Energy&Climate INTELLIGENCE UNIT

Hinkley: What If?

Can the UK solve its energy trilemma without Hinkley Point C?

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EXECUTIVE SUMMARY

The saga of the Hinkley Point C nuclear power station has been with us now for nearly a decade. But still, the conclusion is unclear. The Government is due to make a final decision next month; however, even if its decision is "yes", many potential hurdles remain.

Proponents of Hinkley argue that it is absolutely necessary for solving the energy trilemma – ensuring security of supply and reducing carbon emissions while keeping bills under control. But how true is this? The nature of electricity networks is changing rapidly, renewable technologies are falling in price, and UK demand is also decreasing.

In this report, we ask and answer a few simple questions: If Hinkley C does not happen, for whatever reason, does it matter? Are alternatives available that can generate as much low-carbon electricity over the course of a year *and* keep the lights on during periods of peak demand? If there are, would these alternatives cost more or less?

Our conclusion is that Hinkley is not essential for solving the trilemma. Alternatives include:

- We could bring as much electricity into the grid as Hinkley would generate by building as few as **four big offshore wind farms** (additional to those we will build anyway), or building **three additional interconnecting cables**
- We could negate the need for at least two-fifths of Hinkley's electricity by **cutting waste** – using electricity more efficiently and productively
- We could supply Hinkley's 3.2GW of peak demand through additional **interconnectors,** or additional **gas-fired units** generating only at peak times – or switch usage away from peak times through **demand-side response** (additional to that we will introduce anyway)
- All of these alternatives on their own work out cheaper than Hinkley. For example:
    - replacing all Hinkley electricity with additional **offshore wind** farms would cut the average household bill by **£10-20 per year**
    - replacing all Hinkley's peak-time availability with **gas-fired units** would save **£16bn** in infrastructure costs
    - enhancing **energy efficiency** and **demand-side response** would save energy and therefore **reduce bills**.
- **We calculate that a scenario incorporating sensible amounts of "all of the above" could save the UK around £1 billion per year**
- Under all these scenarios, and with a few additional caveats, **carbon emissions are not increased** compared with a future that includes Hinkley.

Our analysis is ultra-conservative. We consider only mature technologies, leaving aside those that are just entering the market or those yet to be commercialised. We use highly conservative estimates for the possible increases in energy efficiency. We do not include the option of building additional numbers of new nuclear reactors of other designs. With wind, we take conservative estimates of technological progress and cost reduction. As such, Hinkley is likely to be even easier and cheaper to replace than our analysis concludes.

As the next "final" decision on Hinkley C nears, we think that our conclusions represent good news for Government. The power station is not essential for any arm of the trilemma. If Mrs May decides to go ahead, well and good; if she decides not to, or if the project falls at a later hurdle, the lights can stay on, carbon emissions can continue to fall, and our electricity is likely to be cheaper.

INTRODUCTION

Hinkley Point C – the story so far

Hinkley Point C has been subject to criticism since it was first conceived in 2006, which grew even fiercer after financial terms were agreed in 2013. Much of the criticism focusses on the fact that two sister plants utilising the same reactor design (the European Pressurised Reactor or EPR) are under construction in France and Finland – both heavily delayed and running way over budget – raising doubts whether Hinkley will be providing the 7% of British electricity demand promised in 2025.

At a cost of £18 billion, Hinkley has been branded the most expensive object ever built in Britain.[1] Further, a 35-year deal with an agreed price of £92.50 per megawatt hour (MWh)[2] for electricity produced – more than double the current wholesale market price and increasing with inflation each year – leaves the British public on the hook for upwards of £30 billion in subsidies, more than five times the initially forecast value.[3]

On the other hand, proponents (including the Government) maintain that the power station is essential for solving the energy trilemma – ensuring secure supplies, reducing carbon emissions and keeping bills down – and that cancellation would potentially leave the UK with little chance of making essential upgrades to an ageing and increasingly unreliable power infrastructure. They further argue that several new nuclear power plants are needed, to provide low-carbon baseload electricity.

The UK's power grid is changing

The UK has one of the oldest electricity systems in the world, seeing very few upgrades since it was privatised in the 1990s. As more of this old kit approaches retirement, and the private sector remains reluctant to invest in anything but renewables and interconnectors, the Government has a choice: to try to preserve the current model of centralised, inflexible power generation feeding passive consumers, or to incentivise all ingredients required for a transition to a dynamic, decentralised system based on renewable generation and measures that balance supply and demand.

The UK's energy system is clearly already in transition, largely because of the need to reduce carbon emissions in line with national and international targets based on scientific, economic and technological understanding. The Climate Change Act requires the UK to cut emissions by 80% by 2050, relative to 1990 levels. Accordingly, unabated coal is set to be removed from the grid by 2025 and large parts of the gas fleet will reach the end of their lives within the next 15 years.

1 http://www.ft.com/cms/s/0/4dcca732-e6d9-11e5-a09b-1f8b0d268c39.html#axzz45RU3hxyN

2 In 2012 prices, index linked. Current contract value ~£97.50/MWh.

3 http://www.ft.com/cms/s/0/b8e24306-48e5-11e6-8d68-72e9211e86ab.html#axzz4FPLND3CN

Meanwhile due to age alone, only three of the eight operating nuclear power stations will still be generating in 2030.

Recent reports from the Government's National Infrastructure Commission (NIC)[4] and the industry body Energy UK[5] both suggest that continuing and accelerating the transition to a smart flexible grid is the logical course for Britain. They outline the 'trilemma-solving' benefits of smart grids based on increased renewable energy deployment coupled with more interconnection with other European nations, greater prevalence of demand management and developments in storage technology. The NIC sees benefits of moving to a smart grid reaching £8 billion per year.

Across Europe and the rest of the world, many countries are also embarking on a similar smart grid transition based around a similar recipe of renewables, demand management and interconnection. Some argue that investing a colossal amount of money into Hinkley would run contrary to this 'generational shift' underway in grids across the world.

Methodology

In this report the Energy and Climate Intelligence Unit (ECIU) investigates what the options are if Hinkley does not materialise. We take no view on whether it should or should not, but ask whether substituting a mixture of other measures could compensate for the absence of Hinkley's 3.2GW of baseload power. We analyse the alternatives in terms of the energy trilemma: security of supply, cost and carbon emissions. We look at replacing both the total amount of electricity generated by Hinkley over the course of a year, and the 3.2GW of power delivered at times of peak winter demand. We focus on a single year – 2030. It is sufficiently close that investment decisions made now are relevant, as are current costs; but far enough away that Hinkley could be operating, and if not, there is sufficient time to build alternatives.

We begin with a "business as usual" projection for the electricity system in 2030, based on an average of the four National Grid Future Energy Scenarios (FES),[6] which Grid calls Gone Green, Consumer Power, No Progression and Slow Progression. From this "business as usual" scenario we "deduct" Hinkley, and examine options for replacing its energy and power with alternatives.

"Business as usual" – 2030 essentials

	2015	2030
Annual Demand	334 TWh	329 TWh
Peak Demand	61.1 GW	62.5 GW
Total Capacity	97 GW	142 GW
Gas Capacity	28.3 GW	29.5 GW
Nuclear Capacity	8.9 GW	6.1 GW
Wind Capacity	13.1 GW	37.8 GW

According to this "average" National Grid forecast, in 2030 electricity demand will be 329 terawatt hours (TWh) compared with 334 TWh today. Renewables will have expanded to make up more than 50% of the total capacity (of more than 140GW), and wind alone will provide one-third of electricity consumed. Hinkley would amount to just over 2% of capacity. The system will also

4 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/505218/IC_Energy_Report_web.pdf

5 https://www.energy-uk.org.uk/publication.html?task=file.download&id=5722

6 http://fes.nationalgrid.com

feature new gas capacity, increased interconnection, storage and demand-side measures.

Power output from Hinkley is calculated using a load factor of 90% (referring to the plant running at full output for 90% of the time). This is a value typical for new nuclear plants, with the remaining 10% apportioned to maintenance and refuelling; it is also almost guaranteed given the Hinkley contract, which would incentivise EDF to run the reactors as much as possible. Taking this value would see the 3.2 GW Hinkley plant pump out 25.2 TWh per year, equivalent to more than 7.5% of forecast annual demand.

We report all prices in 2016 values, for easier comparison across technologies. On this basis the price we use for power generated by Hinkley C is calculated by increasing the agreed (£92.50, 2012) price by inflation using the consumer price index (CPI).[7] The current (2016) price is in the region of £97.50 per MWh.

Capacity requirements for alternative technologies are based on latest technology that is either in use in the UK or could be applied in the UK, with load factors and installation costs scaled accordingly.

7 http://www.parliament.uk/business/publications/written-questions-answers-statements/written-question/Commons/2015-11-02/14398/

SECURITY OF SUPPLY

In this section we consider options for a) replacing the electricity generated over the course of a year by Hinkley C, and b) replacing its always-available power at times of peak demand.

Options in a) include wind, interconnectors and improving energy productivity/efficiency. We do not consider new gas-fired plant in this section, as unabated gas generation in anything other than a peaking configuration would not be compatible with climate change targets. In b), we consider demand-side response (DSR), interconnectors again, and gas as a peaking technology, only running occasionally when demand is at its highest.

We do not include in our analysis the option of building additional numbers of the alternative nuclear designs that EDF's competitors are planning for sites such as Wylfa and Moorside, as the costs are currently unknown and it is not clear whether they could be built in sufficient numbers by 2030. We also do not consider nascent technologies such as tidal generation or small modular reactors, as both are unproven at utility scale and have uncertain economics.

We also do not consider energy storage in detail. Although there is no doubt the technology has the potential to change greatly the ways in which electricity supply matches demand, costs are as yet uncertain; and it is not clear to what extent storage would be used to regulate short-term fluctuations as opposed to keeping the lights on for a couple of hours on a winter evening. All conclusions in this chapter are based on conservative estimates of technological development, demand and supply forecasts, and cost reductions.

a) REPLACING HINKLEY'S ELECTRICITY OUTPUT

1. Wind

By 2030, the UK is forecast to have 37.9 GW of installed wind capacity, of which 22.5 GW will be offshore and 15.4 GW onshore. Together, these wind farms are expected to generate more than 113 TWh of electricity per year, with nearly three quarters of this total produced at sea.[8]

When comparing nuclear with wind, it's important to recognise that the different technologies have different load factors. Nuclear power stations provide full output to the grid for 80-90% of the time, while the load factor of wind is lower, ranging from 25-50% depending on technology, long-term weather conditions and location. More recent wind farms generally achieve higher load factors than their predecessors, due to larger and more efficient turbines and improved siting. Currently, 33% for onshore and 40% for offshore would be reasonable figures to use.

On this basis, just **5-6 large new onshore windfarms** would be needed to generate the 25.2 TWh per year afforded by Hinkley's two reactors.[9] The latest figures from the National Audit Office show onshore wind as the cheapest new generation source available to the UK.[10]

8 Forecast values based on average of four National Grid scenarios

Despite low and falling costs, expansion of onshore wind was ruled out in the 2015 Conservative Party manifesto[11] forcing interest offshore, although public support for onshore farms is still seen in Scotland. Offshore turbines have a higher output than those onshore, due to windier conditions at sea and the ability to install larger units. Based on existing technology, enough offshore wind capacity to replace the output from Hinkley could be spread over five windfarms.[12] Looking at larger turbines set to enter the market by 2020,[13] this could be cut to just **four,**[14] with this number likely to fall further as technology improves over the next decade. In recent years, turbines have become 10% more powerful each year,[15] driven by competition between a large number of market participants – a different picture from the nuclear industry which is characterised by a few suppliers and bespoke contracts.

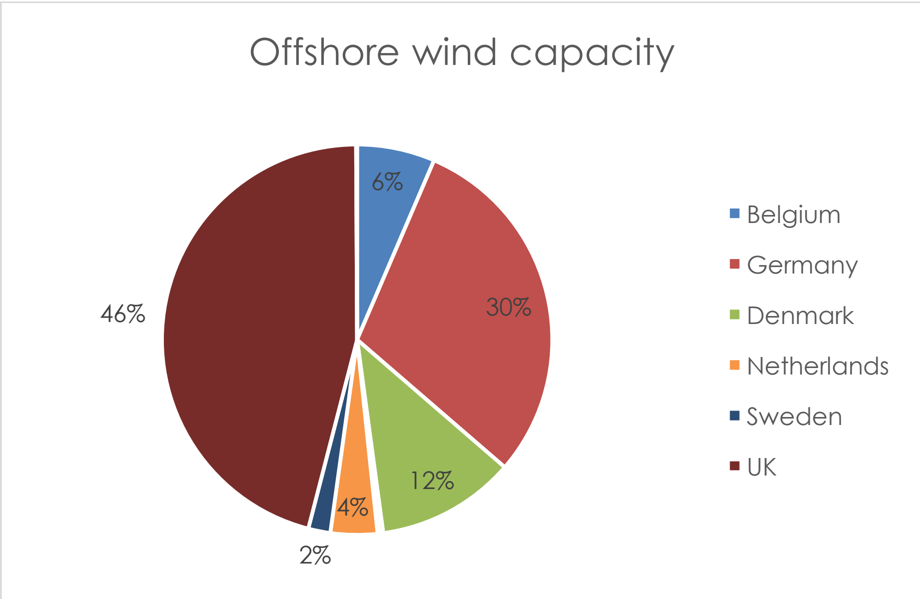

Figure 1: Offshore wind capacity in Europe, by country**. Source**: EWEA

2. Interconnectors

Interconnectors are cross-border connections that link electricity grids in two countries or regions, generally benefitting both parties. The exporting nation secures another source of demand, while the importing nation is able to acquire cheaper energy. Furthermore, interconnectors offer flexibility, providing market-determined flows of power without subsidies. However, if one country

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9 ECIU calculations show 8.6 GW capacity required, operating at a load factor of 33%. Based on 7.5 MW Enercon E126 units currently installed in Germany, Belgium and the Netherlands, 1147 turbines would be needed. This is equivalent to 5.3 times the number in operation at Scotland's Whitelee windfarm.

10 https://www.nao.org.uk/report/nuclear-power-in-the-uk/

11 https://www.conservatives.com/manifesto

12 ECIU calculations show 7.2 GW capacity required, operating at a load factor of 40%. Based on 8 MW MHI Vestas V164 units currently under installation in the UK, 900 turbines would be needed. This is equivalent to 5.1 times the number in operation at the London Array windfarm.

13 http://www.rechargenews.com/incoming/article1363463.ece

14 Based on 10 MW Siemens or SeaTitan units, 720 turbines needed.

15 https://windeurope.org/wp-content/uploads/files/about-wind/statistics/WindEurope-mid-year-offshore-statistics-2016.pdf

imports much more electricity than it exports, this can lead to a balance of payments issue. So far, interconnectors have been built without subsidy.

The UK is already part of an interconnected grid. Four high-voltage undersea cables with a combined capacity of 4 GW link us to France, the Netherlands and Ireland. However, these links are insufficient to meet demand, and currently act as bottlenecks in the system. Accordingly, finance for three new projects has already been agreed, connecting the UK grid with Belgium and Norway, as well as installing a second link to France. These will collectively add 3.4 GW of capacity by the end of 2021 (Table 1). Three further links are currently in development, two more to France and one to Denmark. From these six interconnectors alone, the UK could expect to import **42 TWh** per year, equivalent to more than 12.5% of 2030 UK demand or **1.67 times** the annual output from Hinkley Point C.[16]

The Government supports building a total of 13 GW[17] of interconnection; and taking an average of National Grid forecasts, this is likely to rise to around 18 GW by 2030, with market forces and political will for increased security of supply driving progress.

Name	Capacity	Connection	Online date	Cost £m/MW
NEMO	1 GW	UK-Belgium	2019	0.52
Eleclink	1 GW	UK-France (Channel Tunnel)	2019	0.33
NSN	1.4 GW	UK-Norway	2021	0.88-1.88
IFA2	1 GW	UK-France	tbc	0.58
FAB	1.4 GW	UK-France	tbc	0.88
Viking	1 GW	UK-Denmark	tbc	1.00

Table 1: Planned interconnectors to the UK**. Sources**: National Grid, Policy Exchange, DECC, developer websites

Interconnectors' capacity is 'de-rated' to account for the fact that they do not operate in one direction all of the time. Ofgem recommends that new links to Belgium and France are de-rated to 65% of nameplate capacity (reducing a 1 GW link to 650 MW), those to the Netherlands are 75%, while links to Norway are expected to be able to import power 85% of the time.[18] On this basis, as a direct replacement for Hinkley, between **3.8 and 4.9 GW** of additional new interconnector capacity would be needed – in other words, three or four additional new cables.

16 ECIU calculation based on construction of NEMO, Eleclink, NSN, IFA2, FAB and Viking links, running at 65% load factor to France and Belgium, 75% to Denmark and 85% to Norway.

17 https://www.gov.uk/government/publications/budget-2016-documents/budget-2016

18 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/535271/DECC_IC_letter_FINAL_June2016.pdf

The implementation of links on this scale is far from ambitious. Political sentiment is already in place for an expansion of interconnector capacity, while other European countries are heavily connected, with more new links on the cards.[19]

3. Energy efficiency/productivity

Measures to increase energy efficiency can reduce the UK's need for new generating capacity. Insulating buildings and switching to less energy-intensive appliances and processes have the same effect on the balance of supply and demand as building new power stations. However, some comments about the potential of energy efficiency to offset the need for Hinkley have been somewhat simplistic as they do not acknowledge that some improvements (such as condensing boilers and home insulation) affect gas demand far more than electricity. In this analysis, we only include the electricity component.

The average of the four National Grid scenarios suggests that energy efficiency enhancements will cut around 20 TWh off residential electricity demand by 2030. However, its most ambitious scenario Gone Green, would see demand fall by a further 10 TWh. Making this additional saving happen would be enough to **offset two-fifths** of the output from Hinkley.[20] This figure is certainly an underestimate as it does not include potential improvements in businesses or the public sector.

b) Meeting peak demand

During periods of peak demand – stereotypically, a cold winter evening – nuclear power is virtually guaranteed to be available, barring technical faults. This is not true of wind farms.

In this report, we consider that none of the additional wind capacity built to replace Hinkley's electricity is necessarily available during periods of peak demand. This is an ultra-conservative position, as some wind power is generated almost all of the time.[21] Therefore, we need other ways of replacing Hinkley's 3.2GW of peak-demand-time output.

1. Demand side response

An underexploited, and often ignored, means of meeting the highest levels of demand comes in the form of demand side response (DSR). DSR involves the rescheduling of non-essential processes away from times of highest demand, alleviating pressure on the grid and rewarding participants

19 http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=URISERV%3Al27081

20 http://fes.nationalgrid.com

21 In calculating the margins between supply and demand, National Grid usually adds up all of the available generating capacity and multiplies the capacity of each technology by the proportion of time for which it will be available (for example, about 90% for nuclear, 40% for offshore wind, and so on)

financially.[22] The National Infrastructure Commission calculates that shifting just 5% of current peak demand by DSR could avoid building a new nuclear power station.

DSR is established among energy intensive industries, with participants opting in to reduce energy bills and save on network charges (fees to maintain the grid that are passed on to heavy industry based on electricity consumption). It is employed by a multitude of big energy users, from water company United Utilities to Oxford Brookes University.[23,24] Non time-essential processes such as air-conditioning, pumps and chillers can be used in DSR, with examples seen through heavy industry, food processing and utilities.[25] Both the Energy Intensive Users Group and the Major Energy Users Council support the approach[26].

In its scenarios, National Grid predicts peak demand reduction between 1 GW and 5.5 GW by 2025 using DSR. For this report, we average those scenarios and assume that "business as usual" will see about 3 GW in place in 2030.[27]

The difference between the National Grid scenarios shows there is headroom to be more ambitious, with other studies reporting the potential to reduce peak demand by several times the capacity coming from Hinkley. Element Energy identifies 4.5 GW of peak demand as movable.[28] The most recent study on DSR, carried out by the Association for Decentralised Energy, identifies a possible 9.8 GW of flexible demand by 2020.[29] Other estimates are even higher, topped by a study by Sustainability First which contends that 18 GW of the winter peak could be rescheduled.[30] A review of real-world evidence to date shows that day-to-day peak demand can be slashed by 22% in normal conditions, rising to 38% (more than 20 GW) if critical conditions apply.[31]

Using DSR to shift demand during the winter peak directly corresponds to a reduction in generation capacity needed on the grid. However, National Grid assumes that only 29% of DSR capacity would be guaranteed to be available when it is needed.[32] On that basis, around **11 GW of DSR** would be needed to replace Hinkley.

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22 http://eciu.net/briefings/uk-energy-policies-and-prices/demand-side-response

23 http://www.powerresponsive.com/media/1140/ng_meuc-dsr-book.pdf

24 http://www.biu.com/oxford-brookes-university-adopts-demand-side-response/

25 http://www.theade.co.uk/medialibrary/2016/07/19/e0bd71e7/Flexibility%20on%20demand%20full%20report.pdf

26 http://www.eiug.org.uk/large-users-plan-to-help-keep-lights-on-and-costs-down/

27 http://fes.nationalgrid.com

28 http://www.element-energy.co.uk/wordpress/wp-content/uploads/2012/07/Demand-Side-Response-in-the-non-domestic-sector.pdf

29 http://www.theade.co.uk/flexibility-on-demand--giving-customers-control-to-secure-our-electricity-supply_4180.html

30 http://www.sustainabilityfirst.org.uk/index.php/energy-demand-side

31 http://www.frontier-economics.com/documents/2013/10/frontier-report-demand-side-response-in-the-domestic-sector.pdf

32 Based on 242 MW capacity acquired in December 2014 transitional auction, de-rated to 84 MW.

DSR providers believe Grid's 29% is a vast under-estimate. They contend that 80% is more realistic. Their case is backed by evidence from countries where DSR is more established. For example, in the USA, the PJM network – the largest grid operator in the north-east – reports that 63% of capacity is available within 30 minutes of a request being lodged.[33]

There is little doubt, then, that the UK could do without Hinkley's 3.2 GW of power delivered to the grid at times of peak demand simply by exploiting demand-side response to a fairly modest degree beyond 'business as usual'.

2. Gas

It would clearly also be possible to replace Hinkley's peak-demand output by building additional gas-fired power stations designed to fire up quickly and run for fairly short periods of time. Such stations have capacity in the hundreds of megawatts, so perhaps 6-10 such facilities would be needed.

33 http://www.pjm.com/~/media/markets-ops/dsr/2015-2016-dsr-activity-report-20151221.ashx

COSTS

At current prices, the total annual cost of Hinkley will probably be about **£2.5 billion**, equivalent to around **£92 per household** if costs were assigned to domestic consumers.[34] Extrapolating over the course of the 35-year contract, the total cost of Hinkley adds up to more than **£3,000 per household**, recouped through electricity bills.[35] How do the alternatives compare?

1. Wind

The cost of renewables continues to fall, but nuclear power has grown increasingly expensive as technology becomes more complicated and the number of vital safety features increases. Onshore wind is now the cheapest new source of power in the UK, undercutting even coal and gas,[36] while measures to balance the output of renewables are also improving year by year. Latest predictions from both Government and National Grid see renewables forming the largest share of the UK's domestic capacity by 2030, even based on the assumption that there will be no major developments in storage technology.[37]

The next round of offshore wind auctions is due to take place later this year, with a limit of £85 per MWh for projects coming online from 2026.[38] It is likely, however, that the auction will come in under this limit. A recent offshore project in the Dutch North Sea – in comparable conditions to UK waters – has been agreed at €72.70 per MWh, around £60 per MWh at current exchange rates.[39] If transmission costs comparable to other UK offshore projects are included, using offshore wind to offset the output from Hinkley would cost £1.9 billion per year. Compared simply with Hinkley's electricity, offshore wind represents a saving of nearly **£600 million** per year, equivalent to more than **£20 on the average household electricity bill**.[40]

Another factor that must be considered is balancing costs. Maintaining the balance between generation and consumption currently costs the National Grid around £1 billion per year.[41] The Committee on Climate Change estimates additional balancing costs for renewables at £10 per MWh,[42] which would add a further £250 million to this bill. Even with this additional cost (around £9 per household), the cost of wind power **still undercuts Hinkley, saving about £10 per year on the average bill**. Balancing costs may increase as more wind capacity is connected to the grid, but

34 25.2 TWh per year at £97.50 per MWh. Assuming cost split among residential customers only.

35 Assuming no significant deviation from DECC-forecast wholesale electricity power prices. Value in 2016 (real) price, not including effect of inflation on CfD deal.

36 http://about.bnef.com/press-releases/wind-solar-boost-cost-competitiveness-versus-fossil-fuels/

37 https://www.gov.uk/government/publications/updated-energy-and-emissions-projections-2015

38 http://www.offshorewind.biz/2016/03/16/eur-929-million-for-offshore-wind-in-uk-budget-2016/

39 http://www.dongenergy.com/en/investors/company-announcements/company-announcement-detail?omxid=901157

40 Based on total cost of £75/MWh. CfD comparable to Dutch offshore project plus £15/MWh transmission costs.

41 http://link.springer.com/article/10.1007/s40844-016-0041-6

42 https://documents.theccc.org.uk/wp-content/uploads/2015/10/Power-sector-scenarios-for-the-fifth-carbon-budget.pdf

could also be suppressed by demand shifting, developments in storage and increased interconnection.

Over time, an additional cost saving will also accrue from the fact that wind farm operators agree contracts shorter than the unique 35-year deal proposed for Hinkley C. Under the Renewable Obligation Certificate (ROC) scheme, a plant operator is entitled to claim certificates for up to 20 years, after which electricity will be generated with no governmental support. With the first deals handed out in 2002, these historical assets will be generating subsidy-free electricity from 2022. With the change from ROCs to Contracts for Difference (CfD), contracts will run for just 15 years. Offshore wind farms are expected to have a lifetime of 25 years, providing near-zero cost energy for a decade once CfD terms have lapsed. Retiring turbines after 25 years will allow frequent updating to the latest technology. Wind prices will almost inevitably fall further with further technological development, expansion and competition.

2. Interconnectors

With wholesale electricity prices generally being lower in other European countries than in the UK, interconnectors are a way to bring cheaper electricity to UK customers.[43] Historically, they have been built without subsidy, with operators recouping costs through transmission charges on the cables.

To provide the same capacity and availability as Hinkley, 3.8-4.9 GW of interconnector capacity would be needed.[44] Based on costs of links under construction and in late stages of development, installing interconnectors on this scale would cost between £1.4-£9.2 billion, a saving of **£8.8-£15.6 billion** – some of which would be passed on to UK consumers through lower bills.

If the UK went full throttle for interconnection, the cost to replace the 25.2 TWh of power produced from Hinkley each year would be £1.66 billion, a saving of more than **£840 million**, or more than **£31 per household**.[45]

The UK imports more electricity than it exports, which has implications for balance of payments. The deficit has persisted for the past 15 years, jumping to an all-time high in the final quarter of 2015.[46] Net imports of electricity cost the UK **£871 million** last year, up more than £750 million in just five years despite a significantly weaker wholesale price.[47, 48] Relying purely on additional interconnection to replace Hinkley's output would worsen this situation, despite providing cheaper

43 http://www.policyexchange.org.uk/images/publications/getting interconnected.pdf

44 Taking a conservative estimate of 65% load factor, equivalent to current connections to France and Belgium but lower than to other nations.

45 ECIU calculation based on £66/MWh power price used, extracted from DECC forecasts, reference scenario. Indexation of Hinkley contract not extrapolated beyond 2016.

46 https://www.ons.gov.uk/economy/nationalaccounts/balanceofpayments/timeseries/hbop/pnbp

47 https://www.gov.uk/government/statistics/dukes-foreign-trade-statistics

48 https://www.ofgem.gov.uk/data-portal/wholesale-market-indicators

power. However, expansion of both interconnection and renewable capacity together could see the UK become a net power exporter by 2030,[49] bringing cash into the country as wind power is exported.

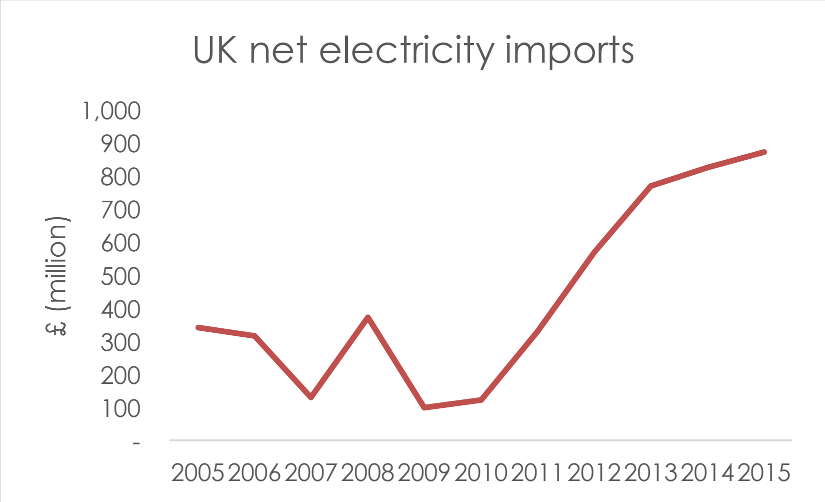

Figure 2: Net UK electricity imports, £ million**. Source:** BEIS

3. Demand side response

DSR cuts bills by shifting usage away from periods of peak times, when power is at its most expensive and the grid is under its highest stress. However, it is not cost-free; contracts must be procured, and sometimes payments are also made to compensate customers for switching demand.

There is a cost of procuring the 11.2 GW capacity necessary to eliminate the need for Hinkley's peak-time power. DSR can be funded by two methods: investing upfront and recouping the costs through contracts with National Grid, or by bidding into the capacity market and receiving an annual payment based on availability.

Building 11.2 GW of capacity would entail an upfront, one-off payment of around £2.25 billion. Averaging this over 15 years – the probable length of wind farm CfD contracts – equates to an annual cost of £150 million. At an approximate cost of £200,000 per MW, this leads to an investment saving of around **£15.75 billion.**[50] This dramatic cut in construction costs would be passed onto households and businesses through lower electricity bills.

If financed through the capacity market, the annual cost will be £310 million per year, although this is likely to be significantly lower as the industry scales up and cuts costs. This cost is based on the £27.50/kW/year awarded to providers in the 2016 transitional arrangement auction.[51]

49 http://tyndp.entsoe.eu/projects/Executive-report.pdf

50 £200,000 figure from DSR provider Open Energi. De-rating factor of 0.29 renders 11.2 GW capacity needed.

51 https://www.emrdeliverybody.com/Capacity%20Markets%20Document%20Library/Transitional%20Auction%202016%20-%20%20Provisional%20Results.pdf

As noted earlier, the 11.2GW figure would only apply if National Grid's estimate of 29% availability holds true. Less than half as much capacity would be needed if availability approached the levels obtained by PJM in the United States, increasing savings still further.

4. Gas plants

Building an equal capacity to Hinkley in peaking gas plants, at a build cost of around £1.6 billion, would save more than **£16 billion** in infrastructure costs.[52] There would be a cost from the gas used, but this would be quite small if plants run only at times of peak demand.

The government plans to incentivise building of new gas-fired stations through the Capacity Market reforms announced earlier this year.[53] However, it is not yet clear whether the reforms will yield bids to build new capacity. Therefore it remains possible that another mechanism may be introduced at some point, possibly with additional cost attached.

52 Based on 3.2 GW capacity needed with OCGT build costs of £500,000 per MW.

53 https://www.gov.uk/government/consultations/consultation-on-reforms-to-the-capacity-market-march-2016

DECARBONISATION

In addition to maintaining a secure and affordable supply of electricity, the UK is legally obliged to reduce its emissions in line with successive Carbon Budgets.[54] While the power sector has reduced carbon intensity by 44% since 1990, power stations are still responsible for a quarter of the current total, and provide the easiest opportunity for further cuts.[55]

As a general rule, renewables and nuclear power plants generate electricity without producing carbon dioxide. So using offshore wind to replace Hinkley's electricity would have no impact on carbon emissions. Increasing energy efficiency decreases overall emissions (except in the unlikely event that the power sector produced no emissions whatever, in which case it would be emissions-neutral).

Under current government plans, unabated coal-fired generation will have ceased by 2025, leaving gas-fired power stations as the only significant net sources of CO_2 in the power sector. With the UK's decarbonisation plan[56] calling for power sector emissions of no more than 100g per kilowatt-hour in 2030, anything more than a cameo role for additional unabated gas plants would put the UK at risk of breaching its CO_2 targets. However, running at a 5% load capacity (a generous but not unrealistic value for a peaking plant), the small number of gas plants needed to step in for Hinkley would produce around 0.64 $MtCO_2$ per year, **less than 0.2%** of annual carbon emissions allowed under the Fifth Carbon Budget.[57]

A common criticism of interconnectors is that they 'offshore' emissions by importing power from polluting coal plants on the continent. However, all countries to which connections are proposed have a lower carbon intensity associated with marginal power generation, the section of capacity called upon to meet upturns in demand (Table 2).

Country	Carbon intensity of marginal power tCO_2/MWh
UK	0.44
Ireland	0.40
Belgium	0.37
France	0.43
Denmark	0.40*
Norway	0.00

Table 2: CO2 intensity of marginal power generation in the UK and countries to which interconnectors are proposed. *intensity of whole system, marginal value not available **Source**: Policy Exchange, Danish Energy Agency

54 https://www.theccc.org.uk/2016/06/30/ccc-welcomes-government-backing-for-fifth-carbon-budget-and-continued-ambition-to-meet-2050-target/

55 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/511684/20160331_2015_Provisional_Emissions_Statistics.pdf

56 https://documents.theccc.org.uk/wp-content/uploads/2015/11/Committee-on-Climate-Change-Fifth-Carbon-Budget-Report.pdf

57 https://documents.theccc.org.uk/wp-content/uploads/2015/11/Fifth-Carbon-Budget_Executive-Summary.pdf

Connecting to hydro-intensive grids, such as that in Norway, would further reduce carbon emissions incurred by UK electricity use, with the handy ability to send carbon-free power in the reverse direction when supply is abundant. In addition, with other European nations also decarbonising their electricity systems, average carbon emissions associated with importing electricity will inevitably fall still further over time.

Demand side response, if administered through the "turn down" of non-essential processes, also carries no carbon penalty. If, however, it occurs by switching to on-site generation – small-scale gas or diesel generation – carbon emissions will be produced. Per megawatt-hour, open cycle gas turbines produce around 460 kg of CO_2, while diesel emissions equate to roughly 1 tonne per MWh. The government is planning to limit diesel use through planning regulations, both for emissions and air pollution reasons, suggesting it will not find favour as a long-term solution. Additionally, the government could easily incentivise genuine "turn-down" DSR over diesel farms through reforms to the Capacity Market.

DSR via on-site generation does carry a carbon penalty. Tight constraints would ensure that additional DSR as part of a Hinkley replacement package did not put UK power sector decarbonisation at risk.

WHAT COULD A GRID WITHOUT HINKLEY LOOK LIKE?

Throughout this report, alternatives to Hinkley have been presented in isolation, in terms of capacity and price. However, in reality, a mixture of low-carbon technologies, more dynamic flows of power between countries and better demand side management may well be applied side-by-side. In this section, we draw on earlier findings to construct two feasible Hinkley-replacement packages, and look at what the cost implications might be.

At the bare minimum, two-fifths of Hinkley's annual 25.2 TWh output of electricity could be replaced by improving energy efficiency above business-as-usual, and this would be a pragmatic approach. Bearing in mind balance of payments issues, we assume that it would be considered desirable to generate the other three-fifths by building additional new offshore wind farms rather than by imports (Figure 3).

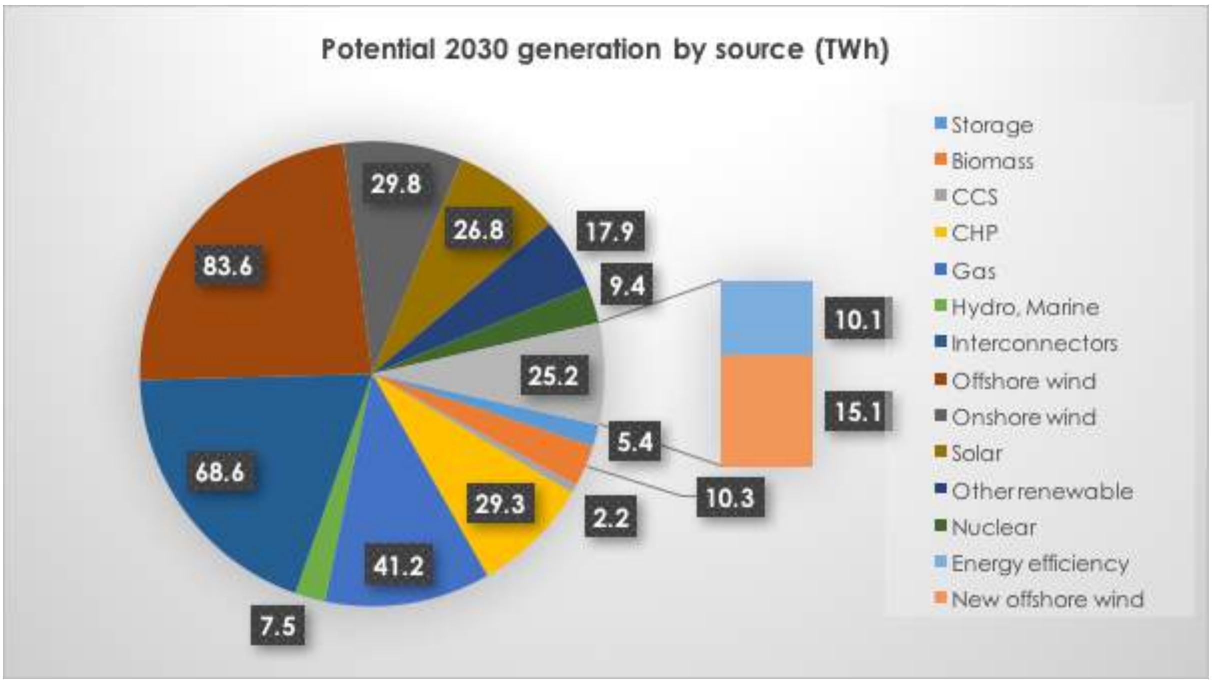

Figure 3: Forecast UK generation by source in 2030, with potential replacement for Hinkley expanded. **Source**: National Grid, ECIU.

As demonstrated earlier, in terms of meeting peak demand, the entire 3.2 GW Hinkley capacity could be replaced by incentivising demand-side response.

This package, then, of 10.1 GW of additional energy efficiency improvements, 15.1 TWh of additional offshore wind-generated electricity and 11.2 GW additional capacity of DSR would be enough to replace Hinkley in its entirety in 2030. Only the offshore wind component would carry a significant ongoing cost, in this case of £1.32 billion – thus saving close to £1.2 billion per year from energy bills.

As stated earlier, the costs of 11.2 GW of DSR would be between £0.15-0.31 billion/year. Thus, either way you do the calculation, this package offers an annual saving of about £1bn per year compared with Hinkley Point C.[58]

In case this amount of additional DSR were felt to be unfeasible, another approach to replacing Hinkley's capacity at peak demand would be to split the 3.2GW roughly equally between DSR, gas plants and interconnection (Figure 4). To provide the same de-rated capacity, this system would require around 3.7 GW of DSR, 1.6 GW of interconnection and 1.2 GW of peaking gas capacity, at a cost of £3.2 billion, around one-sixth the cost of Hinkley,[59] with these savings feeding through into consumer bills.

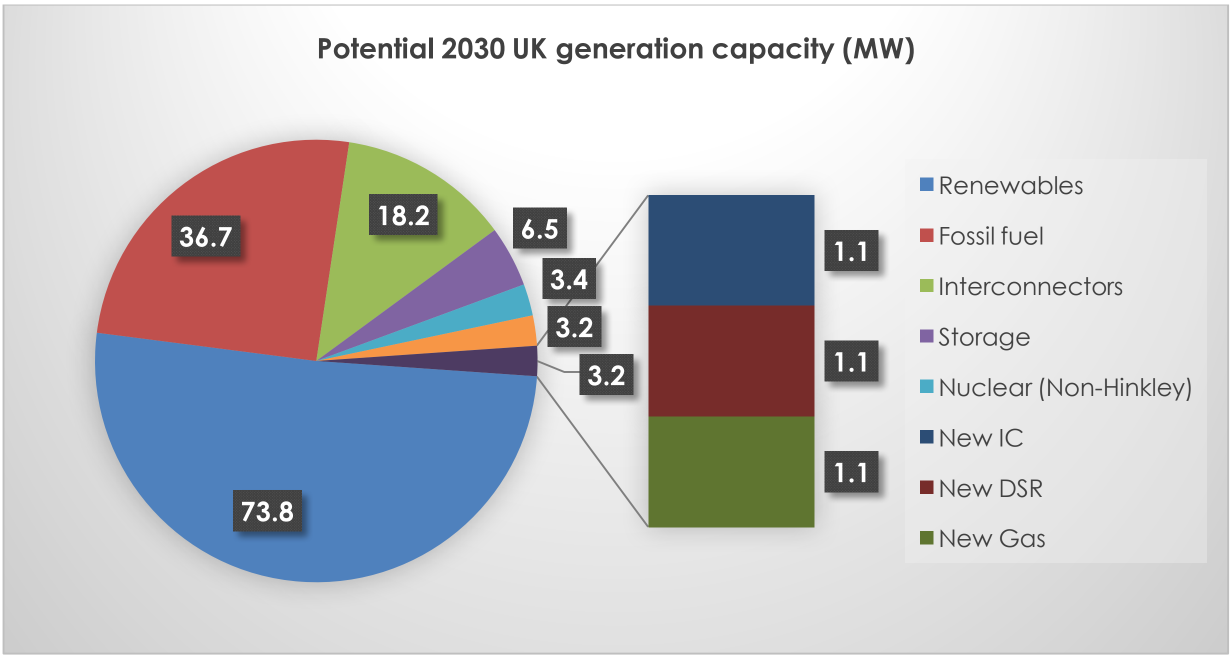

Figure 4: Forecast UK generation capacity in 2030, with potential replacement for Hinkley expanded. **Source**: National Grid, ECIU.

58 ECIU calculation based on £87/MWh wind costs (£60 CfD plus £27 transmission and balancing costs) and power from interconnectors sold at £66/MWh, in line with the DECC-forecast wholesale price for 2030. Energy efficiency assumed to be cost neutral and DSR aggregation costs of £200,000/MW considered

59 New CCGT cost ~ £700,000/MW, DSR ~ £200,000/MW, Interconnector ~ £1m/MW

FURTHER OPTIONS: LESS PROVEN TECHNOLOGIES

1. **Other nuclear technologies?**

In addition to the European Pressurised Reactors (EPRs) earmarked for Hinkley, other nuclear plants in the pipeline are based on different technologies. While these projects may end up delivering electricity at a lower price than Hinkley, the long time scale associated with design approval, financing and planning render it unlikely that additional numbers of these designs could be procured as alternatives to Hinkley on a similar timescale.

Small modular reactors (SMRs) are seen as promising by Government, which is holding a £250 million competition to incentivise innovation.[60] However, with research currently at an early stage, the lead time on development, approval and large-scale construction of these units renders them unlikely to be ready by 2026, the date Hinkley is due online.

Energy storage is advancing rapidly, and batteries are beginning to be installed at utility and customer scale. The widespread view of storage is that it will disrupt the status quo as prices fall, removing the need for 'always on' generation from large, centralised power stations and reforming the role of variable-output renewables, especially solar. Battery costs are tumbling, and expected to become a further 40-60% cheaper by the end of the decade.[61] By 2030, National Grid sees around 3.3 GW of (non-pumped) storage capacity in the UK system, more than doubling over the next decade as close to 7.5 million electric vehicles (EVs) come onto the road by 2040. Batteries in EVs can be used for storage when the car is not in use. As storage becomes capable of backing up electricity at times of low demand and releasing it when needed, the role of baseload power plants will diminish, furthering grid decarbonisation.

Additional low-carbon generation technologies that could potentially be in play by 2030 include tidal current turbines and tidal lagoons. All of these nascent technologies may offer enhanced routes to replacing Hinkley's output by 2030, perhaps at even lower cost.

60 https://www.gov.uk/government/publications/small-modular-reactors-competition-phase-one

61 http://cleantechnica.com/2015/08/04/battery-costs-set-to-fall-60-by-2020-from-energy-storage-megashift/

Conclusion

With a number of factors putting Hinkley Point C in doubt, it is important to consider alternative power sector options for meeting the energy 'trilemma' should the project fail to reach fruition. This report has outlined a range of alternatives that, rather than a like-for-like replacement, can be installed as part of a more flexible, future-proof system. We have shown that there are a number of ways of delivering Hinkley's annual electricity output and replacing its dispatchable generation at times of peak demand. In reality, the exact choice would depend on a number of factors including technological progress, cost, investor appetite, gas price projections and balance of payments considerations.

In all cases, carbon targets can be met, and the "trilemma" objectives delivered at lower cost. All options can be delivered on shorter timescales than the decade proposed for building Hinkley. And it is worth noting that although we have not considered this in detail, cost advantages from taking the offshore wind route would increase in future years, as wind farms move out of the period of guaranteed CfD payments after 15 years.

We see this report as good news for the government. If it decides to cancel Hinkley C, or if it decides to go ahead but the project then founders, energy objectives are not fatally holed, and can be delivered more cheaply.