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N E T Z E R O

W I T H O U T

N U C L E A R

THE CASE AGAINST NUCLEAR POWER

Jonathon Porritt

April 2021

Net Zero Without Nuclear is a personally-authored report, and the views expressed within it are the view of the author alone, and not those of Forum for the Future or any other organisation with which the organisation is associated.

NET ZERO WITHOUT NUCLEAR

		Page
A	**KEEPING AN OPEN MIND**	**1**
B	**THE CASE AGAINST NUCLEAR POWER**	**3**
	1. Cost	
	2. Build rate	
	3. Waste	
	4. Decommissioning	
	5. Proliferation	
	6. Safety	
	7. Radiation	
	8. Security/cybersecurity	
	8.1 Physical security	
	8.2 Cybersecurity	
C	**'YES, BUT WE STILL NEED IT!'**	**11**
	1. 'Yes, but it's impossible for the UK to achieve Net Zero without new nuclear power'	
	1.1 Efficiency	
	1.2 Renewables	
	1.3 Storage	
	2. 'Yes, but only nuclear can provide the low-carbon baseload on which the grid depends'	
	2.1 Baseload: time to move on	
	2.2 Nuclear and renewables just don't mix	
D	**WHAT'S MORE**	**18**
	1. The impacts of climate change on nuclear power	
	2. A just transition?	
	2.1 More expensive electricity	
	2.2 Fewer jobs	
	2.3 Waste: an intergenerational injustice	
	3. Nuclear power/nuclear weapons	
E	**'BUT WON'T NEW TECHNOLOGY SORT ALL THIS?'**	**24**
	1. Small Modular Reactors	
	2. Fusion	
	3. Green hydrogen	
F	**TELL THE TRUTH**	**27**
	1. Beware the 'repentant environmentalists'	
	2. Still keeping an open mind	
APPENDIX: Local groups/National organisations		**30**
REFERENCES		**31**

NET ZERO WITHOUT NUCLEAR

A: KEEPING AN OPEN MIND

I've been 'anti-nuclear' since 1974 – ever since I joined the Green Party. My basic position hasn't changed much during that time. Not because I decided back then that nuclear power was an inherently 'wicked' technology that must be avoided at all costs. I can genuinely claim that I've been waiting more than 45 years for someone to prove me wrong about nuclear power, to falsify my working hypothesis that it's simply 'the wrong technology at the wrong time' for sorting out all the challenges that we face.

As Director of Friends of the Earth back in 1986, I invited James Lovelock to deliver our set-piece annual event, the John Preedy Memorial Lecture. Our Local Groups were instantly up in arms at the prospect of providing a platform for such an outspoken nuclear enthusiast. Supported by our Board, we weathered the storm, on the grounds that genuinely open minds should never be afraid of hearing diametrically opposed voices.

Which is the same reason why Friends of the Earth did <u>not</u> oppose the use of public money to fund research into different nuclear technologies. Yes, we were uncompromisingly opposed to the whole nuclear establishment at that time (Windscale – now Sellafield – Sizewell B, nuclear waste policies and so on), but we also said that if this 'misbegotten child of the nuclear weapons establishment' could demonstrate a genuinely 'fit for purpose' strategy, on what grounds would we then oppose it? This positioning was confirmed by FoE in 2014: 'We do not oppose research into potentially safer forms of nuclear power, but our current assessment is that we are unlikely to need them in the future.'

I hold to that view today. I'm still relatively relaxed about the government of the day deploying taxpayers' money to find answers to the currently overwhelming barriers the nuclear industry still faces – more than 50 years on from the time when the nation embraced nuclear power as a potential source of 'clean energy' that would, at some point in the future, be 'too cheap to meter'. That may well have been a reasonable aspiration in those days, but the industry's record speaks to an endless litany of disappointments and failures.

So I'm not anti-nuclear because I've had a closed mind since 1974. I'm anti-nuclear because my mind is still hungrily open, constantly evaluating the 'case for nuclear power' when weighed in the scales with 'the case against nuclear power'. If and when 'the facts change' in the future (nobody can re-write the factual history of this industry or ignore the continuing liabilities of that history), people should legitimately expect me to change my mind accordingly.

As Chair of the Sustainable Development Commission, this open-mindedness was severely tested in January 2008, when Prime Minister Tony Blair decided that 'the evidence in support of new nuclear power stations is compelling', having bombastically announced in May 2006 that nuclear power was 'back with a vengeance'. I shall return to that critical turning point later.

Five years later, at their Annual Conference in 2013, the Liberal Democrats reversed their historical opposition to nuclear power to fall in line with their Coalition partners in the Conservative Party. Ed Davey, Leader of the Lib Dems today, was Energy Secretary of State at that time, and assiduous in peddling a transparently dishonest fudge by asserting that their support was conditional on there being 'no public subsidy' – knowing full well that no nuclear power station, anywhere in the world, has ever been built without some form of public subsidy.

All three major UK parties are still pro-nuclear today. Which leaves me more than a little baffled. As I hope to demonstrate in this paper, the case against nuclear power is stronger now than it's ever been before; over the last 15 years, many of 'the facts' regarding nuclear power really have changed, further disadvantaging nuclear power when compared with other options. At the same time pro-nuclear advocacy in the public domain, and targeted lobbying within government circles, has significantly ramped up. And is undeniably having some effect, as we'll see.

Even more baffling, there would appear to be a growing number of environmentalists ready to cut the nuclear industry some slack. The principal reason for this is, of course, their wholly justified fears about accelerating climate change and about the yawning gap between what the scientists are telling us about the Climate Emergency and the still largely inadequate political response to that Emergency. As we'll see, advocates for nuclear power are vociferously intent on demonstrating that it's now an essential tool in the toolkit for getting that gap narrowed – and for getting us to that distant prospect of 'a Net Zero carbon economy'.

Nothing could be further from the truth.

The overwhelming impression I've taken away from doing the research for this Report is that this is an industry dominated by its rear-view mirror.

For all the turbocharged rhetoric and boosterish projections, there's little on offer that's genuinely new and innovative. EDF's reactor design for Hinkley Point and Sizewell C, the EPR, was first approved more than 20 years ago, and has only been upgraded since then to take account either of excessive cost issues or new safety features required by regulators after the Fukushima disaster in 2011. For all the new-found excitement about Small Modular Reactors (SMRs – see page 24), there is as yet no new design here in the UK for regulators to approve, even after 65 years of deploying small reactors in nuclear submarines, however different a design challenge that may be. Even fusion is back in the mix (see page 25), recycling the same promises and unsubstantiated claims that were first minted back in the 1970s.

In other words, it's a massive re-tread operation, an industry repurposed to align yesterday's over-hyped promises and broken business models with a policy context now dominated by concerns about accelerating climate change and the need to get to a Net Zero economy by 2050. And given the industry's customary reliance on an army of lobbyists and PR specialists, they're doing as good a job as might be expected in terms of prettifying what is in effect a zombie proposition.

In fact, as we'll see, almost all the innovation that is going to make a material difference to our Net Zero carbon future is to be found elsewhere – in solar, wind, storage, demand management, EVs, heat pumps, eco-efficient design, micro-grids, AI-enabled Big Data, and green hydrogen (see page 25). And this is as much about <u>systems innovation</u> as it is about <u>technological innovation</u>, with much greater integration between generating and distributing electricity, at both national and local level. Ironically, the UK is seen by many other countries as something of a market leader in terms of more efficient and competitive energy systems, providing us with a stable foundation on which to develop much more innovative, low-carbon solutions.

What should most concern environmentalists today is that the astonishing synergistic potential of these mutually-reinforcing breakthroughs will be so negatively impacted by people hanging on to the idea that we have to keep nuclear power in the Net Zero mix.

Hanging on to these recycled nuclear illusions is not just irrelevant and misguided – now that we understand just how fast we have to move on our decarbonisation strategy, it is positively prejudicial to our prospects of securing a Net Zero carbon economy.

B: THE CASE AGAINST NUCLEAR POWER

For years, the case against nuclear power has focused on eight principal concerns. They remain as problematic for advocates of nuclear power today as they have ever been.

B1. Cost

There was a time when it was difficult to talk authoritatively about the cost of nuclear power. Secrecy, obfuscation and deliberate deception were the watchwords of the old nationalised industry under the Central Electricity Generating Board. These days, it's rather harder to conceal the true cost of nuclear power (although every effort is still made to do exactly that), and there is now no serious debate about the fact that nuclear power is an extraordinarily and perversely expensive way of generating electricity.

Every year, the investment bank Lazard produces a comparison of generation costs on what is known as a 'LCOE' methodology – Levelized Cost of Energy. Its 2020 estimates for relative costs per megawatt hour (MWh) of electricity produced were as follows:[1]

Large-scale solar	£27
Onshore wind	£30
Combined cycle gas turbines	£44
Offshore wind	£63
Coal	£83
Nuclear	£121

All such comparisons are controversial, but there is no-one out there today making the case for nuclear on the basis either of its advantageous economics or on its CO_2 abatement potential (as in cost per tonne of CO_2e abated) – an equally critical comparison.

And consideration must also be given to movement in costs over time. On a more historical basis, 'LCOE analysis shows that between 2009 and 2019, utility-scale solar costs came down 89%, and wind power by 70%, while new nuclear costs increased by 26%. The gap has continued to widen between 2018 and 2019.'[2] Nuclear continues to get more expensive, while renewables continue to get cheaper. For instance, that Lazard figure for offshore wind quoted above looks very high in comparison to the UK Government's latest assessment[3] of £47/MWh when one projects through to 2030, and it's certain that this year's auction for offshore wind will see bids at no more than £40/MWh. Just five years ago, the Government's projection was £103/MWh.

This report from BEIS (*Electricity Generation Costs*), in August 2020, is a remarkable document, showing just how dramatically the Government has had to slash its forecasts for wind and solar energy over the last four years. Intriguingly, however, it does not include any cost comparisons for nuclear power!

In terms of future impact on electricity consumers in the UK, the focus now is on Hinkley Point C and Sizewell C, where discussions with Government have been ongoing for the last few years. Électricité de France (EDF) argues that it will be able to keep costs down on the basis of the two reactors proposed for Sizewell C being the same as those at Hinkley Point C – widely recognised as the most costly power plant that has ever been constructed. Hinkley Point C's price tag currently stands at around £23bn – and that's in 2015 prices, which means no account of inflation since then is included in this estimate.

By guaranteeing EDF a price of £92.50/MWh (at 2012 prices – which amounts to around £102/MWh in today's prices) for the first 35 years of output from Hinkley Point C, it's been estimated by the

National Audit Office that EDF will be subsidised to the tune of anywhere between £30bn and £100bn during that time, adding somewhere between £10 and £15 to consumers' electricity bills every year.

As the National Audit Office put it in its report in 2017: 'The Government has committed electricity consumers and taxpayers to a high-cost and risky deal in a changing energy marketplace. Time will tell whether the deal represents value for money, but we cannot say the Government has maximised the chances that it will be.' [4]

There is no-one outside of EDF who believes that we've seen the last of delays and cost hikes at Hinkley Point. These could still prove terminal. That £23bn estimate for Hinkley (which does not include the cost of capital), translates into a direct £15.5bn cost to EDF, with the rest falling to its Chinese partner, CGN. The French Court of Audit has already commented that Hinkley Point 'weighs heavily' on EDF's balance sheet, an issue that led to the resignation of EDF's former Finance Director in 2016. At the moment, city analysts accept that Hinkley Point is 'too big a project to be allowed to fail', but further delays and cost overruns, as with EDF's reactors in France and Finland, could easily change those dynamics.

Its power station at Flamanville began construction in 2007, with plans to be online by 2012. It now seems that 2023 is the earliest possible start for commercial operation. Costs have risen from a projected €3.3bn to at least €10bn, and significant additional costs will be incurred at a later date to meet further regulatory demands. The power station at Olkiluoto in Finland began construction even earlier, in 2005, with plans for it to be online in 2009. It now seems unlikely it will be operating commercially until 2022. The initial budget of €3.2bn has tripled since 2005.

Looking ahead, no-one believes EDF's projected costs for Sizewell C (which it still claims to be around £20bn) to be anything other than the usual grotesque underestimate. Apart from the fact that lessons are rarely learned from one nuclear project to the next, as EDF claims, the principal reason for this is the cost of capital (with nuclear power stations taking so long to build before producing any income-generating electricity), which is not included in that £20bn estimate.

Despite the Government's assertions in its Energy White Paper in December last year, the funding for Sizewell C is by no means secured. EDF only survives as a quasi-commercial entity because it is 84% owned by the French Government, but it cannot possibly find such a huge sum from its own (largely fictitious) balance sheet. It is also facing massive additional costs to extend the life of many of its existing reactors in France and to start decommissioning the rest.

The UK Treasury has remained steadfast in its refusal to provide direct subsidies to enable construction to proceed. An undisclosed contribution may be available from the Chinese company CGN (wholly owned by the Chinese Government), as is currently the case with Hinkley Point C. But third party investors (including both Aviva and Legal & General, two key players in this area), have already declined to step into this particular breach, given EDF's lamentable track record with its EPR reactor.

The Government's favoured solution at the moment is to make use of a device called the 'Regulated Asset Base' (RAB), which means that consumers in the UK will pay up front for an as yet unspecified percentage of the construction costs. This could amount to as much as a £40 per annum surcharge on consumers' bills, for at least five years. Once construction is completed (notionally in 2035), consumers will then have to pay all over again for the still highly expensive electricity that Sizewell C will be generating. As Tom Burke, Chairman of the think tank E3G, puts it: 'We are being subject to a confidence trick which uses financial engineering as cover for the failure of nuclear engineering to reduce costs.'[5]

At the moment, the principal question for Ministers seems to be whether there's any reasonable expectation of getting away with such a monstrous boondoggle.

B2. Build Rate

EDF's new power station at Hinkley Point C epitomises the difficulties faced by companies involved in nuclear construction projects. After lengthy discussions with EDF from 2010 onwards, the UK Government finally approved the project in September 2016, and work got under way in 2018. In January this year, EDF announced that the earliest date for Hinkley Point C generating any electricity would be June 2026. Further delays are considered inevitable.

As recently as 2018, the Government was still talking of a further four nuclear power stations over and above Hinkley Point C and Sizewell C. In 2018, however, Toshiba finally gave up on its plans for the Moorside site near Sellafield in Cumbria. In September 2020, for similar financial reasons, Hitachi pulled back from its involvement in both Wylfa and Oldbury, and confirmed that it was pulling out altogether in February 2021, blaming the UK Government for not coming up with sufficient financial support. That just leaves Bradwell B, where plans for a majority-owned Chinese power station (using CGN's own reactor design) seem more and more implausible at a time when any Chinese investments in the UK are coming under ever-greater scrutiny (see page 9).

Beyond that, there has recently been a huge surge of interest in what are called Small Modular Reactors. I shall look further at this later in the Report – see page 24.

Essentially, it's the ludicrously uncompetitive nature of nuclear power that has led to such a profound collapse of confidence in the idea of new nuclear power stations for the UK – and much of this can be attributed to construction risk: the fact that new plants take so long to build, ramping up huge capital costs before any financial payback. As we've seen, the cost of capital is correspondingly punitive. These days, it's only China that can demonstrate any kind of track record in completing new nuclear power stations (more or less) on time, although it too saw significant delays (of up to five years) with the two EPRs that it has built. Extended overruns are standard, as detailed every year by the World Nuclear Industry Status Report.

This has a huge impact on the contribution that new nuclear can make to any country hoping to achieve a Net Zero carbon target. With Sizewell C, for example, EDF has acknowledged that its carbon payback period (the number of years of low-carbon electricity generation required to 'pay back' the huge amounts of CO_2 embedded in all the construction materials, particularly steel and concrete) will be at least 15 years, assuming that it comes online in 2034, which itself is highly unlikely.[6]

In other words, even if it goes ahead, Sizewell C will make a <u>zero</u> contribution to the UK's target of becoming Net Zero by 2050.

Environmentalists will also be acutely aware of the opportunity costs here. By persevering with its 'we need all of the above' strategy, the UK Government is actually undermining our Net Zero prospects through its continuing ambiguity on a 100% renewables-efficiency-storage-smart grids option – as I'll explain in the next section. It's crucial that all those now focused on Net Zero strategies should get much smarter about the relative 'climate effectiveness' of different generation options; the bottom line here is that high-cost options save less CO_2 per pound invested than low-cost options. As US energy guru Amory Lovins says, such muddled thinking 'distorts prices, crowds out competitors, slows innovation, reduces transparency, rewards undue influence, introduces bias, picks winners, invites corruption, and even threatens to destroy competitive power markets where renewables and efficiency win. These are high prices to pay for small or negative benefits.'[7]

B3. Waste

It's rare to hear nuclear enthusiasts acknowledge the fact that nuclear power produces significant and problematic volumes of nuclear waste, let alone the even more inconvenient fact that the industry has failed to come up with a viable long-term strategy for dealing with that nuclear waste over more than 50 years. The highly influential 1976 report from the Royal Commission on Environmental Pollution (the so-called Flowers Report) made the following recommendation:

> 'There should be no commitment to a large programme of nuclear fission power until it has been demonstrated beyond reasonable doubt that a method exists to ensure the safe containment of long-lived, highly radioactive waste for the indefinite future.'[8]

The consequence of ignoring this recommendation is a jumble of more-or-less unsatisfactory 'meanwhile' fixes pending that long-term solution through some kind of Geological Disposal Facility. Spent nuclear fuel (removed from the reactor core) is stored in cooling ponds on site before being transferred to Sellafield (around 80% of nuclear waste in the UK is located in Sellafield). All the spent fuel from Magnox reactors is now consolidated at Sellafield for reprocessing – a temporary arrangement as reprocessing at Sellafield is due to end later this year. What is left will be transferred into dry storage facilities, as will the waste from Sizewell B. The High-Level Waste generated as a by-product from the reprocessing undergoes an additional process called 'vitrification', and is then stored in stainless steel containers until such time as a Geological Disposal Facility becomes available – which could still be decades away.

There are still <u>many</u> issues to be resolved in this regard, not least the decision as to where any such facility will be located. The Government (through the Nuclear Decommissioning Authority) is currently involved in a fourth consultation exercise with possible 'host communities', dangling the incentive/bribe of £2.5m per annum for local initiatives. Notwithstanding such largesse, even the Government acknowledges that such a Facility will not be fully operational (for dealing with High-Level Waste) until 2075.

Intermediate-level waste is compacted and stored in stainless steel containers at Sellafield's Interim Storage Facility. Most low-level waste is now disposed of in metal containers before being stacked in engineered vaults in the UK's Low Level Waste Repository at Drigg in Cumbria. A small amount is incinerated or recycled.

As the industry correctly claims, this is certainly 'manageable', even if a high price has to be paid to meet stringent safety standards. But the lack of a long-term strategy remains highly problematic, and Sellafield itself is a site riddled with problems and hazards of every conceivable kind, including a stockpile of 140 tonnes of plutonium (the largest stockpile in the world), much of which will need to be completely 'repackaged' and transferred into new storage facilities over the course of the next decade, at a cost of many billions of pounds.

B4. Decommissioning

At the end of their operating life, all nuclear reactors have to be decommissioned, an extended process which takes many decades. Here in the UK, the Nuclear Decommissioning Authority (NDA) is responsible for 17 sites, including Sellafield, Dounreay and all 12 Magnox stations, with an annual budget of around £3.5bn.

An extremely critical report from the Public Accounts Committee in November 2020 highlighted the 'astronomical sums' that taxpayers are having to stump up to deal with the costs of decommissioning.[9] According to the NDA, it will cost current and future generations of taxpayers £132bn to decommission all civil nuclear sites in the UK, with the work not being completed for at least another

85 years, and possibly 120 years! The same report indicated that it will require £8.7bn just to get the 11 closed Magnox stations into the 'care and maintenance' stage of the whole decommissioning process.

It is often asserted that the future costs of decommissioning the UK's Advanced Gas Reactors (AGRs), and the one Pressurised Water Reactor (PWR) at Sizewell B, will be covered by regular contributions from the operator of those reactors to the Nuclear Liabilities Fund, which now stands at around £14.5bn. But the 'accounting' behind this claim is highly tendentious. Any shortfall beyond that (and you can absolutely guarantee there will be shortfalls) will have to be covered by future contributions from taxpayers.

Apart from the occasional investigation by the Public Accounts Committee, or independent commentators, UK taxpayers never get to hear about these massive sums of money, stretching forward decades into the future. It's just one of the many hidden costs of the whole nuclear lifecycle. This lack of transparency is not unexpected, but it is highly regrettable. A Government that inflicted a decade of austerity on its citizens on the grounds that it would be morally wrong to pass on to our children the debts accrued in dealing with the financial crash in 2008, should be rather more focused on this particular intergenerational immorality.

B5. Proliferation

The Treaty on the Non-Proliferation of Nuclear Weapons (NPT) came into force in 1970 in order to prevent the spread of nuclear weapons – but also 'to promote cooperation in the peaceful uses of nuclear energy'. And there's the rub: it's hard to promote nuclear energy without running the risk of those 'nuclear nations' developing nuclear weapons. Four of them (India, Pakistan, Israel and North Korea) have done precisely that since 1970, joining the Big Five nuclear weapons states of the USA, Russia, China, France and the UK. South Africa used its uranium enrichment facility to build a nuclear bomb, but chose not to become a nuclear power. There are continuing concerns that other nations are intent on joining that nuclear weapons club, including the two most bitter rivals in the Middle East, Iran and Saudi Arabia.

With the US company Westinghouse struggling to find buyers for its AP1000 reactor, and France (through EDF/Framatome) having more than enough on its plate, that just leaves Russia, China and South Korea seeking new international orders. In March 2020, South Korea's KEPCO completed the first of four planned reactors in Abu Dhabi, in full compliance with the strict non-proliferation standards enforced through the NPT. But neither Russia nor China would appear to have any such scruples.

The prospect of a massive expansion of nuclear power to help decarbonise electricity supply around the world fills me with dread. One has only to think of the massive challenge that the International Atomic Energy Agency has faced (and still faces) in terms of regulating Iran's nuclear industry, with all the geopolitical fallout this has caused, to baulk at any further expansion elsewhere in the world.

The only fail-safe way of ensuring that the technologies necessary to create a civil nuclear industry do not simultaneously facilitate a nuclear weapons capability is to stop building nuclear power stations.

And the only fail-safe way of ensuring that the materials required for the production of so-called 'dirty bombs' (plutonium or enriched uranium) do not become available to terrorist organisations is to stop building nuclear power stations anywhere in the world.

B6. Safety

Advocates of nuclear energy feel aggrieved that critics continue to characterise nuclear power as 'inherently unsafe'. And with some justification. Setting aside the accident at Three Mile Island in Pennsylvania in 1979, the Chernobyl disaster in 1986, and the Fukushima disaster in 2011, the industry can claim to have a reasonable safety record. It is certainly responsible for far fewer deaths per unit of energy generated than coal, oil, and gas. Over the course of roughly 20,000 'reactor years' since the 1970s, regulators and operators have, for the most part, maintained high safety standards, satisfactorily managed tens of thousands of 'minor incidents', and adequately protected their workforces from both low-level and high-level risks.

And it's always worth remembering that this is an industry that employs tens of thousands of utterly dedicated nuclear engineers and blue-collar workers intent on 'keeping the lights on' in as safe and reliable a way as can be secured.

It was for this reason that I strongly opposed the decision taken by Germany after the Fukushima disaster in 2011 to take all its nuclear reactors off-grid by 2022 – well before the end of their scheduled operating life. Germany has some of the most reliable nuclear power plants anywhere in the world. The inevitable consequence of this was that Germany's increasingly desperate coal industry was immediately given a pretext to 'stay in the game', effectively slowing the transformation to renewables and efficiency that was under way. Germany will still be burning coal in 2038 – an utterly ludicrous state of affairs.

However, as both Chernobyl and Fukushima (and, to a lesser extent, the disaster at Three Mile Island in the USA back in 1979) demonstrate, the nuclear industry is peculiarly vulnerable to 'high-impact, low-probability' events, with devastating consequences. Although the official death toll for Chernobyl remains low (with 31 immediate deaths and up to 4,000 deaths estimated from direct exposure to radiation, although it's important to point out that UNSCEAR (the United Nations Scientific Committee on the Effects of Atomic Radiation) has challenged the validity of the models used to produce that figure), this masks a much more persistent health crisis. The National Research Centre for Radiation Medicine in Kiev, Ukraine, describes Chernobyl as 'the largest anthropogenic disaster in the history of humankind', with millions of people suffering adverse health consequences of different kinds. 1.8 million people in Ukraine have official status as victims of the disaster, with benefits still being paid, 35 years on, to 36,525 widows.

Far fewer people were affected by the disaster at Fukushima, but there are still grave concerns about the impact of radiation on many thousands of people, and growing anger about proposals to dispose of billions of tonnes of contaminated water in the Pacific. Moreover, the financial costs are staggering, with the Government itself acknowledging that the final clean-up bill will exceed $200bn. Independent experts (such as the Japan Center for Economic Research) estimate that the final figure will be between $470bn and $660bn. Some believe that the combination of direct and indirect costs will top $1tn, making it by far the most costly disaster in human history.

We have to be mindful of these 'worst-ever' impacts when appraising the industry's indisputable (though increasingly irrelevant) argument that nuclear power has killed far fewer people than the coal industry. And we also have to take into account the nuclear industry's entire life cycle, including the highly significant health and environmental impacts caused by the mining and processing of uranium.

B7. Radiation

The health impacts of different levels of exposure to radiation remains a highly contested area of medical science. On balance, it's fair to say (as argued persuasively by Trade Unions representing

workers in the industry) that the risks to workers and surrounding communities from low-level radiation can be managed, and, for the most part, are properly managed. For example, the radiation-induced cancer risks to nuclear workers have been compensated fairly quickly and generously via automatic compensation schemes like that pioneered at Sellafield by the GMB and other unions in 1984.

However, there have been far too many examples of poor management practices over the last 50 years, and such reassurances from the industry will never allay the wholly legitimate concerns of anti-nuclear campaigners. There are many studies that reinforce those concerns. Back in 2008, for instance, a highly authoritative report analysed the incidence of childhood cancer in the vicinity of Germany's 16 nuclear power stations, revealing a 60% increase in childhood cancers and a 120% increase in leukaemia amongst children living within five kilometres of those power stations.[10] Similar findings have subsequently emerged from studies in France, Switzerland and the UK.

B8. Security/Cybersecurity

Although industry leaders are (perhaps understandably) reluctant to talk about security issues, any assessment of the potential contribution from nuclear power to a Net Zero economy has to take into account both physical security and cybersecurity.

B8.1 Physical security

By definition, all nuclear reactors and associated facilities are vulnerable to terrorist attacks, necessitating correspondingly high levels of protection, both in terms of deterring ground-based attacks and securing no-fly zones around nuclear reactors to prevent '9/11-type' attacks, given that most existing nuclear power plants were not designed to withstand that kind of impact. There are additional concerns about spent fuel ponds being subjected to such attacks. (It is often forgotten that al-Qaeda originally planned to include a nuclear power plant in its 2001 attack in the USA.)

It remains all but impossible to ascertain the true costs associated with these combined security operations, but they are clearly material.

B8.2 Cybersecurity

It's now more than ten years since the USA and Israel managed to introduce a 'computer worm' into some critical operating systems in Iran's uranium enrichment plant, causing safety devices to be switched off. The 'Stuxnet attack' ushered in a decade of increasingly intense cyberwarfare, often involving critical energy infrastructure assets. In 2014, South Korea's nuclear plant operator (KHNP) was subjected to an extensive hacking operation. Russia attacked Ukraine's power grid in both 2015 and 2016, and is constantly trying to hack the US power grid (including some of its nuclear power plants), just as the National Security Agency in the USA is constantly trying to hack Russia's power grid.

2020 ended with a particularly telling example of the escalating risks in this area. A private cybersecurity firm, FireEye, alerted the US Cyber Command of a massive hack coordinated by Russia's SVR (previously known as the KGB) that had been going on since March – entirely undetected by the National Security Agency. Huge numbers of multinational companies and government agencies were breached, including the Los Alamos and Sandia National Laboratories (where nuclear weapons are developed), as well as the National Nuclear Security Administration, which maintains the US nuclear stockpile.

So is it, as some security experts believe, only 'a matter of time' before a nuclear power plant or other facility is subject to a full-on terrorist-inspired cyberattack? I don't know. Such a prospect is certainly right up there in the list of high-impact, low probability events that I mentioned before. All I do know is

that reassurances from industry leaders that their 'stand-alone' operating systems, with multiple, notionally 'unbreachable' firewalls providing ample protection against even the most sophisticated cyberattack, sound increasingly implausible.

Here in the UK, we have a very particular cybersecurity issue to address – caused by the involvement of the Chinese in our nuclear industry. In the aftermath of the Huawei debacle regarding the rollout of 5G, there's now much greater scrutiny of CGN's involvement as a co-investor in both Hinkley Point C and (potentially) Sizewell C – with Iain Duncan Smith referring to CGN as 'the next Huawei'. The Chancellor, Rishi Sunak, has hinted at a change of heart in referring to the need for an 'eyes wide open relationship with China', which many have read as an implicit 'pack your bags' message to CGN regarding its proposals for a 100% designed, constructed and operated Chinese reactor at Bradwell. In February this year, CGN announced that all current work on Bradwell would be 'paused', and that engagement with local authorities and regulators 'will begin again in future years'. I rather doubt it.

ALL IN ALL …

The case against nuclear power remains very strong. As the annual World Nuclear Industry Status Report demonstrates, this explains why the nuclear industry is slowly declining. There were still 400 nuclear reactors online in July 2020, nine fewer than in July 2019 – which happens to be exactly the same number as in 1988. Even in China, where nuclear power contributes around 4% of the overall generation mix, wind energy in 2019 provided more power than nuclear (406 TWh versus 330 TWh), with solar power (at 224 TWh) growing much faster than nuclear. Both wind and solar provide more electricity in India than nuclear. Nuclear capacity in the USA is rapidly shrinking. In the EU, wind power increased by 14% and solar by 7% in 2019, while nuclear declined by 1%. And EDF's continuing problems with its EPR reactors at Flamanville makes it extremely unlikely that any new reactors will be commissioned in France for a long time to come, despite their being historical plans for a further six EPRs.

The bottom line here, for environmentalists in particular, couldn't be simpler. The UK's 'Net Zero by 2050' commitment demands a profound rethink of every aspect of our energy strategy – a challenge which the Government's 2020 White Paper manifestly failed to deliver. The nuclear industry has itself acknowledged that it has nothing new to add to the need for accelerating decarbonisation over the next decade, and that any contribution it can eventually make (over and above the 10% of low-carbon electricity from Sizewell B and Hinkley Point C combined – see next page) will not kick in until after 2050. Too late!

There are a number of EU countries which still harbour hopes of building new reactors, but the UK Government stands pretty much alone in its unbridled enthusiasm for new nuclear power stations, even as it has witnessed its hugely ambitious dream of a 'nuclear renaissance' fade away over the last 15 years. But no-one can accuse the industry of a lack of effort in promoting its own interests against such an unfavourable backdrop.

C: 'YES, BUT WE STILL NEED IT!'

There's not much that advocates for a nuclear option can do to gainsay the full extent of these problems. All the statistics I've used in Section B are in the public domain, and all my more speculative observations (on security matters, for instance) fall well within the bounds of probability. Which leaves those advocates falling back on two relatively new-found 'yes, but' arguments.

C1. 'Yes, but it's impossible for the UK to achieve Net Zero without new nuclear power.'

I'm putting the emphasis on new nuclear power simply because there will already be a significant contribution to UK electricity supply from nuclear power through to at least 2050. The PWR at Sizewell B (which provides 3% of the UK's electricity) is scheduled to continue generating until 2035, but there's a strong likelihood that its lifetime may be extended through to 2050, assuming it meets rigorous safety checks. If and when Hinkley Point C is finished (providing 7% of UK electricity), it will still be generating low-carbon electricity well into the second half of the century – all being well. So we can assume a combined contribution from 2030 to 2050 of around 10% from those two nuclear plants.

What Net Zero means is that all emissions of greenhouse gases (across the entire economy) must be either eliminated or brought down as close to zero as possible, with all residual emissions compensated for by an equivalent removal of CO_2 from the atmosphere. Net Zero includes all emissions from transport, heating, manufacturing and refining, farming and land use, as well as from shipping and aviation (which are currently not included in the UK Government's Carbon Budgets). In effect, that means we first have to electrify pretty much everything we can, and then ensure that all that electricity is itself low or zero carbon.

This is indeed a massive challenge. Advocates for nuclear power argue that it cannot be achieved without a significant percentage of that total electricity demand being met by new nuclear power – in effect, countering the argument that a combination of energy efficiency, renewables, storage and grid redesign is all that is required. Tom Greatrex, Chief Executive of the Nuclear Industry Association, continues to argue that nobody in the industry has 'ever heard anybody, serious or credible, suggesting that there is any way you're going to get to Net Zero without nuclear being part of it.' This is the nub of the 'Net Zero needs nuclear' case.

Having once argued that nuclear power should be the principal source of generating low-carbon electricity, constantly disparaging and misrepresenting the potential contribution from renewables, the industry has had to fall back a long way from that aggressive positioning, relying instead on the somewhat less ambitious claim that 'we need every low-carbon tool in the toolkit' in order to address the Climate Emergency. And though it is never spelled out as such, there is an implicit assumption behind this 'all of the above' argument that all of the different options are somehow equal in terms of their low-carbon credentials.

The first thing to be said is that it is very misleading to make out that renewables and nuclear are equivalently low-carbon – and even more misleading to describe nuclear energy as zero-carbon, as a regrettably significant number of politicians (including BEIS Ministers) and industry representatives (including EDF's egregiously saccharine TV ads claiming that it is 'the biggest producer of carbon-free electricity' in the UK) continue to do. Many of them in the full knowledge that they are lying.

In 2008, the journal *Energy Policy* published an article by Benjamin Sovacool (now Professor of Energy Policy at the Science Policy and Research Unit at Sussex University) analysing 103 lifecycle studies of greenhouse gas-equivalent emissions for nuclear power plants. It calculated that the mean value is 66g of CO_2e/KWh. This compares to 9g of CO_2e/KWh for offshore wind and 32g of CO_2e/KWh for solar PV.[11]

According to Mark Jacobson, Professor of Civil and Environmental Engineering at Stanford University, when the full life cycle of nuclear is taken into account – from mining, milling and enriching the uranium that provides the fuel, through to fabricating and transporting that fuel, and then on to managing and eventually disposing of the radioactive waste and decommissioning the reactors – emissions from nuclear power are between 10 to 18 times greater than emissions from renewable energy technologies.[12] And all those emissions are over and above the huge embodied carbon costs of construction that I've already referred to.

Having dismissed that myth, let's examine the case for a 100% 'nuclear-free Net Zero' ambition.

C1.1 Efficiency

I've put this first because it's so often (and so frustratingly!) left out of the discussion about Net Zero, or relegated to some also-ran status. Whether nuclear is in the mix or not, it is absolutely critical that we should put efficiency at the heart of our Net Zero ambition: the lower the total amount of energy required, the easier it becomes to meet that demand. And the fact that some environmental organisations, climate campaigners, anti-poverty campaigners and trade unionists continue to treat energy efficiency (and fuel poverty in particular) as a secondary concern tells me they haven't begun to understand the true nature of our Net Zero challenge.

Indeed, if there's one thing that keeps the nuclear industry alive today apart from the continuing interdependencies between nuclear weapons and nuclear power (which I'll address later), it's the continuing complacency of so many campaigning organisations as to the preconditional importance of energy efficiency. It's not just Dominic Cummings, Boris Johnson's former Svengali, who finds energy efficiency 'boring' – despite the fact that the energy efficiency sector was responsible for 114,000 full-time equivalent jobs in 2018, according to the Office for National Statistics, compared with around 50,000 in renewables and a paltry 12,400 in nuclear. (That figure does not include all the jobs involved in decommissioning.)

It's knee-jerk nonsense from the likes of Dominic Cummings that continues to undermine the case for energy efficiency – and not just here in the UK. The International Energy Agency's 'Energy Efficiency 2020' report in August last year predicted that overall investment in energy efficiency improvements would be down by around 9% in 2020, the slowest rate in a decade.[13] But the UK has been particularly badly affected by this institutional bias against prioritising energy efficiency – a pattern compounded by the Conservative Party's deep-seated antipathy to using regulation to drive behaviour change. A report from the Energy and Climate Intelligence Unit in February last year demonstrated how the Conservative Government's axing of the Zero Carbon Homes initiative in 2016 (together with the Code for Sustainable Homes) will drive up energy bills in the UK by around £200 a year for all new homes purchased since 2019.[14]

And without the EU's focus on efficiency and appliances (through the Ecodesign Directive and other measures), it's doubtful that we would have seen anything like the same efficiency gains here in the UK. The latest ecodesign laws, which come into force in April this year, will require manufacturers of fridges, freezers, washing machines, dryers, dishwashers, TVs, monitors and lighting products not only to make their appliances easier to repair or recycle – but even more energy efficient. The UK will still be bound by these new standards (which were agreed back in January 2019), but one wonders what will happen in future now that we're out of the EU? It's critical that Ministers continue to drive down energy demand through further initiatives of this kind, ensuring that 'demand management' is as high a priority in policy terms as new generation.

Beyond that, it's the built environment where the biggest efficiency gains are to be made – not just in terms of new-build but existing buildings. And in particular, existing housing. Household emissions from

heating and hot water (roughly 20% of the UK's emissions) must reduce by a massive 95% if the UK is to achieve its Net Zero target by 2050. According to the Committee on Climate Change, that will require up to 20,000 homes and other buildings to be retrofitted every week. For the next 30 years. The Committee has also pointed out that the number of homes being insulated today has dropped by over 90% since 2012, owing mostly to the Government's axing of Labour's tried and tested retrofit initiatives.

Relative to the cost of gas, electricity is very expensive, making the imperative of 'decarbonising heating systems' (by massively reducing the use of gas) all the more problematic. But the Government's response to this is nothing short of pathetic. Despite endless calls from business and NGOs to put a homes retrofit programme at the heart of its 'Build Back Better' strategy, even the patently inadequate Green Homes Scheme promising grants to individual homeowners was terminated in March after failing to meet any of its targets. This represents a colossal policy failure.

What we've ended up with is the usual 'targetry without delivery': 600,000 heat pumps a year by 2028; 2.2 million homes in the social housing sector to be improved, with a promise in the 2019 Election Manifesto of £6.3bn to help make this happen; no more gas boilers to be installed in new homes from 2025 onwards; a new Low-Carbon Heat Support Scheme from April 2022, etc etc. This on/off approach, with a drib here and a drab there, shows this Government's contempt for addressing fuel poverty strategically – as they're now doing so effectively in Scotland through the 'Warmer Homes Scotland' initiative.

What's needed is a multi-year programme for the whole UK, taking us through to 2030, 2040 and then 2050, focused both on the 'willing and able to pay' and on the social housing sector, as originally called for by the Green New Deal group – and now supported by the Lib Dems and by Labour.

This will indeed cost billions of pounds. But as a general rule of thumb, 'buying efficiency' costs a lot less than 'buying new electrons', wherever they come from. And a retrofit programme of this kind will cost so much less than the utterly nonsensical ideas about a new hydrogen-based gas grid, apparently entailing the installation of millions of new hydrogen-ready boilers, with that notionally 'green hydrogen' being produced from nuclear-generated electricity. This is just the latest in a long line of the nuclear industry opportunistically jumping on a temporarily over-hyped bandwagon in order to strengthen its rapidly diminishing credentials (see page 25).

C1.2 Renewables

Let's assume we get smart in putting energy efficiency first in policy terms. And that we drive that energy efficiency programme hard throughout the next 30 years. In such circumstances, it's reasonable to assume that we could then halve total energy consumption in the UK from around 1,700 TWh/year today to around 850 TWh/year by 2050. Decarbonising total energy use in the UK means all but eliminating the use of oil in transportation, and massively reducing the use of gas for providing heat and hot water. Most scenarios assume this will mean a doubling in the amount of electricity we need to generate by 2050: the Committee on Climate Change's so-called 'Balanced Pathway' scenario suggests electricity could rise to around 677 TWh/year by 2050.

As much as possible of that remaining 677 TWh/year will need to come from a combination of renewables backed by storage. According to Government figures, 42% of our electricity in 2019 came from renewables – that's the equivalent of about 120 TWh/year. So we have to get from 120 TWh (from current electricity) to 677 TWh over the next 30 years. And that's the gap that Tom Greatrex does not believe can be filled without new nuclear-generated electricity, carefully curating his own reading list to avoid various authoritative '100% renewable energy scenarios' from the Centre for Alternative Technology[15] and other international NGOs, from independent experts like Keith Barnham, or even from the International Energy Agency itself. An IEA report in 2019 demonstrated that offshore wind could

theoretically provide enough electricity to meet total global electricity demand, predicting that offshore wind will grow 15-fold to become a $1tn industry over the next 20 years.[16] (To be fair, the IEA is not actually recommending this scenario!)

Suffice it to say that those who believe the gap can be filled are getting more and more bullish by the year, with continuing improvements in technology, continuing reductions in costs, year on year, and continuing confidence in reconfiguring distribution systems.

Just a couple of additional points here: for once, Boris Johnson's resort to hyperbole was justified when he laid out his ambition for the UK to become 'the Saudi Arabia of windpower':

- In July last year, analysts at Imperial College crunched the numbers to demonstrate that when the latest offshore wind farms come on stream over the next few years (at a contracted price of £40/MWh), this is likely to be below wholesale prices at that point.[17] Their report suggested that wind farm operators would then have to pay back the difference between the contracted price and wholesale price, with those savings passed on in the form of lower energy bills for businesses and households. This raises the very real possibility that all future offshore wind contracts will be completely subsidy-free from the middle of the decade. A full ten years before the first (and still massively subsidised) electrons are due to be generated at Sizewell C.

  These figures relate to turbines limited to relatively shallow water with a depth of less than 60 metres. Floating wind turbines have already been deployed in a number of demonstration projects, and as the size of each individual turbine increases, there's no doubt that cost curves will start coming down at the same rate as happened with conventional offshore turbines. And turbines will continue to get bigger: in January, GE secured a contract to build a 14GW turbine at the Dogger Bank Wind Farm; Vestas has just started work on a 15MW offshore turbine – enough to power 20,000 households on its own!

- According to the Government's own figures, large-scale solar will be the cheapest generating technology by 2025 (at half the cost of combined-cycle gas turbines), and will get cheaper still through to 2040 where costs could fall as low as £28/MWh[18]. Which may explain why BEIS called for new evidence at the end of last year as to the potential contribution of large-scale solar to our Net Zero target, and why even the Solar Trade Association's call for a tripling of existing solar by 2030 seems modest.

The simple and most important point is this: the Government itself recognises that renewables can be scaled quickly and cost effectively. We've seen the impact of that over the last five years, even before a recognition of the full extent of the Climate Emergency in which we now find ourselves. So imagine that we started to do that scaling with that Emergency in mind.

And all this (in my opinion) before the Government eventually bites the bullet and commits to significant investment in tidal energy on the Severn Estuary, either through tidal lagoons or a full-blown barrage, generating totally predictable, near-zero-carbon electricity for up to 100 years – and simultaneously protecting the whole Severn Estuary from the extreme disruption which will inevitably be caused by rising sea levels.

It's true that the UK is particularly well endowed with renewable energy resources, but similar '100% renewable' scenarios are becoming more robust every year. Mark Jacobson and his team at Stanford University have argued that 100% of all global energy can come from renewable sources (with biomass excluded) by 2050.[19]

C1.3 Storage

The astonishing potential of renewables can only be realised if massive new investment in batteries and other storage technologies can compensate for 'the intermittency challenge' – those times where 'the sun isn't shining and the wind isn't blowing', a phrase which is ritually trotted out by nuclear advocates in order to disparage the case for renewables. It will require significant breakthroughs in storage to ensure cost-effective integration of variable renewable electricity on to the grid, with the UK remaining dependent on fast-ramping natural gas plants for peak power generation until then.

Like many environmentalists, I'm deeply concerned about the impact of this huge growth in demand for batteries on the environment – particularly in terms of the extraction of raw materials (lithium, cobalt and nickel) required, often sourced from countries such as the Democratic Republic of Congo which have a terrible record on human rights and environmental safeguards. It's imperative that governments act now both to address the supply chain challenges, and to mandate the strictest 'circular economy' conditions to ensure that batteries can easily be disassembled and recycled to limit demand for virgin raw materials.

The cost of lithium-ion batteries has also been plummeting over the last few years as a consequence of growth in EV markets, down from $1,183/KWh in 2010 to $156/KWh in 2019, according to data from Bloomberg New Energy Finance. And BNEF is predicting $100/KWh by 2024 (the price point at which EVs reach cost parity with petrol and diesel vehicles) and an astonishing $60/KWh by 2030. These improvements will come through further incremental innovation in battery chemistry and significant economies of scale.

These reductions in the cost of batteries will ensure that the so-called 'balancing cost' entailed in integrating much larger amounts of variable renewable electricity onto the grid will also reduce – adding somewhere between £10/MWh and £15/MWh to the overall cost of the renewables + storage option. Here in the UK, there's growing recognition of the importance of large-scale storage through the Government's Capacity Market, and the inclusion of storage schemes within the new Contracts for Difference auctions. In February, RenewableUK published its analysis of just how quickly the UK's battery storage pipeline is growing – up 50% over the last year or so – with bigger schemes able to get planning permission much more easily. 'There is now more than 16GW of battery storage projects operating, under construction, or being planned here in the UK.'[20]

Unfortunately, this is something which BEIS currently can't get its head around, with its archaic belief in centralised dispatch based on large power stations – including nuclear. According to Michael Liebreich of Bloomberg New Energy Finance:

> 'There are plenty of ways of managing intermittency in renewables without resorting to expensive back-up power. First, you improve your resource forecasting. Second, by interconnecting the grid over larger areas, much of the variability of renewable energy can be evened out. Third, just when an increased proportion of renewable energy means you start losing control over supply, the introduction of digitally controlled smart grids gives you better control of demand. Finally, there is power storage, currently mainly in the form of pumped hydroelectric power, but, in the future, most likely in the form of batteries for electric vehicles. The cost of each of these techniques is coming down just as rapidly as the cost of renewable energy.'[21]

Beyond that, we shouldn't underestimate the potential for pumped storage from hydroelectric schemes. When renewable electricity is plentiful and cheap, it can be used to pump water uphill from a lower reservoir to a higher one. When power is needed, the water is released and passes through turbines to

generate electricity. The UK has four such schemes at the moment, but Scotland is now actively exploring proposals from both SSE and Drax that would significantly increase overall capacity. SSE's scheme at Coire Glas in the Highlands would be the UK's largest pumped storage scheme with a capacity of 1,500MW at a cost of around £1.5bn.

And there are now plans for smaller, high-intensity hydro projects across the UK. It's estimated that there could be as many as 700 sites with no more than a 200m 'lift' between two small-scale reservoirs, possibly providing as much as 7GW of storage. These are early days, but if we unleash the power of innovation here as much as on mechanical, battery-powered storage, we could see a far more environment-friendly solution emerge.

This all relates to short-term storage, where a combination of improved storage technologies and effective demand management (both for industry and households) shows great promise. What's more, as the number of EVs starts ramping up (reinforced by the Government's very welcome decision to ban the sale of new petrol and diesel vehicles by 2030), even more cost-effective storage and trading opportunities will kick in with 'V2G' (Vehicle-to-Grid) systems. According to the Committee on Climate Change, there could be as many as 25 million electric vehicles on our streets by 2035. V2G technology will enable plug-in vehicles to act as a form of distributed energy storage by providing demand response services to the power grid, with electricity flowing from cars to grid, and vice versa, based on demand needs at any given time.

Long-term storage (ie taking account of the big variations in renewable electricity from season to season) will require different approaches, especially when it's a question of needing to store surplus electricity from wind and solar power. Green hydrogen may have an important role to play here.

The storage challenge is very much one of those areas where steep learning curves yield rapid and substantial efficiency and financial benefits – exactly the opposite of what has happened with nuclear power over the last few decades. It's also the key to freeing ourselves of our current dependency on baseload thinking.

C2. 'Yes, but only nuclear can provide the low-carbon baseload on which the grid depends'

C2.1 Baseload: time to move on

This is the second of the two 'yes, but' arguments used by the nuclear industry. Indeed, as all other arguments in favour of nuclear power fall away under properly rigorous scrutiny, this is now the last redoubt in defence of the case for nuclear power. And it would indeed be a very compelling argument were it not for the fact that the very idea of baseload generation is itself seen as increasingly redundant. Back in 2015, the then Chief Executive of National Grid, Steve Holliday, spelled out the writing on the wall for those still looking backwards rather than forwards in terms of energy systems: 'The idea of large power stations for baseload is outdated.'

This has become increasingly apparent since then as the costs of highly inflexible baseload become more apparent. As more and more variable renewable electricity becomes available, there are inevitably more instances where there is much more electricity available than is needed – meaning that operators of those wind farms and solar installations have to be paid to switch them off. Because nuclear power can't be switched on and off, the National Grid's historical distribution systems is based on an 'always on' assumption for nuclear – when it's available, which is a lot less than people imagine with so many of our ageing reactors closed for long periods of time for maintenance or repair, or for weeks at a time for refuelling. In 2019, the so-called 'plant load factor' for nuclear power stations in the UK was just 63% of their theoretical generating capacity.[22] Some offshore wind farms are already achieving plant load

factors of 55%, and floating wind farms further out at sea will be able to achieve significantly higher yields than that. So much for nuclear's 'always on' comparative advantage.

As is increasingly argued by the International Energy Agency, power system flexibility is now an absolute priority if we are to reap the full benefits of more decentralised generation and demand management technologies. It's been convincingly demonstrated by the National Infrastructure Commission that large-scale nuclear power plants entrench more costly, inflexible distribution systems.

I see this as a classic case of incumbent technology standing in the way of more innovative solutions to the challenge of achieving a Net Zero economy, locking in consumers and businesses to increasingly outmoded ways of providing energy services. Prospective innovations in the UK are indeed 'revolutionary', as we see three disconnected energy systems (electricity, gas for heat, and oil for transport) merging into one. One can only hope that BEIS gets its head around this with its emerging 'Smart Systems Plan' promised for Spring 2021.

C2.2 Nuclear and renewables don't mix

There's one final problem about the 'let's have all of the above, with nuclear as baseload' rationale: nuclear and renewables don't mix.

A study in November last year from the University of Sussex Business School and International School of Management, published in Nature Energy, found that nuclear and renewable energy programmes do not coexist at all well in low-carbon energy systems.[23] Instead, they tend to crowd each other out.

Drawing on World Bank and IEA data from 123 countries over the last 20 years, researchers found that grid systems optimised for large-scale centralised power production (such as from nuclear power) make it much harder in terms of both money and time to introduce small-scale, distributed renewable electricity. Those systems where both financial markets and regulatory institutions are structured around centralised, large-scale power plants, with long lead times, are simply not agile enough to facilitate a much more diverse set of short-term, distributed initiatives. Especially where 'rapid, positive learning' can (and should) result in lower costs and improved performance. This is one further indication of the highly significant opportunity costs entailed in any long-term strategy that continues to favour nuclear power.

This was confirmed by an interesting report from Wärtsilä Energy in November last year, looking at ways of optimising the transition to 100% renewable energy for the UK by 2050:

> 'Renewables plus Nuclear would add £660 million per year to the cost of energy by 2030. As nuclear must run 24/7 to recoup its investment and its lack of flexibility means it continues generating during periods of high renewable output and low demand. It creates further potential costs to export power or curtailment charges to stop renewable generation. With a multi-decade lifecycle, this would significantly affect the UK's ability to achieve 100% renewable energy before 2050.'[24]

All of which means, for any Net Zero scenario by 2050, that the 'full renewables package' (renewables + energy efficiency + storage + new grids) will make a far more significant contribution than any amount of (realistically deliverable) nuclear energy. How ironic for pro-nuclear environmentalists that the principal consequence of hanging on in there for that relatively small nuclear element will be to jeopardise a wholly deliverable, non-nuclear Net Zero outcome.

D: WHAT'S MORE …

I said at the start that I have always set out to keep an open mind on the possibility that nuclear power might have a substantive contribution to make to a genuinely sustainable energy future. But given all of the above, I find it increasingly difficult to believe that environmentalists imagine that nuclear power should still be part of the overall generation mix.

I recognise, however, that many environmentalists are so deeply concerned at the potential impacts of accelerating climate change, on countless millions of people, that even the remote possibility that nuclear might help mitigate that frightful prospect persuades them to keep options open. I'm not talking now about that tiny number of environmentalists who advocate vociferously in favour of nuclear power (who I shall return to in the final section), but those environmentalists who just can't bring themselves finally to close the door on a technology that might just, albeit in some currently unimaginable way, make a positive difference.

So, for all such 'concerned and conflicted' greenies, I would just like to add a few final considerations.

D1. The impacts of climate change on nuclear power

Ironically, given that the principal reason for hanging in there with a nuclear option is environmentalists' profound concern about accelerating climate change, it's clear to me that they are still failing to take into account some of the already unavoidable impacts of climate change on nuclear power stations in the future.

As the nuclear expert Andy Blowers has commented: 'There is an exquisite paradox here. While nuclear power is hubristically presented as 'the solution' to climate change, the changing climate becomes its nemesis on the low-lying shores of Eastern England.'[25]

What he's referring to here are the risks to nuclear power stations in Suffolk and Essex (comprising the two decommissioned Magnox stations at Sizewell A and Bradwell A, the UK's sole operating PWR at Sizewell B, and the new reactors under consideration at Sizewell C and Bradwell B) from rising sea levels, storm surges and ever-worsening coastal erosion and flooding.

I've observed over the last couple of years that most environmentalists carry their awareness of rising sea levels at the back of their mind, a grim reckoning that lies ahead of us whatever we do. They need to foreground that awareness, as the situation is so much worse than most people realise.

In 2019, the Intergovernmental Panel on Climate Change published its 'Special Report on the Ocean and Cryosphere' (the cryosphere is made up of the many different kinds of frozen water on the planet), in which it assessed 'the likely range' of sea level rise by the end of the century to be between 43 and 84 centimetres, with 1.1 metres assessed as 'the upper likely range'. A rise of up to 2 metres 'could not be ruled out'. This assessment was recently challenged in a paper published in *Ocean Science*, where researchers from the University of Copenhagen used historical data to highlight discrepancies in the IPCC's estimates, suggesting that the upper likely range should be 1.35m.[26]

Over the next couple of years, the IPCC will be publishing its sixth major Assessment Report – and it's already crystal clear that 'the likely range' of sea level rise by the end of the century will be significantly increased. To cut to the quick, it's now clear that the <u>minimum</u> average sea level rise by the end of the century will be no less than 1 metre – and possibly significantly higher. With further inexorable increases through into the 22nd century, even if we succeed in limiting the average temperature increase to no more than 2°C by the end of this century.

About a quarter of the world's power stations are on coasts or estuaries, including Hinkley Point in Somerset and all the reactors on the UK's east coast. Sizewell B started generating electricity in 1995. Assuming an operational life expectancy of around 60 years, and a further 40 years for decommissioning and storage of spent fuel and other wastes, that takes us through to 2095.

If the proposal at Sizewell C goes ahead, and it starts generating electricity in 2035 (however improbable that start date may be), it will still be in operation at the end of the century, with much of its spent fuel needing to be stored on site (in cooling ponds) until the middle of the next century (ie 2250) before it can be moved to whatever Geological Disposal Facility will then be in operation.

At the moment, EDF is planning a protective embankment of 10 metres at Sizewell C, designed 'to protect the power station for a one in 10,000-year storm event'. This may sound adequate until one takes into account the profoundly unstable nature of that particular coastline and of the Sizewell foreshore in particular. Indeed, there are many (including experts in the Environment Agency) who believe that Sizewell C will effectively be cut off from the mainland within the next hundred years. Trying to assess the geological and financial implications of protecting such an exposed facility against rising sea levels and storm surges, through to 2250, seems completely futile. After everything we've learned from the disaster at Fukushima, the word 'hubris' seems peculiarly apposite.

Rising sea levels is just one of the many shocks that accelerating climate change has in store for us through the rest of this century. The nuclear industry will need to cope with much more than that. How will reactors in Pakistan or Abu Dhabi (or any new reactors in Saudi Arabia) be kept cool when temperatures exceed 50°C, simultaneously raising the temperature of the seawater needed for cooling? How will inland nuclear plants be kept cool at times of prolonged drought, causing rivers to dry up – as has already happened on a number of occasions with the nuclear reactors located along the Loire in France? Multiple risk factors abound as more and more climate extremes kick in.

D2. A just transition?

One of the most profound shifts in the last couple of years in the debate about The Climate Emergency has been the recognition that the now inevitable transition away from fossil fuels towards a Net Zero carbon world has to be a <u>just</u> transition – ensuring that those already disadvantaged by the structural inequalities of today's model of neoliberal capitalism are not further disadvantaged as we exit the era of fossil fuels. Politicians disregard this imperative at their peril: President Macron has never quite recovered from his inept and insensitive imposition in 2018 of higher fuel prices on millions of people least able to cope with those higher costs, bringing les gilets jaunes onto the streets of many French cities and towns.

In that regard, it's encouraging that a new body has been set up here in the UK (the Getting to Zero Commission) to investigate ways of ensuring that no community 'should be left behind'. New research from a think tank called Onward has warned that up to 10 million jobs will need to be replaced or retrained as part of the Net Zero transition[27], even as 1.7 million new 'green collar' jobs could be created by 2030 if the Government implements the recommendations of the Climate Change Committee regarding its Sixth Carbon Budget.

It's mystifying to me why ministers remain so enthusiastic about supporting nuclear in this context. As is the case with fusion energy (see page 25), throw enough money at something (in that case, £87,500 per job created) and there will undoubtedly be some beneficial economic outcomes. The Government appears to be terminally muddled about this issue of low-carbon jobs: its support for offshore wind is very welcome, in terms of the new jobs that will be created, but its continuing refusal to seize hold of the most inclusive, job-intensive elements of a wider Green New Deal makes no sense at all (see below).

I honestly can't imagine how any caring, empathetic environmentalist could still see the nuclear option as still having any part to play in a genuinely just transition, for the following reasons.

D2.1 More expensive electricity

Let me spell this out for environmental campaigners concerned about social justice: every kilowatt-hour of new nuclear-generated electricity delivered to consumers will be a more expensive kilowatt-hour than a kilowatt-hour delivered from renewables plus storage. That will obviously end up reflected in the prices consumers pay, including around 2.5 million households in England (roughly 10%) living in fuel poverty.

Every time I hear people like Tom Greatrex assert that nuclear power should still be contributing around 20% of the UK's total electricity supply in the future, my first thought is that one-fifth of each and every consumer's electricity bill would at that time be costing them considerably more than it should. I find it particularly indefensible that this 'nuclear tax' would be borne by some of the most disadvantaged citizens in the UK today – without the first idea on their part as to why this injustice is allowed to continue.

It's important to return here to the actual methods for paying for new nuclear, either through the insane subsidies being provided for Hinkley Point C, or through the RAB proposal for Sizewell C (see page 4). The Government published a document on this alongside its Energy White Paper at the end of last year, which was wilfully opaque in indicating exactly how it will take forward negotiations with EDF. It also included the statement that 'cost overruns that were not excluded from the Regulated Asset Base would be shared between investors and consumers'. To all intents and purposes, this sounds like another blank cheque for EDF once the inevitable cost overruns kick in – and I say 'inevitable' as no nuclear power plant already constructed or under construction in the 20th century has avoided such penalties for additional costs through overruns.

D2.2 Fewer jobs

Post-COVID, we're going into a period of high unemployment and prolonged economic hardship – especially for young people. From the point of view of a genuinely just transition, it's crucial that the route we choose to get to a Net Zero economy by 2050 maximises opportunities for good, properly remunerated work. In that regard, nuclear has relatively little to offer.

As of now, the Government's principal response to the pandemic has been to protect existing jobs and businesses. Very little money has been forthcoming to create new jobs – even as unemployment inevitably starts ratcheting up. As laid out in Section C above, a multi-year programme to address the 20% of the UK's greenhouse gas emissions from existing buildings would be by far the most labour-intensive investment the Government could make, especially if it was done in conjunction with local authorities and the metro Mayors.

For instance, the UK100 Resilient Recovery Task Force, a group of 24 Mayors and local leaders, published a report with Siemens in July last year, showing how a pump priming from Government of £5bn could unlock £100bn in sustainable energy projects through to 2030, creating tens of thousands of jobs in the process.[28] As already mentioned, the most articulate analysis of the potential here has been advanced by the original Green New Deal group, with an emphasis on 'jobs in every constituency', and a potential to create up to 120,00 jobs over the next two/three years:

> 'A huge number and range of jobs are required to install, service and update this massive retrofitting programme. The roles needed include plumbers, electricians, carpenters, builders, solar PV roof fitters, engineers, building scientists and researchers. To ensure local expertise,

safety and community acceptability, the involvement of local authorities, unions and neighbourhood groups will be vital.'[29]

All this would obviously need to be accompanied by a national skills and training programme, coordinated through FE and technical colleges.

The Institute for Public Policy Research has analysed the potential for new jobs through to 2030 in its paper on 'Transforming the Economy after COVID-19'.[30] In the area of low-carbon housing, it estimates that energy efficiency retrofits of homes could generate 234,000 jobs, expansion of social housing through low-emission homes could generate 240,000 jobs, and investing in low-carbon heating could support 60,000 jobs during construction and 44,000 jobs in installation. This would have an especially beneficial impact in the North of England.

If Boris Johnson is serious about 'levelling up', it's hard to think of a more effective way of doing just that in a relatively short period of time. Instead of banging on about the notional 10,000 construction jobs that would theoretically be created at Sizewell C, in due course, with both good and bad impacts in one very particular local area (as has already been experienced in Somerset throughout the Hinkley C construction process), he seriously needs to raise his sights when thinking about 'Building Back Better'. Beyond the construction phase, it is estimated that there will be 900 long-term jobs at Sizewell C. With an investment of £20bn (and possibly a lot higher) that works out at £22m per job created.

Anyone who examines these two scenarios (jobs via investment in nuclear versus jobs via investment in low-carbon housing) must come away astonished at the idea that 'nuclear power' and 'a just transition' could ever be uttered in the same sentence. Which makes the pro-nuclear advocacy of certain trade unions especially repugnant, as they self-interestedly protect the relatively small number of jobs of their relatively well-paid members in the nuclear industry at the expense of an infinitely fairer distribution of work and rewards that would benefit millions of people. Especially young people.

D2.3 Waste: an intergenerational injustice

The vast majority of environmentalists I've known and worked with over 45 years are passionate about the concept of justice between generations as well as justice within each generation. We all hang on to that original definition of sustainable development in the 1987 Brundtland Report: 'Sustainable development is development which meets the needs of the present population without compromising the ability of future generations to meet their own needs'.

However, the simple truth of it is that anyone who continues to support nuclear power has, in effect, set aside that concern about intergenerational justice. I've already itemised some of the massive costs associated with the processing and storage of nuclear waste, and the ongoing liabilities regarding the decommissioning of nuclear reactors, imposing legacy costs to the tune of countless billions of pounds. Young people today, as future taxpayers, will bear those costs, as well many generations in the future.

From that perspective, hyperbolic claims that nuclear power has a significant role to play in meeting the Sustainable Development Goals, on a global basis, are particularly offensive.

D3. Nuclear power/nuclear weapons

The vast majority of people who describe themselves as 'environmentalists' also subscribe to the idea that the future of humankind would be more secure in a world without nuclear weapons than in our

world today, where those nations with nuclear weapons command between them a combined inventory of 13,000/14,000 nuclear warheads.

That does not necessarily mean environmentalists endorse the idea of 'unilateral disarmament' (as I do personally, as a member of CND for more than 40 years), but it does mean they would like to see our Government actively engaged in multinational initiatives to rid the world of the threat of nuclear war – initiated either by intent or through miscalculation or accident.

Such sentiments have been reinforced by the new Treaty on the Prohibition of Nuclear Weapons, brokered by the UN over the last three and a half years. In January this year, the Treaty entered into force after ratification by 50 member countries. The Treaty proscribes any activities designed to 'develop, test, produce, acquire, possess, stockpile, use or threaten to use nuclear weapons', with the ultimate goal of eliminating all nuclear weapons. Regrettably, no nuclear-armed country has expressed support for the Treaty, and both the USA and Russia have explicitly opposed it, with the UK and France also declining to have any involvement on the grounds that the Treaty was 'incompatible with the policy of nuclear deterrent'.

Whatever one's views about this, some environmentalists may still be taken aback to discover that 'the case for nuclear power in the UK' is in fact underwritten by the need to maintain the UK's nuclear weapons capability. Taken aback, simply because the nuclear industry in the UK has spent decades trying both to disavow its origins (in the production of plutonium in the UK's first nuclear power station at Calder Hall), and subsequently to deny any continuing interdependencies between the UK's nuclear weapons capability and our current civilian nuclear energy programme. Any suggestion that there is a continuing and <u>inseparable</u> link has been forcefully rejected over the last 50 years.

Interestingly, that is not the position of the nuclear industry in either the USA ('a strong domestic supply chain is needed to provide for nuclear Navy requirements. This supply chain has an inherent and very strong overlap with the commercial nuclear energy.' Ernest Moniz, former Energy Secretary, 2017) or indeed in France, where politicians have explicitly and consistently acknowledged these interdependencies. President Macron was enthusiastically emphasising the critical strategic links between France's nuclear deterrent and its nuclear power industry as recently as December last year ('to oppose civilian nuclear and military nuclear in terms of production and research, does not make sense for a country like ours. Without civilian nuclear, no military nuclear; without military nuclear, no civilian nuclear.' Emmanuel Macron, December 2020.)

In reality, those links are just as strong here in the UK as they are in France and the USA. Indeed, as a matter of record, they've been publicly acknowledged by the defence industry, even as the nuclear energy industry has strained every sinew to deny any such interdependency. One might almost conclude that there's a conspiracy of silence on this. Only very rarely do Ministers break ranks as with this statement from Richard Harrington, Under-Secretary of State at BEIS in 2018: 'I want to include the Ministry of Defence more in everything we do … it is time that the artificial distinction (between civil and military nuclear) came to an end, and I will do my absolute best to bring that about.'

Given that the objective case for nuclear power in the UK is so weak, one is therefore encouraged to look to those interdependencies for our Government persisting so obstinately with nuclear power: the need to ensure a 'talent pool' of nuclear engineers; to support a supply chain of engineering companies capable of providing component parts for the nuclear industry, both civilian and military; to facilitate a network of investors still prepared to invest in generic 'nuclear skills and competencies', regardless of whether that serves military or civilian purposes.

All underpinned, of course, by the UK's increasingly desperate post-colonial determination to maintain its role in the world as a geopolitical power-broker, including our membership of the club of nuclear nations. Our exit from the EU will no doubt exacerbate these 'great power delusions'.

The indefatigable work of Andy Stirling and Phil Johnstone at Sussex University's Science Policy Research Unit has established the depth and intensity of these interdependencies, demonstrating how the UK's military industrial base would become unaffordable in the absence of a nuclear energy programme. What this means is that our nuclear weapons programme is being significantly supported outside the defence budget without public scrutiny, and entirely off the public books.[31] The cost of these hidden subsidies fall on all UK nations, including Scotland, where nuclear power is strongly opposed.

I only became properly aware of these symbiotic linkages as Chair of the Sustainable Development Commission between 2000 and 2009, reporting directly to the Prime Minister, Tony Blair. The Commission contributed substantively both to the 2003 White Paper ('Our Energy Future: Creating a Low-Carbon Economy') which deemed nuclear power to be 'unattractive', and to the consultation leading up to the 2007 White Paper ('Meeting the Energy Challenge'), which waxed lyrical about the idea of a 'nuclear renaissance'. From the point of view of energy policy, nothing in those intervening four years had changed in such a way as to justify such a complete about-face. From a defence perspective, however, the looming costs of having to renew Trident in order to maintain our 'continuous-at-sea-nuclear-deterrent' were already becoming a major concern to the Ministry of Defence.

Those concerns were well justified. In July 2016, the decision to renew the Trident programme was confirmed in Parliament, with the Government indicating likely costs of £30bn for four new submarines, £4.5bn for new warheads, and an additional £10bn for 'contingencies'. Subsequent analysis has indicated that at least £145bn will be required to operate that deterrent capability during its lifetime (including significant infrastructure upgrades), and a further £13bn for decommissioning the submarines at the end of their operational life. All in all, around £200bn – before taking into account the absolutely inevitable cost overruns – imposing an astonishing burden on UK taxpayers far into the future.

Even these estimates may now be understated. In March this year, the Government's 'Integrated Defence, Security and Foreign Policy Review' announced that the UK would be increasing its stockpile of nuclear warheads from 180 to 260, without presenting any evidence that might justify such a massively damaging decision.

One interesting point: the Review unequivocally confirms the interdependencies between civil and defence interests: 'We will work collaboratively across the defence and civil nuclear sectors to optimise the Defence Nuclear Enterprise for the future.'[32]

There's a particular irony at work here in the UK. Our national security depends, we are told, on maintaining our notionally 'independent' nuclear weapons programme – even though we are in fact entirely dependent on the USA. That programme depends, it is now clear, on continued investment in a nuclear power programme to maintain a generic nuclear skills base. That programme depends, as has become painfully apparent over the last few years, on collaboration with China through the wholly-owned CGN (see page 9). And there are many, in the defence and security establishment today, who see China as a highly significant threat to the UK's national security.

E: 'BUT WON'T NEW TECHNOLOGY SORT ALL THIS?'

E1. Small Modular Reactors

The energy/weapons linkage is particularly clear when it comes to the current spasm of excitement about Small Modular Reactors. Rolls-Royce is the most important private sector company involved in the consortium that came together last year to make the case for SMRs with Government Ministers and advisers. Back in 2017, Rolls-Royce issued a brochure with the following comment: 'The expansion of a nuclear capable skilled workforce, through a civil nuclear UK SMR programme, would relieve the Ministry of Defence of the burden of developing and retaining skills and capability.' Nothing like spelling it out!

Rolls-Royce is an iconic British company, and, along with the rest of the aviation sector, is in dire financial straits because of COVID. Keeping it afloat is a top priority for both BEIS and the Ministry of Defence – and punting around £250m into an SMR programme (as announced in the Prime Minister's Ten Point Plan in November 2020) is as good a way of doing this as any other. Rolls-Royce will get a fair slug of this £250m, simultaneously supporting it in the business of building reactors for future nuclear submarines.

In a way that has become standard for all 'nuclear renaissance' announcements, the level of hype around SMRs keeps on ratcheting up. We're now told that industry partners will be putting in around £300m alongside the Government's £250m; that a prototype will be ready by 2029, creating 6,000 jobs over the next five years; that this prototype will be delivered at a bargain basement cost of £2.2bn; that it will be the first of a programme of 16 SMRs rolling off a production line at two a year, delivering electricity at between £40/MWh and £60/MWh (quick time out here to remind readers that offshore wind is already at £39.50/MWh); that this will earn the UK economy more than £50bn, and will in time create a massive export potential of around £250bn, creating 40,000 jobs over 15 years.

Smoke and mirrors come to mind here! The reality is that there's no design available as yet, even though the Government has already invested £18m in producing such a design. There are no agreed sites for deployment. There's nothing on the order book, including from our own Government, for all its warm words. Without the Government guaranteeing an order book of up to 16 SMRs, it's highly unlikely that Rolls-Royce will even complete the design phase, let alone start investing in such an ambitious production line. And there's no recognition in these discussions that the economic case for SMRs only works if it's possible to use the waste heat from the electricity generation process – meaning that they would need to the sited near urban areas or industrial parks. Fat chance of that here in the UK.

This is now a rapidly evolving area of interest. The US company NuScale received design approval for its SMR design in September 2020, and earlier this year signed a Memorandum of Understanding with UK-based Shearwater Energy to develop a hybrid SMR/wind facility to produce green hydrogen (see below). However, it is still not licensed for construction after the US Nuclear Regulatory Commission identified a number of safety concerns – all this after an investment of nearly $1bn over the last two decades!

Critics are increasingly challenging the deliberately manipulative use of the word 'Small'. Rolls-Royce's SMRs are not small. With a projected capacity of 440MW, they're actually bigger than our former Magnox reactors, which will make planning permission as complex and drawn out as planning for big reactors.

No wonder the terminology is now gradually morphing into Advanced Nuclear Reactors (which will apparently use 'novel cooling systems and fuels') rather than Small Nuclear Reactors – with a further £170m promised by the Government for R&D in this area. But so much of the over-excited hype around Advanced Nuclear Reactors has yet to be exposed to proper independent scrutiny. A preliminary

analysis carried out by the Union of Concerned Scientists in March this year looked at safety, efficiency, waste generation and proliferation/terrorism issues, and came to the conclusion that the current designs under consideration 'do not offer obvious improvements significant enough to justify their many risks.'[33]

E2. Fusion

According to the UK Atomic Energy Authority, the Government invested roughly £350m in fusion technology in the decade leading up to 2019, creating 4,000 full-time equivalent jobs – at roughly £87,500 of public money per job created.

In the Government's new Energy White Paper ('Powering our Net Zero Future'), published in December last year, the Government affirmed what was initially an off-the-cuff, somewhat wild-eyed promise from Boris Johnson 'to build a commercially viable fusion plant by 2040', in the fond hope that the UK will become 'the first country in the world to commercialise fusion energy technology'. The price tag for this starts at £400m: £220m for the new STEP programme (STEP standing for 'Spherical Tokamak for Energy Production'), and a further £180m for new fusion facilities, infrastructure and apprenticeships.

Make what you will of this latest bold/foolhardy endeavour to track down the holy grail of nuclear technology: a fusion-inspired dream that has obsessed nuclear engineers since the 1950s.

E3. Green hydrogen

We see the same kind of hype around the idea of 'green hydrogen from nuclear power', using the electricity from next generation SMRs or AMRs to produce 'near-zero-carbon hydrogen' for use in our gas grid or in carbon-intensive, hard-to-abate sectors like steel production or shipping. Or even, in due course, aviation.

Like many environmentalists, I'm cautiously enthusiastic about green hydrogen, and warmly welcomed the Government's commitment in last year's Energy White Paper to support the UK's rapid expansion in the UK's hydrogen production capacity using electrolysis, with a commitment to generate 5GW of green hydrogen by 2030.

But to keep this in perspective, let's just remind ourselves that hydrogen as we know it today is the very opposite of a green fuel – despite the Government's efforts to badge it as a 'clean energy technology' in the 2020 Energy White Paper. 98% of the 115 million tonnes used globally (primarily in refining and chemicals) is either 'brown hydrogen' (from the gasification of coal) or 'grey hydrogen' from natural gas, between them emitting around 830 million tonnes of CO_2 – 2% of total global greenhouse gas emissions! As to the remaining 2%, there's a tiny amount of so-called 'blue hydrogen' – essentially grey hydrogen but with those CO_2 emissions captured and stored – with the rest made up of green hydrogen from electrolysing water, both of which are much more expensive than the climate-wrecking brown and grey hydrogen.

The gulf between that current reality (rarely mentioned by hydrogen enthusiasts) and the prospect of readily available and affordable green hydrogen is absolutely vast. We need to bear that in mind even as we welcome efforts to bridge that gulf, including the Hydrogen Council (which anticipates investment of around $300bn over the next decade) and the newly-launched, UN-backed Green Hydrogen Catapult (involving a number of big companies to halve production costs whilst massively increasing global production up to 25GW by 2026, with investment of more than $100bn), and the UK's 'Hydrogen Strategy Now' consortium set up in November last year, with talk of pumping £3bn into a UK-wide hydrogen economy.

Existing nuclear-generated electricity will self-evidently play no part in these so-called 'hydrogen moonshots' – other than through the contribution existing nuclear power makes to the current grid average. Given that any new nuclear electricity will always be significantly more expensive than electricity from renewables + storage, it's hard/impossible to see that green hydrogen + nuclear is some kind of match made in heaven. And the truth of it is that one needs a lot of electricity to produce not a lot of hydrogen – which makes pipe-dreams about substituting hydrogen for conventional gas in the UK's gas grid, or of producing millions of tonnes of blue hydrogen, look entirely insane.

Decarbonising shipping, steel production and the manufacture of cement should be the priorities for green hydrogen. In the meantime, hydrogen enthusiasts should be ruthlessly focused on decarbonising existing hydrogen production – and eliminating those 830 million tonnes of greenhouse gas emissions.

F. TELL THE TRUTH

F1. Beware the 'repentant environmentalists'

As will be recognised by most environmentalists deeply concerned about climate change, 'Tell the Truth' was the mandate painted on the side of the boat used by Extinction Rebellion to blockade Oxford Circus in the first of their major protests in 2019. It correctly identified the problems caused by politicians (and even by some scientists) refusing to inform citizens of the true nature of the Climate Emergency.

But it's a mandate that should be extended to every single major player in the field of sustainable energy – and pre-eminently to the nuclear industry. Tracking all the way back to its origins in the 1950s, with the electricity it generated at that time nothing more than a by-product of the production of plutonium that justified those early investments, this is an industry that still finds telling the truth almost impossibly difficult. Few if any of the problems faced by the industry, as laid out in Section B, and few if any of the alternatives, as laid out in Section C, are ever mentioned by its representatives.

They never provide accurate cost estimates. They never fess up to the problems they're facing until forced to by independent commentators. They never provide truthful accounts of the times when things go wrong. And they never acknowledge their continuing dependence on the UK's obsession with retaining its notionally independent nuclear deterrent capability.

So why, I keep asking myself, would any environmentalist concerned about the truth, in this inside-out world of fake news, vested interests, mainstream media manipulation and politicians hopelessly marooned in yesterday's received wisdom, give any credence whatsoever to the latest confection of hyperbole, half-truths, outright lies and amnesiac recollection on which the nuclear industry depends?

But they do. And the nuclear industry loves them for it. They're particularly dependent on a motley consortium of pro-nuclear NGOs to do some of the heavy lifting in lobbying within the EU. Over the course of the next few months, the EU has to confirm whether or not it will permit subsidies for nuclear power as part of its low-carbon transition strategy – which many Member States are pushing for. Without those subsidies, the steady decline of the industry in the EU will continue inexorably.

In April, a group of 46 NGOs from 18 countries (27 of which are from within the EU) wrote to Ursula von der Leyen, President of the European Commission, calling for the inclusion of nuclear energy in the EU's so-called 'taxonomy' for sustainable investment. Many of these NGOs are simply a front for the industry itself, representing some classic astroturfing at its worst.

Judging by the websites of 'Greens for Nuclear' or 'Nuclear for Climate', by far the largest percentage of pro-nuclear Greens end up in that position, as I've already said, because they can't see any way of getting to a Net Zero world without it. They're in no doubt about the intensity and urgency of the Climate Emergency, and deeply critical of any residual shade of denialism or what is sometimes described as 'luke-warmism' – as in 'OK, you greenies may have been right all along about the science of climate change, but let's not get carried away and risk damaging the global economy by moving to address that state of affairs too quickly.'

It's clear to me that some pro-nuclear environmentalists have indeed done their homework, are simply not persuaded by the renewables/storage/efficiency/smart grids alternative paradigm, and have therefore come to the conclusion that nuclear simply has to be part of the mix – at whatever cost to consumers today and to future generations tomorrow. These are complicated, morally vexatious judgement calls, and one has to acknowledge the thoughtful and responsible approach that has moved some 'Greens for Nuclear' into that position.

However, beyond that, there are many who have not done their homework. Who clearly enjoy the mantle of 'the repentant environmentalist', as people emerging from the ideologically corrupted prejudices of the Environment Movement to stand in the bright light of a newly-revealed nuclear truth. Part of the deal for those 'moving over to the nuclear side' is to disparage all those benighted greenies still unsighted as to the wonders of nuclear power – as Zion Lights, the UK Director of an organisation called Environmental Progress (see below) so regularly does, seeking at every turn to discredit the work of Extinction Rebellion for whom she was briefly a member of its media team. These more impressionable and self-publicising converts are not too fussy about where the money comes from to support their new-found nuclear enthusiasm.

It's a short step from there to becoming a fully paid-up, pro-nuclear lobbyist, part or wholly funded by right-wing, climate-denying extremists, with the enthusiastic support of the Murdoch press or Fox News. In this regard, Michael Shellenberger remains 'primus inter pares', as founder of the Breakthrough Institute in 2007 and latterly of Environmental Progress – acting as the sales arm for his new book, 'Apocalypse Never: Why Environmental Alarmism Hurts Us All'. This book was launched in June last year, with a classic repentant's line: 'on behalf of all environmentalists, I apologise for the climate scare', offering further reassurance by arguing that 'the Netherlands became rich, not poor, while adapting to life below sea level'.

I find it hard to imagine what the well-meaning founders of Greens for Nuclear must make of this most extreme of all luke-warmists – now that he's recanted on his earlier outright denialism. And how they must react to Shellenberger's explicit enthusiasm for making the links between nuclear weapons and nuclear power. Back in 2018, Shellenberger argued that the world is in fact a much safer place because of nuclear weapons, and how it would be safer still if more nations had access to those weapons, even in the Middle East. And given that nuclear power programmes provide the best 'gateway technologies' to developing such weapons capabilities, he acknowledged that 'national security, having the weapons option, is often the most important factor in a state pursuing nuclear energy'. As if that pro-proliferation, nukes-for-all stance wasn't bad enough, he went on to rub it in further by asserting: 'After 60 years of national security driving nuclear power in the international system, we can now add 'preventing war' to this list of nuclear energy's superior characteristics'.

I wonder how members of the Green Party and other 'greens for nuclear', self-confessed 'reluctant converts' to nuclear power, feel about finding themselves in bed with such an extraordinary reincarnation of Dr Strangelove?

F2. Still keeping an open mind

It's clear to me that there are some pretty 'dark arts' at work here, funding, mobilising and even coordinating a motley choir of pro-nuclear Greens in order to obscure the truth about nuclear power, to provide the media with plenty of 'mea culpa' testimonies from repentant environmentalists, and to help neutralise the growing opposition within political parties in the UK to the idea of new nuclear power stations. That's not a conspiracy theory; it's just the way the world works these days.

Ultimately, however, they're working with some pretty recalcitrant raw material – in terms of today's failing nuclear technologies and declining market share. Ultimately, the truth will out. So I obviously hope that fewer environmentalists will fall for the current wave of pro-nuclear propaganda, and will weigh the endless hype about the future against the constantly underperforming record of the present.

It would therefore also be good to see the UK's Environment Movement much more on the front foot in combating the resurgent propaganda campaigns from the nuclear industry. Most of the heavy lifting here is being done by a handful of under-resourced but extremely effective local groups: Stop Hinkley, which continues to hold EDF to account for every single aspect of the ongoing construction of Hinkley

Point; TASC (Together Against Sizewell C), assiduously highlighting the lack of credibility in EDF's proposals for a new power station at Sizewell C, with the RSPB now lending its weight to the campaign; and the anti-Bradwell BANNG (Blackwater Against New Nuclear Group) , which has done a brilliant job in winning strong support from local authorities, communities and businesses. Local groups at Wylfa (People Against Wylfa-B) and Oldbury (Severnside Together Against Nuclear Development) have also been highly influential in resisting plans from the Horizon Consortium for new reactors, and have been greatly heartened by Hitachi's decision in February to wind down Horizon once and for all. (See further contact details in the Appendix.)

Above all, one thing I hope I've been able to demonstrate is that 'new nuclear' (both big nuclear power stations, as proposed at Sizewell C, as well as SMRs, AMRs or fusion) has either a zero or, at best, a minimal contribution to make to the UK's target of achieving a Net Zero economy by 2050. That's not in dispute. As already mentioned, EDF itself has acknowledged that if Sizewell C does come on stream in 2035 (which seems improbable given its current construction track record with the EPR reactor design), it will then take 15 years of generating low-carbon electricity to 'pay off' all the CO_2 emissions involved in its construction. The Government knows that. It also knows that the likelihood of a completely new generation of SMRs/AMRs being in commercial operation before 2050 is not impossible, but it is extremely unlikely.

So shouldn't everyone in the environment movement just accept that reality, and double down on the only realistic strategy we still have for getting to Net Zero by 2050? And in so doing, celebrate the prospect of the enormous economic and social benefits that will flow from a policy and investment framework finally decluttered of any lingering nuclear fantasies.

In other words, Net Zero without nuclear.

APPENDIX

LOCAL GROUPS/NATIONAL ORGANISATIONS

Blackwater Against Nuclear Group (BANNG)	www.banng.info/
Bradwell B Action Network (Bradwell BAN)	https://bradwellban.com/
Campaign for Nuclear Disarmament	https://cnduk.org/
Friends of the Earth (England, Wales and Northern Ireland)	https://friendsoftheearth.uk/
Friends of the Earth (Scotland)	https://foe.scot/
Greenpeace	https://www.greenpeace.org.uk/
No2NuclearPower	https://www.no2nuclearpower.org.uk/
People Against Wylfa-B (PAWB)	www.stop-wylfa.org/
Scottish CND	https://www.banthebomb.org/
Severnside Together Against Nuclear Development (STAND)	www.nuclearsevernside.co.uk/
Stop Hinkley	www.stophinkley.org
Together Against Sizewell C (TASC)	https://tasizewellc.org.uk/

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Andy Stirling
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David Toke
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