Blind man's buff?

The UK Net Zero Strategy

By Tim Ambler, Peter Edwards and Michael Kelly

DISCUSSION PAPER

EXECUTIVE SUMMARY

- The UK's Carbon Net Zero by 2050 target is an excellent aspiration but there is currently no coherent, quantified strategy for its achievement.
- There are several key areas of uncertainty, including:
    - Energy generation requirements and likely shortfalls:
        - On current plans, the UK will have insufficient nuclear generation capacity to meet conservative estimates of expected baseload requirements. Under reasonable assumptions, renewables' contribution to overall energy needs would need to increase by approximately nine times the current amount;
    - The cost to users of moving to Net Zero by 2050:
        - Different estimates of the cost of Net Zero arrive at wildly divergent conclusions whilst often making questionable assumptions;
    - The likely contribution from anticipated new technologies:
        - Some future technologies are given undue attention despite lack of feasibility or likely cost effectiveness, whilst working estimates of 'technological readiness' for advanced modular reactors require greater scrutiny.
- Just as the government set up a panel of scientists (SAGE) to provide advice on an area with a high degree of uncertainty, a similar approach could be taken towards the Net Zero by 2050 goal. If the Government wants to deliver Net Zero by 2050 while maintaining a low-cost and reliable energy supply, they could do so by establishing E:SEAG—the Energy: Science and Engineering Advisory Group.
    - This could bring together top science, engineering, industry and business skills to help identify the best energy strategy for meeting Net Zero 2050 in the most effective manner;
    - It should learn from the failures of SAGE by, for example, increasing external scrutiny and ensuring experts are specifically regarded as such in their relevant fields.

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Carbon Net Zero 2050 is an excellent aspiration but has generated no coherent quantified strategy showing how the UK's energy needs would then be met, nor the costs to the country and its energy users. For example, the 2020 Energy White Paper[1] simply does not add up. The 368 page Net Zero Strategy[2] published in October has similar blemishes. This paper specifies the main areas of uncertainty, and then proposes the solution, i.e. how the UK government should address the issues realistically.

Net Zero Carbon requires almost all energy to be provided by electricity, which would require an increase of around eight times the UK's current capacity. The variability of renewables (mostly wind and solar) for electricity is why we will need four sources of energy in a carbon zero future; renewables, "counter-renewables" such as storage (batteries and hydrogen) and generators that can be quickly turned on and off, "baseload" (primarily nuclear) which needs to run continuously, and imports.

The UK's 2050 energy needs may be lower than today due to greater economies, e.g. home heating and insulation, but also higher with population growth and greater travel. To be conservative, we assume energy demand remains at 2,210 TWh and the UK should aim to produce all its electricity needs, imports being offset by exports.

Also unknown is the optimal split between renewables, baseload and counter-renewables. Global warming may increase the availability of renewables when it is most needed, i.e. in winter. On the other hand, on current plans, the UK will have nowhere near enough nuclear generation capacity. Given the variability of renewables, the nuclear baseload needs to be about 40%, i.e. 800 TWh.

Existing nuclear plants are all due to be decommissioned by 2035 and the two on the drawing board would only contribute about 6% of such a baseload. Ten of the new generation IV Advanced Modular Reactors (AMRs) are the equivalent of Hinkley Point C, producing about 26 TWh and costing £8bn, rather than £23bn, and are by far the most economic generators but we would require 323 AMRs, at a cost of £254bn, presumably from multiple suppliers for security.

Renewables currently contribute 128 TWh of electricity.[3] In order to generate the necessary 60% of energy needs implied by baseload at 40%, renewable generation would have to increase by about nine times.

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1 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/945899/201216_BEIS_EWP_Command_Paper_Accessible.pdf

2 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1026655/net-zero-strategy.pdf

3 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/904545/DUKES_2020_Press_Notice_.pdf#:~:text=Electricity%20generated%20from%20renewable%20sources%20in%20the%20UK,nuclear%20output%2C%20low%20carbon%20electricity%E2%80%99s%20share%20of%20generation

Unfortunately, the Energy White Paper raises more uncertainties than it answers. They can be grouped into three categories: the amount of electricity we will need to generate and the likely shortfall, the costs to users and the UK as a whole and the likely contribution from anticipated new technologies.

When the government recognised, at the start of the pandemic, that it was entering terra incognita, it very sensibly set up a panel of scientists, SAGE, to provide advice. We propose a similar approach to identifying the best, or least bad, UK energy strategy for the Zero Carbon world of the future, namely E:SEAG – the scientific advisory group for energy. The challenges are indeed colossal. One way or another, the Department for Business, Energy & Industrial Strategy (BEIS) needs to urgently bring our top science, engineering, industry and business skills together to focus on meeting them.

THE 2020 ENERGY WHITE PAPER

The December 2020 paper takes net zero carbon 2050 as given and minimising the cost to consumers as the primary target within that: "Our vision is of a system with consumers at its heart, able to make money or save on bills through using the new technologies net zero will require." (p.7) Speaking in the Chamber, Alok Sharma took a different line: "Once again, a Conservative colleague talks about jobs, which is what the Energy White Paper and the 10-point plan are all about."[4] No doubt the Treasury's rather reluctant approach to net zero carbon is minimising the cost to the Exchequer. The confused direction is perhaps best described as blind man's buff.

The White Paper has no Executive Summary and brings together no conclusions. The introduction simply makes three vague assertions on creating an energy system that "transforms energy, building a cleaner, greener future for our country, our people and our planet; supports a green recovery, growing our economy, thousands of green jobs and…. export opportunities; and creates a fair deal for consumers." (p.4) It makes various claims for the reduction in UK carbon emissions to date without mentioning that they are largely due to exporting carbon - emitting manufacturing. Most absurdly, Figure 1.4 suggests that the UK's total energy needs will decline by one third by 2050 – some 1750 Twh declining to 600 Twh. (p.9)

The modelling then indicates that overall demand for electricity could double by 2050 due to the electrification of transport and its increased use for heating. "As a result, electricity could provide more than half of final energy demand in 2050, up from 17 per cent in 2019." (p.41) The next paragraph after Figure 3.4 reads "This would require a four-fold increase in clean electricity generation with the decarbonisation of electricity increasingly underpinning the delivery of our net zero target." Down, double, quadruple: we admit to being lost by this.

4 https://hansard.parliament.uk/Commons/2020-12-15/debates/82183F03-94AD-42D0-BCB4-1FE1464C086B/BusinessEnergyAndIndustrialStrategy

In presenting the White Paper to the House, Alok Sharma said "We will also keep bills affordable by making the energy retail market truly competitive. This will include offering people a simple method of switching to a cheaper energy tariff and testing automatically switching consumers to fairer deals to tackle 'loyalty penalties'"[5]. But as the Autumn 2021 gas price crisis has vividly demonstrated, switching to a lower price retailer likely means switching to one about to go out of business. Marginal savings are available but if the base wholesale costs go up, they go up for everyone. The total costs are massive.[6]

THE 2021 NET ZERO STRATEGY PAPER

Regrettably, the new paper exhibits many of the same unfortunate characteristics: bold words but questionable numbers. Probably the most egregious is "By 2035 the UK will be powered entirely by clean electricity". (p.19) For that to happen renewables and nuclear would have to increase electricity generation by about nine times by 2035. Given that all existing nuclear plants will be decommissioned by then and the Treasury has been blocking new ones for over 20 years, that is manifestly impossible.

And what the Strategy paper says is inconsistent with what governments actually do: the UK, along with other governments, continue to plan for and support levels of fossil fuel production that are vastly in excess of what we can safely burn.[7] Fossil fuel production is set to surge over the next decade.[8]

The Strategy's claims for hydrogen are similarly unreal as we show below. Page 319 of the new Strategy paper, for example, hypothesises that electricity generation needs will double by 2050 whereas they will actually have to grow by eight times (see below). Furthermore, hydrogen would grow from zero to between 240 and 500 TWh, using up most of the available electricity in the process. But if one is looking for scientific precision in forecasting the split between blue (methane + carbon capture and storage – "CCS") and green (water electrolysis) hydrogen production, look no further. They will each be between zero and 75% of the total: a significant range of possibilities, to put it mildly. "Homes converted to 100% hydrogen" is predicted at between zero and 14% (p.319). Getting to zero looks to be a pretty good forecast in this case.

5 https://hansard.parliament.uk/Commons/2020-12-14/debates/20121429000010/EnergyWhitePaper

6 https://www.thetimes.co.uk/article/households-face-gas-bill-for-billions-2g52v97rw

7 https://productiongap.org/2021report/

8 https://www.bbc.co.uk/news/science-environment-58971131

WHAT DON'T WE KNOW ABOUT THE UK'S 2050 GREEN ELECTRICITY GENERATING CAPACITY?

Recent UK demand for energy, expressed in electricity equivalent metrics, was about 190 Million tonnes of oil equivalent (Mtoe) (p.5),[9] 32% more than the UK produced (129.3 Mtoe) – the difference being imports. One could argue that it does not matter how much zero carbon energy the UK produces in 2050, if it is prepared to import any shortfall. This would be a dangerous assumption since we do not know if that would be feasible in political or economic terms. In 2019, the UK imported 35% of its energy needs, with Norway being the source of 57% of the imports.[10] The UK's suppliers would be likely to take financial advantage of the situation. This paper assumes the UK should aim to produce the electricity it needs.

190 Mtoe of energy is the equivalent of 2,210 TWh in electricity terms. UK electricity consumption has declined steadily from 357 TWh in 2005 to 288 TWh in 2020.[11] In other words, currently electricity only supplies 13% of our energy needs; if our energy needs were static through 2050, a zero carbon, all-electricity energy UK would require electricity supply and demand to multiply about eight times This is in marked contrast to Figure 3.4 of the White Paper which suggests, with no supporting evidence, that electricity generation would merely have to double by 2050. It uses the 2005 figure as the current one and confuses demand with generation.

UK 2050 energy needs might be lower than now due to greater efficiencies, e.g. home heating and insulation, but also higher with population growth and greater travel. To be conservative, we assume energy demand remains at 2,210 TWh p.a. We also assume (but nobody knows) that some manufacturers will be able to use gas and CCS for their energy needs but it will not be economic to maintain domestic gas networks. Domestic use of liquefied natural gas (LNG) will not be significant. As discussed below, hydrogen requires electricity for its production and is therefore not a primary energy source. Taking that into account, we are assuming UK electricity needs will therefore be about 2K TWh p.a.

Also unknown is the optimal split between renewables, baseload (mainly nuclear) and counter-renewables (Grid balancing load-following plus storage). One option would be to set baseload such that average daily renewables + baseload = average daily demand. As both demand and renewables increase in winter vs. summer, we assume the baseload requirement would be approximately constant. When renewables exceed the average, they would be used to produce hydrogen; when below, counter-renewables (gas and biomass) would be switched on, using imports/ exports to balance the Grid. Global warming will probably increase the availability

9 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/877047/Press_Notice_March_2020.pdf#:~:text=Total%20electricity%20generated%20in%20 2019%20was%20323.7%20TWh%2C,of%20the%20generation%20mix%20at%2043.4%20per%20 cent.

10 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/904545/DUKES_2020_Press_Notice_.pdf

11 https://www.statista.com/statistics/322874/electricity-consumption-from-all-electricity-suppliers-in-the-united-kingdom/

of renewables when it is most needed, i.e. in winter, but the UK will have nowhere near enough nuclear capacity.

Suppose baseload is 40%, i.e. 800 TWh p.a. Hinkley Point C and Sizewell C are similar projects, both led by EDF, and each is expected to produce around 26 TWh p.a.[12,13] A final decision on Sizewell C, however, is not due before April 2022.[14] More than 21 years will have passed from the government first announcing it to the station becoming operational on current plans. The only other plant, Wylfa, Anglesey, is no more a than a twinkle in BEIS's eye[15], if not the Treasury's. According to the White Paper (p.48), it should receive approval by the end of this Parliament, meaning that it will not be in operation much before 2050, though Westinghouse claims that their AP1000 plant can be ready 10 years sooner.[16] This is in stark contrast to the situation in Canada and the USA where several Generation IV nuclear power plants will be operational by 2030.

All other nuclear generating plants are due to be decommissioned by 2035.[17] Excluding the possible Wylfa plant, the total baseload available from nuclear, on current BEIS plans, will be only about 6% of a 40% baseload, i.e. 2.4% of the total electricity required. Renewables currently contribute 128 TWh of electricity.[18] In order to generate the 60% of energy needs implied by baseload at 40%, renewable generation would have to grow by nine times which seems challenging.

That baseload could be met by the acquisition of 323 Advanced Modular Reactors (see below) at a cost of £0.8bn each, i.e. £254bn in total. For security, they should be bought from more than one supplier and BEIS would establish relative value for money as deliveries were made. There is no need for the elaborate assessment of these reactors to find the very best value, as BEIS is doing now.

12 https://www.power-technology.com/projects/hinkley-point-c-nuclear-power-station/#:~:text=The%20plant%20is%20predicted%20to%20produce%20approximately%2026TWh,unit%20is%20expected%20to%20be%20operational%20in%202023.

13 https://www.bing.com/search?q=Sizewell+C+electricity+output+in+annual+TWh&qs=n&form=QBRE&msbsrank=0_0__0&sp=-1&pq=sizewell+c+electricity+output+in+annual+twh&sc=0-43&sk=&cvid=ED9DE365FF244A96B80DCACADE1FD687

14 https://www.suffolklive.com/news/suffolk-news/sizewell-c-update-edf-energy-6066543

15 https://www.sizewellcsupplychain.co.uk/tag/operational/#:~:text=Sizewell%20C%20nuclear%20power%20station%20could%20become%20operational,continuing%20controversy%20over%20the%20price%20of%20nuclear%20power.

16 https://www.nucnet.org/news/government-in-talks-over-plans-to-revive-abandoned-wylfa-nuclear-project-9-5-2021

17 https://www.smallcapnews.co.uk/zero-carbon-by-2035-a-very-difficult-target-for-the-uk/

18 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/904545/DUKES_2020_Press_Notice_.pdf#:~:text=Electricity%20generated%20from%20renewable%20sources%20in%20the%20UK,nuclear%20output%2C%20low%20carbon%20electricity%E2%80%99s%20share%20of%20generation

WHAT DON'T WE KNOW ABOUT LIKELY 2050 ENERGY COSTS?

If the government does not know the answers to generating the necessary energy in 2050, it is in a complete fog about the financing thereof. Optimists look forward to "Energy in 2050: Clean, free, and for all"[19] but the Treasury thinks we may well have to pay far more, both individually and collectively as a country: "Britons face higher taxes to pay for climate pledges."[20] In its October 2021 review,[21] it hopped from one foot to the other: "The future price of electricity is uncertain. Projecting future electricity prices is challenging as there are several key uncertainties that will influence them. This makes it difficult to predict how prices and bills may change over the coming decades."

It then lists some of the uncertainties: technological, the role of hydrogen, Small Modular Reactors, biomass with CCS, decisions made by the government and regulators, electricity generation mix – between renewables, nuclear and CCS – market forces and the effectiveness with which green generation is integrated through new networks and complementary flexibility, which will have cost implications for the energy system, future retail market and consumer tariffs and prices of all kinds, not to mention energy demand uncertainty.

According to the UK Committee on Climate Change (CCC), "it will cost 1 to 2 percent of GDP each year (approximately £50 billion per year) to achieve net-zero by 2050. However, other sources speculate that this cost could be considerably higher when considering the impact on different sectors of the economy."[22] Philip Hammond, former Chancellor, claimed it would cost £1trn.[23] The GWPF published a paper by Andrew Montford putting the cost at "£3trn and counting", i.e. the equivalent of the entire UK GDP for a year and a half.[24] They put the per person cost at £8,000.

But sweeping all that aside, "BEIS analysis of the Sixth Carbon Budget scenarios suggests that average domestic unit prices for electricity could look broadly stable over the next thirty years. This is because large capital investments will be spread over a larger user base, as power consumption replaces fossil fuel."

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19 https://www.eco-business.com/opinion/energy-in-2050-clean-free-and-for-all/#:~:text=By%202050%2C%20solar%20energy%20will%20be%20cheaper%2C%20batteries,36%20houses%20in%20Weepatando%20village%2C%20Sumba%20Island%2C%20Indonesia.

20 https://www.thetimes.co.uk/article/britons-face-higher-taxes-to-pay-for-eco-pledges-3d8m9nm3q?utm_source=newsletter&utm_campaign=newsletter_101&utm_medium=email&utm_content=101_15817817&CMP=TNLEmail_7172239_15817817_101

21 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1026725/NZR_-_Final_Report_-_Published_version.pdf

22 https://energy-ts.com/the-true-cost-of-going-zero-carbon-by-2050/#:~:text=According%20to%20the%20UK%20Committee%20on%20Climate%20Change,the%20impact%20on%20different%20sectors%20of%20the%20economy.

23 https://www.theguardian.com/environment/2019/jun/06/cutting-uk-emissions-net-zero-cost-1tn-philip-hammond

24 https://www.thegwpf.org/content/uploads/2020/02/ThreeTrillion-1.pdf

We do know that financing the 2050 energy market will be characterised by high capital costs—be they for renewables, nuclear, CCS, or hydrogen production—coupled with low running costs. That is the Treasury's fundamental difficulty: it hates picking up the tab for capital expenditure. That is why it has blocked new nuclear plants for over 20 years, leaving us in dire straits. The word "nuclear" appears only twice in its 125 page review.

Hydrogen

Hydrogen can be produced in two ways: the more traditional is by steam reforming of methane ("SMR"), i.e. from natural gas. This is known as "blue" hydrogen and has the problem that the CO2 has to be removed and stored (CCS). Putting more CO2 into the atmosphere is exactly what the Net Zero strategy is trying to avoid but, for obvious reasons, the fossil fuel industry likes it and BEIS is going along with that with the announcement of £1bn for two CCS plants. This processing takes electricity and costs money. If the electricity is, in effect, free because it all comes from surplus renewables generation, then most of the cost lies in CCS. If BEIS is aware of the costs of blue hydrogen as a power source versus electricity, it has not shared the figures with the rest of us. It is also clear that hydrogen is not a solution to heating homes.[25]

The more modern production method is electrolysis, i.e. "green" hydrogen generated by passing an electric current through water and splitting it into its constituent parts, H2 and O. A proposed alternative approach is the large–scale manufacture of hydrogen from water using thermochemical cycles, e.g. the closed Hybrid Sulphur Cycle.[26]

Comparative costing requires one to know whether the (free) electricity from surplus renewables will be enough or whether the Grid will have to be paid for it. All we can say for sure is that some hydrogen will be cheap but the rest may not be. Hydrogen is expected to become economic when it drops to $2/kg from its current $6/kg.[27]

Battery storage

In contrast to many viewpoints, such as those of Centrica[28] and Energy Storage[29], we believe that one can discount battery storage as a means of large-scale renewable energy storage. Thus, the aspiration of 60GW of offshore wind generated electricity must be placed only in the context of the required battery storage to include those Dunkelflaute (dark doldrums days) when the wind does not blow and the sun does not shine. Ten successive Dunkelflaute days – surely an entirely reason-

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25 https://www.wired.co.uk/article/hydrogen-uk-heating#intcid=_wired-uk-verso-hp-trending_3e04f3b1-4154-4991-ac14-45b522f22b47_popular4-1

26 https://www.sciencedirect.com/topics/engineering/hybrid-sulfur-cycle

27 https://www.power-technology.com/features/will-china-do-for-hydrogen-what-it-did-for-solar-power/

28 https://www.centricabusinesssolutions.com/blogpost/battery-energy-storage-systems-accelerate-net-zero-transition

29 https://www.energy-storage.news/why-cop26-is-the-crucial-moment-to-bring-battery-storage-into-net-zero-talks/

able safety net – requires a storage capacity of 14TWh at a cost of £4.5trn. This is more than four times the UK public sector spending for 2020/21: based on the (published) construction and other costs of the 640MWh storage system planned for the Thames Estuary.

NEW TECHNOLOGIES

Some new technologies are critical to realising Net Zero 2050. How to exploit them most feasibly, efficiently and economically should be explored at greater pace than BEIS is currently showing if we are to cover the shortfall predicted above. There are also non-starters which should be given no further attention.

Nuclear fusion

Nuclear fusion, for example, was conceptualised in the 1950s but still "seems to be perpetually coming over the horizon."[30] The UK government is considering five sites for its first plant[31] and MIT claim they will have a pilot plant operational in this decade but it seems unlikely that full commercial fusion generation will make a significant contribution by 2050. For a start we have little idea of the likely costs beyond the $65bn currently predicted for the European project, ITER, with no certain outcome.[32]

Fracking

Although fracking may well be revived if we need the gas, it has no bearing on the Net Zero by 2050 challenge as the gas is much the same as that from any other methane-based fossil material and would require CCS if it were used. The only possibility that would be attractive would be "hydrogen stripping" from methane with the only co-product being solid carbon which is easier to store than CO2.

Carbon Capture and Storage

There are two ways to stop CO2 entering the atmosphere whilst continuing to use fossil fuels: capture CO2 from fossil fuels as they burn or capture the CO2 from the atmosphere. Unfortunately, we seem to have forgotten that solid carbon is used for making steel, carbon fibre, sound systems and some people appreciate diamonds. Burying carbon – either as CO2 or solid carbon - may be necessary but it would surely be better to make use of it.[33] The Net Zero Strategy paper announced a £1bn investment for two major sites for carbon capture from fossil fuels with a third in reserve.[34] BEIS commissioned analysis suggests that the global market could be worth £260 billion by 2050.[35] BEIS is commissioning research into both fossil fuel and atmospheric CCS and the marketing of solid carbon.

30 https://www.power-technology.com/features/future-of-nuclear-fusion/

31 https://www.gov.uk/government/news/five-sites-shortlisted-for-uk-fusion-energy-plant

32 https://physicstoday.scitation.org/do/10.1063/PT.6.2.20180416a/full/

33 https://www.ox.ac.uk/news/2019-11-07-capturing-carbon-dioxide-make-useful-products-could-become-big-business

34 https://on.ft.com/3ITU1hg

35 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/984308/ccus-supply-chains-roadmap.pdf

Advanced Modular Reactors

BEIS published a review of AMRs and concluded: "This assessment points to High Temperature Gas Reactors (HTGRs) as the preferred AMR for the UK Government's AMR R&D demonstration programme. HTGRs are assessed to have the greatest potential to meet the UK's primary objectives of making a significant contribution to Net Zero by 2050 via multiple energy vectors. Further development and demonstration of HTGRs is needed to establish the viability to deliver on heat and hydrogen energy vectors and enable demonstration in the early 2030s."[36] This conclusion was based on HTGRs being pretty much like the Advanced Gas Reactors ("AGRs") BEIS is familiar with and their consultants' view of "Technology Readiness" (TR) in particular:

- HTGR / VHTR: High / Very High Temperature Gas Reactors TR: 7 / 5
- SFR: Sodium-Cooled Fast Reactors TR: 2
- SCWR: Supercritical Water-Cooled Reactors TR: 2
- GFR: Gas-cooled Fast Reactors TR: 4
- LFR: Lead-cooled Fast Reactors TR: 4
- MSR: Molten Salt Reactors TR: 4 Thermal, 3 Fast

The report envisaged a wider role for nuclear plants than purely electricity generation: "A key function of the chosen technology must be its ability to contribute beyond electricity through other energy vectors of heat and hydrogen production, and other functions such as the generation of synthetic fuels." (p.52) That helped the score for HTGR.

We wonder how objective this assessment is. For example, MSR developments deserve a higher TR than 4 or 3. Moltex aims to have a plant operational in New Brunswick in the early 2030s. Terrestrial Energy intends to be generating electricity for Ontario Power by the late 2020s.[37] With MSRs being introduced in at least three other major countries, the UK appears to be behind the game. The consultants claimed that licensing MSR would be "extremely challenging" whereas it would, of course, be very easy for HTGR. (p.51) Given the extent of competition in MSR supply, this seems odd.

The report makes no mention of the relative contribution each technology could make to meeting the nuclear deficit described above nor comparative capital or running costs. From other sources such as TerraPower[38], we estimate that a typical AMR has a capacity of 320MWe. Allowing for 10% downtime for maintenance and refuelling, 10 AMRs are the equivalent of Hinkley Point C, producing about 26TWh and would cost £8bn, not £23bn.

On 29th July, BEIS invited "views from industry and the public on the government's preference to explore the potential of HTGRs for its AMR demonstration

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36 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1006752/niro-217-r-01-issue-1-technical-assessment-of-amrs.pdf

37 https://terrestrialenergy.co.uk/

38 https://www.cnbc.com/2021/04/08/bill-gates-terrapower-is-building-next-generation-nuclear-power.html project which is being backed with £170m for delivery in the early 2030s."[39] Views had to be in by 9th September but have yet to be published.[40]

At the same time, we read "Rolls-Royce is leading a consortium to build small modular reactors (SMRs) and install them in former nuclear sites in Cumbria or in Wales. Ultimately, the company thinks it will build between 10 and 15 of the stations in the UK. They are about 1.5 acres in size - sitting in a 10-acre space. That is a 16th of the size of a major power station such as Hinkley Point. SMRs are so small that theoretically every town could have its own reactor - but using existing sites avoids the significant problem of how to secure them against terrorist attacks."[41] The Rolls Royce plants are Pressurised Water Reactors ("PWRs") which were designed for nuclear submarines and are not even mentioned in the BEIS list above. AMRs are Generation IV and as PWRs are Generation II, they are widely considered out of date. It would appear that BEIS has been strongly influenced by traditional British factors.

Nuclear cogeneration

Nuclear cogeneration allows the reactors to be used continuously but when their electricity is not needed due to high renewables, their heat can be drawn off instead and used locally, e.g. for domestic heating. This implies SMRs located in high population areas which seems likely to generate serious regulation, social and thus planning problems.[42] Furthermore, given the high capital cost of creating hot water networks for occasional usage, cogeneration can surely be discounted for 2050.

GROUPTHINK AND SAGE REVISITED

Asking the government's scientific advisory group for emergencies (SAGE) to make recommendations concerning the COVID pandemic was basically a good idea but two faults developed in practice:

1. Their methodologies and findings were excessively shrouded in secrecy, allegedly to allow the work to be published in journals. The absence of rigorous peer review meant that their work and advice was of variable quality. The review by two Select Committees included: "the Government and SAGE should also facilitate strong external and structured challenge to scientific advice, including from experts in countries around the world, and a wider range of disciplines." (para. 159)[43] To facilitate that, advice minutes and papers should be published within a

39 https://www.theengineer.co.uk/government-htgrs-advanced-modular-reactor-amr/

40 https://www.gov.uk/government/consultations/potential-of-high-temperature-gas-reactors-to-support-the-amr-rd-demonstration-programme-call-for-evidence

41 https://www.bbc.co.uk/news/business-51233444

42 https://royalsociety.org/-/media/policy/projects/nuclear-cogeneration/2020-10-7-nuclear-cogeneration-policy-briefing.pdf

43 https://committees.parliament.uk/publications/7497/documents/78688/default/

day or two. Screening methods and findings from peer review inevitably leads to "groupthink" where intelligent people tend to look inward and share opinions rather than challenge each other. Obviously we will never know the extent to which this influenced SAGE in the pandemic but one has to suspect it did.

2. All scientists' opinions seem to have been respected equally, whereas, in reality, a scientist is only an expert in his or her own field. Outside that specialism a scientist is, in reality, an amateur like the rest of us. Putting on a white coat does not make one a scientist, still less an expert. Advice should only be sought from experts in relevant fields and strongly tested against opposing views.

Taking these criticisms on board, we propose that quite a wide list of UK and overseas top energy scientists and engineers should be drawn up to form a high level energy advisory group Energy: Science and Engineering Advisory Group (E:SEAG) from which panels which are highly-knowledgeable about the specific issue would be drawn.

Their conclusions, unanimous or not, would be immediately published for peer review. The panels should obviously advise on the matters submitted to them but also proactively advise on matters that should have been submitted to them but, for whatever reasons, were not.

It is possible that we have eliminated some of the new technologies above too quickly. The panels would be invited to prioritise the new technologies, and possibly others, differently. The key tests would remain: feasibility at scale, safety and cost to users (as well as the UK as a whole) and of course their utility in achieving the stated goal of Net Zero.

This paper is far from the first to draw attention to the enormity of the Net Zero challenge and the inadequacy of government plans and actions to meet it. The Spectator's 23rd October editorial claimed the numbers did not add up.[44] Professor Michael Kelly has been writing and lecturing on the topic since 2008, e.g. "net zero is a goal without a plan."[45]

Sir David King's Climate Change Advisory Group says 2050 is too late and we must meet a global net zero by 2030[46] but they are missing the point. Of course, we must decarbonise as fast as possible, but we need scientists and engineers to tell us what is possible in the real world and when.

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44 https://www.spectator.co.uk/article/the-governments-net-zero-strategy-doesnt-add-up

45 https://capx.co/until-we-get-a-proper-roadmap-net-zero-is-a-goal-without-a-plan/

46 https://www.ccag.earth/newsroom/net-zero-by-2050-is-too-little-too-late-world-leading-scientists-urge-global-leaders-to-focus-on-net-negative-strategies

With China under pressure to halt coal-fired electricity generation, international energy watchers should not have been surprised to see China's natural gas imports rising by 25%[47] as renewables and nuclear were not going to take up the slack immediately. But seismic shifts in fundamentals are hard to appreciate as they happen.[48]

The worrying thing is that this is not just a short-term issue but applies also to the run up to Net Zero 2050. Exaggerated claims have been made for renewables, nuclear and hydrogen which are not supported by the realities or arithmetic. The Prime Minister's 7th October promise that power generation would be decarbonised by 2035 is a claim beyond wild.[49] The government urgently needs a stabiliser in the shape of calm, careful, peer-reviewed science and engineering advice, be it in the form of E:SEAG or some equivalent network.

This paper has highlighted both the inherent concerns with the current path to Net Zero by 2050 and the areas where ministers are getting things wrong. Most importantly, it proposes a way that science and engineering skills should be used to find the best path to decarbonisation.

47 https://rbac.com/a-look-at-chinas-natural-gas-imports-in-the-first-half-of-2021/

48 https://www.power-technology.com/news/industry-news/uk-gas-crisis-timeline-wholesale-price/

49 https://www.gov.uk/government/news/plans-unveiled-to-decarbonise-uk-power-system-by-2035