Committee on Climate Change

Independent advice to government on building a low-carbon economy and preparing for climate change

The Sixth Carbon Budget and Welsh emissions targets – Call for Evidence

Background to the UK's sixth carbon budget

The UK Government and Parliament have adopted the Committee on Climate Change's (CCC) recommendation to target net-zero emissions of greenhouse gases (GHGs) in the UK by 2050 (i.e. at least a 100% reduction in emissions from 1990).

The Climate Change Act (2008, 'the Act') requires the Committee to provide advice to the Government about the appropriate level for each carbon budget (sequential five-year caps on GHGs) on the path to the long-term target. To date, in line with advice from the Committee, five carbon budgets have been legislated covering the period out to 2032.

The Committee must provide advice on the level of the sixth carbon budget (covering the period from 2033-37) before the end of 2020. The Committee intends to publish its advice early, in September 2020. This advice will set the path to net-zero GHG emissions for the UK, as the first time a carbon budget is set in law following that commitment.

Both the 2050 target and the carbon budgets guide the setting of policies to cut emissions across the economy (for example, as set out most recently in the 2017 Clean Growth Strategy).

The Act also specifies other factors the Committee must consider in our advice on carbon budgets – the advice should be based on the path to the UK's long-term target objective, consistent with international commitments and take into account considerations such as social circumstances (including fuel poverty), competitiveness, energy security and the Government's fiscal position.

The CCC will advise based on these considerations and a thorough assessment of the relevant evidence. This Call for Evidence will contribute to that advice.

Background to the Welsh third carbon budget and interim targets

Under the Environment (Wales) Act 2016, there is a duty on Welsh Ministers to set a maximum total amount for net Welsh greenhouse gas emissions (Welsh carbon budgets). The first budgetary period is 2016-20, and the remaining budgetary periods are each succeeding period of five years, ending with 2046-50.

The Committee is due to provide advice to the Welsh Government on the level of the third Welsh carbon budget (covering 2026-30) in 2020, and to provide updated advice on the levels of the second carbon budget (2021-25) and the interim targets for 2030 and 2040. Section D of this Call for Evidence (covering questions on Scotland, Wales and Northern Ireland) includes a set of questions to inform the Committee's advice to the Welsh Government.

CCC Call for Evidence on 6th Carbon Budget

Question and answer form – EDF Response

B. The path to the 2050 target

Question 5: How big a role can consumer, individual or household behaviour play in delivering emissions reductions? How can this be credibly assessed and incentivised?
Consumer, individual or household behaviour will be important in delivering emissions reduction. As the next phase of decarbonisation efforts brings heat and transport into focus, customer choices on energy efficiency, lower carbon transport and heating solutions will impact materially on the speed at which decarbonisation is achieved. For consumer action to be effective it needs to be within a regulatory and economic framework which is providing visible, strong policy and commercial signals for decarbonisation, supported by clear information for consumers about the emissions implications of their actions. Choosing the lower carbon option must be clearly viable, cost effective and deliver functionality and practicality at least on a par with existing fossil fuelled alternatives. This points to a need for government and delivery bodies to use the full range of tools available to them to help grow markets and incentivise consumer switching to lower carbon options which are aligned with a cost-effective pathway to net zero – this includes taxation and policy cost charging regimes, incentives, information and education programmes. Smart digital technologies can also help consumers manage the switch to lower carbon options. Measures such as a long-term commitment to target-consistent economy wide carbon pricing will have a role to play in influencing consumer behaviour. In the area of heat decarbonisation, where consumer and household behaviour will be especially important, there is a need to address current imbalances which mean that the increasingly low carbon fuel of electricity is subject to a carbon tax and a wide range of significant policy costs, but the incumbent fossil fuel gas heating option is not. See our response to Q26 for further evidence on this point.

Question 6: What are the most important uncertainties that policy needs to take into account in thinking about achieving Net Zero? How can government develop a strategy that helps to retain robustness to those uncertainties, for example low-regrets options and approaches that maintain optionality?
There are inevitably a wide range of uncertainties around the role that different technologies will play in achieving net zero. In the power sector, EDF's largest area of focus, there are particular uncertainties around the costs, potential contribution and full life cycle CO2 emissions of a range of technologies including hydrogen, storage and CCS options. There are also significant uncertainties around the future scale of electricity demand and net zero strategies will need to be robust to a range of outcomes on this.

Question 6: What are the most important uncertainties that policy needs to take into account in thinking about achieving Net Zero? How can government develop a strategy that helps to retain robustness to those uncertainties, for example low-regrets options and approaches that maintain optionality?

The CCC has highlighted in its own work the uncertainties surrounding production costs, lifecycle carbon emissions, technical and safety issues with hydrogen. Hydrogen production via steam methane reformation with carbon capture and storage cannot achieve a fully zero carbon outcome and its long-term use is therefore not clearly compatible with net zero ambitions. There are also unresolved questions on underground hydrogen storage capacity. To date, all UK hydrogen storage capacity analysis has been underpinned by a single study from ETI.[1] There is a need to better understand the costs and performance of constructing and operating underground hydrogen storage, including limitations on charge and discharge. Alternative hydrogen storage carriers such as ammonia should also be investigated further.

In a net zero world with high penetration of variable renewables, the economics of storage over various timescales (hours, days, weeks or even longer) become increasingly important. New storage technologies may play an important role alongside batteries – falling renewables costs could help a wider range of storage approaches become economic. For example, there are various, today less mature storage technologies that could play a role in the future generation mix, including liquid air storage, a.k.a. cryo-batteries. These will need to be proven and demonstrated. Lifecycle emissions and social and environmental impacts of storage technologies also need further examination. E.g. a 2017 EU study (here) suggests battery lifecycle emissions of 140-170 kgCO2e per kWh capacity. When paired with solar PV (for which IPCC estimate median emissions of 48g/kWh[2]), a solar + battery system cycled daily would result in lifetime emissions of c. 70g/kWh (vs 11-12 g/kWh for wind and nuclear [IPCC median).

Gas with carbon capture and storage (CCS) is an option which CCC suggests could play a large role to in providing firm low carbon power by 2050. However, this role is today highly uncertain due to the global absence of any large-scale gas + CCS plant. Coal + CCS has been demonstrated in ~350MW of projects[3] outside the UK – but with achieved capture equipment costs being 4-7 times higher[4] than those targeted in the UK CCUS action plan[5]. Moreover, gas + CCS projects would still give rise to emissions associated with incomplete CO2 capture and indirect emissions relating to gas production, transportation and storage. Total life cycle emissions for CCGT+CCS power generation have been estimated by IPCC to be around ~170gCO2e/kWh of which around 50-60gCO2e/kWh are direct from the combustion process and the remainder from indirect emissions[6]. The UK's marginal gas source (i.e. after meeting baseline gas demand in sectors without alternatives) for power CCS is likely to be LNG or Russian pipeline gas, both of which bring significant lifecycle emission risks: e.g. indirect

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[1] See: https://www.eti.co.uk/news/storing-hydrogen-underground-in-salt-caverns-and-converting-it-into-a-reliable-affordable-flexible-power-source-could-help-meet-future-uk-peak-energy-demands-according-to-the-eti

[2] IPCC 5th assessment report, median values from Annex III, Table A.III.2

[3] Boundary dam 120 MW (Canada; CCS retrofit on coal; https://ieaghg.org/docs/General_Docs/Reports/2015-06.pdf) and Petra Nova 240MW (US; CCS retrofit on coal; https://www.eia.gov/todayinenergy/detail.php?id=33552). A review of large-scale global CCS projects is provided in www.globalccsinstitute.com.

[4] Boundary dam capex c£124,200/kW, assuming 50% of total Capex is for CCS, as indicated by IEAGHG (see above). Total Capex quoted is c.£8,000/kW. Petra Nova capex c£122,300/kW (see EIA above), assuming that quoted capex includes c.£300/kW transport and storage Capex (scope of quoted Capex is unclear from announcements)

[5] £75/ MWh for FOAK CCGT+CCS (£ 2012) for baseload operations. UK CCUS Action Plan, 28 Nov 2018 (link).

[6] IPCC 5th assessment report, median values from Annex III, Table A.III.2. https://www.ipcc.ch/site/assets/uploads/2018/02/ipcc_wg3_ar5_annex-iii.pdf; p. 1335.

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emissions of 60g/kWh(th) (consistent with MacKay and Stone 2013 DECC review here for LNG and non-EU piped gas) implies ~ 130g/kWh(elec) indirect emissions. Any residual direct emissions will be added on top of this. While we recognise the question of indirect emissions from fossil gas only partly impacts the UK's territorial emissions accounting, it is a real climate issue that UK policy should account for.

Gas plus CCS projects will also rely on wider infrastructure for the safe transport and secure permanent long-term storage of CO2 in underground aquifers and they will need to address the economic and technical challenges associated with operating flexibly and at low load factors (which could give rise to consequential large variations in CO2 pressure in pipeline infrastructure). These challenges support the case for a full-scale demonstration project to help inform the role of gas + CCS in the power sector.

Uncertainties around future power sector technologies point to a strategic approach which encourages diversity of energy supply, deploys proven approaches and keeps all major options open while exploring approaches. New nuclear power remains today the most proven and affordable form of firm low carbon generating capacity currently available to the GB market. System-wide analyses of the power sector have consistently concluded that least cost decarbonisation will require a balanced generation mix, including new nuclear[7]. New nuclear is a pragmatic and low regrets route to continued power sector decarbonisation and retains optionality. But to maintain this option most cost effectively requires a continuous development path from Hinkley Point C to further projects, thus maintaining supply chain skills, capacity and technical expertise. See also our response to Q30 in this context.

In a similar vein onshore wind is a highly proven low cost and deployable renewable technology and with more supportive policy there remains significant scope to deploy more in the GB market, drawing on the excellent wind resource in Scotland and Wales in particular, to the benefit of all GB consumers.

Looking across all sectors, regulatory and carbon pricing arrangements which preserve technology neutrality – and which provide consistent economic signals in support of all forms of lower carbon approaches – are an obvious policy mechanism which will help to preserve optionality while retaining a robust signal to decarbonise.

[7] See for example the following UK specific studies: Options, Choices, Actions - Updated 2018, Energy Technologies Institute https://www.eti.co.uk/options-choices-actions-2018, and Analysis of alternative UK heat decarbonisation pathways, Committee on Climate Change https://www.theccc.org.uk/publication/analysis-of-alternative-uk-heat-decarbonisation-pathways/ Also the recent Atkins report on engineering for net zero: http://explore.atkinsglobal.com/engineeringnetzero/assets/pdf/Engineering%20Net%20Zero%20Technical%20Report.pdf (p26 has a nice graph)

Question 7: The fourth and fifth carbon budgets (covering the periods of 2023-27 and 2028-32 respectively) have been set on the basis of the previous long-term target (at least 80% reduction in GHGs by 2050, relative to 1990 levels). Should the CCC revisit the level of these budgets in light of the net-zero target?

As the CCC has identified, the UK is not on track to deliver the existing fourth and fifth carbon budgets, let alone any revisions to these budgets which could be made in the light of the net zero target. There is a clear need for the acceleration of decarbonisation policy and actions through the 2020's and Government must take the remedial actions needed to get the UK on track to meet the fourth and fifth carbon budgets.

Beyond that there is also a need to put the UK on course to achieve net zero by 2050. This may imply revisiting the fourth and fifth carbon budgets although, in EDF's view, getting the right strategic decisions and policies in place, and commencing the essential major investment programmes which are needed for net zero, is ultimately at least as important in this timeframe as any formal changes to existing carbon budgets. These critical decisions include the steps necessary to deliver continued progress on the decarbonisation of power (incl. further large scale investment in renewables and new nuclear) the trialling of carbon capture and storage at scale, an acceleration of energy efficiency programmes, making key strategic decisions on the decarbonisation of heat and developing an accompanying policy framework, as well as maintaining and accelerating recent good progress on the market penetration of electric vehicles.

Question 8: What evidence do you have of the co-benefits of acting on climate change compatible with achieving Net Zero by 2050? What do these co-benefits mean for which emissions abatement should be prioritised and why?

There are a range of economic and environmental co-benefits arising from investment in low carbon energy. Improved air quality is one and we refer the CCC to Energy UK's response for further detail on this aspect. Increased security of supply arising from reduced reliance on fossil fuel imports is a further benefit of most low carbon options – investment in domestic low carbon electricity generation also reduces risks associated with high levels of interconnection, including that electricity imported via interconnectors has a higher carbon content than domestic production – see our response to Q30 for further information on this point.

The wider economic benefits of investment in wind power have been analysed in a number of reports prepared by BVG Associates (BVGA). For example, lifetime undiscounted "Totex" (total expenditure) UK content for wind is expected to be greater than 60% in the 2030s (onshore wind estimated at 66% for existing projects – here); and the offshore wind sector deal has an ambition of 60% for projects commissioning in 2030. BVGA have assessed that a commitment to five 1GW CfD auctions for onshore wind could deliver[8]:

- 18,000 jobs during peak construction, and 8,500 long term skilled jobs supporting the operation of the wind farms. 60% of the jobs would be created in Scotland, 23% in England and 17% in Wales.

- £6 billion of investment in new clean generation and £12bn of gross value added.

[8] https://bvgassociates.com/the-power-of-onshore-wind/

Question 8: What evidence do you have of the co-benefits of acting on climate change compatible with achieving Net Zero by 2050? What do these co-benefits mean for which emissions abatement should be prioritised and why?
EDF is leading the revival of new nuclear power in the UK and a feature of investment in new nuclear is the very high level of national and regional socio-economic benefits which arise, both during the construction phase but also during operation in terms of the provision of lasting high skilled employment and regional economic benefit. EDF has been recording information on the socio-economic benefits realised by the under construction Hinkley Point C (HPC) project to date. Our latest information and annual report on socio-economic benefits can be found here: Some specific figures of note are that: • Around 64% of value of HPC contracts is with UK companies • ~8,600 new jobs created on site to date (targeting 25,000 through the project) • £1.7bn of contracts committed with regional companies in the south west • 529 apprentices created to date (targeting 1,000 through the project) • £111m community investment delivered to date New nuclear can therefore be a major component of the industrial and skills renewal of the UK, the spreading of prosperity beyond London and the south-east and an enabler in assisting the "just transition" as we move away from industries and consumption based on unabated fossil fuels. New nuclear can also support future system operation through provision of a large source of inertia. These wider system and economic benefits should be a factor in the overall evaluation and assessment of the value for money of any major investment in large scale low carbon infrastructure.

C. Delivering carbon budgets

Question 9: Carbon targets are only credible if they are accompanied by policy action. We set out a range of delivery challenges/priorities for the 2050 net-zero target in our Net Zero advice. What else is important for the period out to 2030/2035?

EDF recognises many of the policy and delivery priorities set out by the CCC in Chapter 6 of its Net Zero report. In addition to those referenced we would highlight three important additional policy priorities:

- Urgent decisions are needed on new nuclear power and in particular the use of a Regulated Asset Base (RAB) model for further new nuclear investment. The RAB approach has clear potential to enable financing of large scale new nuclear (and other large-scale low carbon infrastructure) at a much lower cost of capital (and thus lifetime costs to consumers) – see our response to Q30 for further detail on the substantial impact of lower financing costs. Developing the RAB in a timely fashion would enable the construction of Sizewell C as a follow-on project from Hinkley Point C, allowing reductions in construction cost and risk to be realised in a next-of-a-kind new nuclear development through the application of a stable approved design and drawing on construction experience from HPC – factors which international experience demonstrates are critical to securing cost and risk reductions in nuclear construction.

- Decisions are needed on the role of carbon pricing within the UK's decarbonisation strategy. In the near term the UK's post Brexit approach to carbon pricing requires clarification (EDF shares the CCC view that a linked arrangement with the EU ETS is the preferred approach) and Carbon Price Support (CPS) needs to be maintained in the power sector to drive continued decarbonisation of the electricity mix, supporting a diverse set of low carbon and flexible generation options, enabling the minimisation of gas generation in an efficient, technology neutral manner.

- An evolution of the policy framework is needed to make lower carbon heating options economically viable for customers, service providers and suppliers. CCC recognise in their net zero report the need to develop electric and hydrogen options for heat decarbonisation. Alongside support for demonstration programmes and pilot projects, and a long-term view of strategic direction, this implies the need to gradually extend carbon pricing to domestic and commercial gas consumption (managing impacts on the vulnerable and fuel poor) and to address current market distortions which place large policy costs on the consumption of increasingly low carbon electricity but not the consumption of fossil fuel gas. Other incentives in the form of grants and taxation measures, as today apply to the electrification of transport, will also be needed to develop early markets in low carbon heat.

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Question 10: How should the Committee take into account targets/ambitions of UK local areas, cities, etc. in its advice on the sixth carbon budget?

EDF welcomes initiatives on the part of local areas and cities to achieve high levels of decarbonisation. Such initiatives can be of specific broader national value where they involve the trialling of new approaches or solutions, which may then be replicated more widely. Regional or local approaches to the decarbonisation of heat (through eg heat networks, hydrogen trials or off-gas grid electrification) will be especially valuable in this context.

Question 10: How should the Committee take into account targets/ambitions of UK local areas, cities, etc. in its advice on the sixth carbon budget?

There is also value in recognising the advantages that local conditions offer for low carbon solutions and in enabling actions to secure the full benefits of these. For example, wind speeds in Scotland are among the highest in Europe and higher still in particular locations, such as islands. Also, some locations within areas or regions offer particular opportunities for innovation and R&D. Local ambitions and targets can take account of these specific opportunities and enable their value to be realised.

However, with respect to electricity consumption, the ambitions of local and corporate entities to decarbonise are today typically achieved through the simple mechanism of purchasing a 100% renewable energy tariff or similar product. While well intentioned, the CCC will be aware that the use of such tariffs (unless directly linked to, and providing funding for, the specific development of a new renewable generating station) make no difference to the composition of the national electricity mix or the carbon emissions associated with it. They do not provide an accurate carbon footprint, encourage meaningful end user action or incentivise new low carbon generation.

The rules and regulations governing the marketing and promotion of such tariffs are today very light touch: they allow for renewable supply to be achieved through the purchase of Renewable Energy Guarantee of Origin (REGO) certificates without any associated acquisition of renewable power. There is also no requirement to match renewable provision with the actual shape of electricity demand. The reality is thus that consumers using such tariffs have not decarbonised their electricity consumption in the way, or to the extent, that they may believe to be true - this issue was also acknowledged in Ofgem's recently published Decarbonisation Action Plan.

EDF considers that there is a pressing case for reform of these arrangements to provide a more rigorous basis on which all forms of low carbon electricity tariffs can be sold and promoted across the market – Revised approaches should also provide more incentive for local authorities, corporate entities and customers generally to initiate meaningful end-user action incl. reducing energy consumption, changing behaviours, and flexible approaches involving demand shifting and storage. The value of such reforms will become even greater over time as we progressively decarbonise our power sector and increasingly rely on electricity to decarbonise transport and heating - the importance of consumer action in these sectors to maximise decarbonisation outcomes has been highlighted in our response to Q5.

Question 11: Can impacts on competitiveness, the fiscal balance, fuel poverty and security of supply be managed regardless of the level of a budget, depending on how policy is designed and funded? What are the critical elements of policy design (including funding and delivery) which can help to manage these impacts?

There will undoubtedly be challenges in managing and allocating the costs and impacts of decarbonisation across the UK economy, taking account of issues of competitiveness, fiscal balance and both government and consumer budgets. Cost allocation should aim to be fair, incentivise the right behaviours and business models and take account of price sensitive consumers (eg fuel poor, energy intensive industry). While there are no perfect solutions in this area EDF believes that better outcomes and tackling of future challenges can be achieved through implementing changes which gradually deliver a better balance in the burden of future costs and which help to contain the scale of lifetime costs to consumers.

Question 11: Can impacts on competitiveness, the fiscal balance, fuel poverty and security of supply be managed regardless of the level of a budget, depending on how policy is designed and funded? What are the critical elements of policy design (including funding and delivery) which can help to manage these impacts?

- With respect to **competitiveness**, it will be important to continue to avoid excessive burden on industry, especially Electricity Intensive Industries (EIIs).[9] Mechanisms to assist industry are already in place with respect to the policy costs arising from decarbonisation of electricity but developing policy on CCS, hydrogen and the decarbonisation of heat and industry will need to consider competitiveness impacts carefully. The concept of carbon border taxes also deserves consideration in this context.

- The goal of **fiscal balance** can be aided by striking the right balance between taxation of carbon emitting activities and incentives for lower carbon options. Strong and broader based carbon pricing (including gradual extension of carbon pricing to gas consumption) can help to drive a wide range of lower carbon options in a technology neutral manner while raising more funds for government. The tax raising potential of broader and stronger carbon pricing should be a factor in UK government efforts to achieve net zero and can help pay for the costs of new schemes and incentives which will be needed in a range of areas to drive change. Various recent reports have highlighted the revenue raising potential of broader carbon pricing – see for example the work by the LSE and Grantham Institute published in May 2019 which illustrated a revenue raising potential for HMG of ~£20bn per year from the implementation of more broadly based and stronger carbon pricing approaches .

- There are recognised risks in relation to **fuel poverty** if all future costs of decarbonisation are placed on energy consumers without protections for lower income groups or the more vulnerable – the CCC has highlighted this issue in its previous reports. Equally energy costs need to provide signals for lower carbon options and there is a need to balance decarbonisation costs across electricity and gas in order to drive the right lower carbon behaviours – see our response to Q26 for further detail. Specific measures and protections can be considered and implemented for the fuel poor.

- **Security of supply** will always be a pre-requisite for a functioning economy and popular acceptance of decarbonisation. In the case of electricity capacity adequacy is is today effectively delivered by the capacity market at relatively low cost, but there is also a need to ensure system and network operability in a shift to low carbon. The gradual electrification of transport and increased electrification of heat will over time increase pressure on the electricity system. This highlights the long-term value of the capacity market principles, but also the need for smart digital approaches to manage demand and maximise flexible approaches. National and local network capacity also requires revised regulatory arrangements to ensure electrification can be delivered in a timely fashion – as recently recognised by Ofgem in its decarbonisation plan.

The challenges described above highlight the imperative of decarbonising at least cost.

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[9] While also noting that most UK companies are not especially exposed to energy costs – eg our own analysis on electricity costs for industry and commerce suggests that electricity makes up <10% of total costs for c.98% of UK business (by GVA). This is based on ONS data for GVA by sector; BEIS for electricity consumption by sector; and BEIS average electricity price for non-residential customers.

Question 11: Can impacts on competitiveness, the fiscal balance, fuel poverty and security of supply be managed regardless of the level of a budget, depending on how policy is designed and funded? What are the critical elements of policy design (including funding and delivery) which can help to manage these impacts?

Mechanisms which attract a wide pool of investors and encourage the private sector to invest at a low cost of capital will therefore be key for a cost-effective transition. Decarbonisation will require huge capital-intensive investments in a wide range of sectors – this implies a clear need to secure capital from a wide range of potential investors – this will also reduce the extent of capital investment burden that government itself may need to contribute. The cost of capital which these investments are made at will also fundamentally impact on the total lifetime costs to consumers. New nuclear power is a striking example of this issue and a Regulated Asset Base (RAB) approach for new nuclear, as consulted on by HMG in summer 2019, has clear potential to reduce lifetime consumer costs in the electricity sector – see our response to Q30 for further detail on the benefits of the RAB model for new nuclear.
While the case of new nuclear is, due to its capital intensity and long lifetime an especially compelling example of the benefits of a low cost of capital, the same point applies more broadly across all other areas where capital-intensive low carbon investment will be required. For this reason cost and availabililty of capital considerations should be critical elements of policy design for net zero and the reduction and allocation of risks are a critical element of this. In addition to specific mechanisms such as the RAB, we believe wider investment vehicles with HMG backing could facilitate low cost financial investor funding for a diverse set of low carbon infrastructure and assets and this approach should also be explored in parallel.

Question 12: How can a just transition to Net Zero be delivered that fairly shares the costs and benefits between different income groups, industries and parts of the UK, and protects vulnerable workers and consumers?

EDF Energy recognises the importance of seeking a "just transition" to net zero. We would make a number of points in this context:

- Companies have a role to play in responsibly addressing the challenges. In our own business we have worked hard with unions and employees to provide opportunities for staff working at our Cottam coal plant which ceased operations in September 2019. We have been successful in identifying continued employment for nearly 70% of the staff employed at the station.

- New industries and low carbon energy sector developments can play a major role in providing substantial new investment and reliable employment– often providing new infrastructure for regions particularly in need of investment as well as new skilled roles. In our Hinkley Point C project we are investing in education, skills and employment, including for those not in education, employment, or training (NEETs). In other sectors there are clear opportunities to, for example, transfer north-sea oil and gas industry expertise to the benefit of carbon capture and storage, and to redeploy gas boiler engineers to address skill shortages in the design and installation of future lower carbon heat pump, hybrid heat pump and hydrogen based systems.

- Vulnerable consumers and energy intensive industries will need protection in the transition to net zero – implying careful policy development and that not all costs should be placed on energy consumers – see our response to Q11 above.

Question 12: How can a just transition to Net Zero be delivered that fairly shares the costs and benefits between different income groups, industries and parts of the UK, and protects vulnerable workers and consumers?

- The allocation and charging of policy costs in the energy sector requires careful consideration in this context. We have highlighted in other answers the issues of imbalance between gas and electricity. Another consideration is to ensure that behind-the-meter generation does not avoid an appropriate share of energy system costs, leaving them increasingly loaded on to those in society and the economy who are unable to install or afford their own on-site generation. This question has recently been addressed by Ofgem in its review of residual network costs but may require further consideration in respect of other elements of the energy bill.

D. Scotland, Wales and Northern Ireland

Question 13: What specific circumstances need to be considered when recommending an emissions pathway or emissions reduction targets for Scotland, Wales and/or Northern Ireland, and how could these be reflected in our advice on the UK-wide sixth carbon budget?

The Scottish Government and the Scottish Parliament has set itself the target of achieving net zero by the earlier date of 2045. However, in order to achieve this, there are a number of actions that will likely be required to be taken by the UK as a whole as part of its reserved powers. A specific example is the re-introduction of CfD support for onshore wind, where Scotland has very large remaining potential from both re-powering and new projects. In addition, although Scotland has some devolved powers relevant to the de-carbonisation of heat and transport, the carbon and energy taxation, and policy cost charging frameworks, which will significantly impact on the decarbonisation of these sectors, all remain reserved powers.

Carbon targets in Wales should also take account of the significant potential for onshore wind in Wales.

Question 16: Do you have any evidence on the appropriate level of Scotland's interim emissions reduction targets in 2030 and 2040?

The Scottish Government had existing interim targets in the Scottish Energy Strategy prior to the adoption of a 2045 net zero target. These should be reviewed in the light of the new target. However, as per our response to Q7, we see the taking of key strategic decisions and necessary implementing measures to be as important as specific interim emissions targets and dates.

Question 17: In what particular respects do devolved and UK decision making need to be coordinated? How can devolved and UK decision making be coordinated effectively to achieve the best outcomes for the UK as a whole?

There are a number of areas where Scottish and UK wide policy needs to be consistent and co-ordinated if sufficient progress on decarbonisation towards net zero targets is to be achieved. As noted in response to Q13, these include policy on onshore wind, and heat and transport – where UK level decisions and mechanisms will be needed to ensure the delivery of Scottish ambitions. Co-ordination between the Scottish and UK Governments on offshore wind is also desirable, including in relation to national targets, approaches to grid connection and exploring the scope and potential for floating offshore wind within overall targets.

E. Sector-specific questions

Question 20 (Surface transport): The CCC recommended in our Net Zero advice that the phase out of conventional car sales should occur by 2035 at the latest. What are the barriers to phasing out sales of conventional vehicles by 2030? How could these be addressed? Are the supply chains well placed to scale up? What might be the adverse consequences of a phase-out of conventional vehicles by 2030 and how could these be mitigated?

EDF supports the rapid transformation of the passenger car market to electric or other zero tailpipe emission options and we note and welcome the Government's recently announced intention to consult on bringing forward the phase out date for conventional vehicle sales to 2035. It remains vital that this long-term target is complemented by nearer-term incentives to encourage motorists to shift to electric vehicles and we consider that the current support framework, which includes consumer grants, tax incentives and support for re-charging infrastructure, working alongside a wider European level regulatory framework to progressively reduce the carbon intensity of passenger vehicles, is now proving effective in rapidly growing the UK market for electric vehicles.

The last 6 months of 2019 have seen record levels of EV sales, reaching a monthly high of 6.3% of new car sales in December 2019[10]. We anticipate further growth in EV sales in 2020 but a key requirement to achieve this continued growth in the market will be maintaining the current set of market measures and incentives over the coming years, with at most only a very gradual reduction in the level of incentives in line with falling new vehicle costs.

Ensuring strong growth in EV sales through the early 2020's is in our view key to creating the conditions which can make the proposed 2035 ban on the sale of new petrol, diesel or hybrid vehicles a viable and sustainable proposition. A growing market will help support continued growth in the provision of charging infrastructure, will facilitate cost reduction in new EVs, will enable the emergence of a large scale second-hand EV market and will support wider popular acceptance that the transition to EVs is happening and that the phase out date is politically and practically viable. Through the 2020's the consumer's active choice to buy an electric vehicle is also an opportunity to build and stimulate greater consumer engagement in the wider steps and behavioural measures needed to deliver low carbon – including smart approaches to charging their car.

We do not anticipate fundamental technical or infrastructure related barriers to a 2035 phase out date. However, it will be important that the right balance of network regulation to allow necessary infrastructure investment and smart approaches to manage rising EV demand are implemented. Without such measures there is a risk of local network capacity problems and higher use of more carbon intensive gas generation. Growing electrification of transport and heat also highlights the importance of achieving continued momentum in the decarbonisation of power through the 2020s and 2030s.

[10] Based on SMMT data, including both pure electric and plug-in hybrid electric vehicle sales.

Question 21 (Surface transport): In our Net Zero advice, the CCC identified three potential options to switch to zero emission HGVs – hydrogen, electrification with very fast chargers and electrification with overhead wires on motorways. What evidence and steps would be required to enable an operator to switch their fleets to one of these options? How could this transition be facilitated?

EDF would support research, development and the piloting of new technological solutions for zero emission HGVs, including low carbon hydrogen-based approaches. In parallel with this, regulatory interventions will be needed to drive long-term market change – we consider that a measure similar to the EU level new car CO2 regulations, requiring progressive reductions in the CO2 emissions of HGVs, may be needed to drive market change in this area. This should be technology neutral so that different electric, hydrogen or other approaches can compete on an even basis.

Question 22 (Industry): What policy mechanisms should be implemented to support decarbonisation of the sectors below? Please provide evidence to support this over alternative mechanisms.

a) Manufacturing sectors at risk of carbon leakage
b) Manufacturing sectors not at risk of carbon leakage
c) Fossil fuel production sectors
d) Off-road mobile machinery

Carbon pricing should remain a significant part of the policy toolkit for addressing industrial emissions – its value in the policy mix as a technology neutral and economically efficient means of stimulating all lower carbon options should not be underestimated. For sectors at risk of carbon leakage there will be a need to consider specific protection mechanisms and carbon border taxes or adjustments are policy options which, while raising some complexities, deserve further consideration in this area. For hard to decarbonise sectors and processes, R&D support to industry in moving to lower carbon approaches will also remain an important part of the policy mix.

Question 26 (Buildings): For the majority of the housing stock in the CCC's Net Zero Further Ambition scenario, 2050 is assumed to be a realistic timeframe for full roll-out of energy efficiency and low-carbon heating.

a) What evidence can you point to about the potential for decarbonising heat in buildings more quickly?
b) What evidence do you have about the role behaviour change could play in driving forward more extensive decarbonisation of the building stock more quickly? What are the costs/levels of abatement that might be associated with a behaviour-led transition?

As the CCC has identified in its own February 2019 report 'UK housing: Fit for the future?', progress in decarbonising the UK's building stock has stalled and the current rate of installation of new energy efficiency and low carbon heating measures is substantially below that which will be needed to deliver net zero by 2050 and to grow new markets for energy efficiency and lower carbon heating products and fuels during the 2020's. We support many of the recommendations CCC has made in this area around the need to significantly

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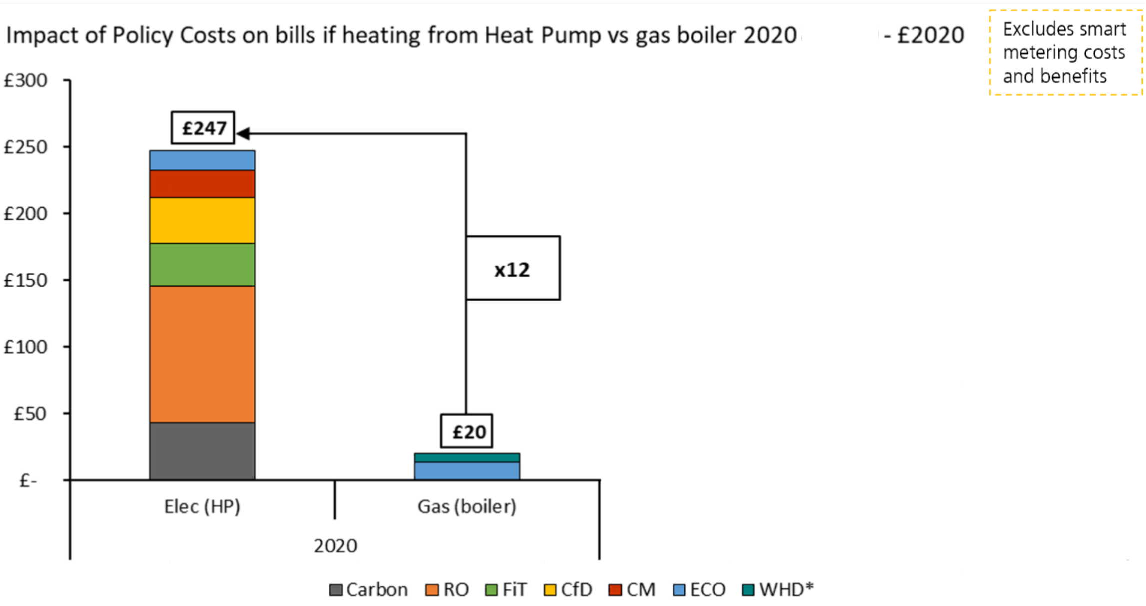
accelerate progress in energy efficiency installations, demonstrate options at scale and grow markets for options such as heat pump or hybrid heat pump systems. We support reform of the ECO scheme to focus on carbon savings, extend availability to all consumers and with a proportion of the scheme focussed on supporting innovative delivery models and measures which have the potential to grow new markets for energy efficiency.

With respect to the specific role of behaviour change, as in our response to Q5, for this to be effective at scale if needs to be within a regulatory and economic framework which provides clear policy and commercial signals for decarbonisation – especially given there is likely to be some consumer inertia and resistance to the changes required.

A critical enabling step will be to at least equalise the lifetime costs of lower carbon heating options compared to the traditional gas boiler. This will require the extension of carbon taxation to domestic and commercial gas consumption and measures to address the current imbalance in the charging of policy costs between electricity and gas. We have recently up-dated our analysis of this imbalance to illustrate – as shown in the charts below – that a typical home using an efficient air source heat pump will pay over £200 pa more (around 12 times) the policy costs on their annual heating bill as a home using a gas boiler. Over an approx. 15 year operational life for a heat pump, this represents a major economic charge on the lower carbon electric heating option, and a clear barrier to consumer adoption of lower carbon heat pump or hybrid heat pump options.



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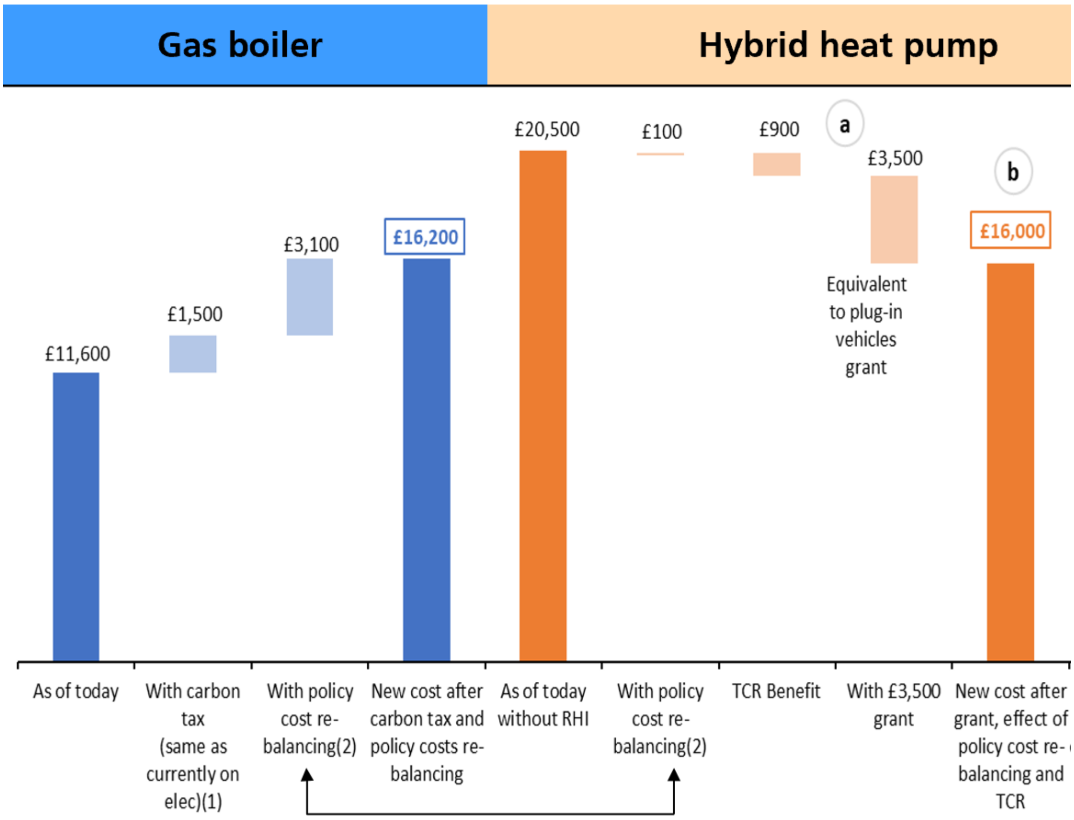
There is therefore a vital need to review charging approaches in this area and move towards arrangements which provide a better balance in policy cost charging between gas and electricity consumers.

Incentives to adopt lower carbon heating options will also be needed, especially when the heat pump market is in its early stages of development and volumes are smaller. We illustrate in the indicative chart below how an up-front grant of £3,500 (the same as currently offered for the purchase of electric vehicles, and materially lower than the lifetime support currently provided by the Renewable Heat Incentive) would, in combination with equivalent carbon taxation of gas, equalisation of wider policy cost charging between gas and electricity, and the recent impact of the Targeted Charging Review changes, broadly equalise the lifetime capital and operational costs (over an assumed 15 year period) between a gas boiler and a hybrid heat pump system for a typical home.



Such equalisation of lifetime costs could enable companies to deliver more compelling lower carbon heating options to the mass market, including through provision of a "heat as a

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service" business models which enable consumers to avoid the typically higher up-front capital costs of lower carbon options.

Another challenge in this area is that homeowners most commonly replace their gas boiler when it has broken, leading them to seek rapid installation of a like-for-like replacement. Policy measures which encourage low carbon home up-grades during periods in which home improvements are most commonly undertaken should therefore be given serious consideration. Variable stamp duty linked to a building's EPC rating has the potential to be an effective intervention in this context – offering the potential for stamp duty tax rebates for homeowners who refurbish their property to a higher EPC rating within a given timeframe after sale. Such a measure would require reform of the current EPC rating system to ensure credit is offered for the installation of lower carbon heating solutions.

Question 27 (Buildings): Do we currently have the right skills in place to enable widespread retrofit and build of low-carbon buildings? If not, where are skills lacking and what are the gaps in the current training framework? To what extent are existing skill sets readily transferable to low-carbon skills requirements?

There are a range of existing skill gaps in this area. These include low numbers of people skilled in the design and installation of heat pump and hybrid heat pump systems and a broader lack of individuals and companies capable of providing homeowners with independent whole-house advice on the range of energy efficiency and lower carbon heating options available to them.

EDF therefore supports initiatives to address relevant skill gaps. Equally if the right policy framework were driving greater demand for energy efficiency and lower carbon heating installations, in a stable and predictable manner, we consider that the market would be able to respond. National skills and re-training programmes focussed on new areas of low carbon building need would be a valuable complement to a growing market and increase the impact of wider policy interventions, but skills programmes introduced in the absence of fundamental regulatory or economic drivers for higher energy efficiency and lower carbon heating solutions will not have the desired impact and will struggle to attract and retain good recruits.

Question 28 (Buildings): How can local/regional and national decision making be coordinated effectively to achieve the best outcomes for the UK as a whole? Can you point to any case studies which illustrate successful local or regional governance models for decision making in heat decarbonisation?

We consider that a national level framework will be needed to drive effective decarbonisation of heat from buildings. This will need to address existing carbon pricing and policy cost imbalances (see our response to Q26 above), provide incentives for the installation of lower carbon heating options and a regulatory framework which requires across all areas the gradual phasing out of unabated fossil fuel building heat. These measures should be structured to provide consistent support to all forms of lower carbon heating.

Within this overall framework there should be scope for local areas or regions to progress regionally tailored approaches – with for example greater use of heat networks in urban areas, regional use of hydrogen where there is a suitable network in close proximity, and greater reliance on electric solutions in the off-gas grid. At this stage there are uncertainties on the respective scale of role between electric and lower carbon gas options for decarbonising heat. Support for the development of hybrid heating systems, as proposed by CCC, for the majority of existing on-gas grid homes therefore makes clear sense at this stage and preserves vital optionality as policy, technology and commercial frameworks in this area develop.

Question 29 (Power): Think of a possible future power system without Government backed Contracts-for-Difference. What business models and/or policy instruments could be used to continue to decarbonise UK power emissions to close to zero by 2050, whilst minimising costs?

CCC's own analysis has identified that a very large (approx. quadrupling) of low carbon generation is likely to be required to achieve net zero by 2050, implying a large increase in power sector investment in new capacity – much of which will be for large projects. Such investments inevitably face significant long-term risks and the scale of capital investment required implies a need to attract new investors into the power sector - including more financial investors such as infrastructure and pension funds. In this broad context some form of public intervention to address and reduce the major risks faced by investors is likely to continue to be needed over the long term.

EDF therefore supports the continuing use of contracts for difference (CfDs) to support further large-scale investment in renewables in the GB market. The CfD scheme has proved highly effective in reducing through competition the costs of offshore wind and facilitating large scale private finance to come into the sector. A key benefit of the CfD regime is that it facilitates investment at a lower cost of capital measure (see our comments in response to Q11) as the revenue predictability that it offers reduces risks substantially and makes projects much more bankable and investable. Future consumers will continue to benefit substantially from this risk reduction, as well as the potential to benefit from the two-way nature of the scheme which allows for funds to return to consumers if achieved power prices are above strike prices. We therefore see no fundamental reason to move away from the broad principles of the approach that the CfD scheme has developed – indeed we consider it should be re-introduced for onshore wind schemes so that the benefits of the approach for the GB market and consumers can be maximised. Any move to abandon, rather than gradually evolve, the CfD regime would add un-necessary risk and uncertainty into the UK market framework when the priority should be to maintain momentum in what has to date been strong progress in the decarbonisation of the power sector.

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While evidence exists of a small number of merchant and corporate PPA backed renewable projects being developed, it is important to stress that the market potential for this approach is very limited - notes of a workshop with BEIS on the potential for corporate PPA's held in 2019 suggested participants could envisage only hundreds of MW or very low GW of renewables being developed through this approach by 2030. It will therefore not be possible to achieve the scale of renewables build required to support net zero targets without the CfD framework and the benefits it brings in terms of revenue certainty and access to external investment.

In addition to maintaining the CfD, a mechanism such as the Regulated Asset Base model will be needed to deliver new nuclear power and is likely to be suitable for other very large-scale capital intensive low carbon infrastructure (for example such as carbon capture and storage networks) where the high capital intensity, lengthy construction periods and requirement for investor protection against remote risks make a RAB mechanism especially valuable in reducing costs of capital and attracting large scale private finance.

Strong carbon pricing will also be needed over the long term in the GB power sector to facilitate the continued operation of many GW of otherwise un-supported low carbon capacity which includes not only the existing nuclear fleet but also hydro, storage assets and the many GW of renewables which are coming off RO support from the mid 2020's – we estimate that there will be 25-40 GW of unsupported low carbon capacity in the period 2027-2040. Such carbon pricing will not only facilitate securing the maximum life and maintenance of these assets but will also impact positively on the merit order scheduling of power sector assets and flexible solutions such as Demand Side Response (DSR) and storage to deliver the lowest carbon mix of GB power on a daily basis. Greater clarity on the carbon pricing framework which will apply in the next decade and beyond is therefore an important policy goal which will support a very wide range of low carbon power sector assets, investments and scheduling decisions.

EDF considers that a combination of the CfD regime, a RAB mechanism for very large-scale capital-intensive projects and strong long-term carbon pricing has clear potential to cost effectively drive very substantial further decarbonisation of the GB power sector over the next decade. We recognise that some elements of market reform may become desirable in time to respond to the specific circumstances of a power sector with very high levels of variable generation – eg to ensure that there are clear incentives for the supply of firm low carbon power at times of system need and to ensure that the system is optimised to meet demand in a low carbon way on an hourly basis. Any changes to policy should be developed with care and with a view to preserving the best elements of the existing market framework which have been successful in encouraging investment and rapidly reducing power sector carbon intensity.

Question 30 (Power): In Chapter 2 of the Net Zero Technical Report we presented an illustrative power scenario for 2050 (see pages 40-41 in particular):

a) Which low-carbon technologies could play a greater/lesser role in the 2050 generation mix? What about in a generation mix in 2030/35?

b) Power from weather-dependent renewables is highly variable on both daily and seasonal scales. Modelling by Imperial College which informed the illustrative 2050 scenario suggested an important role for interconnection, battery storage and flexible demand in a future low-carbon power system:

  i. What other technologies could play a role here?

  ii. What evidence do you have for how much demand side flexibility might be realised?

Part a): Which low-carbon technologies could play a greater/lesser role in the 2050 generation mix? What about in a generation mix in 2030/35?

EDF recognises the large future role for renewables as presented in the illustrative power scenario for 2050 and also supports the CCC finding that the generation mix will also require a significant ongoing role for firm low carbon power.

Our main issue relating to the illustrative generation mix shown visually on page 41 of the Net Zero Technical report is that the scenario envisages only a modest role for new nuclear (in providing up to ~11% of demand) while being noteworthy for the very large contribution envisaged from gas generation with CCS, making up ~23% of and the mix and ~150 TWh of output. While it is recognised in the text to be one scenario, with many possible alternatives (including a scenario with a larger role for new nuclear), the modest role envisaged for new nuclear and the much larger role for gas with CCS are somewhat at odds with the findings of most external 2050 power sector analyses of the optimal lowest cost mix needed to meet net zero[11] - and the consideration that nuclear is today the only globally proven scalable source of firm very low carbon output.

EDF recognises the case for developing and testing of power sector CCS options – through for example, support for an early demonstration project within a CCS cluster, but the very high reliance on gas with CCS in the CCC scenario presented seems ambitious today bearing in mind that power sector fossil fuel CCS still in its infancy with many outstanding uncertainties on costs and full life cycle emissions – see our response to Q6 for further material and evidence on this.

External analyses which envisage a much larger role for nuclear in the 2050 mix include the findings of the Imperial College study on which the CCC net zero power sector analysis is stated to be based. For example the "Hybrid 10 Mt" scenario of Imperial College – which CCC reference specifically on p40, envisages 35 GW of new nuclear in 2050 (rather than the ~9-10 GW in the CCC illustrative power scenario). Indeed all of the Imperial College scenarios which fully achieve zero emissions in the power sector have in excess of 40 GW of nuclear[12], which at a ~90% load factor could be expected to provide ~300-350 TWh of generation by 2050, and Imperial College state in their supporting commentary on this analysis that "*meeting a zero-emission target cost effectively would require a significant capacity of nuclear generation in all pathways, due to the variability of renewable production*

[11] See footnote 7 in our response to Q6

[12] See Figure E.3 at p16 of the Imperial College report: Analysis of Alternative UK Heat Decarbonisation Pathways

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i. What other technologies could play a role here?

ii. What evidence do you have for how much demand side flexibility might be realised?

and the need to eliminate emissions associated with management of demand-supply balance".

EDF recognises that recent issues with the Moorside and Wylfa new nuclear projects may have led CCC to reduce their central case view of the degree of new nuclear which may be realisable by the 2030's. There have also been well publicised delays with some of the early EPR projects. However Hinkley Point C construction is progressing well and the operational reactors at Taishan now demonstrate the EPR design works. Work by the nuclear industry as part of its sector deal with government continues with the aim of delivering at least a 30% reduction in costs, with the costs of Hinkley Point C as the UK First-of-a-Kind (FOAK) benchmark. This work has already identified that there is a relatively small number of key factors that drive the range of outcomes in nuclear construction projects around the world – as set out in the table below. Many of these features are not unique to new nuclear but apply to large construction projects across sectors.

Low cost plants	**High cost plants**
• Design at or near complete prior to construction • High degree of design reuse • Experienced construction management • Highly productive labour • Experienced EPC consortium • Experienced supply chain • Detailed construction planning prior to starting construction • Intentional new build programme focused on cost reduction and performance improvement • Multiple units at a single site • NOAK design	• Lack of completed design before construction started • Major regulatory interventions during construction • FOAK design • Litigation between project participants • Significant delays and rework required due to supply chain • Long construction schedule • Relatively higher labour rates and low productivity • Insufficient oversight by owner

The table illustrates that there is clear potential to realise cost and risk reductions on a next-of-a-kind (NOAK) project (Sizewell C) through a combination of replication of a stable design, construction learning, a more experienced supply chain and detailed construction planning.

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In addition, the use of a Regulated Asset Base (RAB) framework can deliver additional value for money for consumers by enabling a new nuclear project to attract a much wider pool of infrastructure investors and thus be financed at a much lower cost of capital. It achieves this because the risks of construction and operation of the project are shared between consumers and investors, a return is paid during construction and because revenues are underpinned by a regulated, legislatively-backed framework which ensures cost recovery of allowed revenues.

Within a RAB framework construction and operational risks would have to crystallise at severe downside levels before they outweigh the benefits to consumers of the lower cost of capital. The National Audit Office's report into Hinkley Point C identified this issue and the NAO found, by way of illustration, that for a nuclear project with a Weighted Average Cost of Capital (WACC) of 6% (nominal), construction costs could be 75% - 100% greater than for a project with a WACC of 9% (nominal) before consumers' costs would be equivalent[13]. More recently a study by Cambridge University's Energy Policy Research Group (EPRG) has found that developing SZC under a RAB model would deliver very substantial reductions in the levelized costs to consumers, even in worst case scenarios of a substantial construction cost over-run, relative to using the CfD approach where all construction risk rests with the project and its investors[14]. These studies illustrate in compelling terms that the benefits to consumers of developing new nuclear under a RAB model can substantially outweigh the exposure to construction risk borne by consumers and taxpayers.

To further illustrate this point, the table below shows the indicative sensitivity of the customer price of Sizewell C to different construction and financing costs. Reductions in the cost of finance give rise to significant reductions in customer prices, while increases in construction costs result in relatively limited increases in customer costs. Prices shown are in £/MWh.

Table 1 – Illustrative impact of different Internal Rates of Return (IRR) and construction costs on the required Sizewell C customer price in £/MWh

		Construction cost			
		£18bn	£20bn	£22bn	£24bn
IRR	4.0%	36	38	40	41
	5.0%	43	45	47	50
	6.0%	49	52	55	58
	7.0%	56	59	63	66

13 https://www.nao.org.uk/report/hinkley-point-c/

14 https://www.eprg.group.cam.ac.uk/eprg-working-paper-1926/

	8.0%	63	67	71	75
	9.0%	69	74	79	83

These figures illustrate in striking terms the importance of financing costs for the cost to consumers of nuclear and show how, within a regulated framework which achieves a reduced cost of capital, new nuclear can make a substantial and cost-effective contribution to the firm low carbon power that will be required to deliver net zero.

There are also wider benefits which can arise through investment in Sizewell C under a RAB model. Supply chain skills and capacity will continue to be maintained and developed and a new financing model will be developed for the sector - both to the benefit of other UK new nuclear projects (including potentially small modular reactors).. The potential to use waste heat from new nuclear can also be further explored – in the context of Sizewell C EDF is examining the scope for waste heat to improve the efficiency and economics of low carbon hydrogen production, storage and industrial / agricultural processes.

In summary, while there are inevitable uncertainties on how all technology costs will evolve over a 20-30 year timeframe, based around what is known today there is a clear strategic case for continued investment in new nuclear.

Part b)

Power from weather-dependent renewables is highly variable on both daily and seasonal scales. Modelling by Imperial College which informed the illustrative 2050 scenario suggested an important role for interconnection, battery storage and flexible demand in a future low-carbon power system:

- **i. What other technologies could play a role here?**
- **ii. What evidence do you have for how much demand side flexibility might be realised?**

EDF agrees that interconnection, battery storage and flexible demand will all have a role to play in managing the intermittency of weather dependent renewables. With respect to interconnection, it is increasingly important to take account of the carbon content of imported electricity, rather than assuming this is zero or low carbon. Frequent correlation of weather patterns across Europe also mean that the benefits of interconnectors in providing security of supply and access to low carbon imports for the UK market should not be over-stated. A robust method for accounting for the real time carbon content of imported electricity via interconnectors is proposed in this paper and live real time data on the carbon intensity of electricity generation in different European electricity markets is available from electricitymap.

Over time a range of other forms of storage technology, including longer duration storage such as compressed liquid air storage, redox flow batteries and hydrogen manufactured by electrolysis from renewables or nuclear, could all have an important role to play in the power sector. EDF is developing the concept of a new nuclear energy hub which could combine nuclear generation with flexible hydrogen production and other commercial uses of waste nuclear heat. These considerations highlight the importance of continuing to support research, development and demonstration projects for the power sector as well as the value of a strong carbon price in providing a route to market for all technology options which can help to deliver a zero carbon power sector.

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In order to maintain system stability and operability, adequate levels of inertia, short circuit infeed and dynamic voltage support are required. Synchronous Generators currently provide this stability capability. With fewer synchronous generators on the system, significant quantities of new plant able to provide alternative sources of stability will be required. This issue has been recognised by the ESO, for example in the Operability Strategy Report 2020 and the Stability Pathfinder initiative. Synchronous Compensators (including new build synchronous compensators, conversion of shut down thermal plant, retrofitting clutches to CCGTs) would provide an established means to contribute to system stability. Virtual Synchronous Machine (VSM) technology could also contribute to stability, although this approach is still at the development stage and has not been demonstrated operationally.

With respect to the potential for demand side response (DSR) flexibility, we recognise that the electrification of transport and greater electrification of heat should create the potential for a much larger future role for residential DSR than is realistically achievable today – through much wider adoption of smartly charged electric vehicles, Vehicle-2-Grid approaches and greater volumes of heat pumps and hybrid heat pump systems for home and commercial heating. Market regulations and operating structures should aim to facilitate flexible digital solutions (incl. eg utilising the inherent flexibilities of electrified transport) and allow them to compete against alternatives – optimum levels of flexibility should be the outcome of a well-functioning market where different approaches can compete and pricing and environmental signals are acting appropriately and consistently.

Studies of the system benefit of DSR have had a tendency to compare the national level power system before and after the implementation of large volumes of DSR, but without full consideration of the likely practical costs and issues associated with delivering the envisaged DSR volumes and attracting willing consumers – this approach risks some exaggeration of the likely true cost-benefit balance of DSR and achievable volumes. As with other aspects of the future GB power market a strong carbon price will encourage DSR in a technology neutral way alongside other alternatives such as dedicated storage by increasing the value to be had from maximising intermittent low carbon generation and minimising gas generation.

A future power market with much greater volumes of EV and heat pump enabled DSR will still be one in which the main role of DSR is likely to be to shift demand within day (to smooth peaks) rather than over longer time periods – this is a highly valuable role but one which will not remove the requirement for a power system capable of meeting demand during an extended wind lull or period of very high demand due to extreme cold weather. As such, as the CCC has recognised in its technical report, the system will still require substantial volumes of firm low carbon power.

Question 31 (Hydrogen): The Committee has recommended the Government support the delivery of at least one large-scale low-carbon hydrogen production facility in the 2020s. Beyond this initial facility, what mechanisms can be used to efficiently incentivise the production and use of low-carbon hydrogen? What are the most likely early applications for hydrogen?

EDF recognises the important role that low carbon hydrogen could play in a range of sectors in support of the delivery of an economy wide net zero outcome by 2050. However today low carbon hydrogen production and usage is not economic in any sectors or applications where major progress on decarbonisation is required. This reflects both the relative technological immaturity of low carbon hydrogen options but also some inherent full cycle efficiency challenges associated with low carbon hydrogen production, transportation, storage and use, given the energy losses associated with each stage of energy conversion in the chain.

This points to a number of conclusions for hydrogen policy:

- Continued government support is needed for research, development, demonstration and pilot projects to facilitate technology development, learning, cost reduction and practical experience in the use of low carbon hydrogen. Taking advantage of high temperature waste heat from nuclear power production has the potential to significantly enhance the efficiency of electrolytic hydrogen production and this specific option should be further explored – see also our response to Q32.

- Strong economy wide carbon pricing will be very important in supporting low carbon hydrogen options (vs alternatives) in a technology neutral way, and in so doing is likely to provide the strongest market signal for the use of hydrogen in sectors and applications where alternative decarbonisation approaches are unavailable, impractical or very expensive

- There is a need to develop some emerging markets for hydrogen to allow the potential for the technology to be better assessed and realised. These would most effectively focus on those areas of decarbonisation where cost effective alternatives to hydrogen are today not clearly available. We consider these sectors are:

    - **Certain industrial and combustion processes** – eg where post combustion CO2 capture is difficult (furnaces and kilns). Early projects should be linked to CCUS clusters or electrolysis projects to ensure any hydrogen used is low carbon.

    - **Larger transportation vehicles (HGVs / buses and coaches)** – where electrification is today not clearly viable or cost effective and depot or motorway corridor-based hydrogen refuelling is plausible. Hydrogen could also be deployed in future in the **shipping sector** – see our response to Q32

Beyond initial facilities and pilot projects, careful consideration should be given to the case for, and form of, any mechanisms used to incentivise the production and use of low carbon hydrogen in the above sectors. It will be important that any interventions are well designed and justified, take account of sector specific considerations, alternative technological approaches and the full life cycle emissions associated with different hydrogen production methods. Bearing in mind that hydrogen produced from SMR + CCS is a lower but not fully zero carbon option on a full life cycle basis, it will be important to ensure that green electrolytic hydrogen receives at least the same level of support as "blue" hydrogen approaches.

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With respect to industrial uses of hydrogen, the most obvious early applications could be within the carbon capture and storage (CCUS) clusters currently under development. EDF supports the development of a pilot CCUS cluster with a significant element of low carbon hydrogen production and industrial usage. Business models and regulatory arrangements which support industrial use of hydrogen within any clusters will be required. The costs of any such schemes or funding streams in this area should not be charged to electricity consumers, who already bear a large burden of policy costs (see our response to Q26 above).

In the transport sector, specific support for pilot projects to demonstrate the use of hydrogen in larger vehicles is needed. Current government policies tend to treat all zero tailpipe emission vehicles in a consistent way and high fuel duties levied on petrol and diesel already support moves to cleaner fuels. This technology neutral approach to policy should be maintained. However we see a need for more specific regulation to achieve progressive improvements in CO_2 emissions of heavier duty vehicles - in order to drive change in the same way as has been achieved by EU new car CO_2 standards in the light vehicle sector. The scope to amend the Renewable Transport Fuels Obligation to recognise hydrogen produced from nuclear power by electrolysis as an eligible form of fuel should also be explored.

With respect to heat decarbonisation, we consider that hydrogen could play a useful peaking or regional role in the decarbonisation of heat. However a major or total reliance on hydrogen for heating in 2050 is likely to be questionable as processes involving steam methane reformation with CCS are not fully low carbon and meeting all future heat demand via electrolysis would stretch credible electricity generation capacity requirements.[15] Therefore we share the CCC view that a mixed strategy with a major role for electrification alongside lower carbon hydrogen is likely to be the optimal outcome. Hybrid heat pump systems can play a very important role in this context.

Today, hydrogen production via methane reformation and with associated CO_2 capture, transportation and storage is likely to be the lowest cost method of producing a lower carbon form of hydrogen, although we note that no large-scale demonstration projects are currently in existence. Such hydrogen production methods are valid in a period where the priority is to grow early markets for hydrogen. However, over the medium-longer term, a truly net zero outcome will require hydrogen production to switch to electrolytic methods based on zero carbon power from renewables or nuclear. The CCC estimates a range of 45-120gCO_2e/kWh for Hydrogen produced by steam methane reformation combined with CCS, potentially falling to c30-100gCO_2e/kWh with advanced gas reforming + CCS[16]. The higher end of the range may be more representative of GB's marginal gas source in 2050 (LNG / Russian pipeline gas). This compares to EDF's estimates of 0-24g/kWh from Hydrogen produced by low carbon electricity. In addition to R&D and demonstration projects to support electrolytic cost reduction, strong carbon pricing and other regulatory interventions to account for the full life cycle emissions of different hydrogen production processes will be needed to encourage electrolytic hydrogen production over steam methane reformation.

[15] Imperial College 2018 analysis of heat decarbonisation pathways indicates a requirement for 378GW of generation capacity providing 946TWh of low carbon power per annum in a scenario where hydrogen meets all heating demand and is produced via electrolysis from zero carbon sources.

[16] Figures from CCC Hydrogen in a Low Carbon Economy, Nov 2018

Question 31 (Hydrogen): The Committee has recommended the Government support the delivery of at least one large-scale low-carbon hydrogen production facility in the 2020s. Beyond this initial facility, what mechanisms can be used to efficiently incentivise the production and use of low-carbon hydrogen? What are the most likely early applications for hydrogen?

Finally, hydrogen could also be used in the power sector in the future as a source of peak power. As with other uses of hydrogen, this would only be compatible with net zero if the hydrogen produced was via electrolysis and there is some inherent challenge from low round trip efficiency in using electricity to produce hydrogen, then storing it and later burning it to recreate electricity – as opposed to directly using low carbon electricity within the system. Nonetheless, the potentially high value of low carbon peak power, and the scope for some surplus low carbon generation, could make this form of peak power economic in a future power system with high penetrations of variable and nuclear generation, very low carbon intensity but a remaining requirement to reduce to zero carbon. Ammonia produced from low-carbon hydrogen offers an alternative option, that may be more suitable for certain hydrogen applications as it is more easily handled in liquid form (though these benefits will have to be weighed against the costs of an additional conversion process).

However, in the nearer term EDF considers that there is clear scope to achieve substantial and more cost-effective further reductions in the carbon intensity of the power sector through continued investment in new renewables and new nuclear capacity (see our response to Q30 above). This should be the priority for the coming decade. Hydrogen's potential role as a source of peaking power is more relevant from the 2030's onwards when it will become increasingly necessary to remove all forms of unabated gas from the power sector to achieve further reductions in power sector CO_2 intensity.

Question 32 (Aviation and Shipping): In September 2019 the Committee published advice to Government on international aviation and shipping and Net Zero. The Committee recognises that the primary policy approach for reducing emissions in these sectors should be set at the international level (e.g. through the International Civil Aviation Organisation and International Maritime Organisation). However, there is still a role for supplementary domestic policies to complement the international approach, provided these do not lead to concerns about competitiveness or carbon leakage. What are the domestic measures the UK could take to reduce aviation and shipping emissions over the period to 2030/35 and longer-term to 2050, which would not create significant competitiveness or carbon leakage risks? How much could these reduce emissions?

EDF considers that there is potential for the UK to take a global lead in the decarbonisation of shipping via the development of markets for low carbon hydrogen or ammonia which could be used to fuel ships at UK ports. Many of the proposed CCUS clusters are located close to major ports and thus could provide a ready source of low carbon hydrogen for shipping. In addition, EDF's Sizewell C project is also located close to the major ports of Felixstowe and Harwich, creating the longer-term potential for green energy hydrogen production from Sizewell C to be provided to these ports and used for transport purposes (Felixstowe and Harwich are also major hubs for HGV transit of goods to and from the UK). Sizewell C will produce very substantial quantities of heat (~8GW) in the form of clean hot water. This heat has the potential to be used to significantly enhance the efficiency of electrolysis, and thus produce lower cost green hydrogen.

Question 35 (Greenhouse gas removals): What relevant evidence exists regarding constraints on the rate at which the deployment of engineered GHG removals in the UK (such as bioenergy with carbon capture and storage or direct air capture) could scale-up by 2035?

EDF does not have direct evidence to offer in this area. However we note that it is important that any deployment and incentives for Bioenergy with carbon capture and storage (BECCS), or wider schemes to support CO2 removal technologies, take full account of the full life cycle CO2 emissions as well as wider land use and sustainability considerations.

Question 37 (Infrastructure): What will be the key factors that will determine whether decarbonisation of heat in a particular area will require investment in the electricity distribution network, the gas distribution network or a heat network?

At this early stage in the development of decarbonised heating options and markets, it is likely to be difficult to reach definitive views on the relative scale of investment needed in gas or electricity networks. The early priority should be to grow the markets for lower carbon heating options (see our comments on Q26 and Q31 above) and ensure networks are in a position to respond rapidly to rising customer and developer demand for both low carbon electrified transport and heating solutions. This requires a regulatory settlement in the RIIO-2 needed that supports reasonable levels of well justified anticipatory investment and we welcome Ofgem's most recent position on this topic as set out in their decarbonisation plan. In addition, where networks are in any case being up-graded in the nearer term in response to electrification of transport, it is often likely to be economic and appropriate to up-grade to a level which can accommodate much greater electrification of heat – avoiding the need for the additional disruption and costs associated with 2 separate up-grade processes within a period of decades.

Question 38 (Infrastructure): What scale of carbon capture and storage development is needed and what does that mean for development of CO_2 transport and storage infrastructure over the period to 2030?

As CCC has identified, carbon capture and storage (CCS) is likely to be required to achieve net zero and the decarbonisation of all aspects of the UK economy, most clearly in respect of certain industrial processes for which there is currently no viable technological alternative that does not involve post process CO2 capture and storage.

However for most major carbon emitting sectors of the economy where CCS could play a role, including with respect to the decarbonisation of power, transport and heating, there are also credible and deployable large scale options for decarbonisation involving electrification and the use of zero carbon electricity from renewables and new nuclear power, which do not require CCS.

This substantial uncertainty in the ultimate scale of role for CCS within the UK's net zero economy (along with wider uncertainties on CCS costs and the full life cycle emissions of associated processes) suggests there is a strong case for progressing CCS development in a measured way, through a large scale cluster demonstration which can provide essential learning and experience to inform future development. Such a cluster could be underpinned by a Regulated Asset Base (RAB) supported transport and storage network, as proposed in the government's recent consultation on CCS business models.