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Engineering Net Zero

FROM MODELLING TO DELIVERY

Engineering Net Zero
In partnership with our planet

Contents

Foreword

Five years ago, we published 'The Road to Decarbonisation', highlighting critical short-term decisions that were needed to accelerate the UK's progress towards mitigation of climate change [Ref 1].

In it, we noted that, though policy decisions were needed in the near term, they needed to be made along with a clear long-term strategy. A year later, we published the first in a series of reports under the title 'Engineering Net Zero', an interactive timeline of these reports can be found here.

A recurrent theme over these last five years has been that, though diverse and authoritative sources have published many Net Zero scenarios, there has been a lack of engineering risk-based assessment of deliverability of these scenarios at the system-wide level.

Our focus has been–and remains–the transition of our electricity system, which will be the backbone of our evolution to a Net Zero future.

Two fundamental questions

The energy transition is an enormous and very complex challenge. In 2019, Parliament accepted the advice of the Committee on Climate Change (CCC) [Ref 2] and legislated that the UK would achieve a Net Zero economy by 2050.

In 2021, acting on the recommendations of the CCC, government set the policy that decarbonisation of the electricity system should be brought forward from 2050 to 2035 [Ref 3].

2035 is now 12 years away, about the timeframe for development and deployment of a typical large energy project. The UK still does not have a clear plan of what it will build between now and 2035 and beyond.

The acceleration of the decarbonisation of the electricity system has invited two fundamental questions:

- How can we achieve a decarbonised electricity system by 2035? And,
- As we pursue this target, are we creating an optimal power system for 2050 and beyond?

The first question has been addressed in a several recent reports that we reference below. The second question has not yet received the same attention.

How can we achieve a decarbonised electricity system by 2035?

Since January 2023, the 'Mission Zero' independent review of Net Zero [Ref 4], the National Audit Office (NAO) report on progress in decarbonising the power sector [Ref 5] and the 'Independent report of the Offshore Wind Champion' [Ref 6] have been published.

These three reports concluded that we are not currently on track to achieve a decarbonised electricity system by 2035. This conclusion was reiterated by Prof Dieter Helm [Ref 7].

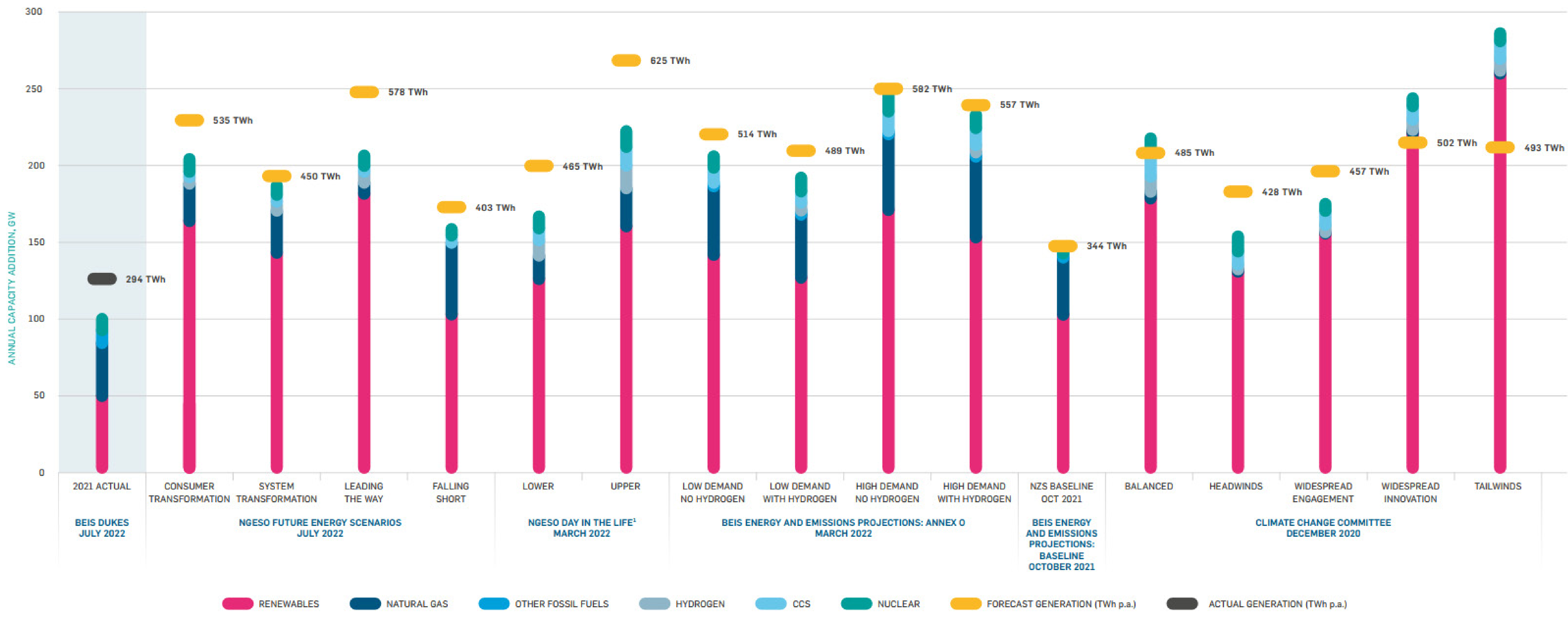
CCC also published a report [Ref 8] showing how it believes UK might achieve a decarbonised electricity system by 2035 but only if there is an immediate step change in delivery. The report stated that government must "publish a comprehensive long-term strategy for the delivery of a decarbonised resilient power system by 2035".

While we agree with this recommendation, in major energy project timescales, 2035 is not long-term. Twelve years is about how long it takes to develop and implement a typical large energy project, and only just long enough for a major large nuclear project. And so, without radical changes across government, **projects that are not under active consideration today will not be delivered by 2035**.

When key strategic goals are set by CCC, theoretical economic modelling of the energy system is used to inform them. However, this does not include risk-based, supply-chain constrained, engineering assessment of the delivery of such a system.

Moreover, nowhere in the network of interdependent energy transitions is there an authoritative engineering-based challenge or risk assessment of the deliverability of the integrated future power system, or an assessment of how well we are delivering against a plan.

Every round of system modelling produces a different set of results and system configurations, a selection of which are shown in Figure 1. Rather than these economics-driven system models, we must now urgently move to definitive delivery plans.



[1]Hydrogen capacity includes low carbon dispatchable energy from other sources.

FIGURE 1: 2035 GENERATING FLEET CONFIGURATIONS FROM VARIOUS MODELS [REF 9].

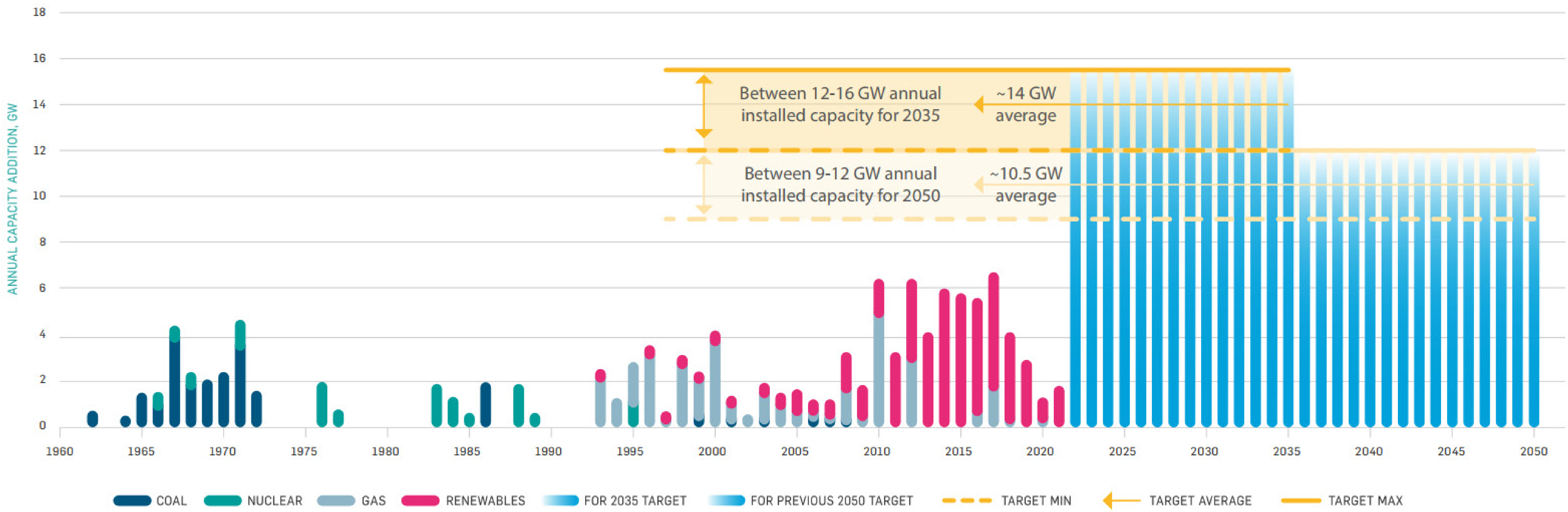


FIGURE 2 PAST AND FUTURE GENERATION CAPACITY BUILD RATES. ANALYSIS AS IN [REF 9].

The build rate dilemma

Figure 2 compares historical build rates achieved and the projected build rate required over the next 12 years and then out to 2050. Over the next 12 years, each year, we need to add more than twice as much power as we have ever built in a single year. To deliver this power to the users we must also massively increase the build rate of grid connection infrastructure.

In 2020 we called for the creation of an Energy System Architect (ESA) [Ref 10] to create a system wide plan for this huge investment programme.

We are pleased to see that the government's foremost advisors are now calling, as their top priority, for the strategic planning that we saw as a key function of the ESA.

It is expected that this function will be assigned to the Future System Operator (FSO) which is currently being established. However, we urge caution in combining daily grid operation and future system planning into a single entity.

In our view one essential role of the Energy System Architect would be to hold the 'authoritative model' of the energy system. The ESA should provide full transparency of its modelling, including the stability of results against reasonable ranges of variation in input parameters and the engineering feasibility of its delivery.

The roadmap to 2035

As we have established, the 2035 goal is extraordinarily challenging, and requires immediate action – but what action must be taken and by whom? In short, system design and delivery planning must now take priority over economic modelling of evolving scenarios. The Department for Energy Security and Net Zero (DESNZ) is responsible for leading the development and implementation of policies that will ensure delivery of the energy transition, and must now move from scenarios to certainty. Investors and industry need a step change in certainty of future energy system configuration.

DESNZ should publish integrated electricity system plans optimised for whole system cost, security of supply and achievement of net zero (the energy trilemma) and bounded by rigorous analysis of feasible rates of delivery. These should be updated annually, coincident with the annual progress report to parliament by CCC.

As we pursue this 2035 target, are we creating an optimal power system for 2050 and beyond?

When DESNZ (or the Energy System Architect (ESA)) prepare their development plan for the power system, we urge them to consider the longer-term impact of measures specifically driven by the 2035 deadline.

In particular, the post 2035 role and lifespan of the current unabated gas fleet, the rate at which hitherto unproven H2 and CCUS can be deployed and the intended increase of nuclear capacity to 24 GW by 2050, must be taken into account and projects started now.

Investments between now and 2035 must be consistent with a policy of 'no regrets' assessment in the context of system configuration to 2050 and beyond.

Firm power beyond 2035?

CCC has frequently referred to 'no regrets' investments, that provide value in both the short and long term, avoiding the risk that assets created to meet short term goals could become redundant 'stranded assets' in the longer term.

The notion that renewable energy is cheaper and faster to set up is one element of a greater issue. The fact is that to secure our future energy system, we need both firm and intermittent power. Although intermittent renewables may offer the cheapest generation, significant future developments will be required in areas such as system management, energy storage and long-distance transmission to enable systems that are highly dependent on intermittent renewable power.

Fortunately, government has recognised the need for firm power and set a goal of 24 GW of nuclear generating capacity, providing 25% of our needs by 2050 [Ref 11]. Providing this firm low carbon power baseload alongside maximum possible renewables should allow a reduction in some of the costs associated with system management, storage and transmission.

We believe that the use of Levelised Cost of Energy (LCOE) when comparing the merits of different generators is not a suitable measure of the cost of power delivered to the customer. In times of low renewable output, there are associated 'integration costs', including switching on standby firm power capacity, utilising energy storage, interconnector imports, and Demand Side Response (DSR) incentivisation. When renewable output exceeds demand or the grid is unable to take their power, then renewables operators are paid constraint payments. All these items add overall cost to the consumer.

Modeling of integration costs is highly complex and often contentious. However, there is general agreement that integration costs rise as the proportion of generation from intermittent renewable increases. This is discussed in Appendix A.

The grid operator, NGESO, has to balance the power generated to match the demand in real time, minute by minute, 365 days per year. The system 'balancing costs' reported by NGESO have risen from £1.2bn in 2019 (3.45£/MWh supplied) to £4.2bn in 2022 (15.38£/MWh supplied) [Ref 12]. **These costs can be expected to rise even further in future as firm power is decommissioned and intermittency becomes more significant**.

Based on these results, the stated UK government ambition for 25% nuclear power in 2050 would appear to be a sensible minimum target. However, with just 12 years to make the 2035 decarbonised electricity system target, it will be challenging to build sufficient new firm low carbon generation to maintain renewable dependency at an optimal level. It may still be necessary to retain unabated gas or possibly retrofit CCUS to ageing gas generation plants to ensure sufficient firm power.

Conclusion – we need a **CLEAR PLAN**

In conclusion, the UK needs a clear power system delivery plan. In the short term this must come from DESNZ, in the longer term from the Future System Operator (FSO) or, preferably, an independent ESA. DESNZ should act as soon as possible to appoint a Chief Engineer for Net Zero to ensure that the delivery plan has a sound engineering basis, and is updated annually to show progress, coincident with CCC's progress report to Parliament.

DESNZ should now identify the pipeline of major projects to be completed before 2035. In the co-ordinated plan, a project list should be drawn up that demonstrates the potential range of generation that is achievable from each major technology: offshore wind, electricity grid transmission, interconnectors, CCUS (carbon capture, carbon transport and carbon sequestration), grid scale energy storage, hydrogen (production, transport, storage and utilisation), gas turbine generation (natural gas with CCS, hydrogen fired), nuclear (large and SMR).

The Powering Up Britain Energy Security Plan [Ref 11] includes a delivery timeline covering many initiatives in the next two years but, given the huge amount of investment needed and the massive workload required, government needs to act fast and define the projects that will deliver the required power mix.

2035 decarbonisation targets are looming, and it is imperative that we move beyond financial modelling to more tangible, engineering-based delivery plans. We also need to change how we talk about comparing different technologies and take a longer-term view of energy security that encompasses the wider system and infrastructure costs that are associated with different forms of generation.

Power balancing remains a costly, high-effort enterprise but to achieve 2035 decarbonisation and secure the energy transition, we need investment in renewable and nuclear energy generation and sophisticated storage and balancing technology, as well as the essential grid infrastructure upgrades.

To summarise, as an energy industry we need a **CLEAR PLAN**:

- **C** **Certainty:** moving from modelling to delivery plans
- **L** **Longer-term view:** ensuring the rush to reach 2035 doesn't undermine the need for optimal system by 2050 and beyond
- **E** **Engineering** needs to be at the heart of planning to ensure deliverability of an integrated system.
- **A** **An independent ESA** to continually develop and plan the decarbonised system.
- **R** **Realism:** major projects that aren't under active consideration today won't be delivered by 2035
- **P** **Pace:** particularly for 'no regrets' asset project decisions
- **L** **LCOE is not the right measure** to consider system costs – understanding of wider energy infrastructure beyond generating assets is required (i.e., storage, networks)
- **A** **An independent ESA** to continually develop and plan the decarbonised system. (Yes, we've said that twice!)
- **N** **Numbers of GW's** and emissions delivered each year by each operating power unit to be defined out to 2050 and reported annually, coinciding with the annual progress report to parliament by CCC.

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Richard is a civil engineer with over 40 years' experience. He has worked in the petrochemical, civil infrastructure and energy sectors in UK and internationally. He was mobilisation manager for the creation of the Nuclear Decommissioning Authority, he championed the mPower small modular reactor in UK, developing a 'fleet deployment' scenario for 10 plants producing 3.6GW, he was Atkins' Project Director for the Techno-Economic Assessment of SMRs conducted for the UK Department of Energy and Climate Change. He has contributed extensively to the Atkins Engineering Net Zero initiative.

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Throughout her career Sarah has championed support for women in Engineering roles and is passionate about the wider diversity agenda. She is passionate about education related to Net Zero.

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Appendix A – Modelling the cost of increasing renewables penetration

The estimation of renewables integration costs is both extremely complex and often disputed. The complexities of whole system modelling are compounded by the need to make multiple assumptions on system flexibility and the complex interaction of market mechanisms. System modelling reports are often opaque with regards to how they estimate integration costs and therefore, there exists a significant risk of bias in results.

There is however a common pattern discernible in results reported by different authors. As the penetration of intermittent renewable generators increases there are four discernible phases described below with very approximate typical penetration ranges:

- Phase 1 from 0 to 20%, integration costs are minimal, low-cost intermittent power displaces higher cost firm power, whole system costs can decrease.
- Phase 2 from 20 to 40%, integration costs increase due to investment in short-term storage, and flexibility.
- Phase 3 from 40 to 75%, integration costs continue to rise as more short-term storage, back-up power, and infrastructure are added.
- Phase 4 – beyond 75% penetration, very sharp rise in integration costs due to large-scale long-term storage.

These phases are illustrated in Figures 3 and 4 below taken from Monterrat et al [Ref 13] Figure 3 shows Integration costs for penetration 0-40%. Figure 4 illustrates, through cost of carbon avoided, the very large cost upswing as penetration exceeds 75%.

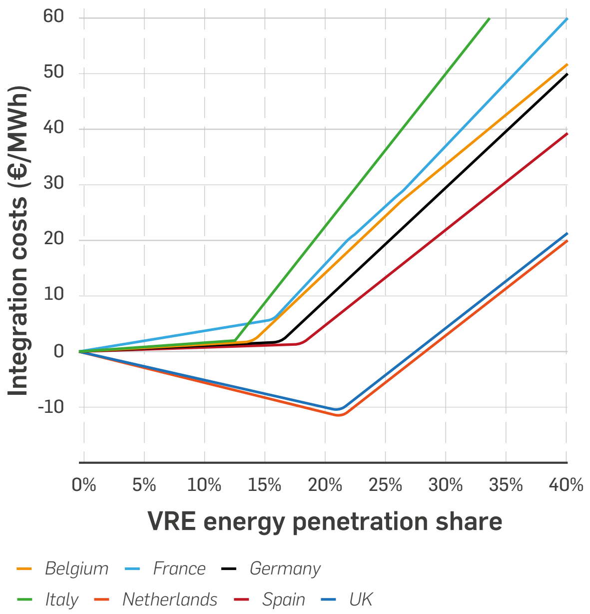

FIGURE 3: INTEGRATION COSTS €/MWHR IN EUROPEAN COUNTRIES (MONTERRAT ET AL [REF 13]. VRE – VARIABLE RENEWABLE ENERGY.

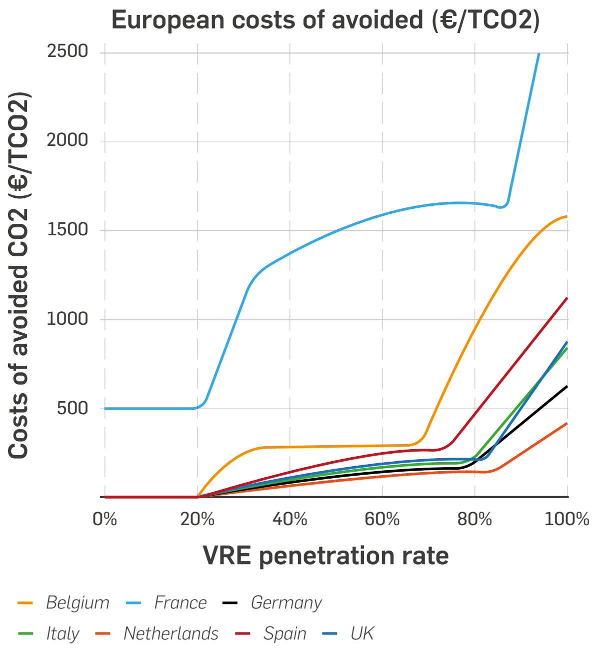

FIGURE 4: COSTS OF AVOIDED CARBON €/TCO2 IN EUROPEAN COUNTRIES (MONTERRAT ET AL [REF 13]. NOTE THAT RESULTS FOR FRANCE APPEAR ANOMALOUS IN THIS MODEL BECAUSE OF THE INITIAL VERY HIGH NUCLEAR CAPACITY. VRE – VARIABLE RENEWABLE ENERGY.

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