UNIVERSITY OF LIVERPOOL | Heseltine Institute for Public Policy, Practice and Place

LIVERPOOL CITY REGION COMBINED AUTHORITY

The UK's nuclear energy future: should we ask for a more sustainable long-term approach?

Professor Bruno Merk

Policy Briefing 2(14)

August 2022

The Liverpool City Region

The UK's nuclear energy future: should we ask for a more sustainable long-term approach?

Key takeaways

1. If nuclear is to provide a significant contribution to achieving Net Zero, we need innovative, more sustainable technologies to reduce the environmental impact of the technology.
2. iMAGINE, an innovative technology using existing nuclear waste material, can provide energy security and reduce mining for new resources.
3. For nuclear to become a more prominent part of the energy supply mix over coming years, the UK will need to invest now to provide evidence on the feasibility and the first steps to industrialisation of the new technology.
4. We also need to invest massively in upskilling experts for reactor physics, to create the basis for designing and building advanced reactors in the future.
5. iMAGINE has the potential to not only deliver energy: it will help to reduce waste and bring us closer to the vision of nuclear energy as a zero waste technology.

1. Introduction

The UK Government recently announced that up to eight more nuclear reactors could be delivered as part of a new energy strategy to boost energy independence and tackle rising prices. These reactors would be based on existing technologies, installed on existing sites. The aim is for nuclear energy to deliver around 25% of the UK electricity demand – equivalent to levels in the late 1990s. This is a strong, positive message for sustainable development as one of the big advantages of nuclear is that it contributes towards meeting Net Zero, in addition to its high reliability, low operational expenses, and high energy density (NS Energy 2021).

From an energy strategy point of view, the announcement is a clear sign for diversification of Net Zero energy supply alongside the usual “sunshine friends” of wind and solar as the most regularly proposed Net Zero sources. In the 1990s, diversity of energy supply – using different resources (e.g. coal, oil, gas, and nuclear), was a major topic for energy engineers to assure reliable and cost efficient electricity supply. In the current transformation of the energy system to achieve Net Zero, the role of diversification is often not considered sufficiently to assure reliable as well as cost efficient supply in the long term. This poses a potential risk on the robustness of the supply of electricity– or to put it in more common language the risk of not having sufficient electricity when we need it.

2. Change in available energy resources due to Net Zero

So, is the decision to expand nuclear electricity production the urgent right step at the right time to assure a reliable energy supply for a successful future for the UK? Unfortunately, it is already too late to take this step, since the construction of nuclear power plants is a tedious, long process. By the time the new reactors come into operation, almost all existing reactors will have already been shut down, creating a gap in energy production. This, in combination with the war in Ukraine and other future risks, has the potential to disrupt the electricity supply, or at least increase costs for consumers.

However, the war in Ukraine has only accelerated and highlighted a long-term challenge, created by the climate agreements of Kyoto, Paris, and COP26, to phase out the use of coal, oil, and gas. This creates a two-fold problem for the energy system. On the one hand, in old times storing of energy has taken place in the form of the primary energy resource – coal, oil, gas – turning it ‘just in time’ into electricity. This opportunity will gradually disappear when we phase out the use of these hydrocarbons as required for a successful Net Zero society. On the other hand, storing of primary resources will not work for renewables since we can’t store wind or sun for later energy production – even if I sometimes enjoy the stored energy of the sun in a good glass of red wine.

Since we can't store wind and sun, we have to store their output – the electric energy itself. However, the storage of electric energy in sufficiently large amounts with current technologies is not possible. Neither pumped hydro storage or battery technology have the storage capacity required at present and future demand will grow.

This two-fold problem brings us to the question of how we either create storage capacity of primary energy to convert it to electricity when needed, or how we can store a sufficient amount of electricity. This challenge is growing with every day due to increasing the capacity of renewables while reducing electricity production from hydrocarbons as part of the UK's Net Zero strategy. Nuclear could deliver at this point a strong contribution which is not yet recognized to the full scale due to limited innovation and technical foresight.

However, to tackle this challenge we need a new sense of urgency – we need to start thinking from the point of demand (latest 2050) backwards, to avoid shortages (or even blackouts) in the electricity supply in the future, like the one unavoidably coming up in electricity supply through closing down of the old nuclear stations while new sites are not yet available.

Nuclear energy can be easily stored in the form of nuclear fuel, and on demand turned to electricity, if we invest in the right, innovative technology. There is a significant opportunity to use spent nuclear fuel and remnants from fuel production to create a sustainable, reliable electricity supply. While we commonly refer to these products as 'waste', they can in fact be repurposed, as they still contain 95% of their energy content. Rather than disposing of these resources at great cost, we need to develop smart technology to leverage this tremendous energy resource for future generations. If used properly, these resources have the potential to deliver the UK's current electricity demand for the next 7,500 years.

3. Why doesn't nuclear energy in its current form solve the problem?

Nuclear energy has significant potential to contribute to the UK's Net Zero target if the right decisions are taken. Nuclear energy is harvested from extremely energy intense physical processes which means only very small volumes of material have to be 'turned around' to produce massive amounts of energy, or only very small amounts of material have to be stored to assure the resources for future energy supply. If we develop the right technology, we will be able to use resources like spent nuclear fuel and remnants of fuel production, currently stored in the UK and declared as waste. Our challenge will be to provide the right breakthrough technology.

The advantages of nuclear in general have been covered earlier in this briefing, but when there is so much light, there must be shadow too. There are issues with today's nuclear technology reactors and with those currently under construction, mainly in relation to financial and ecological sustainability. These problems have to be tackled now, to allow a wider spread of nuclear technologies in the future. Nuclear technology typically involves high costs, with cost overruns and delays in delivery common – potentially deterring investors.

In addition, there is environmental damage: when Uranium is mined and converted into nuclear fuel, and after operation there are concerns about fuel waste disposal given the uncertainties surrounding final disposal. Above all, the sword of Damocles is the limited Uranium reserves which aren't currently a problem, but will become so if demand for nuclear power increases. Modern reactors are designed for 60 or more years of operation, so it is important to ask about the long-term sustainability of decisions we are taking now.

This throws us back to the sense of urgency. We need an innovative solution working on industrial scale and have to act now to invest into the right research and development. The route from first experiment to industrial application is long for almost all large scale technologies, but is longer still for a highly complex technology like nuclear energy. Thus, it is essential to start now with the first steps.

4. Making the existing resources accessible

How would engineers approach this problem? A nuclear power plant is the establishment of a process facility which turns a resource (Uranium, primary energy) into usable energy (heat or electricity, secondary energy). When engineers develop a new process, they think and do so in steps – see e.g. the successful vaccine production during the pandemic.

The process would be: theoretical research (in the case of the vaccine, finding the active ingredient in laboratory research experiments); first table experiments and tests in a laboratory in the gram scale (producing the first vaccine); small scale production in the kg scale (usable for first larger scale test of the reliability), and finally industrial production in tons (to vaccinate as many people as possible in a short time).

Why not replicate these steps for the development of a future nuclear technology? This would help reduce the development risk. In addition, process engineers and developers judge new processes on their potential to deliver cheaper, quicker, better…while they are aware that the advantages have to materialise through the development and optimisation of the process itself.

Luckily, there is already a good starting point for the future of nuclear in the UK. There is a promising development which is currently progressing in the UK. iMAGINE is a system which is designed to operate directly on spent nuclear fuel, almost as soon as it comes out of reactors or fuel production (Merk et al. 2019). Thus, what is currently called a fuel waste storage problem would be turned into a large, secure and independent energy reservoir reducing our need to import energy or energy resources for decades. Until now, we have used our resources inefficiently converting only 1% of the energy content of Uranium. The new technology has the potential to provide 100 times more energy from every gram of Uranium already mined and would significantly reduce the final disposal challenge on the way to the vision of zero waste nuclear.

iMAGINE would eliminate the environmental damage, the cost of mining, and the costly solid fuel production, while it helps us into a new way of dealing with nuclear waste. Our job will be to bring this development, which is currently funded by the Royal Academy of Engineering and UK Research and Innovation, into industrial operation.

Now to the elephant in the room. For new, large-scale technologies – and for nuclear technologies especially – the long construction time-frame and the uncertainties associated with delays and cost overruns, see e.g. the delays already experienced at Hinckley Point C, a real challenge for attracting the required investors. Here, a consequent stepwise engineering approach, as described above, will be key. It will help in the reduction of development risk as well as financial risk. It will be important to start in a safe setting with low risk and quick responses on the quality of the development, in close collaboration with the regulator, rather than jumping quickly to large high-risk projects with long development and response times.

The Royal Academy has recognised the great potential and decided to support iMAGINE by awarding a Chair in Emerging Technologies, while the Department for Business, Energy and Industrial Strategy (BEIS) has invested more conservatively in research on the much less sustainable high temperature gas cooled reactor technology (HTGR). However, BEIS has identified development of non-HTGR technologies as a key theme. There is an opportunity to push government to understand the need for a more sustainable nuclear technology. Developing this technology will take time so it is important to develop iMAGINE now to ensure it is available on an industrial level by 2050, when demand will be high. A reactor experiment for this highly promising technology is the first step to create evidence that it is possible to make nuclear energy an even more attractive investment for future generations as a basis for a safe and sustainable long-term energy strategy for the people of the UK. iMAGINE creates more energy resource for future generations from already mined resources – thus creating an attractive sustainable, green future investment to support sustainable development of the UK through technology development. We just need to make it happen.

5. Conclusions

Nuclear is one of the most promising Net Zero technologies for future generations. However, we need to invest in future oriented technologies which will allow the use of already mined uranium more efficiently instead of digging for new resources. Using these stored resources which are currently declared as waste would open a massive energy resource for the UK and boost energy independence as the materials are already stored locally. What is needed is investment into developing the right technologies to reduce waste and produce energy, now, to assure the required step change for nuclear to become a successful and affordable Net Zero technology that can contribute to the UK government's energy strategy.

iMAGINE offers the opportunity to improve the fuel usage from nuclear and serving as the first step to the vision of a zero waste technology by re-using existing waste materials as a resource; thus, turning a current legacy into a future asset. iMAGINE creates more energy resource for future generations from existing resources – thus it is sustainable development for the UK based on technology development. However, we need the passion and resources to make it possible now, since only with timely investment UK will be able to make Net Zero a timely success.

6. References

Merk, Bruno., Litskevich, Dzianis., Peakman, Aiden. and Bankhead, Mark. 2019. 'iMAGINE: a disruptive change to nuclear or how can we make more out of the existing spent nuclear fuel and what has to be done to make it possible in the UK?'. *Research and Innovation*. 64 (6/7): 353-359. https://livrepository.liverpool.ac.uk/3054017/1/atw_2019-07_MERK-fin.pdf

NS Energy.2021. 'Profiling the top nuclear power pros and cons'. 10 June. https://www.nsenergybusiness.com/features/newstop-nuclear-power-pros-and-cons-5760814/#

The Heseltine Institute is an interdisciplinary public policy research institute which brings together academic expertise from across the University of Liverpool with policy-makers and practitioners to support the development of sustainable and inclusive cities and city regions.

Heseltine Institute for Public Policy, Practice and Place
University of Liverpool, 1-7 Abercromby Square, Liverpool, L69 7WY

Follow us @livuniheseltine

About the author

Prof Bruno Merk is Royal Academy of Engineering Chair in Emerging Technologies at the University of Liverpool. His primary area of interest is the development of advanced nuclear technologies which allow improving the sustainability of energy production and reducing the nuclear waste challenge.

https://www.imagine-nuclear.com/

Policy Briefs can be accessed at: www.liverpool.ac.uk/heseltine-institute