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ENGINEERING NET ZERO

THE RACE TO NET ZERO
JULY 2020

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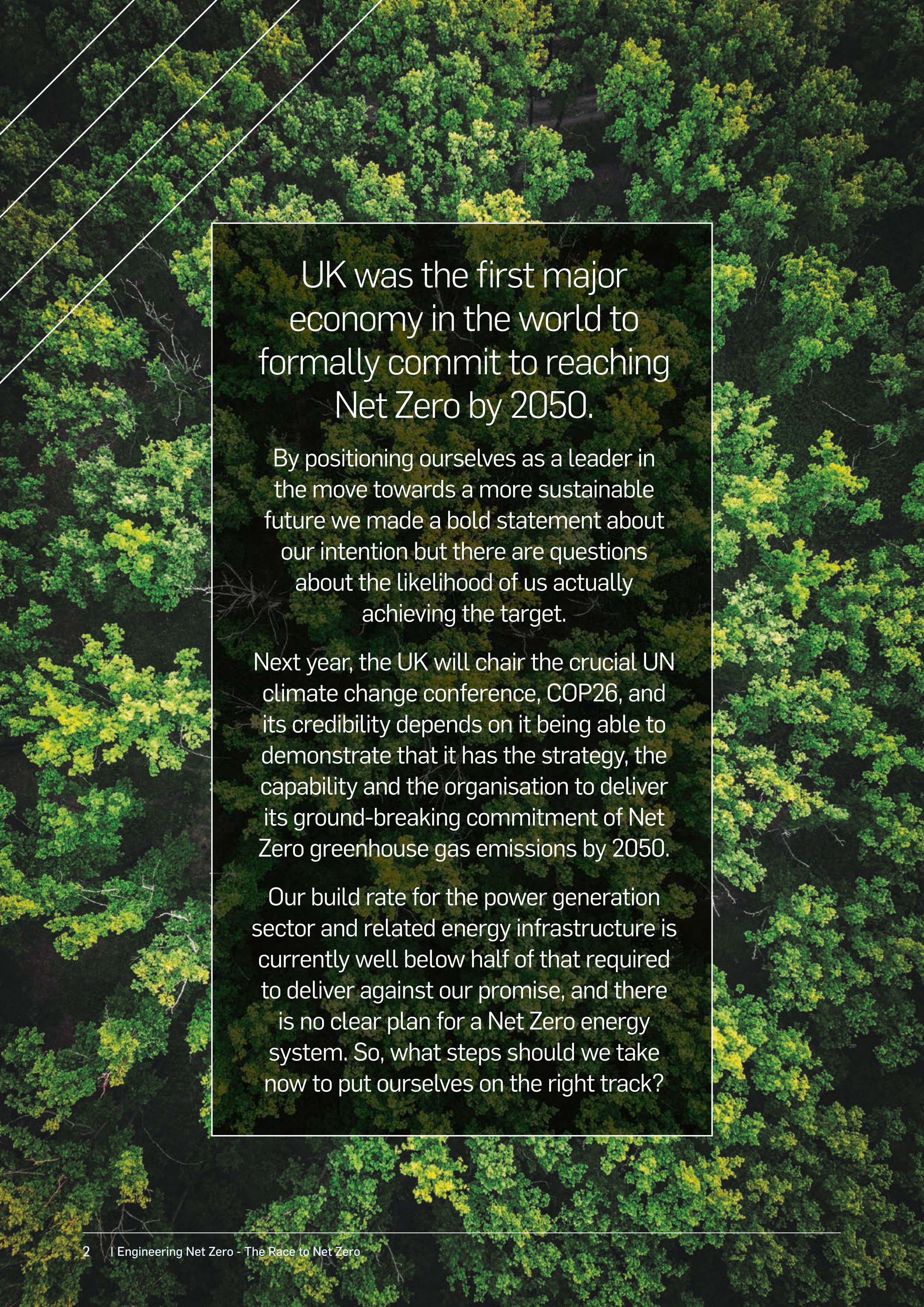
Engineering Net Zero



UK was the first major economy in the world to formally commit to reaching Net Zero by 2050.

By positioning ourselves as a leader in the move towards a more sustainable future we made a bold statement about our intention but there are questions about the likelihood of us actually achieving the target.

Next year, the UK will chair the crucial UN climate change conference, COP26, and its credibility depends on it being able to demonstrate that it has the strategy, the capability and the organisation to deliver its ground-breaking commitment of Net Zero greenhouse gas emissions by 2050.

Our build rate for the power generation sector and related energy infrastructure is currently well below half of that required to deliver against our promise, and there is no clear plan for a Net Zero energy system. So, what steps should we take now to put ourselves on the right track?

The Mythbuster

"We can achieve Net Zero in 2050, CCC has shown us how we can do it"

Maybe, but no they haven't.

CCC's Net Zero report set out a scenario that showed it is theoretically feasible to reach Net Zero in 2050 but CCC are also clear that this scenario is not a plan. Furthermore, CCC subsequently reported that the gap between our achievement and our aspiration is actually widening. We are not on course to meet Net Zero in 2050.

"With more energy efficiency and storage, we can meet Net Zero using renewables"

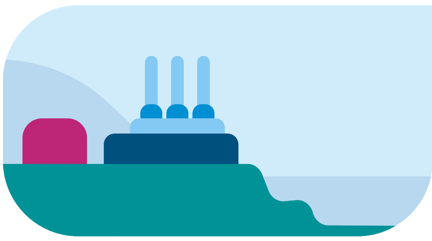
Not So.

CCC has already assumed aggressive efficiency measures, there is no grid scale energy storage technology available today that will enable a system running only on intermittent renewables. Firm Power is an essential requirement for a cost-effective stable system.

"Renewables are now the lowest cost form of generation"

It's not that simple.

Renewables are achieving competitive cost of power at the generator (LCOE) but as the percentage of renewables on the system increases so does the cost of system modification and back up to cover periods of low renewable output. At high penetration, the marginal cost of renewables, measured on a whole system basis, will be far higher than the reported LCOE.



"Carbon Capture and Storage CCS is a proven technology ready to deploy"

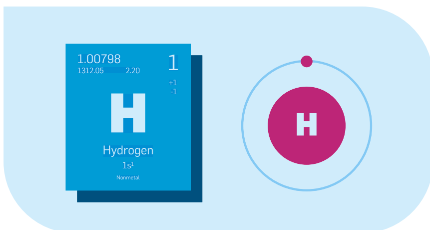
Yes and No.

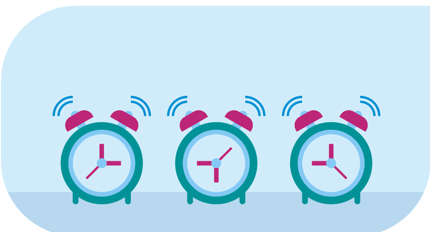
Carbon capture, transportation and geological injection are all proven technologies BUT there is currently no system anywhere in the world that provides large scale CCS to multiple diverse carbon sources including large intermittency. CCS cluster deployment faces significant technical and commercial challenges.

"Hydrogen will be a carbon free source of energy"

Not So.

Hydrogen is NOT an energy source. Free Hydrogen does not exist in nature, it must be separated from methane or from water, both require significant energy input and separation from methane leaves large volumes of CO_2 for disposal. Hydrogen has potential as an energy store and as an energy vector. In both cases there are significant technical issues to overcome and conversion losses can be substantial.





"If time is short, we need to pick a technology and run with it"

No.

There is no single technology that will enable us to deliver Net Zero. We will need to deploy multiple technologies and must retain or develop the capability to deliver them in a dynamic economic environment.

There is a misalignment between ambition and action at a national and global level.

Introduction

The UK's Committee on Climate Change (CCC) published its Net Zero report [Ref 1] in May 2019. The report said the UK could - and should - accelerate its response to climate change to achieve Net Zero greenhouse gas (GHG) emissions by 2050.

The Government accepted this recommendation with remarkable alacrity and a month later the UK became the first major economy in the world to commit – in law - to achieving this ambitious target.

But when the CCC published its 2019 Progress Report to Parliament [Ref 2] soon after it clearly identified an increasing gap between the UK's stated climate change ambitions and its achievement. It noted that of the 25 headline policy actions it had recommended a year earlier only one had been delivered. That demonstrated there was a misalignment between ambition and action at a national and global level. The CCC also concluded that, notwithstanding our commitment to Net Zero, it would be prudent for the UK to plan adaptation strategies for climate change of 4^{0}C but there was little evidence of planning for 2^{0}C.

We have 30 years to get this right. That may seem like a long time, a marathon in racing terms. But in this paper, we suggest the task is huge. There are many uncertainties, even for well performing sectors of the economy, and policy is lacking. That means time is already short. To continue with the marathon analogy, no one wins after falling a mile behind in the first 30 minutes.

To add to the challenge, the world is not the same as it was when the UK committed to achieving its climate change target. Any action we take now must be delivered against the backdrop of the COVID-19 crisis and the economic damage it will cause. Many believe that to avoid a depression, the like of which has not been seen in our lifetime, governments across the world will need to provide massive economic stimulus. We suggest the response to the short-term threat posed by COVID-19 should be heavily focussed on kick-starting the Net Zero programme. Now is the time to accelerate change across all sectors to speed-up our recovery from the virus and address the longer-term existential threat of climate change.

From now to 2050 we must replace or repower almost all our current generating capacity and build almost twice as much again to meet the anticipated increased demand.

The journey towards Net Zero

Net Zero in the power (electricity generation) sector

The Power Sector is the most profoundly impacted sector as the UK attempts to achieve Net Zero. We have already made great progress. We have shut down almost all coal fired electricity generation; in 2019 54% [Ref 3] of our electricity was generated by zero carbon nuclear and renewables.

The carbon intensity of power generation has dropped from 500g/kWhr to 170g/kWhr [Ref 4] over the past decade. But the sector can't be complacent. It has reached the low-hanging fruit and the task from now on is harder. The UK's nuclear fleet, which produced 50 TWhrs of carbon free power (18% of total demand) in the past year, is retiring and its replacement is not yet assured. The increasing dependence on intermittent generators will challenge system stability and there are significant risks associated with the high dependence on carbon capture and storage (CCS).

And yet, the power sector holds the key to achieving Net Zero. Its task is two-fold:

1. Continued decarbonisation

Figure 1 opposite, based on 2017 emissions data reported by the CCC [Ref 2], shows the relative scale of UK GHG emissions by sector. The power sector has reduced from 150 to 65 $MtCO_2e$/yr in the past ten years, but now it must go further.

2. Double the output to well over 600 TWh per annum

It must also double its output to enable extensive electrification, which will reduce the far greater emissions in the surface transportation, industry and buildings sectors.

The power sector is profoundly impacted by the UK's attempts to achieve Net Zero and it has made great progress towards the target.

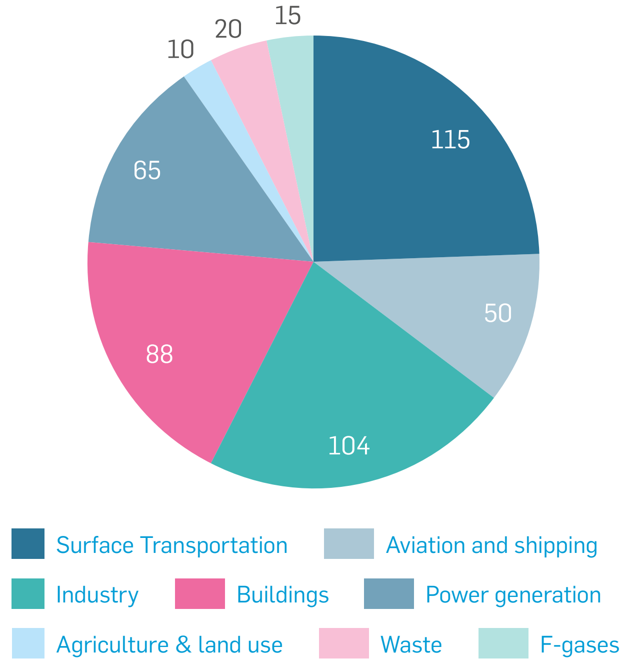


Figure 1 - UK 2017 GHG emissions by sector ($MtCO_2e$/yr) (based on the CCC's report statistics [Ref 2])

The scale of the potential changes in the power generation mix and installed capacity is illustrated in Figure 2.

The life of most modern generating assets (except nuclear) is around 30 years. So, between now and 2050 we must replace or re-power almost all current generating capacity and build almost twice as much again to meet the anticipated increase in demand. In broad terms, that means we must start to build all the anticipated 2050 generating capacity now. Furthermore, as the proportion of intermittent generation increases, the overall system management challenge will become far more demanding than in the past, and may require substantial investment in our transmission and distribution infrastructure, power interconnectors and energy storage. At the same time, we must build an entirely new system of CCS for the UK with capacity four times today's total global capability and build entirely new hydrogen infrastructure.

Installed Generating Capacity by Technology in GW

Today	
Annual Generation	330TWhr
Peak Demand	57GW
Installed Capacity	-100

2050	
Annual Generation	645TWhr
Peak Demand	150GW
Installed Capacity	>280GW

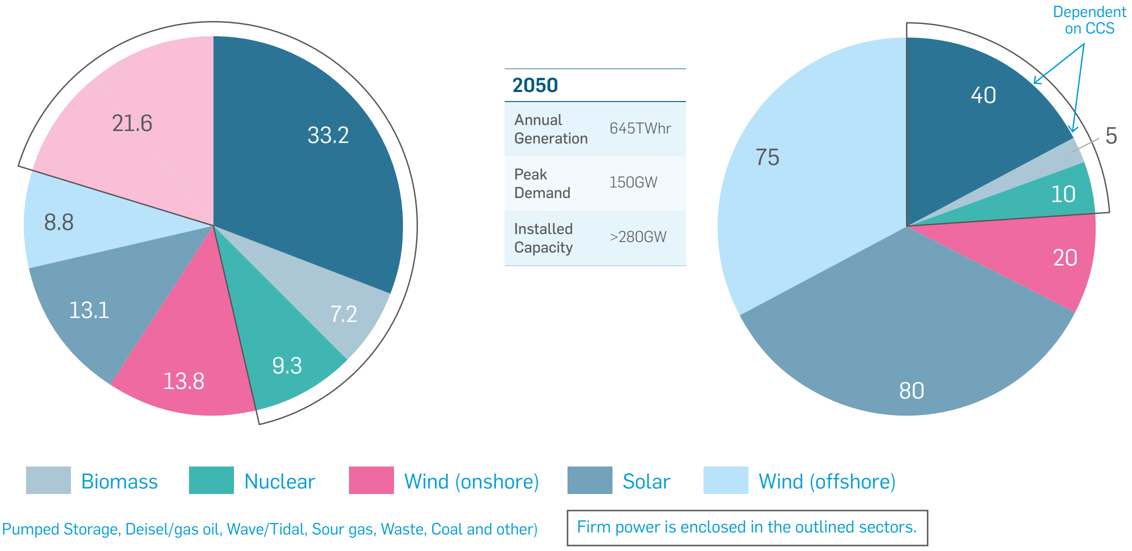


Figure 2 - Installed generating capacity 2020 and 2050
CCC Net Zero 'Further Ambition' scenario [Ref 1].

What does a Net Zero power system look like?

There is no master plan for how the power system will look 30 years from now. A wide range of views have been expressed, often with limited engineering substantiation, and many depend on technical or commercial innovations that are, as yet, unproven. Some of the commonly repeated misconceptions are hi-lighted in the Mythbuster at the start of this paper.

Although the CCC points out that its Net Zero scenario is not a plan, it's all we have. So, we assume the 2050 generation mix will be as described in the CCC's Net Zero "Further Ambition" scenario shown in Figure 2 above.

If we return to the example of the marathon, runners must learn to 'pace' themselves. They need to set a target time and adjust their speed accordingly. In our case, the target time is 30 years. For each of the generating technologies shown in Figure 2 we can calculate our average speed or construction 'run rate' as shown in Table 1.

Technology	2050 Capacity	'Run Rate' GW/yr
Natural Gas	40 GW	1.33
Biomass	5 GW	0.17
Nuclear	10 GW	0.33
Onshore Wind	20 GW	0.67
Solar	80 GW	2.67
Offshore Wind	75 GW	2.5
All	250 GW	7.67

Table 1 - Minimum required new generation 'run rate' to meet Net Zero by 2050

A prudent athlete will always look back on past performance before setting their goal for the next race. The UK's past performance in the construction of new generating capacity is summarised in Figure 3 below [Ref 5]. Our highest single year build-out was 6GW in 2012, comprising 3.5GW gas and 2.5GW renewables.

The CCC [Ref 1] estimated that a sustained construction rate of between 9 and 12 GW per year could be required to reach Net Zero. Our calculated rate of 7.7 GW per year covers only the specific generation technologies listed and doesn't include hydrogen production or make any allowances for infrastructure, energy storage, interconnectors or CCS. We concur that the CCC estimate of a sustained rate of energy-related construction may be in the 9-12GW range.

Every week of delay at the start will require a faster build rate later and we are starting at less than half the required rate. Therefore, a peak year build-out requirement of 12GW or more is very likely. This compares with our 'personal best' of 6GW. To double our highest peak annual output is a significant challenge.

Globally, the power construction industry is mature and improvements can be made but it would be unwise to rely on a sudden increase in the output of the industry, particularly when global activity and competition for resources is likely to be high. Furthermore, the industry will not gear up until there is greater certainty over workflow. This requires a credible plan backed by consistent government policy. Delaying decisions now will greatly increase the risks to the programme later.

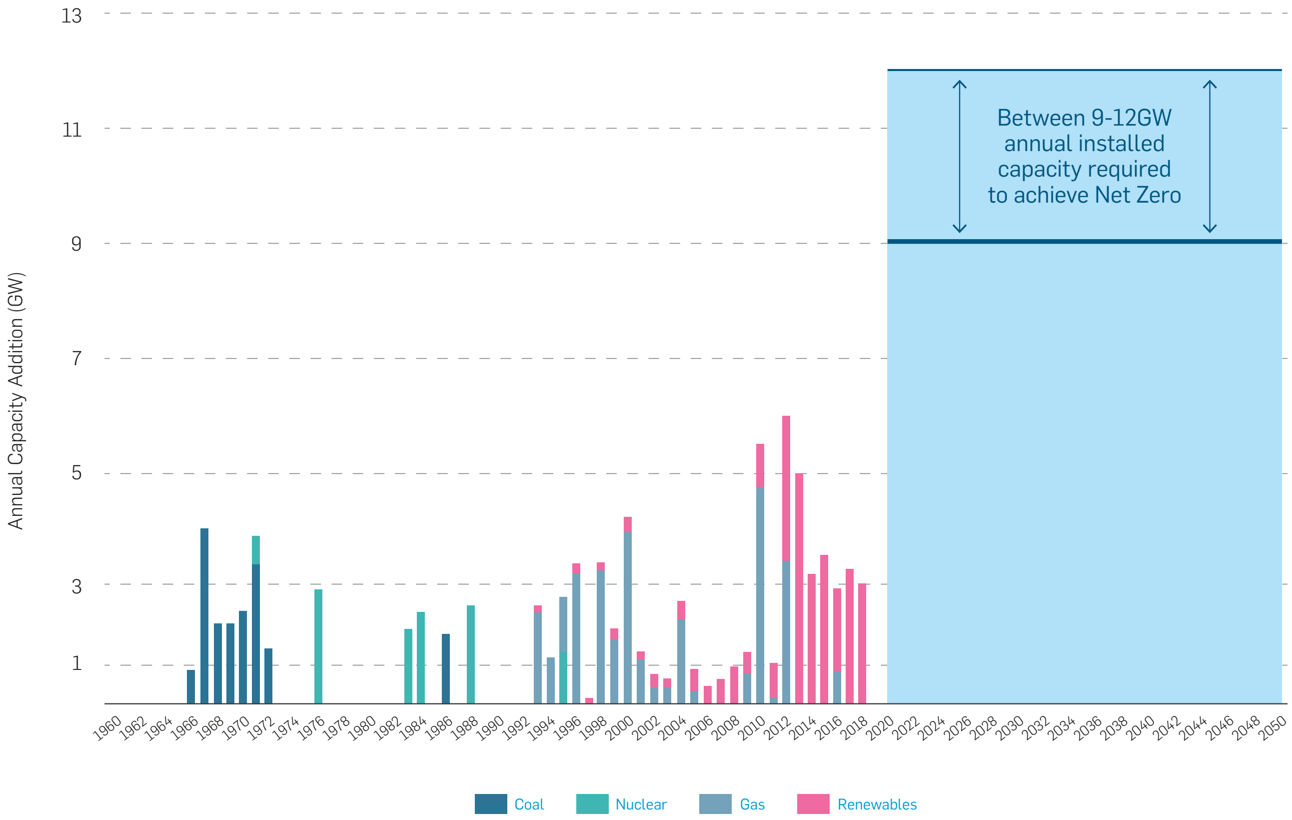


Figure 3 - Historical UK generation capacity building compared with the CCC's future projection [Ref 5]

What capacity do we need to build?

To give the required run rate tangible meaning in terms of manufacturing and construction activity we must consider how delivery will be achieved. Taking the required run rates from Table 1 and assuming the use of currently available technology, the new generating capacity could be achieved as shown in Table 2.

It's prudent to plan using currently available technology. Although technology will advance and innovation must be encouraged, new solutions can be incorporated into the plan as they arise. Due to the scale of the challenge, incremental improvements in technology will make a relatively minor impact. So, to delay action in the hope of an extraordinary development would be a very risky strategy.

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To translate the required units from Table 2 into numbers of projects and durations it's useful to compare them with recent project experience:

Natural gas

The required capacity run rate is 1.33GW/yr. The Keadby II project is an 840MW plant using the latest Siemens turbine technology. The Keadby construction period has been reported to be four years, although many similar plants have been built in three. These schedules do not include CCS. We will, therefore, use a four-year construction period as a conservative estimate.

Technology	2050 Capacity	Typical Unit	Number of Units
Natural Gas	40 GW	Siemens CCGT H class 840 MW per train	48
Biomass	5 GW	Stand-alone new biomass plant 75MW	66
Nuclear	10 GW	Large Gen III reactor 1500MW per reactor	6
Onshore Wind	20 GW	Large number of small projects	N/A
Solar	80 GW	Very large number of v. small installations	N/A
Offshore Wind	75 GW	10-15MW turbines average 12MW per unit	6250

Table 2 - Potential Generating Units Delivered Now Until 2050 (CCC Net Zero Scenario)

If we require 48 units then the total construction activity would be 48x4=192 unit years. To achieve the run rate we set out in Table 1, we'll require 6.4 Keadby projects to be in construction at all times. We note that between 1990 and 2000 in the so-called dash for gas the industry added 2.5GW/yr of natural gas capacity, so the required run rate is well within industry capability. Notwithstanding that many of the plants built in that period were of poor quality and international competition for projects was less than it's likely to be as we build for Net Zero.

The market has not supported investment in Combined Cycle Gas Turbines (CCGT)/Open Cycle Gas Turbine(OCGT) plant in recent years. Between 2015 and 2019, gas fired capacity declined by 540MW. Analysis of the current CCGT fleet confirms that 50% of current capacity is likely to reach retirement in the next decade, 30% in the 2030s and 20% in the 2040s.

With one plant (Keadby II) under construction but potentially offset by other closures, the current run rate can be considered near zero. During the past three years, development consent orders (DCOs) have been issued for 9.9GW of new plant but operators are not proceeding with investment in the current market. None of these projects are proposed to be built with CCS, which would add significantly to the design, construction and operating costs, as well as to the construction timescales.

Biomass

The required capacity run rate is 0.17GW/yr. Stand-alone biomass plants have a typical capacity of 75MW. However, the conversion of retiring coal-fired units, such as Drax, can deliver large projects which, for a short period, will inflate the run rate for capacity additions. Year-on-year capacity additions can therefore be erratic due to the impact of single large projects, although as there are only four coal stations still operating in the UK, there is limited potential for biomass conversion (especially given that two of these plants are over 50 years old).

In 2019, UK biomass capacity increased by 0.29GW, and in the five years from 2015 to 2019 capacity increased by 2.46GW, an annual rate of 0.49GW/yr. Drax dominates the current UK capacity. It has four large coal units converted to biomass with a capacity of 2.6GW, which is more than half the national capacity of 4.7GW. None have CCS yet. Drax and other, older converted coal plants are unlikely to be running in 2050. Therefore, we consider the majority of 2050 capacity will comprise new stand-alone plant with CCS.

If we require 66 such units and each takes three years to construct, we have 66x3=198 unit construction years. This means an average of six units should be under construction at all times. In the past five years, only one such plant (without CCS) has been opened by a major power producer [Ref 6]. In the past three years, only two new biomass plants have received DCO.

Nuclear

The required capacity run rate is 0.33GW/yr. There is one nuclear plant under construction at Hinkley Point C. The plant will comprise two reactors with output of 3.2GW. The construction period for each reactor will be seven years. They are the first new reactors in the UK for over 20 years and subsequent projects should be constructed more quickly.

For planning purposes, we assume each 1.5GW reactor will take six years to construct. Following the same methodology, we need six reactors, which means the total number of reactor construction years will be 2x7 + 4x6 = 38. Thus, 1.27 reactors should be under construction at all times. We are meeting this schedule, as expected, because the CCC has based its scenario on the three new nuclear plants that are planned for the UK. The Hinkley project schedule provides a current capacity run rate of 0.44GW/yr.

We have previously noted [Ref 5] that the CCC's assumption that only three new nuclear plants should be constructed greatly increases the risk of achieving Net Zero. This is discussed in more detail later in this paper.

The CCC does acknowledge [Ref 1] that a higher nuclear build-out may be required. We suggest that to sustain our nuclear capability and increase the certainty of Net Zero delivery, an absolute minimum programme of nuclear construction of approximately 20 GW by 2050 must be considered [Ref 5].

At 20GW capacity, nuclear would provide around 25% of the 2050 electricity demand not dissimilar to the 20% of recent years.

At 20GW capacity, nuclear would provide around 25% of the 2050 electricity demand, not dissimilar to the 20% of recent years. To sustain a viable and stable least-cost Net Zero system with a high percentage of renewables we are likely to require more than this. Any shortfall of CCS delivery would almost certainly require substantially more than 20GW of nuclear capacity.

To achieve 20 GW by 2050 we would have to double the capacity run rate to 0.66GW/yr, which means a project run rate of 2.5 large reactors under construction at all times. To have any prospect of achieving this, the Government must resolve the funding mechanism for new nuclear without delay and enable early investment decisions to be taken on the next three large nuclear plants.

Small modular reactors (SMR) are under development in several countries, including the UK, and may offer an additional stream of nuclear capacity building from the mid-2030s. The combination of firm commitment to large nuclear on the currently approved sites and fleet deployment of SMRs could offer a capacity run rate in excess of 1GW/yr. This would be the only alternative firm low carbon option should CCS prove undeliverable at the scale envisaged in the mid-2030s.

We note that recent papers from the Energy Systems Catapult [Ref 7] and the NIA [Ref 8] have suggested far greater deployment of nuclear than the CCC Net Zero scenario. These analyses tend to confirm our view that an absolute minimum of 20GW nuclear should be included in CCCs next round of modelling. CCC should also demonstrate the sensitivity of model outcomes to variations in assumed critical input parameters.

Onshore wind

The required capacity run rate is 0.67GW/yr. Onshore wind capacity is spread over a large number of installations of widely varying size. Therefore, it's useful to consider national aggregate performance rather than individual projects. In 2019, UK onshore wind capacity increased by 0.63GW, almost matching the required run rate. Aggregate capacity increase over the five years from 2015 to 2019 was 1.12GW, comfortably exceeding the required run rate [Ref 6]. The limiting factor in meeting onshore wind capacity is likely to be the availability of permitted sites and network capacity, rather than the capacity of the industry.

Solar

The required capacity run rate is 2.67GW/yr. Solar capacity is spread across a very large number of mostly small installations. The Department for Business, Energy & Industrial Strategy (BEIS) [Ref 6] classifies installations of more than 5MW as 'large'. At the end of April 2020, total installed capacity was 13.49GW of which 45% consisted of 466 large installations. The remaining 55% was spread across more than 1,000,000 smaller installations.

During 2019, total new installed capacity was 257MW, of which 81.9MW was in large installations. Solar projects are simple in engineering terms, project development costs are low, and the market responds very quickly to changes in the subsidy regime. The current run rate for all sizes of installation is less than 10% of the required run rate.

Offshore wind

The required capacity run rate is 2.5GW/yr. Based on the figures in Table 2, we need 6,250 turbine installations over 30 years, which is a run rate of 208 per year. In 2019, the industry installed 252 turbines, so the required run rate for installations is being achieved. However, the required installed capacity run rate is 2.5GW/yr and the installed capacity in 2019 was 1.76 GW, which was a UK record. In order to hit the required capacity run rate, the industry needs to move to larger turbines as soon as possible.

The development of larger turbines and the move to floating installations in deeper waters will require different spreads of equipment. Our Engineering Net Zero report [Ref 5] concluded that the anticipated build out to 2050 should be feasible. However, the move to floating turbines in deeper waters further from shore for required capacity improvements, combined with increasing global demand, are likely to arrest the recent falls in LCOE and may result in a potential rebound, along with a slowing of the achievable construction rate. International competition for project delivery may also curtail pace and impact price. Offshore wind is critical to the net zero system and these future risks should be addressed.

Technology	Required Run Rate GW/yr	2019 Actual Run Rate GW/yr	% of target
Natural Gas	1.33	0	0
Biomass	0.17	0.29	170
Nuclear	0.33	0.44	133
Onshore Wind	0.67	0.63	94
Solar	2.67	0.26	10
Offshore Wind	2.5	1.76	70
All Generation	7.67	3.34	43

Table 3 - Current Capacity Run Rate Compared to Required Rate

Where are we now?

The historical rate of construction compared with the average run rate needed to achieve Net Zero by 2050 were shown in Figure 3. If we start below the required average run rate, we will have to run faster to make up lost ground later in the race. If we leave it too late we have no chance of winning.

Based on current figures, our 2019 actual achievement compared to the required capacity run rate is summarised in Table 3 and illustrated in Figure 4. Across all technologies, we're achieving 43% of the required rate. In this current 'snapshot' the shortfalls are in natural gas, offshore wind and solar but, as discussed below, we cannot be complacent about the other technologies. All the required technologies must reach and sustain their target rate over the full course of 30 years.

We can improve offshore wind capacity and the development of solar could be accelerated, and we could justify it more easily if its diurnal intermittency was compensated by low cost battery storage which is highly challenging. Natural gas will not speed up until there is a more level playing field and the uncertainties of CCS operations and costs become clear. Meanwhile, nuclear, the only alternative firm low carbon resource which could be brought forward, is being held back by the current financial structure and lack of transparent whole system marginal cost analysis.

In Table 3 we compared the current run rate and the required 30-year average run rate to give a snapshot of current activity. Another, potentially more valuable comparison, would be between the forecast run rate for known prospective projects and the required average. But it's difficult to gain an insight into the intentions of the market given the commercially sensitive nature of investment plans.

We can analyse the backlog of already permitted sites and the process of bringing forward a future project pipeline. Setting aside solar and onshore wind, which will comprise a large number of smaller projects on very many sites, we find:

- Natural gas – there is no coordinated programme. In the past three years, DCOs for 9.9GW have been approved. A sustained run rate of 2.5GW/yr was achieved between 1990 and 2000. The industry could deliver a marked acceleration but the uncertainties and cost of CCS and the present market dynamics are preventing investment.
- Biomass – this has been dominated by large coal plant conversions, which have delivered quick results but will not support our move towards Net Zero by 2050. Consequently, there is a poor pipeline to deliver future capacity and the recent adequate run rate will not be sustained.

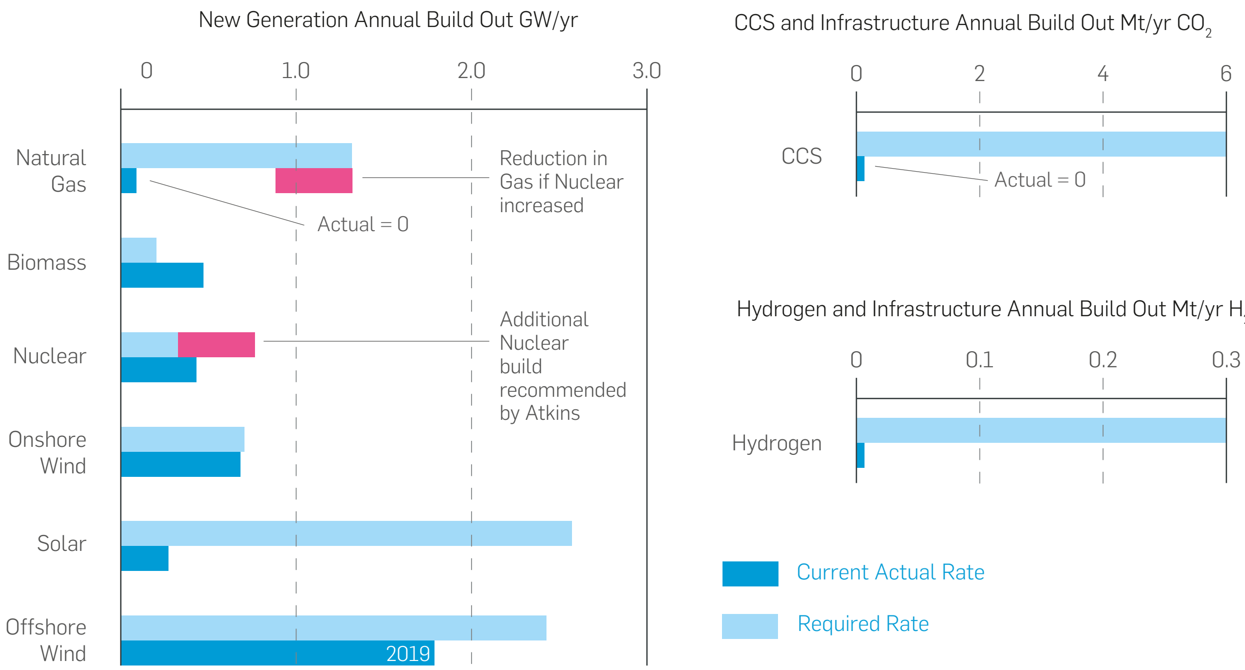


Figure 4 - Construction Activity Run Rate to Reach Net Zero and Actual Rate

- Nuclear – the current run rate is matching the CCC requirement. But, as already noted in this report, we believe the current target capacity is less than half that required to sustain a viable capability. The future pipeline has recently diminished as projects at Wylfa, Oldbury and Moorside have been put on hold or cancelled. Urgent action is needed to improve the project financial framework to restore an investible project pipeline.
- Offshore wind – the Government is effectively controlling the programme through its process of auctioning tranches of capacity support. We believe the industry should be able to deliver the capacity required but there is a risk that costs could rebound.

Overall, the situation is concerning. Firm power (natural gas, biomass and nuclear) is currently achieving less than 40% of its required run rate. Natural gas, which does have a project pipeline, is currently un-investable, and biomass has a poor project pipeline. Both of these, comprising 80% of the proposed firm power capacity, are dependent on CCS and that remains uncertain and will add to costs. Nuclear, which is a proven technology, is currently stalled due to investment challenges and has a diminishing project pipeline.

The direction of travel is clear. The Government's decision to pursue offshore wind and its continuing support are succeeding. This success, though welcome, may severely limit our future power options unless near-term action is taken to ensure continuing capability and capacity in firm power, and all the required components of the Net Zero energy system.

Carbon capture and storage (CCS), hydrogen and energy storage

In addition to the new electricity generating capacity listed in Table 2, the CCC Net Zero scenario states the UK must build a completely new infrastructure to capture and securely sequester 176Mt/yr of carbon dioxide (more than four times the current total global capacity). We also need to create a hydrogen industry and infrastructure capable of delivering 30% of our energy demand.

CCS

The required run rate for integrated CCS (capture, transport and sequestration) is 5.97 Mt/yr. We estimated [Ref 5] that CCS will require up to 100 carbon capture plants with 160 process trains. Currently, we have zero CCS capacity, and no facilities are under construction.

Hydrogen

We have limited hydrogen production capacity and that is dedicated to industrial needs but in terms of the hydrogen infrastructure required to achieve Net Zero, the situation is similar to CCS - and closely tied to it - as the majority of hydrogen production will be dependent on CCS. The CCC [Ref 1] estimates that we will need 30 to 60 methane reforming hydrogen production plants with CCS and 200-700 electrolyser units, which combined could produce 7Mt/yr of hydrogen. The required run rate for building hydrogen production and infrastructure is 0.23Mt/yr. Notwithstanding early stage demonstration projects, we assess the current hydrogen status as zero relevant capacity and zero run rate.

Energy storage

Energy storage is one of the least well-defined requirements of Net Zero. Estimates of the required storage capacity vary widely between studies. The CCC has not specified its anticipated 2050 energy storage requirements.

esults from 28 studies of the future electricity system, comparing the amount of storage that gets built in the coming decades jainst the amount of energy from variable renewables. Installed storage capacities are divided by the peak demand for electricity each region to account for the relative size of countries.

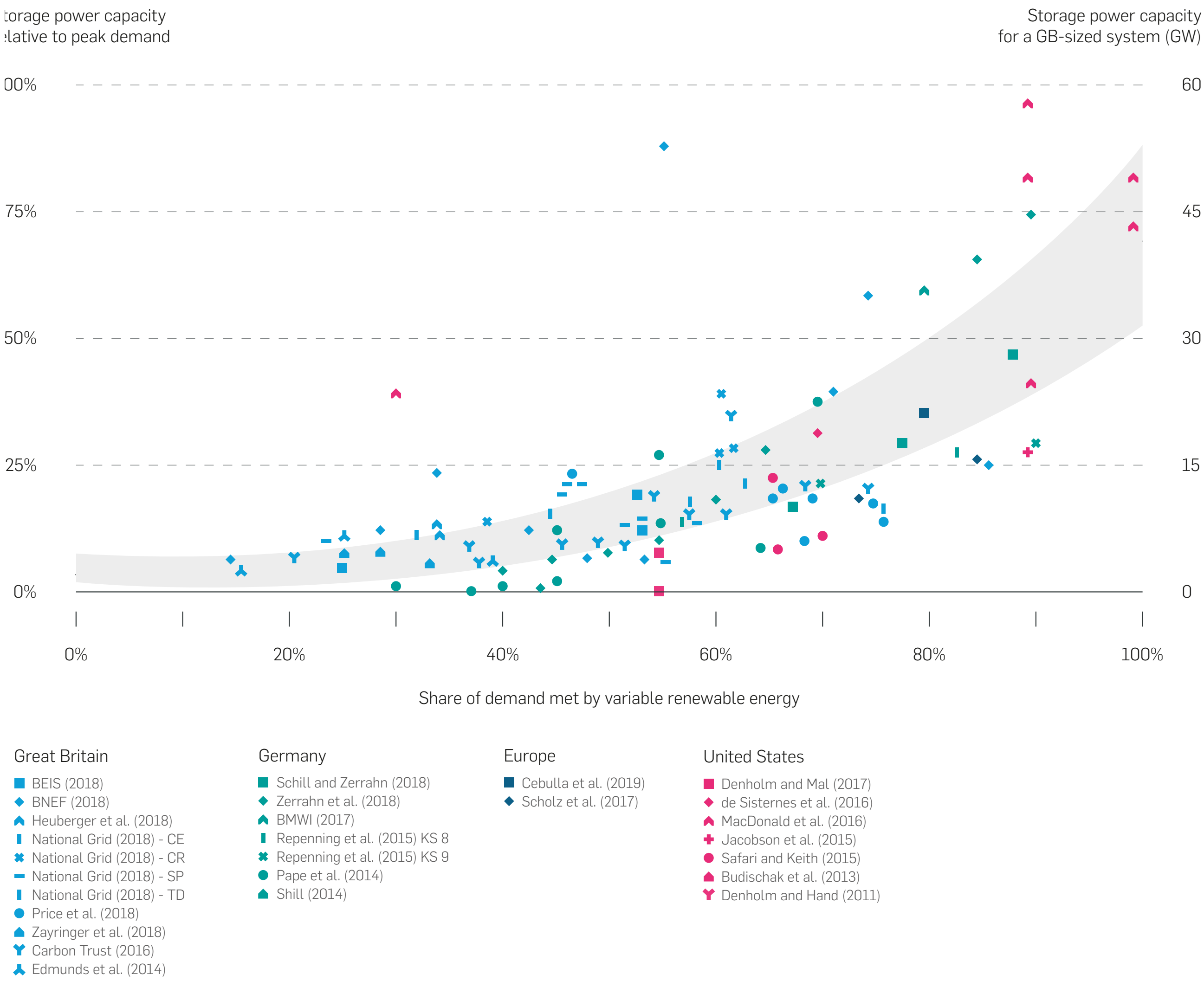


Figure 5 - Energy storage capacity required as renewable generation increases
Ref Zerrahn et al, 2018; reproduced from Drax Energy Insights [Ref 4]

Studies usually report an estimated power input required from storage, which is in MW or GW. The power may be needed to maintain system stability and frequency, which is generally a short-term input (could be seconds or minutes); or it could be required to bridge a shortfall in generation from intermittent supplies, and that be could be minutes or hours.

Inter-seasonal storage of weeks or months is unlikely to ever be economic given so few cycles of operation and the very high capital costs.

Figure 5 presents a summary of various international studies and shows potential UK storage requirements, which go up as the percentage of renewable generation increases. We believe the UK system may need between 15 and 30 GW of storage.

But the power requirement alone does not tell us anything about the actual size of the storage. If we compare it to a water storage reservoir, the power in GW tells us the flow rate needed – analogous to the size of the pipe from the reservoir. To know how big the reservoir must be we also need to know for how long we have to provide that flow. The important measure for understanding energy storage is how much energy we need to store, measured in GWhrs, and this isn't estimated in the literature.

That means it's not possible to estimate our required run rate in energy storage at the moment but we can say the UK currently has 3.1GW of capacity in pumped storage plus about 1GW in batteries. We may need up to ten times this to achieve Net Zero.

For completeness we have included CCS and hydrogen in the run rate assessment in Figure 4.

What progress have we made on CCS, hydrogen and energy storage?

We should be worried about CCS, hydrogen and energy storage. The CCS capability underpins the system and is essential to the delivery of 40% of the nation's energy in 2050. The current build rate is zero. Similarly, hydrogen is projected to deliver 30% of our energy, and the current build rate is also effectively zero. Energy storage plans are yet to be determined.

The Government's intention is that we should have the option to deploy CCS at scale from the mid-2030s. In terms of our marathon, we are planning to implement the most critical element of our Net Zero strategy when the race is half over. Furthermore, under the CCC scenario, we will effectively stand down our new nuclear capability in the early to mid-2030s with only 10GW constructed and with CCS still in early stage deployment. The sequencing is shown in Figure 6.

The consequence of failure to deliver CCS at the anticipated scale and the pre-emptive demobilisation of new nuclear would be that the UK's energy strategy would be completely disrupted just 15 years from 2050. The system would be left with offshore wind as its only large-scale zero carbon power generation option, less than 10% firm power, inadequate storage, and inadequate transmission and distribution infrastructure.

Returning to our marathon analogy, we will 'blow up' and retire at the half-way point. Our best insurance against such a catastrophic failure is to keep all technology options available.

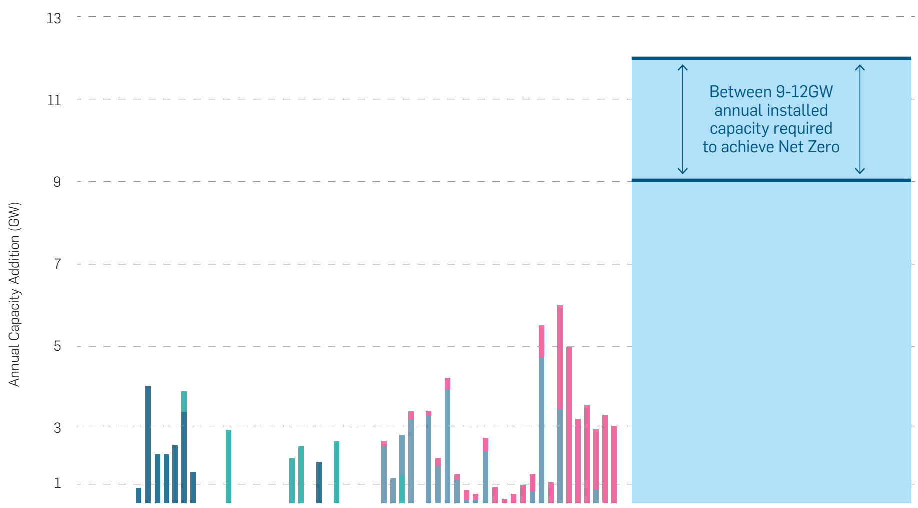
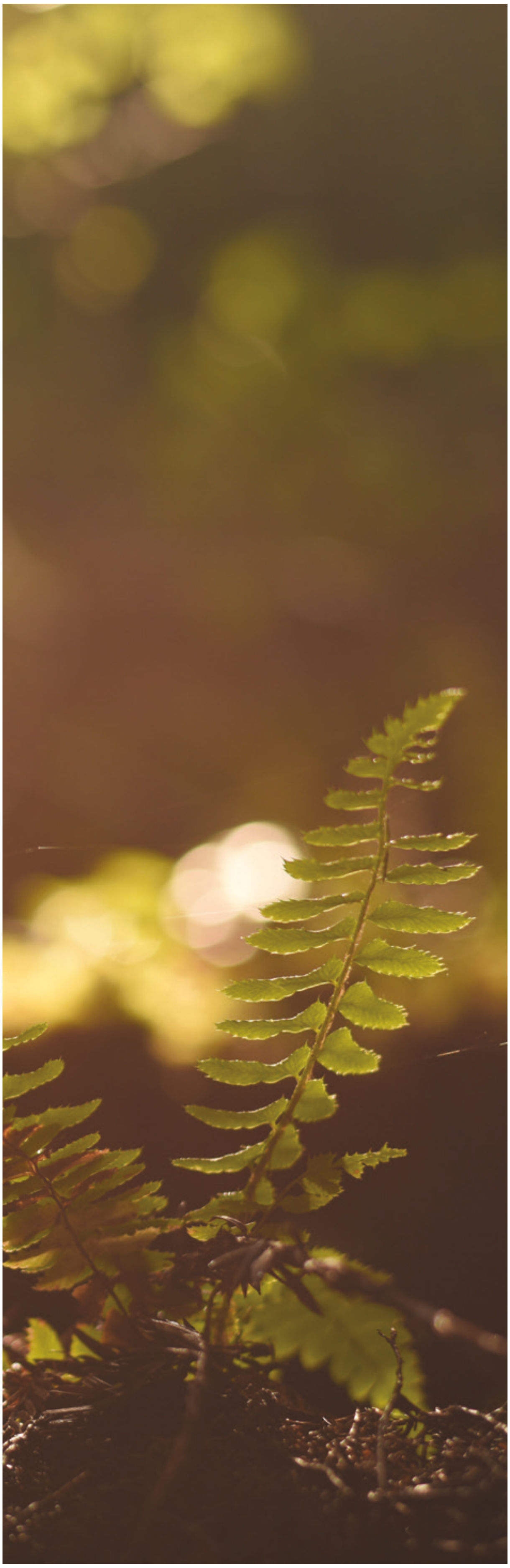


Figure 6- Critial Strategic Development Decisions



We need to accelerate our building programme and bring forward all technologies without imposing upper limits on a specific solution. Over time, experience and actual project performance will determine the optimal mix of the system and the extent of new technology adoption.

Barriers to success

An unrestricted and liberalised power market will not deliver an optimal Net Zero scenario. Significant market intervention was needed to kick-start offshore wind generation. The nuclear replacement programme has stalled pending reappraisal of the funding model. There will be no large-scale CCS or hydrogen projects without government intervention and support. And yet, there is no evidence to suggest there is a holistic approach to energy system development that would ensure, for example, that support for one technology doesn't freeze out other technologies that will be needed for overall system security.

We frequently talk of system stability, referring to the physical need to balance the power flows between generation and demand on a real time and second-by-second basis. This is a task that is undertaken with great skill by the system operator, National Grid. Its job will become ever more difficult as the percentage of intermittent renewable generation increases and available firm power decreases.

There is, however, another form of stability that could significantly affect our ability to deliver Net Zero and its cost. This is market stability. The impacts of technology-specific support schemes can easily distort and destabilise markets. Recent media coverage of record curtailment payments to offshore wind operators and the increasing frequency of negative power prices and high price spikes make returns on other technologies less certain. Ultimately, this will impact our willingness to invest in diverse technologies.

Our Recommendation

We're calling on the Government to create an energy system architect (ESA) that will bring detailed and risk-based engineering judgement to the development and implementation of the Net Zero strategy.

The ESA would set out a broad framework with likely bands of capacity for each technology in an integrated system. The plan must be flexible to respond to changing conditions but it will give the market confidence in a likely minimum requirement for each technology.

We're not advocating a centrally planned system - "the return of the CEGB". Instead, we believe we need a mechanism to guide the markets, boost confidence and - most importantly - bring engineering judgement to the risks and trade-offs between different elements. It would also highlight areas in which the current market structure doesn't support development of an optimal Net Zero system, most notably in its failure to attract investment in CCGT with CCS, new nuclear and energy storage.

We don't yet have the clarity a marathon runner has:

- We know the start point.
- We know the finish point.
- We know the time limit.
- But our route hasn't been defined and different teams are free to run in all directions.

Our current build rate for power generation is less than half the required rate and we haven't even started on the critical elements of CCS and hydrogen, upon which 40% of our energy in 2050 could depend. Meanwhile, replacement of our nuclear fleet, the only viable firm power alternative, has stalled.

The CCC [Ref 2] has called for urgent action. It said: "The need for action has rarely been clearer. Our message to government is simple. Now, do it."

This call to action was reiterated in the CCC 2020 progress report [Ref 9] in which it stated that "action taken in this parliament will define the pathway towards Net Zero".

> When we face an enormous challenge and uncertainty people often ask, 'what is plan B?'. The truth is we don't have Plan A.

We echo its call and emphasise that regardless of the eventual system configuration we must accelerate project delivery now. Every month of delay will result in increased risk and cost later. The benefit to our country, our people and the planet of achieving Net Zero would be transformational.

When we face an enormous challenge and uncertainty people often ask, 'what is plan B?'. The truth is we don't have Plan A.

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References

1. Net Zero
The UK's Contribution to stopping global warming. Committee on Climate Change, May 2019
2. Reducing UK Emissions, 2019 Progress Report to Parliament. Committee on Climate Change, July 2019
3. Carbon Brief, online
4. Drax Electricinsights, online
5. Engineering Net Zero
Atkins, October 2019
6. Energy Trends
BEIS
7. Nuclear for Net Zero, Energy Systems Catapult, June 2020
8. Forty by '50, Nuclear Industry Association, June 2020
9. Reducing UK emissions. Progress report to parliament. Committee on Climate Change, June 2020