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Q1. Dr Dorfman, let's start with nuclear: many supporters of nuclear keep saying that nuclear is the solution to the energy transition. Is it true? If so, to what extent could it contribute to the objectives of the European Green Deal and the "Fit for 55" package? If not, why?

Recent Oxford University research states renewables are comfortably the cheapest and most effective form of electricity production and CO2 mitigation, with University College London (UCL) concluding that "the current favourable UK Government policy towards nuclear is becoming increasingly difficult to justify."

And the nuclear waste problem has not gone away - according to the former Chair of the UK Nuclear Decommissioning Authority, "nuclear disposal cost is enormous, with no certainty they will perform the long-term task required ... These considerations sadly receive little attention in current debates about new nuclear-generation capacity," with the head of operations at Sellafield's nuclear waste storage noting that the decommissioning programme is "laden with assumptions and best guesses".

Not forgetting the nuclear experience 'par example' in France. With more than half of EDF's nuclear fleet off-line with key safety problems in 2022, EDF are in deep trouble - essentially bankrupt. €64 billion in debt, reporting a record €19 billion loss this year, with exponential radioactive waste and decommissioning costs on the horizon. With an estimated €50-100-billion bill for reactor safety upgrades, French

President Macron is now forced to fully nationalise the ailing and failing nuclear corporation.

With just these opening facts in mind, stuffing vast sums of public money into the deep pockets of nuclear corporations just doesn't seem to make any sense. This is because, as Prof Andy Stirling says, in terms of cost, time, and do-ability, it's "renewable expansion in all sectors, energy management and efficiency, rapidly advancing storage technologies, grid modernisation, interconnection, and market innovation from supply to service provision" that will power our shared net-zero energy transition.

Q2. Followers of nuclear power, who readily engage in public or social discussions in defense of this technology, say that "100% renewable fantasies in industrialized countries with tens of millions of inhabitants do not work", or even that "without nuclear investments, achieving a sustainable energy system will be much more difficult," quoting an IEA report from 2019. Or, about the fourth generation nuclear: "meanwhile we wonder if there is the 4th generation in the world there are already reactors in the network cooled by helium at high temperature and sodium reactors that close the fuel cycle use mox". As an expert, what can you answer, synthetically?

The International Energy Agency's World Energy Outlook 2022 report concluded that "renewables are the most important way to reduce CO2 emissions in the electricity sector," from a vastly expanded grid to electrify heating, transport, and industry.

Nuclear will only be only marginal - perhaps because, as Lazard (one of the world's leading financial services) notes, whilst nuclear-levelised cost of electricity is $151 per MWh, renewables come in at just $41 per MWh. All this, because utility-scale renewables can be built on time and to budget.

In terms of new designs, as Stephanie Cooke (former Editor, Nuclear Intelligence Weekly) concludes: "advanced reactor designs now under development are tweaked versions of older ones that failed when they were tried in the early days of atomic energy - notably, for example, fast neutron reactors. Fast reactors, cooled by sodium, were particularly vulnerable to fires. They could not work without continuous reprocessing of used fuel, which proved expensive and increased the risk of proliferation. Commercial versions later developed in France were a disaster. None of these reactors is expected to operate this decade."

Meanwhile, with the rhetoric for small modular reactors (SMRs) ramping, Prof Steve Thomas notes that whilst, "the claims being made for SMRs will be familiar to long-time observers of the nuclear industry: costs will be dramatically reduced; construction times will be shortened; safety will be improved; there are no significant technical issues to solve; nuclear is an essential element to our energy mix," in the real world, "such claims have proved hopelessly over-optimistic and there is no reason to believe things would turn out differently this time. Indeed, the nuclear industry may well see itself in the 'last-chance saloon'. The risk is not so much that large numbers of SMRs will be built, they won't be."

Prof Thomas concludes, "the risk is that, as in all the previous failed nuclear revivals, the fruitless pursuit of SMRs will divert resources away from options that are

cheaper, at least as effective, much less risky, and better able to contribute to energy security and environmental goals. Given the climate emergency we now face, surely it is time to finally turn our backs on this failing technology?"

The 'clincher', for Prof Mark Jacobsen, is that "we face a humongous crisis not only in terms of climate but air pollution and energy security … requiring immediate and drastic solutions. Any technology that takes 10 years between planning and operation is really no solution at all." Here. It's important to realise that for SMRs and advanced reactors, 10 years is just yet another significantly optimistic nuclear forecast.

The fact is, new nuclear is just too late, just too slow to help us with our shared climate and energy crisis – taking valuable time and resources from the proven technology we have, here and now, which can and will drive the global energy transition.

Q3. Recently, Mark Jacobson, Professor of Engineering and Director of the Stanford Atmosphere/Energy Program, has conducted a study that states, in brief, that it is possible by 2050 to reach 100% renewable in the energy mix, ensuring energy security, without thinking about other technologies (nuclear, biofuels, CO2 capture and storage). Which is also the trend that IPCC and UNEP (just to name two of the most authoritative sources on climate change) are outlining in their reports. According to you is that really possible?

A hard-hitting article in the UK Guardian broadsheet newspaper writes, "after a 10,000-year journey, human civilisation has reached a climate crossroads: what we do in the next few years will determine our fate for millennia." Timescale is key - we are, in effect, now playing for time. In this context, any window for nuclear has just slammed shut - we just don't have time.

The fact is, the most recent IPCC AR6 report makes clear that renewables, solar and wind are still our best bets for deep, rapid and low-cost emission cuts - offering nearly ten times the emission cut potential than nuclear, and 20 times that of carbon capture. Defying a global energy crisis and supply chain issues, the global renewable generation capacity soared in 2022, growing by 295GW to reach 3,372GW.

Energy storage hit another record year in 2022, adding 16 GW/35 GWh of capacity, up 68% from 2021. The deep, rapid and sustained cuts in greenhouse gas emissions which the IPCC AR6 reports says are essential to avert a climate catastrophe can only be achieved if we accelerate the transition to clean renewable power.

Not forgetting the lowest hanging fruit of energy efficiency and management. Reducing the overall energy demand is at the heart of a fair, affordable, and sustainable net-zero. The UK Centre for Research into Energy Demand Solutions has done the most comprehensive assessment to date, and it turns out that all our energy use can be hugely reduced, whilst maintaining energy security and quality of life.

Q4. Many critics of sceptics or opponents of solar and wind keep claiming that these technologies have problems of discontinuity in energy production.
In your experience, are these problems real? If so, how can they be resolved so that in Europe and the rest of the world they can reach 100% of the energy mix?

As for the idea that renewables are too variable to hack it, McKinsey (leading international consultants to governments, corporations and institutions) say renewables are on track to dominate new electricity supply for global energy markets. Nuclear isn't just slow and expensive, but too inflexible to go up and down with the swings of demand. The variability of wind and solar technologies are far more easily integrated into evolving flexible electricity grids.

Whilst nuclear claims it can 'load-follow' (power up and down to back up renewables) – as the UK Parliamentary Office of Science and Technology reports: 'Nuclear stakeholders claim existing reactor types can, to a limited extent, moderate generation to match demand depending on the reactor type. However, this has not substantially been observed in practice.'

Here, it's important to recall that the former head of UK National Grid said that "baseload is an obsolete concept". This is because, as Prof Amory Lovins notes, "modern grids are base cost, with renewables cheapest to dispatch and everything else following the net load that's left over. Whilst variable output is a challenge, it's not new nor hard to manage, and operating a grid always involves managing variability of demand at all times. Variability and flexible renewables can reliably serve steady loads and have the lowest operating cost."

To pick a much tougher case, "'Dunkelflaute' or 'dark doldrums' of UK and European winters are often claimed to need significant battery storage for an all-renewable electrical grid. But experience shows that grid operators find Europe needs only one to two weeks of renewably derived backup - not a huge challenge. The bottom line is that electricity grids can deal with much larger fractions of renewable energy at modest cost, and this has been known for quite some time."

The reality is, it's entirely possible to sustain a reliable electricity system based on renewable energy.

Q5. *Let's close where we started: nuclear. Is there a safe nuclear today?*
Which risks exist today and what potential environmental threats are there today?

Nuclear reactors, which need cooling and discharge, are located by the coast or rivers, large bodies of water. The key problem is this: Nuclear infrastructure, whether coastal or inland will be one of the first and most significant climate casualties.

The unfortunate truth is that Greenland's glaciers are melting 100 times faster than estimated, which means that coastal nuclear will be at ramping risk from sea-level rise driven storm surge flooding. As the UK Parliamentary Office of Science and Technology recently notes: "Climate change has been highlighted as increasing the investment risk profile of nuclear.... The coastal location of nuclear power stations makes rising sea levels and storm surge flooding a future risk that will need to be considered."

The U.S. Nuclear Regulatory Commission (NRC) say 55 U.S. nuclear sites have already experienced flooding hazard beyond design-base. And the U.S. Army War College states that nuclear power facilities are at high risk of temporary or permanent closure due to climate threats – with 60% of U.S nuclear capacity vulnerable to major risks including sea-level rise, severe storms, cooling water shortages.

All this means is that coastal nuclear sites are literally on the front line of climate change, and not in a good way - with the UK Institute of Mechanical Engineers saying coastal nuclear infrastructure, may need considerable investment to try to defend against rising sea levels, even relocation or abandonment. Importantly, Sir David King, UK's former chief scientific adviser and a long- standing nuclear supporter, says new nuclear will be "very difficult to protect from flooding" due to rising sea levels.

And in terms of inland river-based nuclear, the French financial regulators, Cours des Comptes, have just concluded that "the impact of global warming on France's nuclear fleet could become critical by 2050, with three to four times more outages than today." French rivers are becoming low-flow.

So, to sum up in just one sentence: The weight of evidence shows that due to the pace, scale, economics, flexibility, sustainability and safety of the Renewable Evolution, all nuclear can do is make promises it just can't keep.