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What are the biggest engineering challenges to the UK meeting its 2050 net zero target and what should be done about them? What risks and opportunities do they present for the UK?

In 2019 the UK adopted a net zero carbon emission target for 2050, making it the first major economy to pledge to get to net-zero emissions. Net zero means not adding new emissions to the atmosphere. Emissions will continue but will be balanced by absorbing an equivalent amount from the atmosphere.

As the urgency around climate change intensifies, decisions across Government must accelerate if the UK is to match ambition with action. The Committee on Climate Change's (CCC) Net Zero scenario is theoretically achievable, but the risk of failure is high. The potential generating capacity build rate of up to 9-12 GW per annum is higher than anything achieved in the UK in the previous 50 years. Moreover, integrating multiple technologies complicates this challenge even more.

Carbon Capture and Storage (CCS) is critical to achieving Net Zero. The Net Zero scenario requires 176Mt/year of CCS, which is four times the current global capacity. Net Zero assumes that over 40% of the UK's energy will depend on CCS. However, the UK currently has zero CCS and no firm plan for a demonstration-scale project. To mitigate the risks, pilot projects need to be accelerated, or alternative scenarios for varying reductions in available CCS need to be developed. Failure to implement CCS would impact 28% of the proposed electricity generation, over 80% of the proposed hydrogen production (combined, this represents over 40% of total energy), and all of the non-substitutable industrial emissions.

With UK gas production declining, nuclear offers the only source of firm power with assured security of supply. With considerable risk linked to the Net Zero reliance on CCS, nuclear is a critical yet currently undervalued element within the system. Although Energy Technologies Institute is suggesting that up to 35GW of new nuclear could be required by 2050, it appears that only 3 new stations are factored into Net Zero which total 8.6 GW. The nuclear industry must focus on innovation to reduce design and construction times and risk, as well as greater collaboration with the renewables industry to develop approaches to whole system optimization.

Offshore wind has prospered by being the only power generation technology that has benefited from clear and consistent UK policy and appropriate funding. The anticipated rapid growth of offshore wind is achievable in terms of build rate but there are uncertainties regarding assumed capacity factors and challenges around integration, system balancing and stability. The UK has opportunities to lead in floating wind, but it must increase UK supply content and capture intellectual property.

Hydrogen may serve as both an energy vector and an energy store. It can contribute to industry decarbonisation, domestic heating, and transportation. Hydrogen has great potential flexibility but also some fundamental challenges to be addressed. Net Zero assumes 30% of UK Energy will be delivered through hydrogen, of which 80% is produced by methane reformation (MR). But MR depends on CCS, thereby significantly increasing the risks associated with hydrogen's potential role.

With high renewable penetration, system balancing depends on firm power, interconnectors, demand-side response, and energy storage. Battery technology capable of grid-scale balancing storage is pioneering and was introduced for the first time in the UK in 2021. In addition to the system storage potential of hydrogen, current electrical storage systems' capabilities must be clearly identified.

Reaching Net Zero following the path described by CCC will require a four-fold increase in low-carbon electricity generation, a ten-fold increase in hydrogen production and infrastructure for its use, and the creation of an entirely new industry to capture CO_2, where currently the UK has zero capacity. In addition, there will need to be substantial changes to the supporting infrastructure. A sophisticated smart grid will also be required to integrate, interface, and match supply and demand on a real-time basis. The rollout of electric vehicles will also impact electricity demand. It also might provide an opportunity for energy storage through vehicle-to-grid arrangements supported by smart grid infrastructure. Charging infrastructure will require significant investment and presents challenges in the urban environment, particularly where only on-street parking is available.