Economic Affairs Committee inquiry:

UK energy supply and investment

UK Energy Research Centre response

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About UKERC

The UK Energy Research Centre (UKERC) carries out world-class, interdisciplinary research into sustainable future energy systems.

UKERC is a consortium of top universities and provides a focal point for UK energy research and a gateway between the UK and the international energy research communities.

Our whole systems research informs UK policy development and research strategy.

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Introduction

1. UKERC has particular expertise in the energy system changes needed to deliver decarbonisation. In our submission the questions where we have expertise and insights, providing a summary of some of the main issues. In many cases the issues are complex and wide ranging, with interactions between and across questions. UKERC has the capacity to organise workshops, roundtables and briefings and we would be happy to discuss any of the issues presented in our submission in more detail.

Questions

1. To what extent are the causes of recent rises in energy prices likely to be long-term features of global energy markets? Are the Government's policies for reducing the impact of higher energy prices on consumers sustainable and in line with long-term energy objectives? If not, what alternatives are there?

2. Recent rises in gas and oil prices have their origins in the record low prices experienced in the first Covid-19 lockdowns. This is best understood as a boom-and-bust cycle with the amplitude exaggerated by unprecedented events as the world has never experienced a demand shock quite like Covid-19. In very simple terms the collapse in demand due to world-wide lockdowns led to reductions in supply, and supply then failed to keep pace with demand rebounding, compounded by geopolitical and geographical or climatic factors. A sequence of events that UKERC has described in a variety of blogs and publications[1,2,3] includes the cold Asian winter and hot summer of 2021, what now looks like deliberate restrictions on gas supply to Europe from Russia, leading to low levels of gas storage at the start of last winter and now the war in Ukraine. It is important to emphasise that the levels of price volatility in the gas market are unprecedented. Swings of 50% have been seen before, increases of 500% have not. However, it is not possible to conclude from any of this that high prices are now permanent. High prices for the next year look extremely likely and we must prepare for next winter on that basis. Beyond that, it is simply too soon to say.

3. Short term policies have focused on helping consumers cope with increasing prices, principally through various rebates or tax breaks. In the coming 12 months or so it will be important to continue to provide financial support, particularly to vulnerable consumers. Whether this sort of fiscal and/or redistributive intervention is financially sustainable is not a question for energy policy. However, the recent cuts on VAT on energy efficiency products demonstrate how it is also possible to align short term concerns about prices with longer-term goals, since improved energy efficiency is a long-standing policy goal. Energy efficiency and energy saving also offer some short-term opportunities. This is because there are simple measures many households could implement this summer, in time for next winter. The so-called lower hanging fruit include insulating lofts and cavity walls, servicing boilers, fitting thermostats and attending to draft-proofing. Alongside tax incentives for insulation, government also

[1] Bradshaw. 2021. UK consumers pay for the cost of 'Gas by Default'. Access here.
[2] Bradshaw. 2022. Energy prices are unlikely to fall in 2022 or beyond. Access here.
[3] Gross et al. 2021. Review of Energy Policy 2021. Access here.

needs to provide a programme of information and advice. It is also important to make a start on long overdue investment in the capabilities we need to overhaul the UK's building stock and ramp up the skills and supply chain we need to insulate our homes better. We discuss energy efficiency in the answer to Q8.

4. However, we cannot physically change the energy system very much in time for next winter. Over and above what is already under construction, we cannot build new wind farms, nuclear power stations, gas storage facilities or even implement widespread home insulation that fast. It is important to make a start and do what we can in the short term, but it is also important to be realistic. For this reason, the solutions to the price crisis need to be seen in terms of timescales. What we can do can be divided into actions that can take place in the short, medium and long term.

5. *Short term* (this year) the primary focus needs to be on helping consumers financially and on the quickest and easiest energy efficiency improvements. Within the constraints of the global market, we also need to work with our European partners in a collaborative effort to secure gas supplies and to share both shipments of gas and storage. We elaborate on this point in our answer to Q3.

6. *Medium term* (over the next 2 to 5 years) we need to go further with energy efficiency. Some additional renewables schemes could come on stream in this timeframe (new offshore windfarms are already under development but more onshore wind and solar could be brought forward, particularly schemes that already have planning permission). We may also be able to temporarily extend the life of some existing assets such as nuclear and coal-fired power stations.

7. It is only in the *longer-term* of 5 years and beyond (in some cases many years hence) that we will be able to deliver some of the options that seem to attract most media attention – new nuclear stations, further expanding offshore wind, substantial shifts to electric heat pumps and cars, or indeed developing new oil and gas fields.

8. Once the timescales for significant changes to the energy system are properly understood it is also clear that many of the things already planned as part of the net zero strategy align very well with the current emphasis on energy security and prices. The prices of renewables and storage have fallen and are not volatile. Energy efficiency insulates households and businesses from price swings. The surest way to reduce the impacts of fossil fuel price volatility on our well-being and economy is to continue and accelerate existing efforts to diversify away from gas and oil.

2. What are the main challenges as regards energy supply and storage which public policy must address over the next decade?

Expanding low carbon energy supply

10. The emissions associated with the production of energy need to reduce significantly in the coming years. While those associated with production of electricity reduced by 70% between 2008 and 2019, in 2019 electricity served only 17% of final energy consumption.[4] The other 83% of energy demand must switch away from high carbon sources, notably to electricity, and the emissions intensity of electricity production must further reduce such that the sector meets the UK Government's target of zero emissions by 2035. In other words, emissions from the production of electricity must fall while demand grows, with total electricity demand more than doubling by 2050 according to the Climate Change Committee's (CCC) Balanced Pathway.

11. The UK Government has set a target of 40 GW of offshore wind capacity by 2030. A total of 10.4 GW had been installed by the end of 2020 along with 14.1 GW of onshore wind capacity and 13.5 GW of solar PV.[5] The 2030 offshore wind target requires an average of around 3 GW of additional capacity each year throughout the decade. This can be compared with the highest annual expansion of the UK's offshore wind fleet of 1.7 GW in 2017 and 2019 (Figure 1).

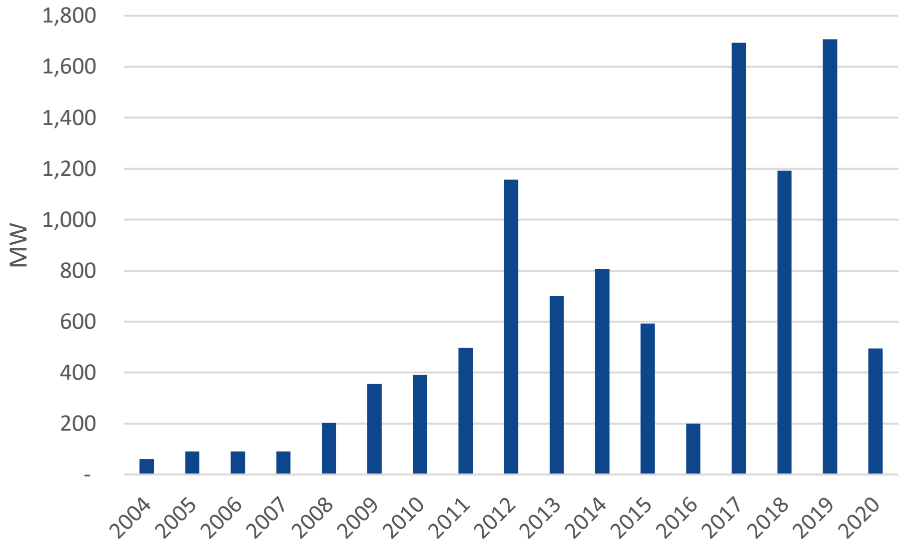

Figure 1. UK offshore wind capacity added each year[5]

12. As we discuss in our answer to Question 4, it is clear that substantial investment is required, not just out to 2030 but beyond, to reach offshore wind capacity of over 100 GW and solar PV capacity of over 120 GW by 2050 as envisaged in the CCC 6th Carbon Budget 'Balanced Pathway' if capacity factors of 45% and 10% respectively

[4] James Dixon et al., *Energy technologies for net zero*, The Institution for Engineering and Technology, 2021

[5] BEIS. 2021. Digest of UK Energy Statistics (DUKES): renewable sources of energy. Access here.

are assumed.[6] Assuming a capacity factor of 30%, the CCC's Balanced Pathway also envisages over 40 GW of onshore capacity by 2050.

Balancing supply and demand throughout a year

13. According to the most recent estimates of the costs of electricity generation, published in 2020 before the recent escalations in the price of gas,[7] in terms of the simple 'levelised cost of energy' (LCOE) for projects commissioning in 2025 or thereafter, wind and solar power are by far the cheapest sources. However, LCOE does not tell the whole story of what is required to satisfy demand for electrical energy all year round.

14. As can be seen from Figure 2, the daily demand for energy varies significantly through the course of a year and from year to year. Demand also varies substantially within each day.

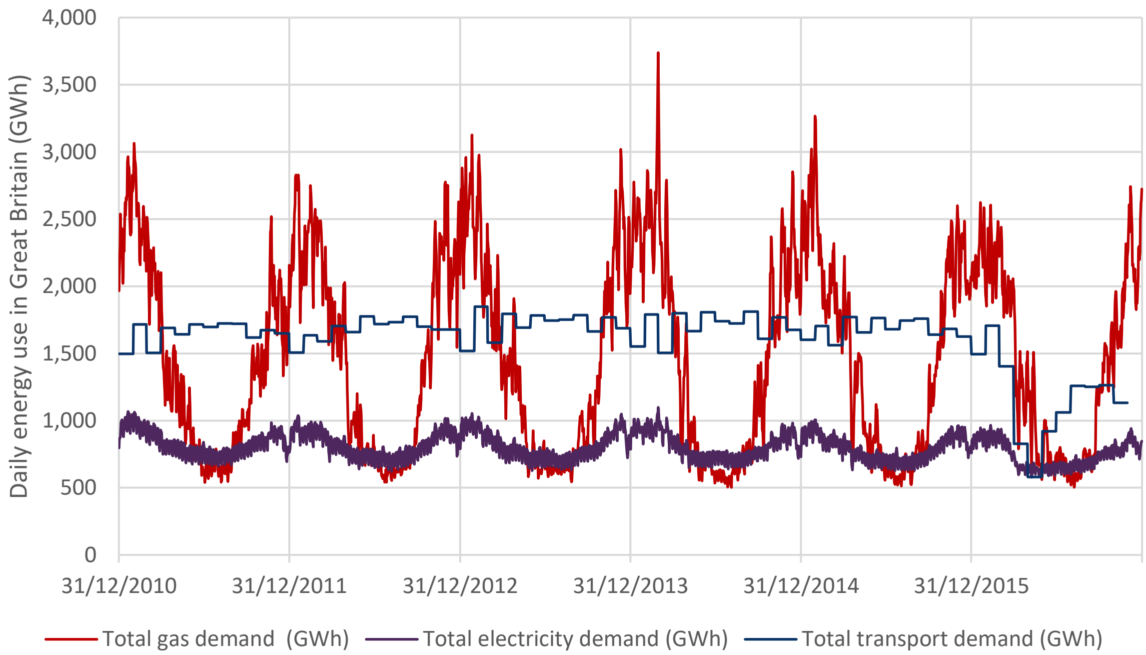

Figure 2. Britain energy carriers by volume: gas, electricity and transport fuels[8]

15. The gas and transport demand (the latter served by petroleum products) shown in Figure 2 are unabated, i.e. greenhouse gas emissions are not captured and stored. In future, those uses of energy will need to be served by low carbon sources, e.g. electricity from wind and solar. Conversion of demand for heating and of transport will massively increase electricity demand, but not by as much as might be assumed from looking at Figure 2. This is because electric heating using heat pumps and mobility using electric motors is significantly more energy efficient than approaches using fossil fuels. However, as can seen from **Error! Reference source not found.**, the

[6] Capacity factor is the annual average output relative to a generator's capacity.
[7] Dept. for Business, Energy and Industrial Strategy, Electricity Generation Costs 2020, August 2020.
[8] Figure courtesy of Grant Wilson, University of Birmingham. Data from National Grid, Elexon, and Department for Business, Energy & Industrial Strategy.

availability of power from wind and solar varies significantly through the year and, as evident from **Figure *4***, hour-hour.

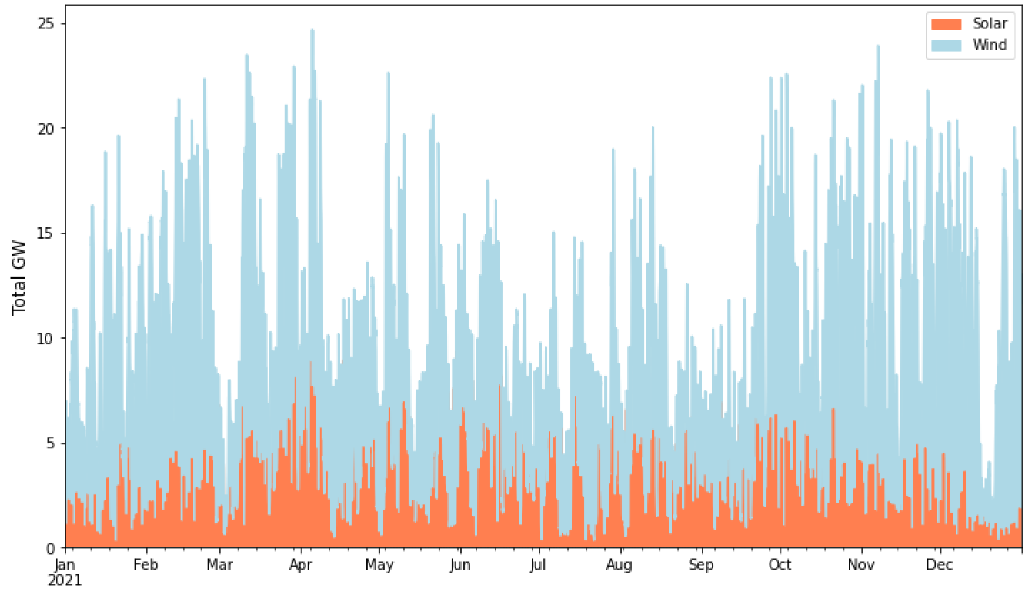

Figure 3. Total power available from wind and solar in Great Britain in 2021 showing the proportions from each source[9]

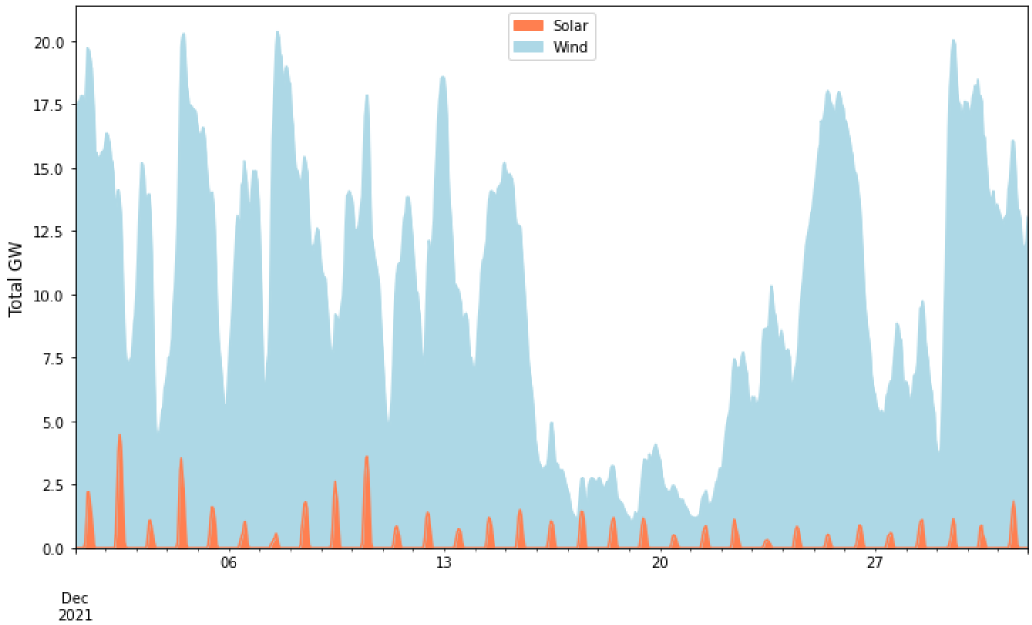

Figure 4. Total power available from wind and solar in Great Britain in December 2021 showing the proportions from each source

[9] **Figure *3*** and **Figure *4*** by Graeme Hawker, University of Strathclyde. Data from Elexon BMReports archive (Fuel Half Hourly data and logs of system operator balancing actions), NGESO Data Portal (demand and data on generation connected to distribution networks) and Sheffield Solar API (extrapolated solar PV production). It has been assumed that uncurtailed production of generators participating in the Balancing Mechanism reflects their 'Final Physical Notifications' submitted to that Mechanism.

16. Stable operation of the power system depends on matching generation and demand second-by-second. This has been achieved in Britain to date predominantly through use of stores of fossil fuels, used to generate electricity as demand varies through a day and across the year. The same stores of fossil fuels enable the meeting of demand for heat in industrial processes and the very large seasonal variation in demand for heat in buildings.

17. If we are to achieve net zero, future use of fossil fuel stores will be dependent on the capture and storage (CCS) of CO_2 emissions associated either with their combustion to produce heat for the generation of electricity or their conversion into 'blue' hydrogen or similar fuels.[10] At present, none of Britain's electricity generation capacity is connected to a CCS system.

18. The extent of the potential gap in the supply of low carbon electricity can be understood in terms of the residual demand for power. Residual demand is that which remains to be met at any one moment after the use of whatever power is available at that time from variable renewables (wind, solar and hydro) and must therefore be met by other sources such as conventional power plants, storage or imports.

19. Much has been made of the need for a 'flexible' system to manage variations in residual power demand. This will be useful, but it must be better understood to ensure the provision of the right mix of facilities at an appropriate scale. These must be able to adjust the production or consumption of energy quickly enough to balance ramps in residual demand, and at short notice in response to unexpected changes. They must also be 'schedulable', i.e. capable of having their performance planned, with confidence, at a few days' notice. Finally, there must be some degree of 'persistence' with performance available beyond a few hours. As **Table *1*** shows, few of the facilities currently envisaged for the future power system provide all three of these features.

Table 1: power system resources and aspect of 'flexibility'

	Flexible?	**Schedulable?**	**Persistent?**
Wind	If it's windy, yes	No	Sometimes
Nuclear	No, not really	Yes, for the most part	Yes
CCGT burning blue or green H_2	Yes	Yes, for the most part	Yes, if fuel is available
CCGT burning CH_4, with CCS	Perhaps, but at a cost	Yes, for the most part	Yes, if fuel is available
Batteries	Yes	Yes, for the most part	To an extent, if power is rationed
Pumped hydro	Yes	Yes, for the most part	Only if power is rationed
Flexible demand	Yes	Depends what it is	Not beyond a few hours?
Interconnectors	Yes	Depends on what is available within the system from which we would be importing	Depends on what is available within the system from which we would be importing

[10] 'Blue' hydrogen is that manufactured using reformation of methane, i.e. natural gas, with the capture and storage of the associated CO_2 emissions. 'Green' hydrogen uses low carbon electricity in electrolysers to split water in oxygen and hydrogen.

20. The extent to which heat and transport demand are electrified will be the biggest influence on the scale of need in the power system. Arguably, the seasonal variation in demand for heat is the biggest challenge. However, if buildings are well-insulated and stores of heat such as hot water cylinders are sufficient, supplies of power to electric heating in buildings might be interruptible for a few hours without detriment to occupants' comfort. Similarly, the total energy storage capacity of batteries in electric vehicles and the potential for them to be charged at times that closely match the availability of wind and solar power, or even for these batteries to be discharged into buildings or 'the grid', could offer significant flexibility. While helping to reduce the scale of challenge, such flexibility is insufficient on its own to meet residual electricity demand during a 'wind drought' of between one and three weeks for which persistence of a service is required.[11]

The need for energy storage

21. A recent report[12] suggests that the future need for 'long-duration storage' to be added to the existing 30 GWh of pumped hydro storage[13] on the GB power system is between 30 and 90 GWh, complemented by between 0.9 and 1 TWh of hydrogen storage. Another study has noted that Britain's natural gas system currently provides 3-4 TWh of flexibility to balance daily variations in energy demand and around 100 TWh towards seasonal balancing.[14] Before it closed in 2017, the Rough gas storage facility under the North Sea had a capacity of around 35 TWh.[15]

22. Our own initial assessment of the volume of energy required to meet residual electricity demand during a one week 'wind drought' in 2030 is around 6-10 TWh. Because of the variability of the wind resource, whatever mix of resources is used to balance variations in residual demand it should have a low annual capacity factor but must be capable of a peak rate of production of between 30 and 40 GW[16]. By 2050 when

[11] Although it occurred in late June/July – so not the most challenging time from the perspective of electricity demand – there was a 33 day period in 2018 across which the average capacity factor of Britain's wind fleet was only 8.4% compared with the year-round capacity factor for that year of 28.1%. More recently, there was a 6.5 day period in December 2021 within which the half-hourly wind fleet capacity factor never exceeded 20%.

[12] See Pudjianto, et al. 2021. Whole-System Value of Long-Duration Energy Storage in a Net-Zero Emission Energy System for Great Britain. Access here.

[13] Scottish Government. 2017. Scottish Energy Strategy: The future of energy in Scotland. Access here.

[14] MacLean et al. 2021. Net Zero – Keeping The Energy System Balanced. Access here. The same study estimates that, based on recent actual/proposed installation costs of large 'grid-scale' projects in Australia and the UK, 3-4 TWh of battery energy storage would cost over £1 trillion.

[15] By way of further comparison, if all 32 million passenger cars in the UK were electric with a 40 kWh battery, there would be 1.28 TWh of storage. According to the Government's National Travel Survey, before the pandemic, the average daily driving distance of passenger cars was 33 km/day. We estimate the average energy used in driving an electric car to be around 0.18 kWh/km meaning that the average energy used would be approximately 6 kWh per day. With 40 kWh batteries in each car, that would imply that the average energy left per battery would be 34 kWh and the total energy left in batteries across the fleet would be 1.09 TWh. If 30% of cars were parked and plugged in, in theory there would be 330 GWh of energy available to be used for purposes other than travel.

[16] The peak demand for electricity can be reduced by flexible demand, e.g. for electric vehicle charging or heating or cooling in buildings being switched off at the time of peak residual demand, thus reducing the size of that peak. In addition, in our initial modelling – not yet published – we assumed that 5.7 GW of nuclear generation capacity would be operational and able to help meet demand.

Britain's annual demand for electricity may have doubled, these required energy and power ratings may also have roughly doubled.

23. It should be noted that, with the very large total wind generation capacity envisaged for Britain, there will be periods when, relative to demand, there will be a surplus of power from variable renewables and quite inflexible nuclear production. By 2030, this surplus could be as big as 30 GW. The combination of large surpluses and deficits of residual demand with continued use of nuclear power points to a role for storage capacity capable of conversion both to and from electricity.

24. The sources of energy to meet high residual demand might be located within the UK or, as they have been to a large extent in recent years, elsewhere. Whereas large volumes of energy are currently imported via gas pipelines and ships carrying liquefied natural gas (LNG) or petroleum products, the capacity for imports in future will depend on the form of the energy, e.g. electricity or some type of low carbon fuel such hydrogen produced from low carbon sources. Stores of energy within the UK that make use of surpluses of production from wind and surplus and, in effect, move that energy around in time, would reduce the dependency on imports.

25. Different stores of energy have different characteristics in terms of: cost per unit of energy stored; the capability to 'charge' or 'discharge' the store at different rates and the cost to achieve particular rates; the 'round trip efficiency', i.e. how much energy is lost in converting from a directly usable form into that used in the store and then back into a usable form; and the resources required and their availability within the UK. Particular forms might therefore be better suited to some uses than others, e.g. batteries for fast discharging of modest amounts of energy to help stabilise the electricity system in the seconds following a disturbance, pumped hydro storage for smoothing out daily variations in residual demand, or geological stores of hydrogen manufactured from electrolysis to help manage annual variations.

26. We believe there is now an urgent need for more work to assess more precisely the volume of need for different flexible, schedulable and persistent resources alongside an evaluation of what sort of risk we would accept being exposed to in a one, two or three week 'wind drought'.

27. Work is also needed on what sorts of commercial or regulatory instruments would best incentivise the development and optimal utilisation of different resources. A key question is whether 'scarcity pricing' in wholesale markets and the currently quite narrowly framed capacity market (which addresses only a few hours of need around the time of peak electricity demand) will suffice. Major considerations in respect of utilisation of each store of energy will be: will it be full when energy is needed from it? How much of the energy should be used (and at what rate) when a need arises, and how much should be held back for when the need might be greater and there is unlikely to be an opportunity to replenish the store in the meantime? And, when there is surplus of production of energy relative to demand, will the store of energy be empty and able to absorb that surplus? Will electricity spot market price signals lead to optimal utilisation of storage, not just to help manage daily variations but also events such as 1-in-10 year wind droughts? Or will some kind of strategic management of resources be necessary?

3. What are the main international and geopolitical factors and risks affecting the security and affordability of the UK's energy supply? How should the Government work with international partners on energy policy and respond to greater international competition for energy supply?

28. Writing in 2009, in his report entitled Energy Security: a national challenge in a changing world,[17] the late Malcolm Wicks MP wrote: "…the loss of relative energy self-sufficiency takes place at a time of rapid energy change and challenge. My conclusion is that the era of heavy reliance on companies, competition and liberalisation must be re-assessed… The time of market innocence is over." Despite the prescience of his report, it was largely ignored. In the more than a decade since much has changed. In terms of the UK's energy system, coal has just about been removed from the energy mix and should be totally gone by autumn 2024, the role of renewable power generation has increased significantly and replacing the UK's nuclear fleet has proved challenging. Today the power system relies on aging nuclear baseload and intermittent renewables with natural gas providing a balancing role. The vast majority, over 85% of households, rely on natural gas for heating and gas remains an important raw material and source of heating for industrial processes. As noted above, the energy system leans on natural gas for flexibility and meeting winter heat demand, neither of which can easily be replaced by low-carbon alternatives at present. So, gas has a role to play for some time yet. At the same time as the energy system has been changing, the UK has left the European Union and it is now outside the EU's Single Energy Market, the full implications of this remain unclear and, as yet, untested.[18] So, what does all of this mean for energy security?

29. The Wicks Report identified three elements of energy security that "energy policy must aim at achieving:

- **Physical security**: avoiding involuntary interruptions of supply;
- **Price security**: providing energy at reasonable prices to consumers; and
- **Geopolitical security**: ensuring the UK retains independence in its foreign policy through avoiding dependence on particular nations."

30. This provides a useful frame for assessing the risks currently facing UK energy security in the current context of the war in Ukraine. It is fair to say that the UK's approach to energy security has focused on assessing **physical security** of supply. Time and again we are told that we have sufficient infrastructure to import the energy that we need and that we have a diversity of sources to ensure physical security. Both are true, but the situation is very different for oil, where we export most of the oil produced in the North Sea and then import crude oil to suit our refineries and additional oil products to meet domestic demand. Russia supplies about 8% of UK oil demand (18% of diesel).[19]

31. The UK consumes all the natural gas produced from the North Sea, meeting about half of domestic demand, a further 30% comes as pipeline gas from Norway and the

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[17] Unfortunately, this report is no longer available on the BEIS/DECC website.
[18] Blondeel et al. 2022. Brexit and Decarbonisation, One Year On: Friction, fish and fine tuning. Access here.
[19] HM Government. 8th March 2022. UK to phase out Russian oil imports. Access here.

remaining 20% is now largely imported as liquefied natural gas, with a small residual coming from continental Europe via the two interconnectors. In the current context, Russia accounts for less than 4% of UK gas consumption in the form of LNG from the Yamal LNG project in the Arctic[20] and the back-fill of supplies from Europe through the interconnectors. However, despite the low level of reliance on Russia oil and gas, the adequacy of our infrastructure and relative diversity of sources of supply, the recent global gas price crisis and now the impact of the war in Ukraine have made clear the significance of **price security**.

32. The annual statutory security of supply statement produced by BEIS and Ofgem[21] makes clear the UK's reliance on market actors and market signals to ensure physical security of supply. Consumers in the UK are exposed to high prices and volatility because the price they pay for energy services delivered by oil and gas are subject to global market forces. Furthermore, the gas price largely sets the price of electricity.[22] Notwithstanding the need of our refineries for particular grades of crude oil, it is a fungible commodity. Natural gas is more complicated with the UK standing between price competition in European gas market and the global LNG market. As the global economy started to recover from the Covid-19 pandemic, both oil and gas supplies struggled to match demand, resulting in high oil prices and record high gas prices.[23] Thus, even before Russia's invasion of Ukraine the UK, Europe and Asia were already experiencing very high costs of energy. The implications for energy suppliers under the price cap in the GB market are well-known and the impact on consumers is already significant.

33. Russia's war in Ukraine and the actions of Western Governments now mean we are having to deal with the challenges of **geopolitical security**. The UK Government has followed the US by announcing a ban on oil imports by the end of 2022. The situation with gas is less clear. The ban on Russian ships (and cargoes) landing at UK ports has de facto stopped imports of the Yamal LNG and deliveries bound for UK LNG terminals have been redirected to continental Europe. In 2021, Russia supplied 19% of UK LNG imports and this will need to be replaced in an already tight market with heightened competition with other European and Asia consumers. In this context, LNG is fast becoming a 'zero-sum market' with a fixed amount of supply subject to a bidding war. The US and Qatar are the UK's most important suppliers of LNG, but market conditions still determine how much gas arrives. Unfortunately, the lack of domestic storage capacity means that much of this gas transits to Europe. For understandable reasons, the EU has, at present, not followed with a ban on Russian imports of oil and gas, and, at present, both continue to flow from Russia.

34. The IEA has published a 10-point plan[24] to reduce the EU's reliance on Russian oil and gas, and the EU has announced an ambitious plan – REPowerEU - to accelerate action on more affordable, secure and sustainable energy.[25]

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[20] Total Energies. Yamal LNG: the gas that came in from the cold. Access here.
[21] BEIS and Ofgem. 2021. Statutory security of supply report: 2021. Access here.
[22] Grubb. 2022. Renewables are cheaper than ever – so why are household energy bills only going up? Access here.
[23] Fulwood et al. 2022. Ukraine Invasion: What This Means for the European Gas Market. Access here.
[24] IEA. 2022. A 10-Point Plan to Reduce the European Union's Reliance on Russian Natural Gas. Access here.
[25] European Commission. 2022. Factsheet – REPowerEU. Access here.

35. Although we are no longer a member of the EU, the UK remains exposed to the consequences of the EU's energy diplomacy and actions in relation to energy security and climate change. The recent agreement between the US and EU on LNG supplies is a case in point.[26] While the EU way wish to paint the UK out of the picture, the fact is that the EU is affected by decisions made in the UK, since LNG cargoes that arrive in GB regularly deliver gas to mainland Europe through the interconnectors. Current LNG import capacity into the EU is limited and poorly connected with the wider European market and the UK can help. The UK could assist the EU in accessing the additional 15 bcm of LNG promised this year by President Biden on the 24th March.[27] Since the UK has very little storage the interconnectors could flow gas into European storage. Those same interconnectors also provide the UK with access to European storage. So, there is a strong case for reciprocity and cooperation. **In the current context, the UK should promote an integrated and collaborative approach to energy security across Western Europe, including the UK, Norway, and the EU.**

36. At the time of writing, we await the UK Government's revised energy security of supply strategy. While there are short-term actions that can be taken to reduce the impact on consumers and encourage efficiency savings and demand reduction,[28] the reality is that other measures, such as bolstering renewable power generation and increasing domestic oil and gas production, will not deal with the immediate crisis and the threat of a significant reduction in the supply of Russian oil and gas to global markets, and the reality of physical security of supply challenges. It should be clear that notions such as 'energy independence' and 'energy sovereignty' are hollow rhetoric when dealing with globally priced commodities and a market-based approach to energy security. In the short-term, the focus must be on building resilience to get through the coming months. Medium-term and long-term, the emphasis should be on accelerating the deployment of clean energy, while reassessing the future role of the UK Continental Shelf (UKCS); however, actions taken now in the name of energy security should not compromise the long-term target of a net-zero economy by 2050. Ultimately, moving away from a reliance on fossil fuels will remove our vulnerability to crises such as the one we now face.

37. Finally, we need to understand the challenges posed by the process of energy system transformation - on the one hand, a move away from fossil fuels, and on the other hand, the build-up of low carbon energy services. The latter comes with its own energy security challenges that need to be assessed. The 2020s is shaping up to be a decade of a 'messy transition' where we are still held captive by the geopolitics of fossil fuels, and a new geopolitics of low carbon energy is emerging. The question posed by Malcolm Wicks remains, how much can we rely on companies, competition, and liberalisation to deliver secure, affordable and sustainable energy services for a net-zero future?

[26] European Comission. 2022. EU-US LNG Trade. Access here.
[27] BBC. 2022. EU signs US gas deal to curb reliance on Russia. Access here.
[28] Britchfield and Guertler. 2022. The home energy security plan: demand-side measures to lower bills and get off gas. Access here.

4. What level of investment will be needed in the UK's energy supply to secure an orderly transition, particularly over the next decade? Is sufficient private capital being invested in reliable and affordable energy sources that are in line with climate objectives, including the commitment to net zero (for example, hydrogen and nuclear)?

Economy-wide investment needs

38. Achieving net-zero will require economy-wide investment to rise extremely rapidly in the next decade. The Climate Change Committee's (CCC) 6th Carbon Budget scenarios show investment rising at least five-fold. By the early 2030s, the CCC's 'Balanced' pathway scenario shown in Figure 5 indicates annual capital expenditure in the UK being dominated by three sectors: electricity supply (£21bn/year, 40% of total), residential buildings (£11bn/year, 21% of total), and surface transport (£10.5bn/year, 20% of total). Since this consultation relates to energy supply, we focus mainly on the electricity supply sector in our comments here.

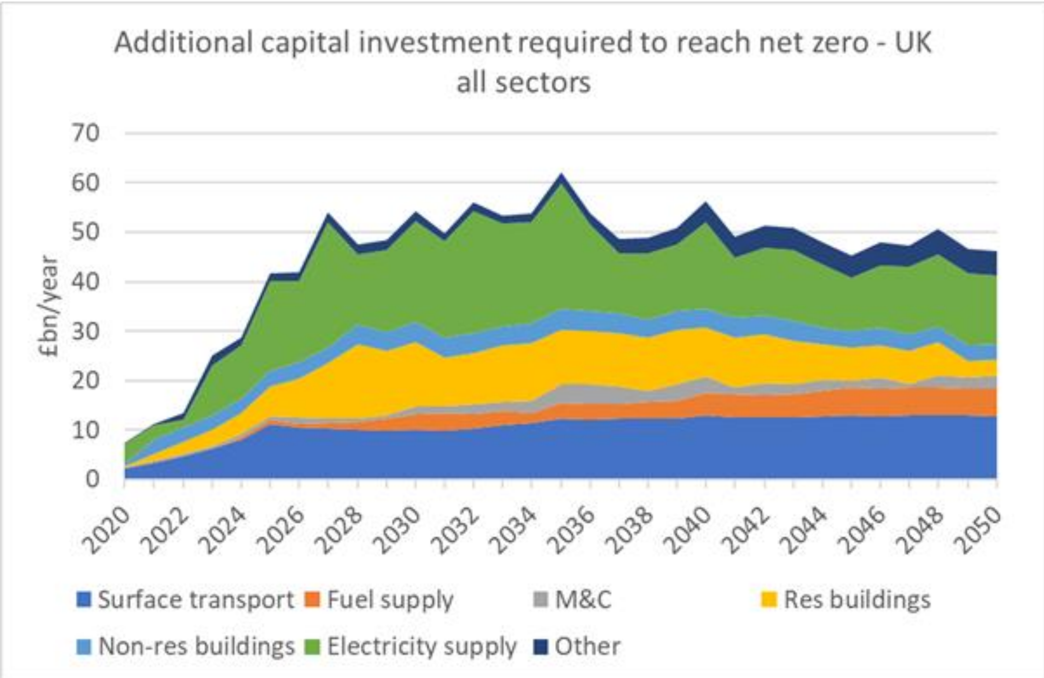

Figure 5. UK Change in CAPEX – 'Balanced' scenario, all sectors[31]

Electricity supply investment needs

39. The electricity sector transition to net zero energy will involve replacing and redesigning a very substantial proportion of the UK's existing capital assets on the system, as well as expanding the scale of the system to meet increasing levels of electrification of the economy as a whole.

40. Zero carbon scenarios suggest that annual investment in the electricity sector needs to be in the range of £13-21bn/year by the early 2030s. This is high by historical standards. Average annual investment between 1992-2010 was around £1.5bn/yr. Since 2010, investment has risen to an average of around £4.3bn/yr driven by the increase in capital-intensive renewables. This increased trend is expected to continue.

National Grid forecasts average investment of £5.8bn/year for the period 2021-2025, or £9bn/year over this period if the costs of Hinkley Point C nuclear are included.[29]

41. Figure 6 shows estimates of historical investment levels. Future investment scenarios for zero-C are taken from the 2021 edition of the Future Energy Scenarios[30] (FES) developed by National Grid ESO (NGESO) and for net-zero scenarios developed for the CCC 6th Carbon Budget.[31]

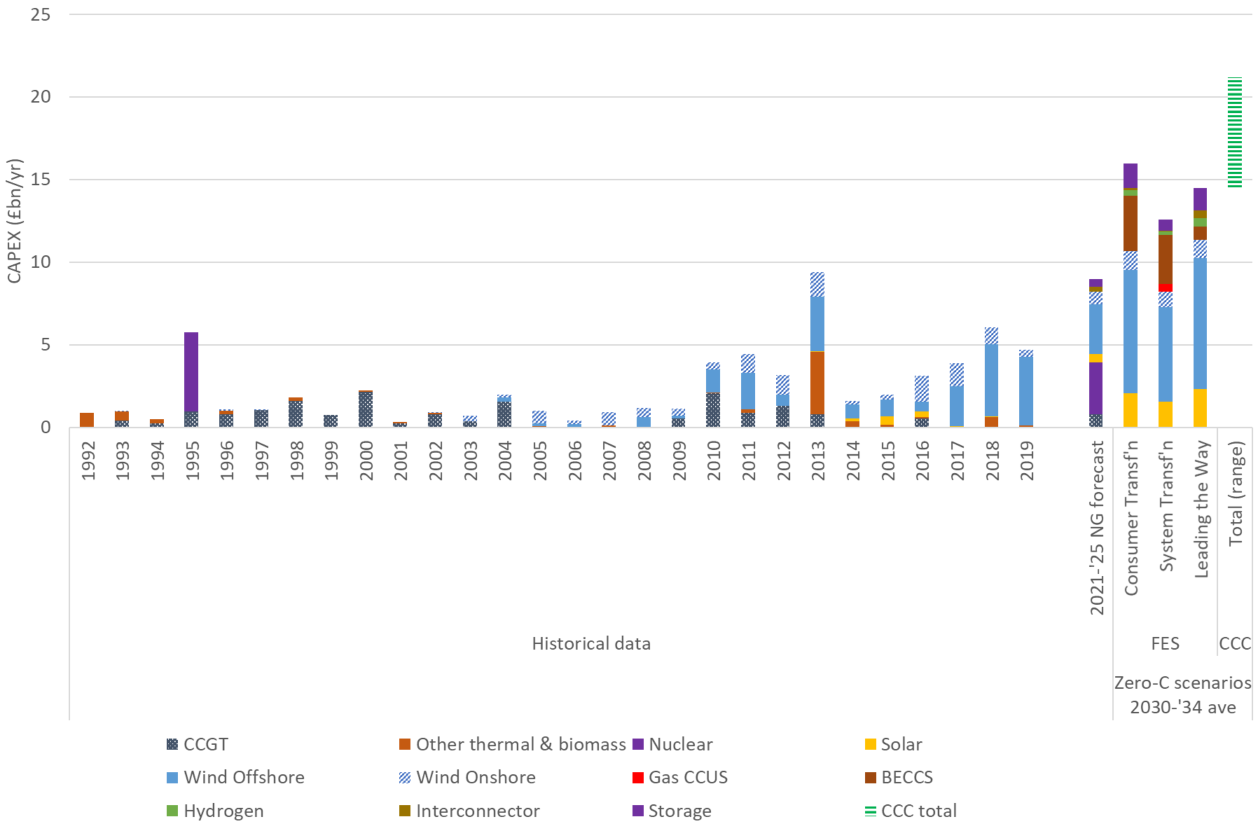

Figure 6. Annual capital investment in power generation: historical[32] and future[33]

42. Points to note from the 2021 FES scenarios:

- Variations in total investment are due to differences in the rate of decarbonisation of the power sector, the rate of electrification of the wider economy, and the degree of end-use energy efficiency in buildings and industry affecting demand for electricity.

[29] Using simplified assumption that £22bn CAPEX is spread over 7-year construction period.
[30] National Grid ESO. 2021. Future Energy Scenarios 2021. Access here. The scenarios considered are: Consumer Transformation, System Transformation and Leading the Way.
[31] CCC. 2020. Sixth Carbon Budget. Access here. Figure shows range of values for total gross investment across CCC's five different scenarios. Net costs are reduced by around £3-5bn per year compared to the gross costs shown due to savings in network investments.
[32] Based on update of methodology used in UKERC study. McCarthy et al. 2017. UKERC Energy Strategies Under Uncertainty – Financing the Power Sector: Is the Money Available? Access here.
[33] Update for future costs: Generation – BEIS, 2020, Electricity Generation Costs, access here. Interconnectors, Poyry, 2016, Costs and Benefits of GB Interconnection, access here. Storage – Mott MacDonald, 2018, Storage cost and technical assumptions for BEIS, access here.

- The technology mix varies between scenarios, but relatively stable proportions of the mix are expected from offshore wind (46-55% of new capacity), onshore wind (7-8%) and solar (13-16%).
- The need for emissions removals through bioenergy carbon capture and storage (BECCS) depends strongly on the success of efforts to decarbonise other sectors of the economy at source, so this component of the mix varies considerably between scenarios and remains highly uncertain.

Investment needs for offshore wind

43. The largest share of investment needed in the NGESO scenarios comes from offshore wind. The Government's current target of 40 GW offshore wind by 2030 is an appropriate milestone towards continued strong growth in capacity during the 2030s. Figure 7 shows that reaching 40 GW by 2030 requires a significant further acceleration in investment rates in the latter part of this decade, and that continued investment at these elevated rates will be needed for much of the following decade. The scenarios shown reach between 68-83 GW of offshore wind by 2040.

44. 11.8 GW of offshore wind capacity had been built in UK waters by the end of 2021.[34] An additional 21.1 GW of offshore wind is currently in the development pipeline. This comprises: 2.4 GW under construction, 15.8 GW with consents approved and 2.9GW awaiting consents. Reaching 40 GW would require 6GW to be built in addition to this existing pipeline. A further 85GW are in the scoping phase for delivery after 2030.

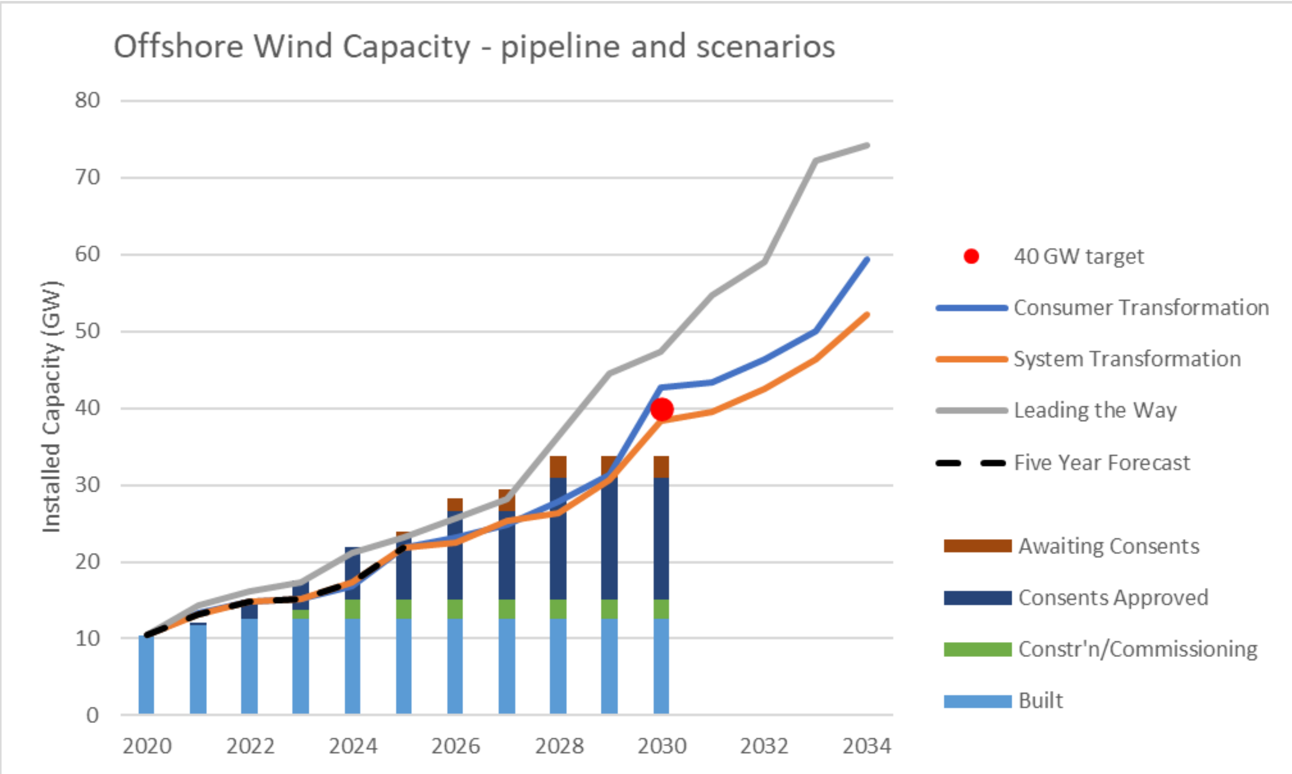

Figure 7. Offshore wind capacity pipeline (bars)[34], net-zero scenarios (lines)[30] and 2030 policy target

[34] NGESO, Transmission Entry Capacity (TEC) Register. 2022. Access here.

Need for investment in system flexibility

45. The shift to a renewables-dominated generation mix requires the electricity system as a whole to become much more flexible. Although the investment needs for system flexibility are not as high as the investment needs for the low-carbon generation itself, they are essential for the system to work. Different types of flexibility are needed in order to:

- Meet demand for energy when variable renewables aren't available, i.e. when it's not windy and sunny (sometimes for considerable lengths of time);
- Avoid wasting energy from variable renewables, i.e. avoiding the curtailment of wind and solar output that would be necessary to keep the system in balance and within the network's limits minute-by-minute;
- Be able to change production or consumption quickly to balance out changes in residual demand, i.e. the demand that's still be met after using the power available from variable renewables;
- Avoid the necessity to reinforce networks – transmission or distribution – for needs that arise in accommodating power flows that reach high levels in just a small number of hours a year.

46. The 2021 FES scenarios in Figure 6 indicate the scale of increased investment in flexibility measures including electricity storage (5-9%), interconnectors (1-3%), and flexible low carbon generation such as gas with CCS (0-4%) and generation using hydrogen as the fuel (2-3%). The investment needed to make demand more flexible is not included in these figures, but will be an important additional measure.

Role of private investment and public policy

47. Virtually all the finance raised for the low carbon transition has been and will continue to be from private sources of capital. As noted in Figure 7, the current pipeline of private investment is sufficient to reach around 33 GW leaving a gap of around 7GW to reach the target of 40 GW by 2030.

48. The bulk of the pipeline yet to begin construction is in the 'consents approved' category (15.8 GW). It is currently unclear to what extent such projects face the risk of not being delivered in practice. In particular, the war in Ukraine is changing some of the fundamental risk characteristics of the energy sector, though it is unclear how long-lived these effects will be. Possible impacts on financial risk for new projects could arise from higher energy prices, higher volatility, higher inflation, higher construction and resource costs, higher interest rates, and higher cost of capital. Evidence shows that low cost of capital has in the past been an important contributing factor to encourage investment in low-carbon generation.[35] Further work is needed to assess the extent to which these factors may affect the likelihood of the current pipeline of projects being delivered in practice.

49. Much of the private investment in low-carbon generation is currently largely underpinned by public policy. The key mechanism is the contracts for difference (CfDs) which set a fixed price for the generation of different types of low-carbon generation. For mature renewable technologies such as wind and solar, this fixed price is typically below electricity wholesale market prices (particularly during periods of elevated prices

[35] Hirth and Steckel. 2016. The role of capital costs in decarbonizing the electricity sector. Access here.

as we're currently experiencing). During these periods, the contracts return money from the generators to consumers.

50. The main purpose of these CfDs is not to subsidise generation (since costs are already below market prices) but to stabilise revenue over a reasonably long period of time. This is needed because renewables are capital-intensive investments (i.e. all the expenditure occurs upfront), and there is considerable uncertainty over how prices will be determined in a future market where fossil fuels play a declining role, creating considerable investor risk. We elaborate on some of the issues in the answer to Q6. Work by UKERC[36] suggests that exposing renewable energy project investors to this risk could increase the cost of financing projects by several percentage points, representing an increase of around 30% or more on the cost of financing the transition in the power sector.

51. 'Merchant' investments do occur outside of the current public policy framework, in other words some renewables projects are built without a CfD contract and/or with some output sold independently of the CfDs. Merchant projects take the form of long-term contracts being struck between renewable project developers and major energy users. However, it is highly uncertain that these deals will be sufficient to drive the scale of increase in investment needed (Newbery 2021)[37].

52. It therefore seems likely that policy intervention of a form similar to the current CfD arrangement will need to continue to set the investment framework for the private financing of renewables for some time to come if ambitious expansion of renewables is to be achieved at least cost. How long this will be necessary is unclear, but it appears likely to be at least until the build-out phase of the transition to a near zero-carbon electricity system is considerably further advanced, when investors will have the chance to observe the physical and financial operating characteristics of the system.

53. Interconnectors are also large-scale infrastructure investments, and also currently benefit from a revenue stabilisation mechanism – 'cap and floor'[38] – that limits the downside risk, while also limiting the potential upside gains. A 'cap and floor' mechanism has also been proposed for large scale energy storage[39]. Therefore, similar considerations on the need for continued revenue stabilisation over the next decade apply to interconnectors and storage. It is likely that similar considerations will also pertain to other infrastructure-heavy investments, such as CCS and hydrogen electrolysis.

54. Other flexibility measures like batteries and demand-side flexibility have a different risk profile, so may not need the same degree of public policy support. Unlike renewables, price volatility is beneficial for these technologies, allowing them to buy electricity when it's cheap and sell when it's expensive. Individual investments are also often smaller and modular, and require less fixed infrastructure. They can also often provide high-

[36] Blyth et al. 2021. Risk and Investment in zero-carbon markets. Access here.
[37] Newbery. 2021. Designing an incentive-compatible efficient Renewable Electricity Support Scheme. Access here.
[38] Ofgem. 2021. Cap and Floor Regime Handbook. Access here.
[39] Drax. 2022. Potential solution to unlock investment in climate-critical storage technologies. Access here.

value ancillary services such as fast reserve and frequency response which often attract a higher payment per unit of energy than the bulk wholesale market.

6. What should the Government do to incentivise and enable investment in, and financing of, reliable and affordable energy that is in line with its climate objectives, including net zero by 2050?

55. Incentives are needed to continue to deliver new renewable energy projects, bring forward new nuclear beyond the single scheme currently under construction, and to expand the role of storage (including possible long-term storage as discussed above), interconnection and demand response.

56. As we discuss in the answer to Q4, incentives already exist that provide for some of the above. Most notably Contracts for Difference (CfDs) with a Feed in Tariff were created in the 2013 Energy Act to create long term stable contracts for renewable energy, new nuclear and (in principle) carbon capture and storage (CCS). New legislation has created the capability to underwrite some nuclear construction risk through a regulated asset base model. A capacity market provides support for technologies able to provide firm power to meet peak demand. Interconnectors are subject to a cap-and-floor regime.

57. In this submission we focus on the allocation of wholesale market price risk, and how that affects both cost of capital and the likely availability of capital in the power market in Great Britain. The rising share of zero marginal cost generators such as wind and solar will have a significant impact on wholesale electricity prices, and the UK has set ambitious targets for such generators. The 40 GW offshore wind in 2030 target is the most obvious and immediate, but far greater roll out of zero carbon generation and a phasing out of unabated use of fossil fuels are prerequisites for net zero. Most decarbonisation scenarios envisage in the region of 80 to 100 GW of offshore wind, together with considerable expansion of onshore wind, solar, nuclear and CCS (the mix depends on the scenario).

58. As Q4 makes clear, a key challenge for the UK is to galvanise a large volume of investment in a historically short timeframe. Questions remain about the underlying market designs that create incentives for flexibility and deliver best value for customers whilst also providing incentives for generators to invest in low carbon generation – in substantial volumes.[40] A conventional ‘energy only’ wholesale/retail market is not well suited to deliver large volumes of new low carbon capacity at minimum cost to consumers. This is because a competitive wholesale market where price is set by short run marginal cost (SRMC) will, in the long-run, tend to under compensate participants who have a high sunk cost and very low SRMC. Investors evaluating the potential returns to investment on large schemes such as offshore windfarms will anticipate these problems. The gas price crisis is currently driving wholesale electricity prices to record highs, but there is no guarantee this will sustain over a 10 or 20 year time horizon – indeed we very much hope that it will not.

[40] Rhodes et al. 2019. Electricity markets, incentives and zero subsidy renewables: Do Britain’s power markets and policies need to change? Access here.

59. One reason for this is the problem known as 'price cannibalisation' where price falls to low levels or even goes negative during spells when wind or solar output is high and demand is low. Price cannibalisation has emerged as a phenomenon in a number of markets and in the GB market, with price cannibalisation already visible during periods of low demand as were observed during the first Covid-19 lockdown.

60. There is then a separate question regarding how best to provide investment signals for the flexibility needed to accommodate rising shares of low carbon generation and to provide essential system services – through storage, demand response, schedulable generation or interconnection. It is important that low-cost sources of flexibility come forward to accompany the growing role of renewable and other low carbon sources of bulk electricity.[41]

61. Underlying all of this debate is the difficulty of satisfying the principle that risks should be allocated to those best able to manage them, when these risks are multiple and linked. In particular, we see two main types of risk:

- Steady-state risks. These pertain to a situation of dynamic equilibrium, where physical infrastructure has largely been established, supply and demand are roughly in balance, and investment is largely driven by the need for plant renewal and incorporation of new innovations, consumer demands and business models.
- Non-equilibrium risks. These pertain to systems that are in a state of flux, shifting to substantially different infrastructure for supply and different patterns of demand, with many of these changes driven by policy, and very little historical pricing information to inform future investments.

62. For at least the next 10 years, to get substantially onto a trajectory of zero carbon electricity during the 2030s, and meet goals such as the 40 GW of offshore wind, the non-equilibrium risks are substantial. The policy-dependency of many of these risks makes them potentially unsuitable to be wholly managed by the private sector. The rate of electrification of heat and transport will be largely policy-driven and determines overall demand in the market. Likewise, support for carbon capture, use and storage (CCUS) and nuclear and other low-carbon generation options affects overall supply, whilst the rate of infrastructure build-out for flexibility options such as hydrogen and interconnectors determines price behaviour in markets. The relatively early stages of this transition are perhaps the most uncertain.

63. When considering the future market arrangements for variable renewables, it is therefore also essential to look at how these can also be used to ensure sufficient investment in system flexibility. However, not all flexibility options are market-ready. Whilst some options such as interconnectors and some storage options are already deployed at scale, other storage options require research into new materials and manufacturing methods,[42] and a system-wide view is needed of how and when these can best be brought to market, and what support mechanisms may be needed to do so.

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[41] Heptonstall, P.J., Gross, R.J.K. (2021). 'A systematic review of the costs and impacts of integrating variable renewables into power grids'. *Nat Energy* **6,** 72–83. Link

[42] Catherine Jones (2020) 'UKERC Energy Storage Landscape Report' Link

64. For example, analysis by the Climate Change Committee and others provides a role for inter-seasonal storage.[43] This suggests that a particularly important element of inter-seasonal storage could be green hydrogen, produced from renewable energy at times of lower demand, and stored in either new or existing gas storage sites. This hydrogen could be a zero-carbon balancing medium for a much more flexible energy system although other technologies such as compressed air storage or ammonia could perform a similar function. In any case, the novelty of these technologies and the associated demand risk mean that some more strategic policy support around inter-seasonal zero carbon storage may be needed to replace the current model of increasing fossil gas imports.

65. Finally, current and likely future public policy decisions directly affect the systemic risks of the energy transition. It would therefore seem useful from a policy perspective to differentiate between long-term market arrangements that might be put in place once a new electricity system structure and market equilibrium conditions have been achieved, and the interim policy arrangements that are needed to drive the system through the transition phase to this new state. This provides important context to the answer to Q4 about how much longer CfDs should be maintained.

66. In order for offshore wind to meet the 40 GW target by 2030, the rate of installation needs to triple in the coming decade relative to the previous decade. This only seems feasible if the market is able to build on the experience of the previous decade. This very likely includes the need to replicate the success of financing models that have become established to deliver the first 10 GW. These financing models typically rely on the ability to raise relatively high levels of low-cost debt to keep the cost of capital low. This model relies crucially on the revenue stabilisation effects of CfDs. As we explain in the answer to Q4, UKERC analysis suggests that removing this element of derisking could have significant implications for the cost of capital.[44] This is important not only for the financing structure of individual investments, but also for creating long-term signals on market structure and price expectations during the long project development cycles needed for offshore wind (typically in the region of 8-10 years[45]).

67. It seems likely therefore that for many of the low carbon options and certainly for the largest schemes (offshore wind and nuclear) some form of continued revenue stabilisation will be necessary over the next decade, at least. This is in order to maintain confidence and momentum in the market given both the magnitude of the scale-up required over this time period, and the significant uncertainties in the evolution of the wider system discussed above. This could be managed through incremental change to CfDs, or through transferring to some other type of equivalent mechanism. A number of alternative approaches have been proposed and UKERC reviews the range in a number of publications.[46,44] However, some of the alternatives to the CfD are largely unproven and require quite radical market reforms. These would take time to implement and increase regulatory risk, deterring investment. Our general position is that whilst not without problems the existing mix of policies has considerable

[43] Climate Change Committee. 2020. Sixth Carbon Budget. Access here.
[44] Blyth et al. 2021. Risk and Investment in zero-carbon markets. Access here.
[45] Offshore Wind Industry Council. 2019. Enabling efficient development of transmission networks for offshore wind targets. Access here.
[46] Bell et al. 2021. BEIS call for evidence: Enabling a high renewable, net zero electricity system. Access here.

advantages in terms of reducing the cost of capital. Any changes to market design and incentives should be gradual, incremental and cautious.

7. What role will oil and gas play in the UK's energy mix as it transitions to net zero? How should we ensure that these sectors receive sufficient investment to guarantee supply, while not slowing the move to renewable energy sources? What level of investment will be needed?

68. Energy system decarbonisation scenarios such as those developed by the Climate Change Committee and National Grid Energy System Operator all generally envisage a considerable reduction in natural gas and oil use from around 2030. The Climate Change Committee's 'Balanced Net-Zero Strategy' would see gas demand fall 27% by 2030 and 57% by 2040 (Figure 8, below). If gas prices remain very high then we would expect that the role of gas would decline further. This is because the relative economics of using gas with carbon capture to make hydrogen or provide electricity system balancing would deteriorate. Hydrogen from other sources would be likely to look more attractive. Quantifying this would require new modelling with changed input assumptions on gas prices.

69. UKERC has also had a long-standing interest in the use of gas in the transition. Back in 2016 we published our own modelling of gas scenarios.[47] Although the Climate Change Act target then was 80% rather than net zero emissions, the findings are broadly consistent with more recent analyses – how much gas we use depends on the role of CCS and sources for hydrogen. Since 2017 UKERC has been arguing for a much more carefully managed and strategic approach to gas security, as we explain in the answer to Q3. The message has been clear throughout; the UK Government has been relying on a policy of 'gas by default' which assumes there will always be a secure and affordable supply of natural gas to meet demand. This is guaranteed by sufficient physical infrastructure, diversity of supply and a reliance on market forces. At present, reliance on the market is coming at a very high price.[48]

70. UKERC research suggests at least three challenges demand a different approach.[49] First, although domestic demand has fallen in recent years, production from the North Sea (UKCS) has fallen faster and import dependence has increased making the UK evermore reliant on pipeline gas and Liquefied Natural Gas (LNG). Second, the rapid growth of renewable power generation has changed the role of gas, being now a key source of flexibility as the output of wind and solar varies within each day and across the year. Third, ambitious plans to decarbonise domestic heating could result in a significant reduction in gas demand, raising questions about maintaining the integrity of the pipeline networks and the possibility of repurposing them to support a future hydrogen economy. All this uncertainty requires an approach of 'gas by design' that ensures energy security in the short-term and in the medium-term maintains the

[47] McGlade et al. 2016. The future role of natural gas in the UK. Access here.
[48] UKERC. 2021. Talking Energy Episode 3: the rising price of gas. Access here.
[49] Bradshaw, M. 2018. Future UK Gas Security: a position paper. UKERC & WBS. Access here.

integrity of critical infrastructures while managing down the role of gas in line with the net zero target.

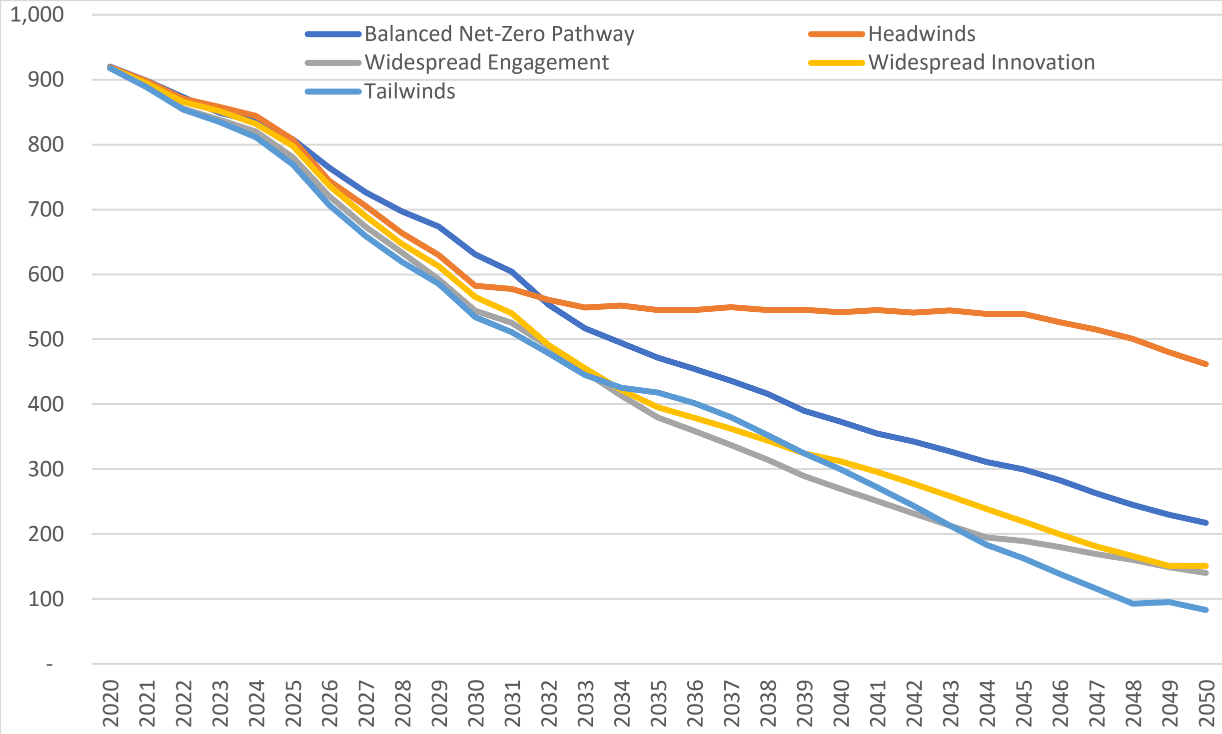

Figure 8. Role of Natural Gas in UK Energy Mix: CCC 6th Carbon Budget Scenarios (TWh)[50]

71. Unfortunately, it is not a simple matter of turning down the dial from gas mark 10 as decarbonisation gathers pace and results in lower and lower gas demand. As gas demand falls, under the current system where the gas network is funded through gas bills, fewer and fewer customers would end up paying to maintain the system. Whilst this seems appropriate on many levels, it also overlooks the additional value that everyone benefits from i.e., providing resilience and flexibility to the UK's wider energy system. In the medium-term it may be possible to blend biogas and hydrogen[51] in the existing system.

72. Longer-term it may be possible to repurpose the gas network to support hydrogen and significant work is ongoing here,[52] but timing is everything. There is likely to be a movement away from a national transmission system to regional networks, with the possibility that some regions will reduce their dependency on the gas grid entirely. In other areas there could be a more limited role for the gas grid, such as where hybrid heat-pumps have a greater role to play. These questions, that are far from the only ones, highlight the complexity of managing the changing role of gas as the energy system is transformed.

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[50] Climate Change Committee. 2020. Charts and Data in the Report. Access here.
[51] Cadent Gas. 2020. UK's first grid-injected hydrogen pilot gets underway. Access here.
[52] National Grid. 2020. National Grid to launch £10m trial project to test if hydrogen can heat homes and industry. Access here.

73. In sum, it is relatively easy to model and chart the gradual reduction in the role of unabated gas in the UK energy system,[47] along with the redeployment of some existing assets and investment in new ones, to deliver a net zero energy system by 2050. The real challenge is working out how to get from where we are today, where gas is the most important element of the UK's energy mix, to where we need to be by 2050. That is the purpose of a 'gas by design' approach, to ensure that the current energy services supplied by natural gas - both to the energy system itself and to consumers - continue to be available until no longer needed as the energy system transforms to become net zero.

74. At the time of writing UKERC has not investigated issues in the supply of oil in the same level of detail as gas. In very general terms, petroleum products are more fungible than gas, for the reasons set out in the answer to Q3. Nevertheless, similar high-level concerns are relevant, both geopolitical and how the costs of maintaining infrastructure will be borne by a declining volume of consumers.

8. What incentives could the Government provide to households and businesses to reduce demand for energy or to improve energy efficiency?

75. There is robust evidence that a resilient, affordable energy supply, in line with net zero greenhouse gas emissions, will be more feasible if we significantly reduce the need for energy by reducing waste and improving energy productivity.[53] Reducing demand lessens the impacts of steep increases in energy prices; it also avoids or defers costs of investment in power and heat generation and supply infrastructures, which may be on stand-by for large periods of the year. In addition it will reduce the need for, and risks of, very high cost, and unproven, Carbon Dioxide Removal technologies.

76. Reducing household and business demand for energy, and improving energy efficiency, covers multiple sectors: notably space heating, hot water and power in buildings; transport and travel; energy use in industry.

77. In each of these sectors, there are three approaches to reducing demand: *avoid* the need to use energy for the required service (such as providing more local services to avoid need for car use, and designing buildings to use natural lighting and passive ventilation); *shift* to provide the same services in a different way (such as shifting more journeys from car to public or shared transport, or walking and cycling); *improve* efficiency of energy use (for example through progressive increases in standards applied to electrical appliances, industrial processes and building insulation).

78. Effective incentives to address all sectors and approaches require an over-arching policy and planning framework to ensure consistency and minimise any contradictions between different policy measures. Currently there are no published UK government targets and incentives for demand reduction in each relevant sector. Barrett et al.[53] for example recommend establishment of an Energy Demand Reduction Delivery Plan to support Net Zero Strategy. Without this systematic framework, we are likely to

[53] Barrett et al. 2021. The role of energy demand reduction in achieving net-zero in the UK. Access here.

continue as at present with piecemeal, stop-start initiatives, which effect only incremental change, and which may have the perverse outcome of discouraging participation by businesses and households. The latter was evident in relation to homeowner and supply chain reactions to the introduction and then rapid closure of the English Green Home Grants voucher scheme.[54]

79. Focusing on the 'improve' category *energy use in buildings* and action by building owners, incentives can be considered under a number of categories including financial, organisational, social, reputational and regulatory. The best use of incentives is as part of a coordinated, systematic strategy; relying on individual property owners to take action under their own initiative is too slow and unpredictable for the scale and speed of change required to secure the benefits outlined above.

Feasible incentives which can be used in many combinations include:

80. Financial:

- Significantly reducing VAT on labour and materials for energy efficiency retrofit.
- Incentivising retrofit through Stamp Duty Land Tax reductions.
- Routinely, and continuously, providing an accessible element of government grant funding, particularly to support adoption of more difficult, less-routine retrofit such as for solid wall insulation.
- Routinely providing upfront, accessible low cost or interest free loans to cover costs of whole building retrofit, including from mortgage lenders and banks, as well as UK Infrastructure Bank, which could for example support financing of public and commercial sector building retrofit.
- Ensuring that the Energy Company Obligation (ECO) scheme is used in coordination with local governments and community enterprises to benefit the most vulnerable and low-income households.

81. Organisational:

- A coordinated, publicised and stable strategy, providing access to an area-based, planned scheme, can provide significant incentives to participation by removing most of the burdens experienced by owners in a 'one building at a time' approach. This manages the timing and practicalities of retrofit, performance standards and quality assurance guarantees on behalf of building owners. It can also include central procurement of materials, for example by local government and contractors, to reduce cost per building. Early findings from evaluation of the English Green Homes Grant-Local Authority Delivery (GHG-LAD) pilot schemes show the incentives to participation resulting from a coordinated approach, and trust in the local authority-contractor partnerships. Scottish Government's Heat in Buildings Strategy is also an example of a structure for national/local coordination.
- A coordinated strategy also has economic incentives associated with jobs and skills development for building stock retrofit at scale.

82. Social:

- Social networks influence willingness of building owners to participate in local schemes; this may include a wide range of civil society, family, friends and

[54] NAO. 2021. Green Home Grant Voucher Scheme. Access here.

neighbourhood networks; trade associations; chambers of commerce or other business networks. Such groups need to be engaged in discussing and developing strategy for upgrading energy performance of buildings; they should also share responsibility for implementation.

- Early findings from GHG-LAD pilots suggest the incentive arising from recommendation through family, friends and neighbours. For SMEs, there should be a similar impact through business networks.

83. Reputational:

- Businesses investing in insulating their property can manage the rising costs of energy supply and lessen the inflationary impacts on goods and services. They can also develop, and trade on, 'reputational capital' associated with responsible, progressive business conduct.
- Commercial sector energy performance benchmarking schemes have for example been associated with increased corporate reputation, employee health and productivity, and a 'green premium' from rental income and lease length.[55]
- Building renovation passports have long been discussed as a route to accurate data on energy use and feasible renovation strategies[56]. They also have reputational capital for building owners, including for letting and leasing property.

84. Regulatory incentives are highly cost effective in stimulating action by building owners and property developers.

- The 'net zero', or Future Homes, Standard for example can be implemented without further delay, to avoid the need for spending on retrofit of new housing in a few years, and with immediate benefits from lower energy bills.
- Regulation focuses attention of property owners on action ahead of time, and hence pulls demand forward, supporting growth of skills, jobs and supply chains, as well as take-up of financial, and area-based, incentives.[57,58]
- An associated 'one stop shop' advisory service, and 'trusted trader' databases, for building owners provide an incentive to progress with necessary work.

9. What lessons are there for the UK from comparable countries in terms of securing investment in reliable and affordable energy?

85. There are many different prospective dimensions to how best to secure reliable and affordable energy in a global context where the majority of nations have signed up to binding climate change targets, and most are now impacted by escalating fossil fuel prices. In our answer we focus on two relatively narrow aspects – support for renewable electricity generation, and the existence of capacity mechanisms, to ensure that power systems can meet peak demand. As we have highlighted above,

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[55] Mallaburn et al. 2021. Australian non-domestic buildings policy as an international exemplar. Access here.
[56] Green Finance Institute. 2021. Building Renovation Passports: Creating the pathway to zero carbon homes. Access here.
[57] BEIS. 2021. Non-domestic private rented sector minimum energy efficiency standards regulations: evaluation. Access here.
[58] BEIS. 2021. Domestic private rental sector minimum energy efficiency standards: interim evaluation 2020. Access here.

electrification appears to be the most likely route to decarbonise many sectors of the economy. This is common to almost all countries. Internationally there has also been a great deal of focus on renewable energy support schemes. Some 145 countries have some form of support for renewable power. Sixty-five countries have policies that target transport sector emissions and only 22 countries have policies that target heating and cooling.[59] The Committee may also wish to consider which countries support new nuclear, development of hydrogen, research into batteries, role of biofuels and so on. If this is of interest UKERC would be happy to provide supplementary evidence.

Renewable energy support and the role of auctions for offshore wind

86. Most countries steer the buildout of renewables, mostly through auctions and with some form of support for renewable energy. The spotlight is on offshore wind (being the most relevant UK technology), but principles apply to other options.

87. Almost every offshore wind scheme developed so far has had government support, and the price for this is generally set by an auction. Some European countries have had lower "headline bids" than those in UK auctions, but this is often driven by differences in the details of their auction designs. Figure 9 below, shows that harmonising bids across auctions shows that the UK schemes offer better value, in terms of the expected revenues relative to their headline bid, than many of those in other countries.

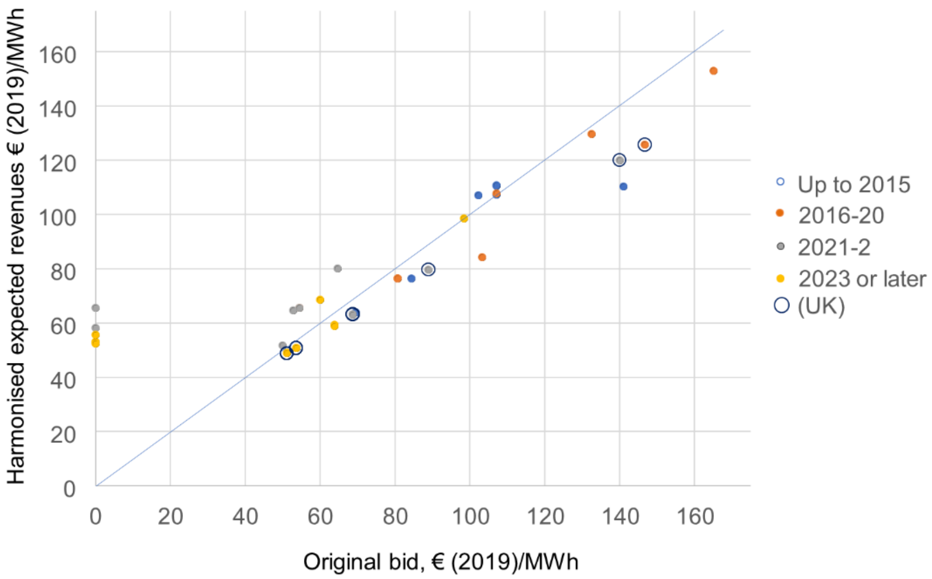

Figure 9. Offshore wind auction bids in Europe: original and harmonised[60]

88. It is worth noting the "zero" bids for Dutch and German wind farms; these are in auctions offering a price floor (a 1-sided Contract for Differences) rather than the UK's effectively fixed price with its 2-sided CfD. If those farms were generating at current

[59] https://www.ren21.net/wp-content/uploads/2019/05/GSR2021_Key_Messages.pdf
[60] Jansen et al. 2020. Offshore competitiveness in mature markets without subsidy. Access here.

wholesale electricity prices, they would receive very high revenues, but they also face the risk that future prices will be low, affecting their cost of capital. The UK's 2-sided CfD offers insurance against price risk for both generators and consumers. A relatively small volume of capacity currently has a CfD in the GB market (around 6GW), but those that do are helping to hold prices down, if only a little.

89. Some auctions (e.g. in Denmark) are to develop a specified scheme, so the environmental and grid connection studies have already been done. This reduces the risk to the developer of winning an auction but being unable to build their scheme, as happened to the Navitus Bay wind farm off the Isle of Wight; however, it requires a "system planner" to decide which schemes should be put up for auction.

90. There is a tension between how much bidders are required to do to pre-qualify for an auction, including the size of any financial guarantees that they may have to post, and the amount of competition in that auction. If pre-qualification is hard, the auction is likely to attract fewer bidders and produce a less competitive price, but the winning scheme is more likely to be successfully completed.

91. Renewable generators in the US can receive a Federal Production Tax Credit (PTC) of 2.3 cents for each eligible kWh they generate in their first ten years of operation. This low-risk revenue is important when arranging finance for a project.

92. The experience in Europe has shown that some wind farms in Europe are able to be built based on market revenues expectations. The late 2021 Danish Thor auction results, indicate that bidders are willing to pay for the right to operate an offshore wind farm, under the Danish 2-sided CfD. The long awaited financial close from Germany's 2017/2018 has been achieved, despite the current turmoil in energy markets, sending another strong investment signal, confirming the viability of merchant renewables for the current wave of offshore wind farm. The Dutch 759 MW "Hollandse Kust Noord" offshore wind farm is not only completely subsidy-free, but will incorporate 200 MW of hydrogen production in the port of Rotterdam. This was achieved by setting out the auction requirements to include additional capabilities, on top of the expectations that the actual bid will be zero.

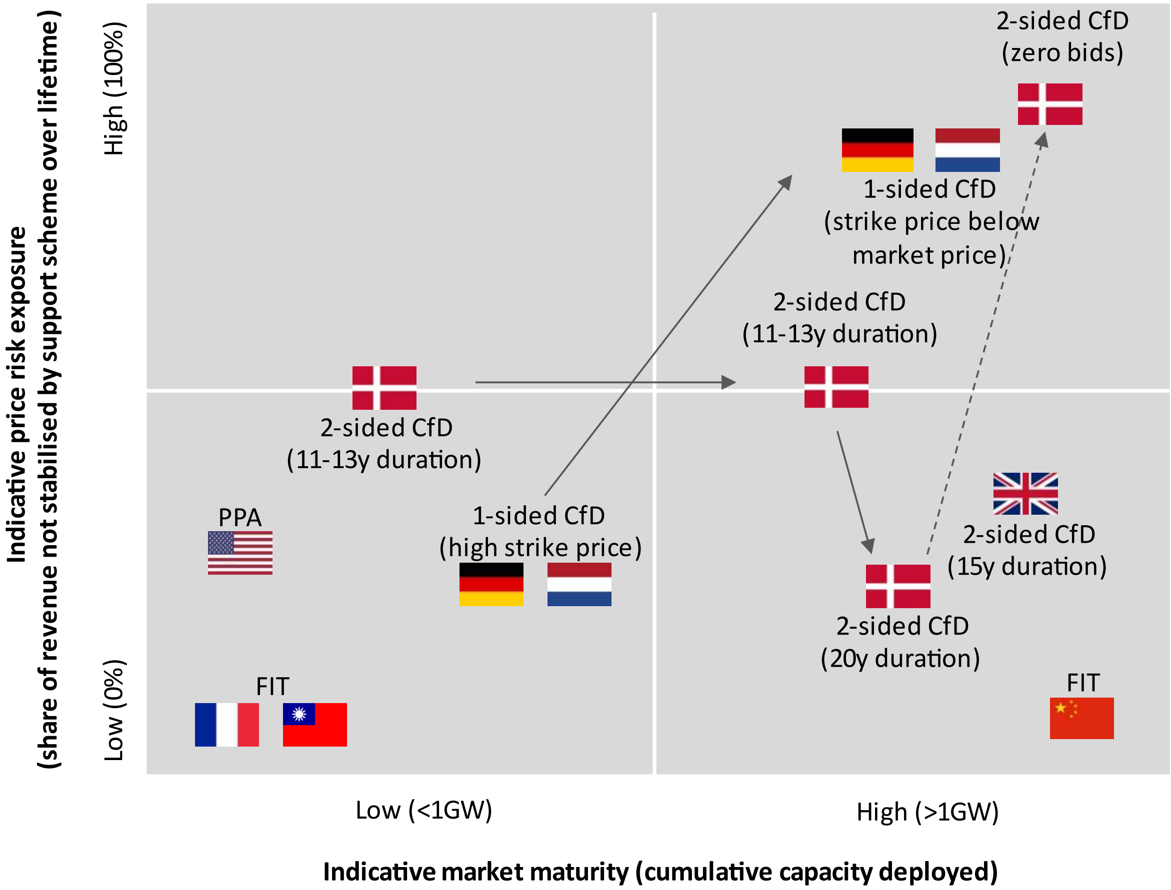

Figure 10. Auction schemes indicative maturity and price risk exposure managed by revenue stabilisation of these schemes. All markets with more than 1 GW installed are placed in the "high" area of the market maturity scale. Price risk exposure is qualitatively estimated based on Beiter et al.[61]

93. However, as we note in the answer to Q4, this does not mean that it will be possible to build out 40 GW, or 80 to 100 GW off offshore wind on market revenues alone. Indeed, UKERC analysis indicates that wholesale market price revenues decline significantly with high penetrations of renewables. This is consistent with evidence from across Europe that 'capture price' falls as renewables penetration rises. This is illustrated in Figure 11, below. This shows that revenue cannibalisation of variable renewable energy is a global phenomenon, which some markets are better suited to address than others.[62] With a clear downward trend on capture prices for wind and solar with increasing penetration, this has knock-on effects for generators, and more importantly, their ability to make investment decisions.

[61] Beiter et al. 2021. Toward global comparability in renewable energy procurement. Access here.
[62] Halttunen et al. 2020. Global assessment of the merit order effect and revenue cannibalisation for variable renewable energy. Access here.

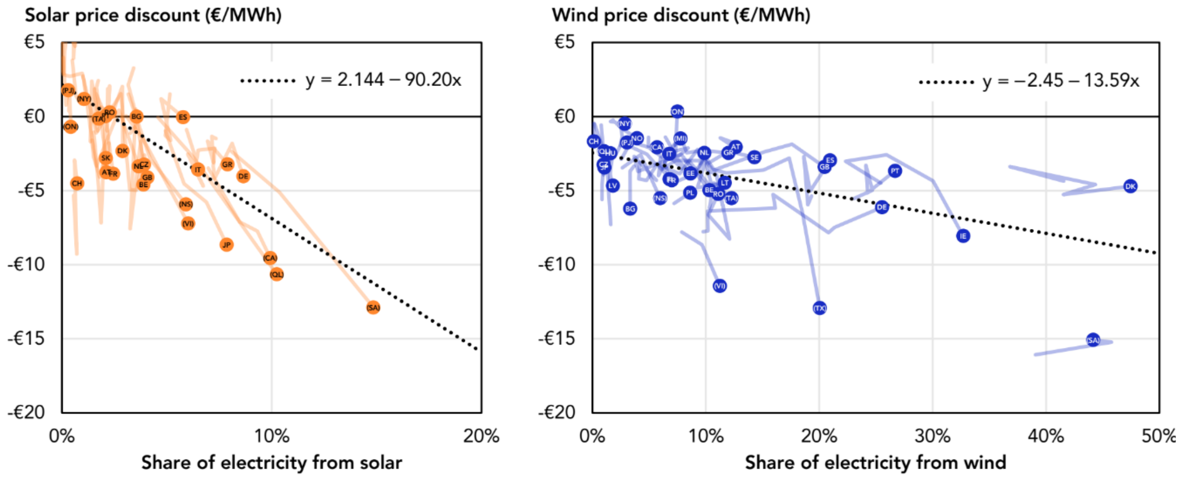

Figure 11. Solar and wind price discount in 37 global electricity markets[63]

94. The frequency of auctions is important as well. Few and large auctions gather a lot of liquidity. This was the case in South Africa Bid Window 5 auctions in 2021, the first auction since 2015, leading to the auction being oversubscribed. However, infrequent auctions could encourage developers to bid lower than economically justifiable, so as not to miss out altogether. This is coined by the term 'Winner's Curse', with the winning bidder losing money, creating delivery risks for the projects. On the other side, frequent and smaller auctions allow for near-perfect price discovery. This is the case in Germany's solar PV auctions, where prices have had a sidewards trajectory for some years. Auction take place every 3-4 months, which leads to "just enough" competition, but has reduced the pressure on prices, as the projects get more challenging to develop with less favourable sites and increased land and labour costs.

95. More recently, land and seabed lease costs have come into focus. Recent record-breaking auction results for seabed leases in the Crown Estate's Round 4, ScotWind and $4.4 bn lease auction in the United States have emphasised the increasing cost pressure from this side. This stands in contrast to countries like Germany and the Netherlands where leases are awarded free of charge, at the time of CfD award. It stands to questions whether uncapped seabed lease costs create a fair and equitable use of a (public) good. When seabed leases are not in competition with other uses (e.g. CCS, oil & gas, fishing) this is an indirect taxation of electricity generation, benefiting the treasury. Whilst seabed lease payments can cover some of the pre-development costs for the sites, a balance needs to be struck between revenues for government and the strategic deployment of low carbon options at least overall cost.

96. As we have noted in other sections, part of the response to the energy price crisis is to implement the energy transition faster. This means rolling out the necessary flexibility options already with the rollout of intermittent generation. Some countries, for example, Germany and the Netherlands, have taken steps to create hydrogen production and flexibility alongside additional offshore wind generation. This could also work in the UK, allowing for the mitigation of some of the price cannibalisation of

[63] Halttunen et al. 2020. Global assessment of the merit order effect and revenue cannibalisation for variable renewable energy. [Access here](#).

renewables, and establish a long-term business model, whilst decarbonising the economy. For example, one could wish to mandate building a certain amount of flexible consumption alongside new offshore wind farms (e.g. hydrogen production), as a pre-condition for new CfDs being awarded. However, there are important questions about the overall cost effectiveness and efficiency of requiring individual renewables schemes to invest in balancing capacity, rather than incentivising flexibility at the system level.

Market design for reliable energy

97. The role of and need for so-called capacity mechanisms has long been debated by energy market economists. Within Europe and the US there is a mix of approaches. For example, the Nordic countries maintain a strategic reserve, whereas the GB market has a capacity market, as does France. In the US some electricity transmission areas have capacity mechanisms, such as 'PJM', which operates on the East Coast, others such as that in Texas, don't.[64] In the UK context, a capacity mechanism existed during the 1990s, was removed in 2002, then reinstated in 2013.

98. In this submission we do not try to provide a comprehensive discussion of the pros and cons of capacity mechanisms of different forms, or the long-standing reasons that economists disagree about the need for, and best approaches to, capacity adequacy issues. Instead, we provide a short sketch of some of the issues and decisions in comparator countries.

99. Around twenty countries have schemes to ensure enough generating capacity of all kinds is available to meet peak demands. The two main types are capacity markets based on regular auctions, offering additional revenue to a high proportion of the generators in the country or region, and strategic reserves which only involve a few plants, held back to be used at times of greatest need. This second mechanism may not do anything to protect plants outside the reserve, which may also be at risk of closure if prices are low.[64]

100. The UK's capacity mechanism offers successful generators a fixed payment per kW as long as they are available when required, fixed at the level set in the auction held either four or one year ahead of time. This increases the amount of capacity available in the market, but does not offer any price insurance. Some economists[65] prefer the design used in New England, sometimes called a reliability option. This is effectively a 1-sided contract for differences. The generators refund the excess if the spot market price rises above a strike price set at a high level, above generators' normal operating costs. The auction sets the fee generators get in return for the prospect of having to make these refunds, which gives them the revenue certainty to keep older plants running. The generators have a strong incentive to be selling in the spot market (and so providing electricity) when prices are high and they might have to make refunds under the reliability option, and those refunds offer insurance to retailers and their customers.

[64] Kozlova & Overland. 2022. Combining capacity mechanisms and renewable energy support: A review of the international experience. Access here.

[65] Newberry. 2020. Capacity Remuneration Mechanisms or Energy-Only Markets? The case of Belgium's market reform plan. Access here.

101. The Irish electricity system operator faces particularly strong challenges[66] from the increasing level of wind power connected to a relatively small system (the market covers both the Republic of Ireland and Northern Ireland). Wind generators normally have no inertia as they are connected via power electronics (unlike thermal or hydro turbine generators); the DC interconnectors to Great Britain also use power electronics. (Denmark is another relatively small country with a lot of wind, but it shares inertia with Germany (and beyond) through AC interconnections.) If inertia is low, any faults on the system quickly lead to a change in frequency and potentially catastrophic disconnections from it. However, the Irish system operators have learned how to manage these risks; while they still constrain-off some generators during high winds to reduce the risk of black-outs, they are accepting higher levels of wind power than they believed possible in the past.

102. Germany is operating a "strategic capacity reserve" which resembles a mandated capacity mechanism. Generators are remunerated on a cost basis to maintain their grid connection capacity. This is mostly applicable to generators at the end of their economic cycle, who whish to decommission. Disconnecting from the grid is subject to the regulator's and system operator's approval, and if denied, will trigger mothballing and maintenance cost reimbursement, levied onto the grid fees.

[66] Newberry. 2021. National Energy and Climate Plans for the island of Ireland: wind curtailment, interconnectors and storage. Access here.