Written Evidence Submitted by EDF

(HNZ0065)

Summary and Introduction

1. EDF is the UK's largest producer of low carbon electricity. We operate low carbon nuclear power stations and are building the first of a new generation of nuclear plants. We also have a large and growing portfolio of renewables, including onshore, offshore wind and solar generation, as well as coal and gas stations and energy storage. We have around five million electricity and gas customer accounts, including residential and business users. EDF aims to help Britain achieve net zero by building a smarter energy future that will support delivery of net zero carbon emissions, including through digital innovations and new customer offerings that encourage the transition to low carbon electric transport and heating.

2. EDF welcomes the opportunity to provide evidence to the Science and Technology Committee on how hydrogen can best contribute to decarbonisation of the UK economy and on what policy measures are needed to develop viable markets in low carbon hydrogen. EDF is exploring a number of projects using electricity from renewable and nuclear sources to produce low carbon hydrogen in the UK. As well as projects linked to our wind and solar farms we are examining the role hydrogen could play within a low carbon energy hub linked to the Sizewell C new nuclear project, with the possibility for a demonstration project (to reduce emissions during construction of Sizewell C) powered by the adjoining Sizewell B nuclear power station. EDF Group's hydrogen subsidiary, Hynamics, provides a turnkey solution for the generation and distribution of hydrogen by electrolysis from low carbon electricity. Hynamics will invest, manage and ensure the maintenance of hydrogen facilities – providing a complete end-to-end solution for customers. Additionally, the Sizewell C project is exploring heat-assisted electrolysis to generate hydrogen (which is more efficient than traditional electrolysis, and the technology for which exists today).

3. Low carbon hydrogen can play an important role in achieving a net zero outcome by 2050, potentially contributing significantly to the decarbonisation of industry, transport, heating and power. A truly net zero outcome will require hydrogen production to switch mainly to electrolytic methods based on zero carbon power from renewables and nuclear. In our view the most promising markets for hydrogen will be in harder to decarbonise sectors such as industry, heavy transport (HGVs, aviation, shipping) where electrification may not be able to offer a complete solution – and hydrogen may also serve as a base for synthetic fuels. Hydrogen may also play an important longer-term role in heating and in the power sector as a source of low carbon peak power.

4. To date policy support for low carbon hydrogen in the UK has very largely taken the form of funding for research and demonstration projects exploring the use of hydrogen in a range of sectors and applications. This support is welcome and must continue to stimulate further innovation, but there is now a need to develop market mechanisms to create meaningful early markets in hydrogen, facilitate learning by doing and generate economies of scale. EDF welcomes the steps the government is taking in this direction and looks forward to further progress this year. New mechanisms should support a range of low carbon hydrogen production methods and take full account of life cycle carbon emissions of different approaches. The scope of existing supporting mechanisms such as the Renewable Transport Fuels Obligation ought to be extended to nuclear-generated hydrogen. Supported by strong

and broad-based carbon pricing, these measures could create sustainable markets for low carbon hydrogen over time and allow the technology's potential and role in supporting the transition to net zero to be realised.

Commentary on specific topics raised by the Committee.

1.The suitability of the Government's announced plans for "Driving the Growth of Low Carbon Hydrogen", including:

- **the focus, scale and timescales of the proposed measures;**
- **how the proposed measures—and any other recommended measures—could best be co-ordinated;**
- **the dependency of the Government's proposed plans on carbon capture and storage, any risks associated with this and how any risks should be mitigated; and**
- **potential business models that could attract private investment and stimulate widespread adoption of hydrogen as a Net Zero fuel;**

5. EDF welcomes the recently announced support for hydrogen announced in the Prime Minister's 10 Point Plan, including the adoption of a 5GW target for low carbon hydrogen production capacity by 2030 and the commitment of £240m of funding to support low carbon hydrogen production. The government has also committed to publish a hydrogen strategy in 2021, including proposals on preferred business models for supporting low carbon hydrogen production and adoption.

6. EDF has been participating in the BEIS expert group looking at potential business model options and associated policies. This work is identifying a range of credible interventions which have the potential to grow the early market for low carbon hydrogen production. These include approaches which draw on elements of the contracts for difference regime operating in the renewables sector. These could provide vital long-term certainty to developers on the revenues that would be available for low carbon hydrogen production, as well as confidence to potential users around the prices they would pay for hydrogen. Such elements are key to attracting private sector investment at an acceptable cost of capital and will be essential to make early projects work, as low carbon hydrogen production will come at a cost premium to existing fossil fuels or to "grey" high carbon hydrogen derived from fossil fuels which it will displace.

7. It will be important delivery of these interventions progresses in a timely manner, with any associated legislative or regulatory changes being delivered in the next 1-2 years. Visibility to the market on the nature of the interventions, their scale and when they will come into force, will be essential in delivering greater confidence and certainty to the private sector. This will enable low carbon hydrogen production projects to be progressed to the point where they can benefit from the new business models and final investment decisions can be made.

8. As the committee notes, the successful deployment of "blue" hydrogen produced from steam methane reformation will remain inherently dependent on the wider development of plans for carbon capture and storage (CCS) clusters. The government is developing business models to support all aspects of CCS deployment in line with its objectives of bringing forward a number of clusters by the end of the decade. This creates the potential for successful CCS deployment but there remain risks and challenges in co-ordinating the different elements of a CCS cluster. Ensuring that high CO2 capture rates and acceptable full life cycle CO2 emissions are associated with any blue hydrogen production will also be important.

9. These are some of the reasons why we consider a substantial proportion of the 5GW target for low carbon hydrogen production should be allocated to electrolytic (including heat-based) forms of hydrogen production, including from both nuclear and renewable power. Electrolytic hydrogen from low carbon power has significantly lower full life cycle greenhouse gas emissions than blue hydrogen – due to a combination of residual emissions from incomplete CO2 capture in blue hydrogen production and fugitive methane emissions associated with the production and transportation of natural gas[1].

10. Alongside support for low carbon hydrogen production, potential users of hydrogen will need incentives to adopt a new fuel. The nature of the necessary interventions and regulations to encourage this may vary by sector and this implies HMG's hydrogen strategy should give some attention to those sectors where early hydrogen adoption is to be most encouraged. In our view sectors such as heavy transport, and a range of industrial processes, which are hard to decarbonise and where electrification may be difficult or impossible, should be the focus. In the transport sector the Renewable Transport Fuels Obligation (RTFO) is an existing mechanism which includes support for renewable hydrogen. Eligibility for RTFO support, or similar levels of support, should be extended to low carbon hydrogen produced from low carbon nuclear power.

2. The progress of recent and ongoing trials of hydrogen in the UK and abroad, and the next steps to most effectively build on this progress;

11. A range of hydrogen trials and very small-scale demonstration projects have been progressing in recent years. These have largely focussed on the blending of hydrogen into the gas network, the use of blended or pure hydrogen for heating, and the use of hydrogen buses (most notably in London). These trials are providing valuable information and early stage experience of hydrogen usage and the PM's 10 Point Plan sets out a programme of further developments to test the use of hydrogen for heating, first at neighbourhood scale and then in a small town by the end of the decade.

12. To build on this progress over the next few years will require a gradual expansion of both the scale and scope of early hydrogen projects. While the government's hydrogen business model work aims to develop a framework for a fully-fledged early commercial market for hydrogen, this may take several years to be consulted on, refined and implemented in legislation and regulations. In the meantime, EDF can see real value in using some of the £240m funding for hydrogen production to support some more early stage, small-medium sized demonstration and pilot projects. This would help maintain momentum in a nascent industry, deliver vital learning and practical experience - and thus help inform and improve the larger scale projects which will follow.

3. The engineering and commercial challenges associated with using hydrogen as a fuel, including production, storage, distribution and metrology, and how the Government could best address these;

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[1] The Climate Change Committee has estimated a range of 45-120gCO2e/kWh for full life cycle CO2 emissions associated with hydrogen produced by steam methane reformation combined with CCS, potentially falling to c30-100gCO2e/kWh with advanced gas reforming + CCS. These estimates can be compared to IPCC estimates of 15g CO2e/kWh from hydrogen produced by electrolysis from nuclear or wind power.

13. Widespread adoption of hydrogen will bring new engineering and technical issues. The operation of gas networks with blended hydrogen pose some specific new challenges, as blend levels may vary by location but will need to remain within safe, approved limits, and accurate measurement of hydrogen content and consumption will be essential from safety, commercial and carbon accounting perspectives.

14. Overall hydrogen usage has already been safely and successfully demonstrated in a range of settings and we anticipate ongoing trials and testing programmes will develop safe parameters and technical guidance for hydrogen adoption in new sectors. There are few reasons to think that there will be technical barriers to widespread use of hydrogen in a range of sectors. The larger challenge is likely to be how to grow hydrogen markets over time and in so doing make low carbon hydrogen economics viable against incumbent fossil fuels which are today lower in cost. This will require a market framework which supports continued innovation and competition, which allows demonstration projects to expand to become commercial scale undertakings and which allows economies of scale to be realised and "learning by doing".

15. The hydrogen electrolysis sector illustrates the benefits of a market framework of this kind. A range of technological developments can significantly improve the efficiency and economics of electrolysis. Electrolysers have potential to achieve higher efficiencies, less degradation, higher availability, larger cell sizes, higher operating pressure, and reduced critical material usage. Electrolysis is a modular technology, which can be sized to meet demand and scaled up over time as demand grows. Typically, electrolyser projects to date have been small in scale and involving relatively bespoke manufacture. However, as the industry matures, manufacture is moving to modular and more automated assembly lines where a much greater scale of production is possible, allowing significant economies of scale to be achieved. Larger electrolysis developments will also achieve economies by reducing balance of plant and project development costs per kW of capacity. These considerations mean that, with the benefit of growing markets, the electrolyser industry is confident of achieving cost competitiveness with methane reformation + CCS methods of hydrogen production within the next 5-10 years.

16. The most significant other contributor to the future cost of electrolytic hydrogen will be the cost of electricity. Wind and solar have achieved substantial reductions in cost in recent years and there is further potential for cost reductions. Nuclear power also has significant cost reduction potential arising from the benefits of replication of a stable design and new financing approaches which reflect the lower risks involved in series production of an established design. The Sizewell C new nuclear development is a good example of this – replicating the model being built at Hinkley Point C.

17. The potential role of nuclear power in supporting hydrogen production is explored in the recent Energy Systems Catapult report Nuclear for Net Zero[2]. Linking nuclear power with electrolysis has a number of advantages. As a reliable source of baseload power, nuclear can help achieve high load factors for electrolysis projects, improving their economics. Combining nuclear power with electrolysis can also make the future electricity system more flexible - at times of very high renewable output, nuclear power could divert more of its output to electrolytic hydrogen production and on days of high demand but low renewable output, nuclear can provide firm low-carbon power to help meet national demand. Nuclear power could also be particularly useful as a source of power and heat for high temperature solid oxide electrolyser cell (SOEC) electrolysis. This is one of the most promising options for

[2] https://es.catapult.org.uk/reports/nuclear-for-net-zero/

improving the efficiency and thus future costs of electrolysis (and a project utilising the technology is already in place in Germany).

18. For these reasons the Hydrogen Council and hydrogen advisory groups which have been put in place to support government policy development on hydrogen should actively look to involve relevant academic and industry expertise in this area. A strand of innovation and demonstration funding for hydrogen should similarly focus on exploring and developing the potential of nuclear power to provide large volumes of low cost and very low carbon hydrogen.
19. Electrolytic hydrogen production from nuclear power is something EDF is actively considering in relation to the Sizewell C new nuclear development. In the short-term, and to green construction at Sizewell C, the project is exploring hydrogen production powered by the adjoining Sizewell B nuclear power station – given the difficulty in transporting hydrogen, production location is very important and as such, hydrogen from Sizewell could also help to kick-start the hydrogen economy in the East of England. The business model and regulatory framework for new nuclear projects such as Sizewell C will be key to the economics of the hydrogen it can produce and we therefore welcome the Government's recent confirmation that it will enter into negotiations in relation to Sizewell C.
20. In the medium term hydrogen production could also be relevant for other new nuclear projects around the UK, including at other large sites or in relation to small modular or advanced reactors in the future

4. The infrastructure that hydrogen as a Net Zero fuel will require in the short- and longer-term, and any associated risks and opportunities;

21. Aside from sites specifically associated with low carbon hydrogen production, the infrastructure required for widespread use of low carbon hydrogen relates mainly to its storage and distribution. At this stage there are a wide range of options for how the hydrogen storage and distribution sector could evolve, with options ranging from national or localised pipeline distribution, storage in salt caverns, storage in the form of liquid ammonia and electrolytic hydrogen production very close to demand. Blue hydrogen will also require additional infrastructure in the form of CO2 transport and storage networks, and 100% hydrogen used in residential heating would require conversion of gas burning home appliances and the co-ordinated transition of all buildings in specific locations to burning hydrogen as a fuel.

22. At this stage, with many uncertainties as to how the sector may evolve, the key role for government and regulators is to avoid closing off options, to support trials of a range of approaches and to seek to avoid, whether deliberately or inadvertently, from the use of regulations or incentives which artificially distort the market in favour of specific approaches. Over time, with continued growth in markets for hydrogen, the most cost-effective options for its distribution and storage, which may vary by sector, should more clearly emerge.

5. Cost-benefit analysis of using hydrogen to meet Net Zero as well as the potential environmental impact of technologies required for its widespread use; and

23. A wide range of energy system wide analyses have attempted to forecast, or provide scenarios for, the long-term role of hydrogen in supporting net zero[3]. Most of these

scenarios are consistent in concluding that hydrogen will play an important role, but the extent of this and the sectors in which hydrogen is used, vary widely between scenarios and depend today on underlying assumptions which are inherently uncertain.

24. Given these limitations on the extent to which cost-benefit analysis or other forecasting techniques can predict the optimal long-term role of hydrogen in achieving net zero, it is important to develop regulatory approaches which keep options open and are technology neutral. This point highlights the valuable role that strong and broadly applied carbon pricing can play as part of any policy package in this area. Strong carbon pricing will facilitate the development of markets for low carbon hydrogen in a range of ways:

- As a technology neutral mechanism, it will support the most cost-effective and efficient deployment of low carbon hydrogen (vs alternatives) in a range of markets

- It would reduce the level of support needed from government in the form of consumer subsidies and/or taxpayer funding needed to make low carbon hydrogen projects economic

- It would incentivise fuel switching away from fossil fuels, and, as hydrogen costs fall with growing markets and innovation etc, it would in the medium-longer term provide a route to a sustainable subsidy free market.

- It will create ongoing incentives for the lowest carbon forms of hydrogen production, creating incentives to maximise low carbon electricity (and steam) usage for electrolysis options and maximise CO2 capture for CCS based options.

25. With respect to environmental impacts, the hydrogen industry should, like any major industrial sector, be subject to rigorous, independent safety and environmental regulation. A specific issue raised by the large-scale use of blue hydrogen will be the substantial fugitive greenhouse gas emissions associated with the production and transportation of the input fuel, natural gas. In most cases these emissions will occur outside the UK and so will not be counted within the UK's greenhouse gas inventory. However, the emissions will retain their climate impacts and so it will be vital that future regulation and incentives in this area take account of the full life cycle emissions and environmental impacts associated with different forms of hydrogen production.

6. The relative advantages and disadvantages of hydrogen compared to other low-carbon options (such as electrification or heat networks), the applications for which hydrogen should be prioritised and why, and how any uncertainty in the optimal technology should be managed.

26. Today low carbon hydrogen production and usage is not yet economic without support in any sectors or applications where major progress on decarbonisation is required. This reflects a range of factors including the relative technological and market immaturity of low carbon hydrogen options and limited carbon pricing or decarbonisation signals in some sectors. There are 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 – these constraints are likely to mean that

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[3] These include, as recent examples, National Grid's Future Energy Scenarios, CCC's work on net zero and the 6th carbon budget and work by energy consultants Aurora.

hydrogen will not always be the decarbonisation technology of choice, where alternatives exist.

27. EDF considers that the early development of low carbon hydrogen markets could most effectively focus on a combination of displacing existing grey carbon-intensive hydrogen (e.g. for ammonia production) and those sectors where cost effective decarbonisation alternatives to hydrogen are today not clearly available. We consider these sectors are:

- A wide range of industrial processes where hydrogen could displace natural gas – (for example metal works, ammonia production and the electronics industry) and for industrial processes where post combustion CO2 capture is difficult (eg furnaces and kilns). Current incentives to shift industrial processes to low carbon hydrogen are currently very modest – being limited only to the carbon price coming from the European Union Emissions Trading Scheme (EU ETS) or its UK successor.

- Larger transportation sectors (such as HGVs / buses and coaches, shipping and construction vehicles such as forklifts and excavators) – where electrification is today not clearly viable or cost effective and depot, port or motorway corridor-based hydrogen refuelling is clearly plausible. Electrolytic production methods produce a purer form of hydrogen which is more readily suited to transport applications – e.g. in a fuel cell.

28. With respect to decarbonisation of the heat and power sectors, we consider that the most useful long-term national role for hydrogen is likely to be in the provision of peak heat and peak power. This is because it will likely remain more efficient, and therefore usually more economic, to consume available low carbon electricity directly in the power system - including to provide electric heating directly (via an efficient air source heat pump) - than it will be to convert low carbon electricity to hydrogen through electrolysis, store it, and then burn it later, with associated energy losses at each point of energy conversion. This view is in line with CCC's analysis in its advice to government on the 6th carbon budget.

29. In a future energy sector with much higher levels of intermittent renewable generation and continued fluctuations in demand for both heat and power, there are likely to be both increased periods where there is excess power relative to demand, and periods where demand is high but supply is constrained. These scenarios create greater opportunities for low carbon hydrogen, taking advantage of its capacity to be used as a form of energy storage, which can be produced via electrolysis from renewables or nuclear when the supply of power is high relative to demand, and supplied later to meet demand in a range of sectors.

30. In this way low carbon hydrogen could play a valuable role in decarbonising heat as national peak heat demand is high and full reliance on electrification of heating is likely to be challenging in terms of the scale of network and generating capacity which would be required. Hydrogen could also be used for heating at a regional and local level linked to available low carbon hydrogen sources. Therefore, we consider 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 an important role in this mixed strategy by making substantial progress towards lower carbon heating through electrification for many existing buildings, while retaining the potential for low carbon gases such as hydrogen to complete the decarbonisation process.

31. Similarly, hydrogen could also be used in the power generation sector in the future as a source of peak and flexible power providing a low carbon alternative to unabated gas which currently performs this role – hydrogen combustion plant would likely have relatively modest capital costs but relatively high running (fuel) costs, but these could be acceptable for plant providing peak power. While hydrogen may be an important source of future low carbon

power, 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 over the next decade. Hydrogen's potential role as a source of peaking or flexible power will become more relevant from the 2030's onwards when it will become increasingly necessary to remove unabated gas from the power sector to achieve further reductions in power sector CO2 intensity.

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