# Written evidence submitted by Dr Michael Bluck, Director of the Centre for Nuclear Engineering, Imperial College London

**Introduction**

I am the Director of the Centre for Nuclear Engineering at Imperial College, coordinating research, teaching and outreach activities in nuclear. I am also the Director of the Rolls-Royce Nuclear University Technology Centre at Imperial. In these roles I have provided advice and guidance to Government, Parliament, and industry across the whole spectrum of nuclear related issues. I am a firm believer that nuclear is an essential component of an energy system capable of achieving net-zero and maintaining energy security.

1. **What role can, or should, nuclear power play in achieving net zero and UK energy security?**

   In regard to whether nuclear *can* play a role, there are two main factors: Technological capability and timescale for deployment. As regards technology, we have had an operating fleet since 1950s. There are ~430 operating reactors globally and as such, it is a mature technology. There is a claim that nuclear is itself not low-carbon, but such views are exceptional and have been discredited. The vast body of respected work on this issue is clear: nuclear has CO2 emissions similar (or better than) renewables[1]. In regard to timing, targets to net zero have been set at 2050 or thereabouts. Critics of nuclear power have, with some justification, made the point that nuclear power takes far too long to deploy. Examples such as the European sites for EPRs give strength to this argument. That said, this does not have to be the case. France constructed ~50 reactors in a little over 15 years. Our newest operating reactor, Sizewell B (essentially a first-of-a-kind in the UK) was constructed in 7-years once the build had started. Paradoxically the build start was delayed due to a complex 5-year public enquiry hindered by the anti-nuclear lobby. It follows then that nuclear is capable of delivering net-zero and energy security, but to meet 2050 deadlines would require commitment and ambition. The criticism that nuclear deployment is too slow to address climate change, is a profound irony in this position itself has been the cause of delay. Too paraphrase others, the best time to start building nuclear was 15 years ago, the next best time is now. The target of 2050 is an artifice – we should do whatever is possible to reach net-zero as quickly as possible by any means available to us.

   The arguments for whether nuclear *should* play a role are more complex, involving considerations of effectiveness and cost. Assuming we can set aside de-growth strategies, then this a question of energy mix. Some (many in the Green Party, Friends of the Earth, etc) advocate for a renewables-only scenario and consider reaching net-zero to be simply a matter of increasing the deployment of renewable energy (RE) sources such as wind and photo-voltaics. Were this a viable solution to net-zero, it is then difficult to explain the performance of the German 'Energiewende' policy. This policy has seen huge deployment of renewables over more than a decade, yet Germany has specific CO2 emissions (gCO2/kWh) greater than that of the UK[2]. This is in stark contrast to France (heavily nuclear), which have specific CO2 emissions a fraction of the UK and Germany. The failure of RE to significantly reduce CO2 output is a result of inherent intermittency on a range of timescales and is reflected globally. There are a handful of cases where RE is integrated with hydro schemes (RE-H) but this requires the availability of appropriate natural geography (eg Norway) where hydro can act as baseload and/or storage. This is certainly not the case for the UK, where there is only one such hydro facility at Dinorwig. This is modest and unscalable in the UK. As an alternative intermittency mitigation, advocates of renewables-only scenarios propose battery technology (RE-B). However, despite leaps and bounds in battery technology, since the invention of lithium-ion technology in the 1980s, we remain orders of magnitude away from its deployment as grid storage. There is much research into new battery technologies, but none has gone beyond the lab to become the disruptive technology needed to address intermittency. Any strategy must surely be based on existing or near-term technology - otherwise it is simply a hope. In short, without nuclear, it is unclear how we could achieve net-zero even for existing electricity demand, still less for a future involving extensive electrification. Of course, net-zero is not simply about electricity generation. Most/much of our CO2 emissions arise from domestic & commercial heating, industrial process heating and transport. In principle almost all of these could be migrated to electricity (needing a concomitant expansion of generation capacity). Nuclear offers another possibility, cogeneration - where heat (direct or waste) generated by the reactor could be used to provide heat directly to the user (domestic, commercial or industrial), supplanting their current dependence on fossil fuels.

Cost is a key factor in the selection of generation technology. It would be uncontroversial to state that recent nuclear deployment appears much more expensive than RE. The latter have seen rapid cost reduction in recent years as a result of mass-production and technological development. Comparison of nuclear and RE are often based on the 'Levelized Cost of Electricity' (LCOE). By this measure, a kW of nuclear electricity appears to cost 2 or 3 times that of RE. There are two serious problems with this analysis – firstly, as discussed above, RE alone does not seem likely to provide us with a route to net-zero with any security. Secondly, the comparison is valid only with a means to address intermittency of RE. The cost of RE-B with enough generating capacity and storage so as to make generation comparable to nuclear, is many times that of the cost of nuclear alone. This is not to say that RE should not play a major role in the energy mix, it certainly should, but nuclear offers a necessary baseload to stabilize a renewables heavy grid at reasonable cost and at the moment is the only low-carbon technology available to do so. The anti-nuclear lobby claims that RE and nuclear cannot mix – that nuclear is unable to load-follow the fluctuations of a RE heavy grid. This is plainly not true (again, see France) and nuclear cogeneration can provide an additional buffer for load management.

Overall, It is notable that the significant deployment of nuclear correlates well with low CO2 emissions (France, Sweden, etc) and where nuclear is being reduced (either as a deliberate act or as a result of failure to replace ageing reactors), CO2 emissions increase (eg Germany, US and very soon the UK)

Space precludes a wider review, so I mention other possible contributors to net-zero in passing: Carbon-capture and storage (CCS) purports to retain the use of our existing fossil fuel infrastructure without the release of CO2. Carbon sequestration goes one step further and claims to enable the removal of CO2 from the atmosphere. As with many other technologies - these are pilot-scale at best and to rely on them is hope rather than strategy. Other potential renewable technologies include tidal and biomass. The former has not been deployed at any scale and there is some debate as to whether the latter is actually a form of renewable energy at all, causing significant environmental impact[3].

To summarize, in my opinion, only nuclear can currently support RE to provide energy security, grid stability and has been proven to be able to eliminate CO2 emissions from the energy system.

2. **What are the main challenges to delivering the UK Government's commitment to bring at least one large-scale nuclear project to final investment decision by the end of this Parliament?**

The construction and operation of a nuclear reactor is an activity with short, medium and long-term implications and is necessarily political, albeit with timescales beyond a single Parliament. Political will influences financing decisions (HPC was a case-in-point, where the internal politics of the then coalition Government ruled out public financing and had profoundly negative implications for the project cost). Unlike RE, one cannot sensibly 'dip your toe in' - commitment is essential. This has been done, notably in the UK and France in the past, and currently in China, for example.

The financing model is a key factor; HPC required borrowing on the open markets and has resulted in interest payments of ~40% of the total project costs. Governments can borrow at comparatively negligible cost. If we had done so (in whole or in part), it would have radically changed the headline cost of the project and hence the strike price, which at the time, appeared poor value for money. That said, in the current and likely future circumstances, this is appearing to be less of an issue. Some public investment is also likely to attract private investment, as it provides additional long-term confidence. Indeed, this appears to be the case for the potential new EPR at Sizewell (see 3 below).

Whilst the public acceptance of nuclear in the UK is and has been, historically high, the narrative is often dominated by interest groups with a largely ideological stance against nuclear energy. These include the Green Party (Wales?), Friends of the Earth, XR, etc. These groups have well developed PR machinery and despite their small membership, have, I would argue, a disproportionate influence on politics generally in regard to nuclear. (That said, there is an increasing number of members of such groups which have already reconsidered or are prepared to reconsider this position, in light of catastrophic climate change scenarios). There is much misinformation emanating from these groups and any Government intending to deploy nuclear must be prepared to embark on a transparent public information campaign to counter misinformation which will inevitably result. This issue may seem trivial - little more than arguments between technocrats and ideologues - but they have a profound impact on the public and political discourse and have played a significant role in delaying deployment in the past, resulting in increased CO2 and paradoxically reduced the chances of meeting climate targets.

3. **How important is the finance model to ensuring a successful nuclear project, and is the regulated asset base (RAB) model the best one to deliver this?**

As referred to in 2 above, the finance model is extremely important - indeed it can be a deal breaker. Where nuclear differs from fossil fuel energy sources is the disproportionate cost of construction. Much of the cost of a nuclear reactor is upfront; O&M costs and fuel is modest in comparison. This means that much of the total cost of nuclear electricity has to be spent before any revenue is recovered. The financing of a project is necessarily a strong function of risk (real or perceived). This is true for all investments, but particularly those that require large upfront investments such as nuclear. Inter alia, the finance model will reflect that risk. In terms of financial model, much depends on what the project involves. If the reactor project is based on mature technology (eg LWR), then the risk will be substantially lower than for a novel (eg Gen IV) reactor design. Indeed, the proposed Rolls-Royce SMR is an interesting midway point. SMR is considered to be an advanced technology class, but apart from being 'small', the RR SMR is a mature, low risk LWR technology. What innovation it represents is in the nature of manufacturing and construction - indeed this is typically the greater part of the project cost in the deployment of nuclear reactors. Advanced reactors (Gen IV & AMR) necessarily present considerable further risk, depending on the particular technology. They will require much R&D before they reach the point of deployment and the inherent risk must, to a greater extent, be borne by public money, although it should be noted that there is significant private backing for some of these ventures.

As I have suggested earlier, public funding to some degree, is very important, providing greater assurance to the private sector and a concomitant reduction in financial risk. The question is then, what should the balance of risk (and correspond balance of contribution) be? The higher the private sector risk during construction, the greater the financing cost (Governments borrow at much lower rates than the private sector) and this then increases the required recovery rate and hence the cost to the user - see HPC CFD as a case in point. The RAB model shifts some of the risk from the investor to the taxpayer, reducing overall financing costs and ultimately the end user cost. It is unclear what the net effect is (essentially all taxpayers are bill payers), but risk reduction for the private sector inevitably increases the chance of securing private funding and realising the deployment of nuclear reactors.

To summarise, there are two main elements to consider: How much is the Government (ie the taxpayer) willing to contribute upfront, and what is the financial risk presented to the private sector (upfront and during operation). These are interrelated and there are a spectrum of approaches. HPC, funded through CFD is one extreme - all of the risk is borne by the private sector. Indeed, it is largely unique in terms of the development of nuclear energy globally. At the other end of the spectrum are wholly public enterprises (France in the 1980s, China) and form the bulk of nuclear deployment globally. RAB sits someway between, and I think is likely the best model in the current circumstances.

**4. What practical steps can the UK Government take to support the nuclear industry in developing a range of nuclear technologies, including small modular reactors?**

Steps to support nuclear reactor technology development are dependent on the technology involved. UK designed large 'conventional' LWRs seem unlikely and are arguably not worth considering here. Non-UK large 'conventional' LWRs (eg EPR, AP1000) as are currently under construction at Hinkley Point C and potentially at

Sizewell require long-term maintenance of the existing skills base and a migration of staff from the shrinking AGR fleet to support these new reactors.

SMRs of the kind discussed in 3a which are based on mature technology require a skills pipeline, but relatively modest R&D. Government support for manufacturing capability would accelerate and aid the production of prototype and NOAK reactors. Such a programme of deployment requires scientists and engineers at all levels and would have positive impacts on GDP.

More generally, SMR/AMR and Gen IV technologies are some way off deployment and require considerable R&D before they get to the build stage and can contribute to net-zero targets.

Waste is a feature, to varying degrees, of all fission reactors. There are essentially three routes: Long-term disposal of waste in geological repositories, recycling (eg MOX), or closed-cycles using 'fast reactors' such as those identified as Gen IV. The first of these requires siting, which has so-far proven difficult, but there is no technical reason why this cannot be achieved. The latter, as stated above, are at a nascent stage (although much is known from the early history of nuclear) and require considerable R&D. That said, once developed, they would greatly reduce the quantity of nuclear waste produced overall.

**5. What would the likely cost be to the taxpayer of the UK Government supporting the development of a new nuclear power station at Wylfa?**

This is difficult to quantify, not least as it is somewhat outside of my knowledge and expertise. Build cost is clearly dependent on the nature of the reactor technology itself (see 3a, for instance). For a twin-reactor of the scale of an EPR, the total project cost is circa £25Bn for 3.2GWe based on HPC. Experience from HPC would likely lower this cost for subsequent installations, as would the RAB financing model. So-called 'NOAK' deployment has been demonstrated to reduce build costs in nuclear and in other industries. For an SMR of the kind proposed by RR the build costs are claimed to be ~£1.8Bn for 0.45GWe. The development of AMR/Gen IV technology would add great upfront R&D costs to this, simply because of the greater technological uncertainty.

The cost to the taxpayer cannot be sensibly quantified as a single number. The taxpayer is also the bill payer and costs can be attributed to either depending on the financial model, pricing and the lifetime of the reactor. For the CFD funding model used for HPC, there is essentially no cost to the taxpayer and this was its attraction at the time. Similarly, RAB insulates the taxpayer, but some risk (and possible cost) is shared between the investors and bill payers. In the case where the Government invests in a project, taxpayers become investors, bearing some risk (and reward). There are opportunities; in a future where low-carbon electricity is priced at times at a premium (likely in a renewables-heavy grid), nuclear electricity could be exported at significant profit as constraints on price only apply to UK consumers.

**6. What is the potential economic impact for Wales of a new nuclear power station at Wylfa?**

Again, quantifying the potential economic impact is outside of my expertise but depends largely on the nature of the power station deployed. Again, things may be quite different for different reactor types.

A new nuclear power station is a large industrial undertaking and constitute some of the largest building projects globally. It will, during build, provide many thousands of jobs in the construction sector and its associated supply chains. Once operation begins, there will be some ~2000 skilled jobs created, guaranteed for the lifetime of the reactor (60 years +).

If there is significant UK component manufacture involved (this certainly the case with a UK developed reactor), then many more jobs will be created in the manufacturing supply chains. Wales has a long history of steel production and it is entirely conceivable that Wales could play a major role in this regard. Nuclear grade materials and components are high value and this would insulate the steel industry from the threat of cheap imports.

## References


1. Wagner, F., *CO2 emissions of nuclear power and renewable energies: a statistical analysis of European and global data.* The European Physical Journal Plus, 2021. **136**(5): p. 562.
2. Scarlat, N., M. Prussi, and M. Padella, *Quantification of the carbon intensity of electricity produced and used in Europe.* Applied Energy, 2022. **305**: p. 117901.
3. Jeswani, H.K., A. Chilvers, and A. Azapagic, *Environmental sustainability of biofuels: a review.* Proceedings of the Royal Society A: Mathematical, Physical and Engineering Sciences, 2020. **476**(2243): p. 20200351.


**Glossary**

| | |
|---|---|
| AGR | UK gas cooled reactor; mainstay of UK nuclear power since the 1980s; now reaching end of life with the last closure in 2028. |
| AMR | Advanced modular reactor; UK terminology usually (but not exclusively) designating SMRs that operate at high temperatures and possible closed fuel cycles (see Gen IV) |
| AP1000 | A US designed PWR (1.2GWe per reactor) |
| CFD | Contract for Difference; A funding model based on a fixed electricity price with no risk to the taxpayer, investors bare all financial risk |
| EPR | European Pressurized Water Reactor; A large PWR (1.6GWe per reactor) |
| FOAK | ‘First of a kind’; typically involves greater uncertainty, time, risk and cost |
| Gen IV | A class of reactors using gas or liquid metal coolants, operating at high temperatures with a closed fuel cycle to reduce waste |
| HPC | Hinkley Point C; UK site for an EPR, currently under construction |
| LWR | Light water reactor; includes PWRs and BWRs (boiling water reactors) |
| NOAK | ‘nth of a kind’; benefits from technical and construction knowledge, reducing uncertainty, time, risk and cost |
| RAB | Regulated asset base; A funding model based on a risk sharing basis between investors and the bill-payer |
| SMR | Small modular reactor; generally lower power (<1/3 of a conventional reactor), factory built and benefitting from NOAK savings |

| | |
|---|---|
| RE | Renewable energy, typically wind and photovoltaics |
| RE-B | Renewables with battery storage |
| RE-H | Renewables with hydro storage |

*August 2022*