deployed after 2025 is robustly[2] ready for CCS or hydrogen burning. Delays in legislating a gas phase-out risks creating stranded assets. The UK capacity mechanism recently awarded 15-year contracts to 1.4GW of new gas capacity. As exposed by Ember, all winning units were below the 300GW threshold that would currently require them to be "CCS-ready" [2].

US

- For the US, a recent review of modelling studies targeting net zero by 2050 shows that coal is universally phased out of electricity production before 2035, and in some cases as early as 2030. In the 90% clean scenario by UC Berkeley, coal is phased out of power by 2035 with base assumptions, or as early as 2033 with a lower than expected gas price.
- In the UCB '90% clean' scenario unabated gas provides approximately 10% of generation in 2035, down from 40% in 2020, and importantly **no new gas capacity** is developed from today.

EU

- Detailed analysis of the EU-COM figures by Ecologic and Climact [3] reveals that the new -55% GHG target leaves room for only 50TWh (approx) of coal-fired electricity in 2030. This implication is, however, yet to sink in with some member states. Ember analysis of Poland's recent energy plan [4] reveals that anticipated Polish coal generation alone would exceed this limit. Other MS coal strategies also demand a slice of this coal budget in 2030: Germany plans to phase out coal as late as 2038, and ongoing discussions in Czechia and Slovenia only consider phase-out after 2033.

2. details

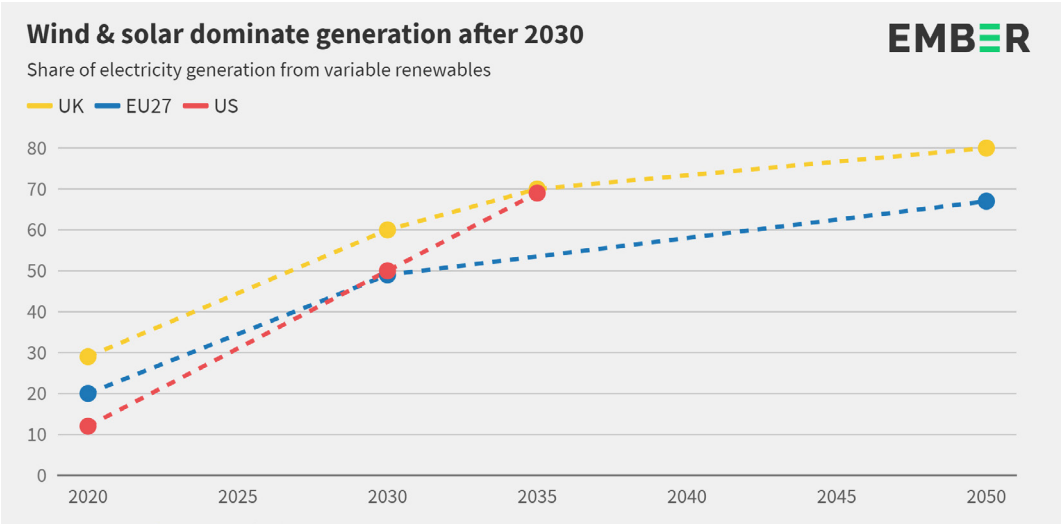
- The future of fossil gas-fired electricity according to the EU-COM's assessment is one of long, slow decline. This is seemingly at odds with recent comments by Vice-president Timmermans that "fossil fuels have no viable future … and that also goes for fossil gas, in the longer run". The EU-COM numbers foresee a 15% contribution to electricity production in 2030, similar to the 20% share in 2020. In absolute terms this is a modest reduction from 545TWh to 490TWh. In contrast to pathways for the US and UK, a 2035 phase-out is not visible, with 'unabated fossil generation' still accounting for 3% of production (~200TWh) in 2050.

2) Ramping-up variable renewables:

Scenarios for the UK and EU show huge increases in electricity generation from wind and solar, which together become the dominant source of electricity from 2030 in both regions (Figure 2). In the US, a similar rise to dominance for wind and solar is indicated by the Berkeley '90% clean' scenario.

FIGURE 2

Share of generation provided by variable renewable sources (wind & solar)



As indicated by official analyses for the EU27 and UK, and by the UC Berkeley 90% clean scenario for the US.

All scenarios analysed will require unprecedented expansion of wind and solar capacity, requiring a step-change in deployment rates if existing capacity targets are to be hit. Figures 3-5 compare historical growth to that implied by each scenario.

The rate of additions in recent years has fallen short of what will be required over the next decade. That being said, erratic growth of capacity in the UK and EU over the last decade has seen growth temporarily hit the levels needed in the near future. It is a different case in the US. To keep pace with the Berkeley scenario, combined growth of the wind and solar fleet would have to average 100GW per year until 2035, compared to an average of 13GW over the last 5 years. Aligning policy and unlocking finance to deliver the infrastructure needed is a core challenge for all administrations.

UK and EU

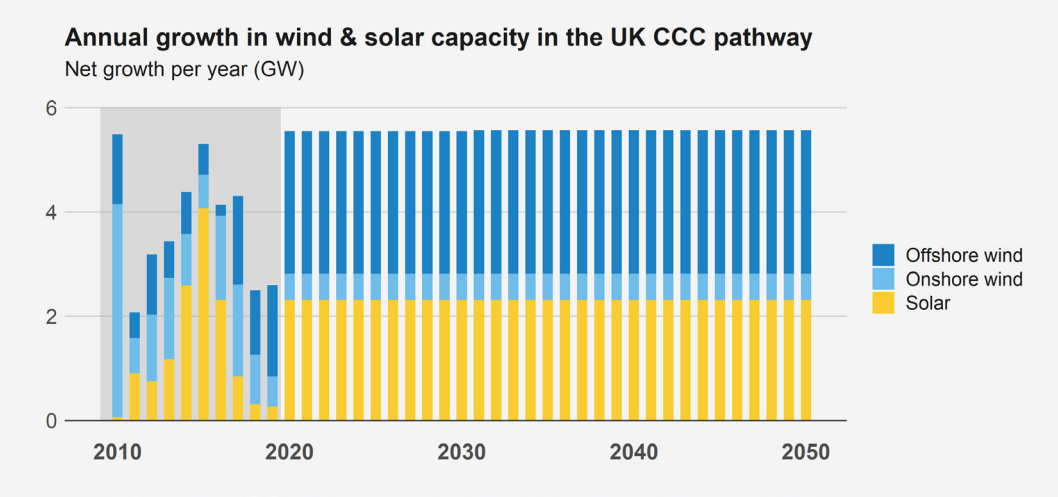
- The CCC pathway for the UK sees the share of wind and solar in generation increasing from 29% in 2020 to 60% in 2030, 70% in 2035, and 80% in 2050.
- The EU starts from a lower share of 20% in 2020. By 2030, the EU-COM figures show an almost three-fold increase in wind and solar, which combined provide 49% of generation, increasing to 67% by 2050.
- Although the EU starts from a lower share of variable renewables today, the contribution of renewables in total in the EU (38%) is similar to the UK (42%). Non-variable renewable sources, i.e., hydropower and bioenergy, providing 18% to the EU mix compared to 14% in the UK. The reason for this stems largely from greater hydropower resources in mainland Europe than the UK.
- Despite current differences, both UK and EU scenarios agree that wind and solar dominate growth in renewable generation to become the dominant source of electricity after 2030.
- A step-change in deployment rates will be required in order to hit capacity targets. Figures 3 and 4 show that growth in the last ten years has been erratic. Some years in isolation have seen fleet expansions reach the levels that will be required consistently over the next ten years.
- Both the UK and EU have set capacity targets for offshore wind, and the scenarios analysed here indicate the sizes of wind and solar fleets required. These targets and projections, and their implications for growth, are detailed in Box 1 and Figures 3-5.

US

- It can only be assumed that the US plan for zero-carbon power by 2035 will show a similar evolution in the generation mix. President Biden's administration has already taken steps towards this with a commitment to expanding offshore wind. The US starts with a comparatively low wind and solar share of 12% (2020). The Berkeley '90% clean' scenario indicates that a 70% share by 2035 is possible, which would be enough to overtake the EU and match the UK pathway.
- The US wind and solar fleets would need to expand at unprecedented rates to keep pace with the Berkeley scenarios. Figure 5 shows that historic growth has remained well below what would be required. Combined growth in wind and solar fleets has averaged 13GW over the last five years. This would need to accelerate to an average of 100GW per year until 2035.

FIGURE 3

Average annual additions of solar and wind capacity required to keep pace with the CCC balanced pathway

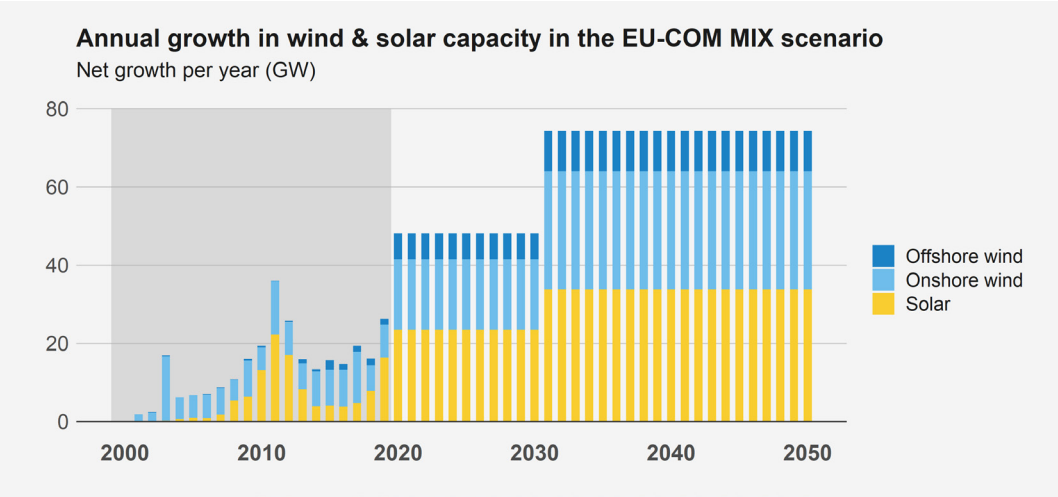


Actual deployment may need to be higher to account for retirements. The UK has historically achieved the solar and onshore wind growth required in individual years. Offshore wind growth must accelerate to meet the UK government's 40GW by 2030 target.

Source: Eurostat (2010-2019).

FIGURE 4

Average annual additions of solar and wind capacity required to keep pace with the EU-COM policy scenarios

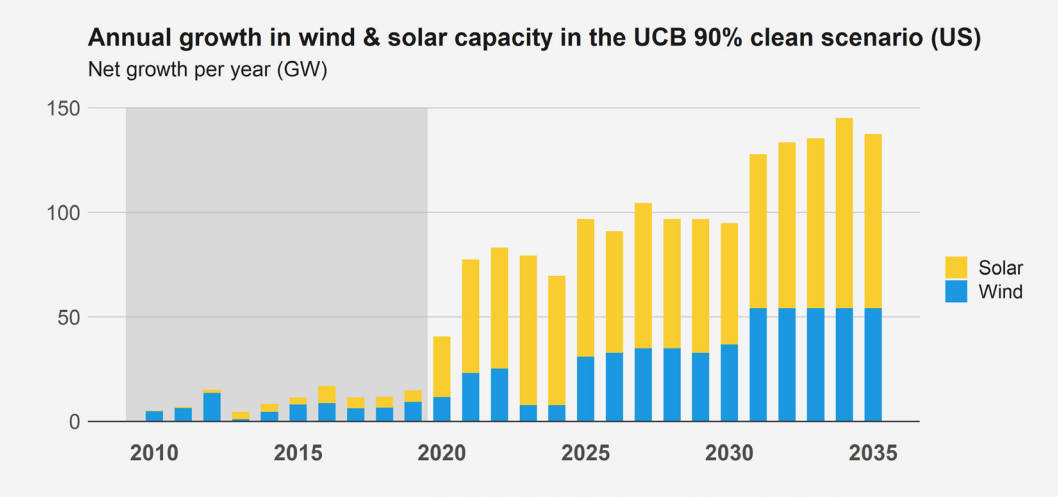


The EU wind fleet will need to grow faster than ever before. High solar growth has been achieved before (the 2011 peak can be attributed mostly to Germany's feed-in-tariff scheme), but this needs to be replicated every year to 2050.

Source: Eurostat (2000-2019).

FIGURE 5

Annual additions of solar and wind capacity required to meet the UC Berkeley 90% clean (2035) scenario for the US



Source: EIA (2010-2019) existing nameplate capacity (EIA-860)

BOX 1:

Wind and solar capacity targets and deployment rates

Historic installed capacity data is taken from Eurostat (UK and EU27) and the EIA (US, EIA-860).

- **UK:** The UK government is targeting 40GW offshore wind by 2030. The CCC Balanced pathway matches this increase, and sees the total grow to 95GW by 2050. Meeting these targets would require the fleet to grow at an average of 2.7GW per year until 2050. Average growth over 2010-2019 was approximately 1GW per year (Eurostat). The UK government has not equally embraced onshore wind, despite cost advantages over offshore. Nevertheless, the CCC pathway sees this expand from 14GW today to 30GW in 2050. Likewise, there is no official target for UK solar, but the CCC recommends 85GW by 2050, from approx. 14GW today. This would require the solar fleet to grow 2.3GW per year until 2050, compared to an average 1.3GW per year between 2010-2019.
- **EU:** The EU-COM figures indicate the need for 84GW offshore wind, 354GW onshore wind, and 376GW solar by 2030. The EU Commission has targeted 60GW offshore wind by 2030 as part of the offshore wind strategy. To reach 84GW by 2030, the offshore fleet will need to grow by an average of 6.5GW per year, a significant acceleration compared to the 1.1GW per year average between 2010-2019. Onshore wind growth will need to double from 9GW per year to 18GW per year. Similarly, growth in solar capacity will need to more than double from 10.1GW per year to 23.5 per year.
- **US:** UC Berkeley estimates the US will require 1100GW of wind and solar combined by 2035. This would require the addition of 70GW per year on average. In comparison, combined growth in wind and solar was only 3.7GW per year between 2010-2019

3) System flexibility and low-carbon firm power:

With electricity systems dominated by wind and solar after 2030, we compare how the scenarios propose to meet the challenge of integrating these sources while securing supply at all times. An in-depth review of security of supply in high-renewables systems is beyond the scope of this briefing, but the feasibility has been explored and proven by numerous studies [5].

The general changes necessary to transition the power system in a cost-effective way are well understood. Expanded transmission grids (including interconnection) play a crucial role in moving weather-dependent power across countries and continents. Strengthened distribution grids support a growing amount of distributed renewable generation. Increased storage capacity shifts abundant wind and solar to times of lower availability. Active participation on the demand-side helps to shift load away from peak times. Controllable generation still plays a role, supporting the system through periods of unfavourable weather. The available scenarios begin to outline progress on these fronts.

UK

- The UK CCC balanced pathway assumes hydrogen and/or gas CCS will be available by 2035, and therefore conditions the phase-out of unabated gas on these technologies. Notably, neither the gas phase-out nor the projected low carbon intensity in 2035 are contingent on Bioenergy with CCS (BECCS).
- So-called 'low-carbon dispatchable sources'[3] provide 13% of generation in 2030 and 9% in 2050.
- Nuclear capacity is assumed to remain at current levels to 2050, requiring 8GW of new capacity to replace units expected to retire. As a result, nuclear provides 10% of generation in 2050, down from 20% today.
- Electricity storage is provided by 18GW of batteries in 2035 and hydrogen plays an increasing role thereafter. This increased storage capacity, plus hydrogen electrolysers and more interconnection with Europe combine to limit curtailment of the large wind and solar fleet by 2050.
- Interconnection of the UK with neighbouring countries has a current capacity of 6GW. The CCC pathway sees this double by 2030 and triple by 2050.

EU

- For the EU27, the EU-COM figures show approximately stable nuclear generation and capacity until 2050, implying new capacity to replace nuclear plants either scheduled to retire or closing as a result of policy. As a result, nuclear provides 9% of generation in 2050.
- No gas CCS or BECCS feature in 2030. However in 2050, Fossil CCS and BECCS provide 4% and 2% of generation respectively. In total, low-carbon dispatchable sources provide 21% of generation in 2050.

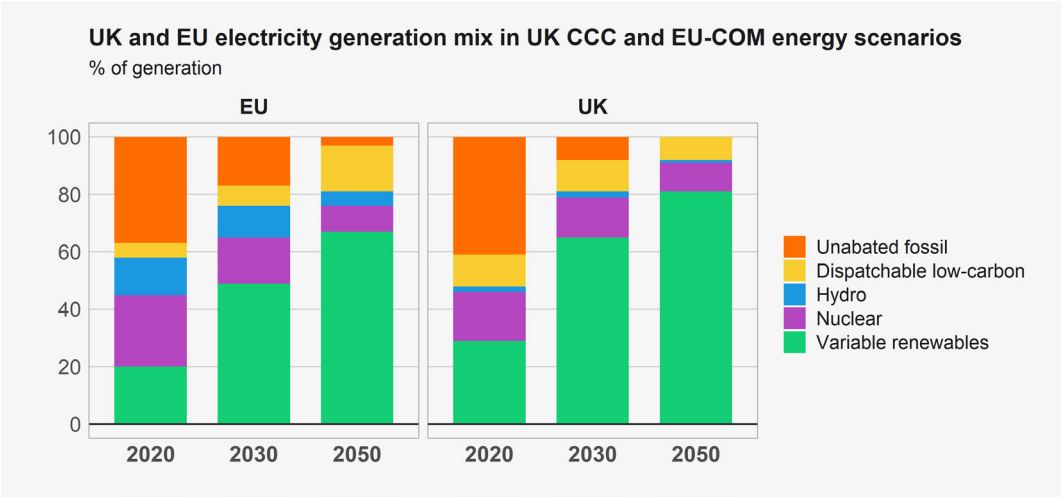
3. Including fossil CCS, BECCS, bioenergy, hydro, and other dispatchable renewables.

- Assuming the EU-COM scenarios are consistent with the latest Ten-Year Network Development Plan by ENTSO-E, transmission capacity across the continent is expected to increase 10% by 2030 [6].
- The EU system integration strategy features energy efficiency, energy storage and the synergies between renewable electricity and hydrogen electrolysis as key themes.

Figure 6 compares the overall generation mix in UK and EU scenarios in 2030 and 2050. By 2050, both indicate nuclear resources will retain an approximate 10% share of generation, indicating new nuclear capacity. Other low-carbon dispatchable sources provide an additional 10% in the UK and 20% in the EU. This difference is primarily driven by existing differences in the use of hydropower, with no major expansions planned in either region. After 2030 or 2035, both make use of yet unproven low-carbon dispatchable sources, however, the low carbon intensities reached in the 2030s are not contingent on these technologies, as their contributions remain small in 2050.

FIGURE 6

Comparison of the generation mix foreseen in the UK and EU by the scenarios compared in this briefing



For the CCC pathway, we assume all 'firm' generation comes from nuclear. In the EU-COM scenarios, we include 'other renewable' in the low-carbon dispatchable category, along with fossil CCS and BECCS.

US

- It's not clear how the US plans to provide low-carbon firm power. The 90% clean scenario maintains current output levels from non-fossil sources until 2035 (mostly nuclear and hydropower).
- The fleet of fossil gas generation halves to 360GW by 2035, and runs at decreasing capacity factors. CCS is not utilised.
- Battery storage is quickly and cost-effectively scaled-up to reach 150GW (600GWh) by 2035, and covers 20% of demand.
- It is widely acknowledged that an expanded transmission system will be required, although estimates of the extent vary.

The OECD should step up to the challenge of zero-carbon power by 2035

In the wake of the US leaders' summit in April, and in advance of COP26, the stage is set for a high-ambition coalition on zero-carbon power by 2035 to emerge. Following in the footsteps of the successful Powering Past Coal Alliance (PPCA), this coalition could spur international progress towards clean electricity while adding integrity to net-zero targets. The PPCA was instrumental in forging a consensus that OECD countries should be coal-free by 2030. The emerging consensus revealed by this briefing suggests the time could be right to extend a similar benchmark to all fossil fuels by 2035.

This begs the question; how are the power sector plans of OECD nations shaping up to meet these challenges? Coal phase-out commitments are a useful proxy for serious near-term intent to decarbonise electricity, and so it's informative to compare national net-zero pledges with their plans for coal.

FIGURE 7

G7 / OECD members, coal phase-out, and carbon intensity

Country	Net-zero status	G7	Coal phase-out date	Coal power share 2020	Carbon intensity trend
Canada	Proposed legislation	Yes	2030		
France	In law	Yes	2022		
Germany	In policy document	Yes	2038		
Italy		Yes	2025		
Japan	In policy document	Yes			
United Kingdom	In law	Yes	2024		
United States	In policy document	Yes	2035 (effective)		
Australia		No			
Austria	In policy document	No	Coal-free		
Belgium		No	Coal-free		
Chile	Proposed legislation	No	2040		
Colombia		No			
Czech Republic		No			
Denmark	In law	No	2028		
Estonia		No	Coal-free		
Finland	In policy document	No	2029		
Greece		No	2025		
Hungary	In law	No	2025		
Iceland	In policy document	No	Coal-free		
Ireland	In policy document	No	2025		
Israel		No	2025		
Latvia		No	Coal-free		
Lithuania		No	Coal-free		
Luxembourg		No	Coal-free		
Mexico		No			
Netherlands		No	2029		
New Zealand	In law	No			
Norway	In policy document	No	Coal-free		
Poland		No			
Portugal	In policy document	No	2021		
Slovakia		No	2030		
Slovenia	In policy document	No			
South Korea	Proposed legislation	No			
Spain	Proposed legislation	No	2030 (effective)		
Sweden	In law	No	2020		
Switzerland	In policy document	No	Coal-free		
Turkey		No			

According to ECIU's net-zero tracker [7], 29 countries are targeting net-zero, plus the European Union. Six of these have net-zero in law, another six have legislation proposed (one of these being the EU), and another 18 have net-zero in a policy document. These net-zero countries include six of the G7 and 21 of the 37 OECD members. However, some of these countries stand out as being particularly far off the pace in the power sector transition. The following statistics assume that a US coal phase-out before 2035 is implied by the zero-carbon power sector target.

- Japan is the only member of the G7 without a coal phase-out commitment.
- Germany's coal phase-out date of 2038 is the latest in the G7 and incompatible with the Paris agreement.
- In the OECD:
  - » Of the 37 members, 21 are targeting net-zero and 18 have coal policies aligned with the Paris agreement[4]. Only 14 can claim both. This would rise to 15 were the US to announce coal phase-out by 2030.
  - » Japan and South Korea are the highest coal users in the OECD committed to net-zero without accompanying this with a coal phase-out commitment. They are also the 4th and 5th largest coal users in the world.

The disparities between net-zero targets and near-term power sector plans expose a credibility gap that must be closed. Coal phase-out is just the first step in this process. Leaders committed to mid-century climate neutrality should heed the emerging consensus and join the US in a commitment to zero-carbon power by 2035

4. Analysis of IPCC scenarios by Climate Analytics shows that EU and OECD countries should end coal-fired electricity generation no later than 2031 to remain consistent with the Paris agreement.

Conclusions

This briefing has explored the most detailed energy scenarios currently informing policy-making in the EU and UK, and compared these to the US target for zero-carbon power by 2035. Taken together these plans reveal a consensus among climate leaders that zero-carbon power in the 2030s is a necessary stepping stone to net-zero by 2050. While the economic logic for this is well established, and the same conclusion is reached by many other contemporary studies, seeing it borne out in official policy analyses brings into focus the immediate actions required. Given the long timescales involved in deploying electricity infrastructure, and the long lifetimes of assets, it is paramount that policy and finance begin to align with this zero-carbon power future today.

The direction of travel in all three power systems is set towards major reductions in coal generation by 2030, followed by varying but substantial reductions in fossil gas. The UK and US appear aligned on an exit from unabated fossil gas by 2035, while the EU leaves room for a marginal role. Solar and wind grow rapidly to become the dominant sources of electricity in the UK and EU from 2030, and the same is possible in the US. The importance of expanded grids and storage is emphasised across all scenarios to incorporate large shares of wind and solar. All scenarios feature a mix of controllable, low-carbon sources of electricity. The precise mix of CCS, nuclear, bioenergy, or hydrogen appears to depend on uncertain technological progress, future costs, and political priorities.

Despite an increase in mid-century net-zero targets, we find evidence that OECD countries are falling short on key clean power targets in the near term. In the wake of the US leaders summit, and in the run up to COP26, the stage is set for leaders to raise ambition and join the US in targeting zero-carbon power by 2035.

Notes on methodology:

- Historic carbon intensities in Figure 1 are calculated using generation data reported in Ember's Global Electricity Review (2021). Standard carbon intensities for each fuel type were applied for all regions. These were 850gCO2/kWh for hard coal, 1050gCO2/kWh for lignite (EU only), 400gCO2/kWh for fossil gas, and 650gCO2/kWh for other fossil fuels. A more accurate approch would account for regional differences in intensity by fuel type. However, we found that applying these standard intensities to fuel-specific generation data reproduced reported power sector emissions with reasonable accuracy (within 10%).
- Future carbon intensity for the UK was taken as presented by the CCC for the balanced pathway. It was not possible to confirm whether carbon intensities by fuel are consistent between historic calculations and future predictions.
- Future carbon intensity for the EU supply was calculated using data extracted from the EU Commission's 2030 Impact Assessment (IA). Power sector emissions for policy scenarios are given in Table 39 of the Annex, from which we take 289MtCO2 for the MIX scenario in 2030. Generation data presented in Figure 46 of the Annex shows approximately 200TWh of unabated fossil in 2050, which we assume to be all fossil gas, and by use of emissions factors estimate power sector emissions of 80MtCO2. The trajectory of emissions between these points is implied from Figure 20. Power sector emissions in 2035 in the MIX scenario are estimated to be 200±20MtCO_2.
- Figures 3-5 assume even annual growth in wind and solar capacity to achieve the capacity totals available for 2030, 2035, 2040, 2045, or 2050. This is not equivalent to deployment, which will have to be higher to accont for retirements.

References and sources

[1] *UNFCCC NDC Synthesis report* (Feb 2021) https://unfccc.int/process-and-meetings/the-paris-agreement/nationally-determined-contributions-ndcs/nationally-determined-contributions-ndcs/ndc-synthesis-report#eq-5

[2] Ember (Mar 2021): *UK spent £350m on new gas power despite nearing fossil phase-out* https://ember-climate.org/commentary/2021/03/12/uk-new-gas-power/

[3] Ecologic (Sept 2020): *Analysing the Impact Assessment on Raising the EU 2030 Climate Target* https://www.ecologic.eu/17589

[4] Ember (Mar 2021): *Disappointing lack of ambition in Poland's Energy Policy until 2040* https://ember-climate.org/commentary/2021/03/15/pep2040/

[5] Brown et al. (2018), *Response to 'Burden of proof: A comprehensive review of the feasibility of 100% renewable-electricity systems,* Renewable and Sustainable Energy Reviews, 92, 834-847

[6] ENTSO-E Ten-Year Network Development Plan 2020 https://tyndp.entsoe.eu/maps-data

[7] ECIU Net Zero Tracker https://eciu.net/netzerotracker

Executive Order: *Tackling the Climate Crisis at Home and Abroad*

EU Commission Impact Assessment: Investing in a climate-neutral future for the benefit of our people, (Sept 2020) https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52020SC0176

UK Climate Change Committee: Sixth Carbon Budget Advice, (Dec 2020) https://www.theccc.org.uk/publication/sixth-carbon-budget/

UC Berkeley: 2035 report, (June 2020) https://www.2035report.com/

Breakthrough institute: What New Net-Zero Studies Tell Us About Electricity Decarbonization, (Feb 2021) https://thebreakthrough.org/issues/energy/new-net-zero-studies-on-electricity-decarbonization

Historic electricity generation data presented in this briefing is taken from Ember's Global Electricity Review 2021

EMBER

COAL TO CLEAN ENERGY POLICY