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# Scoping a Systems Approach to Low Carbon Energy in the UK and possible roles for Nuclear

*Report from a workshop held at the Royal Academy of Engineering, London, 9th July 2013*

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# SCOPING A SYSTEMS APPROACH TO LOW CARBON ENERGY IN THE UK AND POSSIBLE ROLES FOR NUCLEAR

## FOREWORD:

By Lord Oxburgh KBE

I was delighted to be asked to provide a Foreword for this report, much as I was delighted to introduce the Systems Approach to Low Carbon Energy in the UK Workshop on the 9th July.

I have long held an interest in energy issues and my perception remains that this essential part of our national physical and social infrastructure has not been served well by successive Governments failing to provide strong policy leadership and any overarching strategic energy policy.

The UK is facing acute energy difficulties - we urgently require new power stations to replace capacity which is being withdrawn from operation; we have treaty and regulatory obligations to reduce carbon emissions and meet climate change targets; we have little idea of what energy market futures the UK should be endeavouring to meet, and more importantly, how much will this cost: we currently cannot predict that rolling blackouts will not become a regular occurrence.

We are failing to recognise that the requirements of a UK energy system have to integrate across all the needs that such a system is being asked to fulfil. It's not just about electricity supply and the technologies, be it nuclear or renewable, deployed to generate low carbon power. We have to think about how transport and space heating can be decarbonised and what this means for the wider energy sector; we need to think about energy storage and its capacity. We need to understand the impacts around transmission systems and how we can continue to underpin industrial and domestic energy demand. We need to provide the market stability and longevity that investors want to see before making major infrastructure decisions, and we need to ensure that an overall systems approach is taken so that the impacts of introducing or withdrawing different technology combinations can be fully appreciated and reflected in UK energy policy. A strategic and workable energy system should have a number of complementary elements, addressing different roles and energy needs and providing enough diversity for a robust and affordable future.

I was heartened to participate in the workshop convened by The University of Manchester's Tyndall Centre for Climate Change Research and the University's Dalton Nuclear Institute – both groups are obviously keen to promote an integrated approach to future UK energy systems and have been able to gather together a wide range of experts from industry, policy and academe. I would be more than happy to receive your views about this report and wider energy issues as it is only through continuing dialogue can the energy dilemmas and challenges we face in the UK be effectively dealt with.

## EXECUTIVE SUMMARY

On the 9th July 2013 The University of Manchester's Tyndall Centre for Climate Change Research and University's Dalton Nuclear Institute hosted a workshop at the Royal Academy of Engineering to establish the research scope for a systems approach to low carbon energy in the UK and possible roles for nuclear technologies. The event brought together leading representatives from industry, policy and academia who are actively engaged in developing the UK's response to climate change and energy security challenges.

The core theme of the day was to consider how technologies will function within a UK energy system that will be very different from today, and which must still ensure the secure provision of energy services. Nuclear energy is a very interesting test case for applying a systems based approach. Decades of research and development into commercial nuclear reactors have been premised on a vision of providing base load electricity from concentrated, high output sites (i.e. co-locating multiple large reactors). However, features of proposed very low carbon energy systems present quite different requirements from the incumbent energy mix. The workshop invited participants to discuss and debate what the requirements of a low carbon UK energy system are, and to consider what this means for nuclear technologies within a rapidly changing international context.

The key themes arising from group discussion during the workshop included; nuclear energy's role beyond electricity generation, demand-side system balancing, understanding system level costs and benefits, responses to climate impacts, political uncertainties and the UK's position within a global energy sector.

The workshop presented the generic feasibility assessment (GFA) approach, which offers robust and transparent comparison and appraisal reflecting the technical system impacts of nuclear reactor and fuel cycle technology options. Although this workshop explored the possible roles for nuclear in a very low carbon energy system, the need for a systems based approach to assessing the technical feasibility of emerging energy systems is common to all low carbon technologies. The GFA and other aspects of the workshop are therefore relevant to all aspects of low carbon energy systems.

The event stimulated engaged discussions, summarised in this report, and provided a novel forum for experts on nuclear technology, systems integration and climate change to exchange knowledge and make connections. Therefore while the day was extremely valuable for establishing the scope for future research, its main outcome was highlighting the benefits of a systems based approach and establishing dialogues in important areas where specialisms overlap.

## CONTEXT

Climate change will require major alterations to the UK's energy system through decarbonisation to mitigate greenhouse gas emissions and in response to climate impacts. Furthermore, if the UK is to make a fair contribution to an emissions target with at least a 50:50 chance of limiting global warming to a 2°C mean average, emissions from energy must be reduced more rapidly and to a greater extent than suggested by the UK Climate Change Act (2008) and subsidiary interim budgets to date. Scenarios of how the energy system will look in the future in response to this are numerous, and the recent DECC 2050 Calculator shows the variety of pathway options available. These future energy systems are very different from the current system and therefore raise questions about how their diverse aspects will interact. A systems based approach is essential to evaluate the technical feasibility of these scenarios.

The role of nuclear as a low carbon energy source is frequently constrained to base load electricity provision in energy scenarios, but the demands of a very low carbon energy system will be quite different. Integration with variable generation, smart grids, district heating, hydrogen production and other possible features of a very low carbon energy system introduces a range of challenges around the technical feasibility of energy scenarios.

## ABOUT THE DAY

This event was the first workshop to be jointly hosted by The University of Manchester's Tyndall Centre for Climate Change Research and the University's Dalton Nuclear Institute. Funding for the event was provided by the Engineering and Physical Sciences faculty to develop a collaborative research agenda relevant to policy and industry, drawing on the combined expertise of Tyndall and Dalton. Knowledge gaps in assessing energy technologies as part of a wider, internationalised energy system radically different as a result of actions to decarbonise the UK and/or climate impacts were identified. This was seen as an important aspect of technology assessment not presently incorporated into UK energy scenarios. The workshop, bringing together leading experts on nuclear technologies, energy systems integration and climate change, was therefore designed to scope out the research aspects most relevant to industry and policy makers in the UK. The workshop process design was planned with the experienced facilitation team from Integrated Decision Management (IDM) to deliver the following aims;

1. Examine an integrated approach to a very low carbon UK energy system within a global context;
2. Consider the role of nuclear energy in future integrated UK energy systems;
3. Provide a collaborative, expert and practitioner forum and follow-up report, to better inform UK energy policy and research institution priorities;
4. Establish scope for further collaboration, assign & agree actions and evaluate progress against the aims.

Representatives from leading industry, policy and academic organisations were invited to event. In total there were twenty five attendees representing National Grid, National Nuclear Laboratory, University of Manchester, Imperial College London, the Nuclear Industry Association, Horizon, EDF, Areva, Lloyd's Register, DECC, the Committee on Climate Change, Office for Nuclear Regulation, and the Environment Agency.

The workshop was structured to be highly interactive and to encourage varied and collaborative discussion between specialists from different backgrounds. The event began with a table discussion whereby participants formed four groups to express their immediate views on the significant issues associated with a very low carbon energy system in the UK. This was followed by four short presentations that outlined salient points from different perspectives on the challenges for UK energy systems;

- Professor Kevin Anderson - **UK Carbon Budget Implications of a Real Chance of Avoiding 2°C:** *There is a divergence between political rhetoric and what the science says about avoiding 2°C global warming. Acting on the science means reducing emissions from energy at a much faster rate and to a greater extent than envisaged in UK policy to support a 50:50 chance of not exceeding 2°C. The current pathway is in reality consistent with a 4°C or 6°C climate future which requires different preparations.*

- Dr Pierluigi Mancarella - **The Challenges of Energy System Integration:** *Low carbon energy systems provide a number of system balancing challenges. Smart grids may help to flatten load peaks but*

*they do not solve the problem of matching variable generation with demand. These issues will be exacerbated if heating and transport are electrified, therefore nuclear output may need to load follow, and, should a hydrogen energy vector be chosen for transport decarbonisation, to supply high grade process heat for hydrogen production.*

- Malcolm Grimston - **UK Energy Systems in the Global Context:** *The UK's hybrid between a market based and a centrally directed energy policy and the ambiguity about whether energy is a social service or a commodity, has resulted in the worst of both worlds. The tension between these incompatible concepts means progress in new UK energy infrastructure will require either abandoning the market approach or dropping climate change targets.*

- Professor Andrew Sherry - **UK Nuclear Futures –Determining what Nuclear can do:** *As a low carbon technology nuclear can play a major role in a decarbonised energy system. The requirement to load follow would drive different nuclear options, but the technical capability of LWRs has been demonstrated in France and Germany using current reactors. Nuclear reactors can produce very high temperatures (depending on reactor type) to suit thermal demands if required. Estimates on uranium availability vary greatly, and although uranium price does not greatly affect reactor economics, the UK has enough depleted uranium to support a fast reactor fuel cycle that could provide energy for centuries.*

The participants were then mixed into three groups for 'carousel' style facilitated discussions on three broad themes;

- Ability of supply, demand and storage technologies to meet instantaneous needs and provide long-term security
- Challenges and implications for the UK energy system in a global context
- Mitigation and adaption of the energy system in response to climate change.

Outputs from these discussion groups were fed-back to the wider group through a summary of the key points raised within each theme presented by the theme's designated facilitator.

Later in the day the participants were given a presentation of a novel **'generic feasibility assessment' (GFA**) tool by Professor Gregg Butler and were invited to give feedback on the methodology and its possible roles and applications. The GFA approach has been developed by Dalton and the National Nuclear Laboratory (NNL) as part of a decision-making research package commissioned by DECC. The GFA compares nuclear technologies (reactors and their fuel cycles) to a reference case (such as the proposed new build light water reactors in the UK) on the basis of a range of criteria, including aspects of system integration.

In the final participatory session of the day, attendees were split into groups based on whether they represented industry, government or academia. The groups were asked to identify research topics that they see as important to their sector and comment on how this research may be developed (in terms of partnerships, resources required, timescales and priorities.

## KEY THEMES

Through the discussion sessions a number of key themes recurred. These themes are described in the following section and indicate the areas of research seen as of particular relevance to industry, policy making and academia.

**Beyond Electricity:**
A recurring theme across different discussion groups in various sessions throughout the day was the need to look beyond electricity when thinking about decarbonising the energy system. It was noted that although electricity is currently only around 20% of final energy demand, it dominates the decarbonisation agenda.

Looking at the wider energy mix, some contributors raised the issue of how to switch domestic heating from gas and address transport energy use. Participants stated that to electrify heating will require a substantial upgrade of electricity distribution infrastructure, probably doubling cable capacity even if heating demand is halved. The fact that heating demand is far more 'peaky' than current electricity demand would pose balancing problems. In another session the uncertainties around electrifying transport through electric vehicles or hydrogen fuel cells supplied by electrolysis were cited as an important issue to consider in system planning.

Consequently questions were asked by participants about whether decarbonisation should mean electrification to the extent that is currently assumed. The potential to use high temperature reactors to provide heat for industrial processes including hydrogen production was discussed in two of the sessions. Looking to other energy vectors such as hydrogen and district heating with thermal storage to take pressure off the electricity network was highlighted. District heating from nuclear was also identified in the final session on research needs.

**A Holistic Approach to Supply and Demand:**
Considering a different approach to supply and demand was another recurring theme. It was suggested that there has been a tendency to focus on the supply aspects in discussions about the electricity system in particular. While the focus on supply might prioritise the development of load following from nuclear to accommodate greater demand peaks from heating and transport electrification and variable supply technologies such as wind, demand side options that could provide system benefits were discussed.

Firstly was the importance of demand reduction, particularly if there is a high degree of electrification. In one group participants discussed whether demand reduction would reduce incentives for power generators, however it was decided that overall electricity consumption must grow significantly in a low carbon system, even with substantial demand reduction. With current UK total energy demand at around 1,700TWh, the potential for the electricity grid needing to support 850TWh of power supply, up from the current figure of around 320TWh, to decarbonise the energy system was discussed. This would have major implications for electricity transmission and distribution infrastructure and therefore it was remarked that significant reduction in overall energy demand is a requirement for high electrification scenarios.

The potential for altering demand patterns to reduce the requirement for load following from technologies such as nuclear in a low carbon energy system was mentioned on a number of occasions during the day. One participant referred to this as thinking about 'flexible demand' to flatten demand curves instead of only responsive supply and maintaining a high capacity margin. Load shifting

through smart grids that can control consumer appliances and aggregate their demand to better suit supply characteristics was discussed. Knowledge gaps about the extent to which this can be applied – to what appliances and what proportion of demand – were highlighted. A participant in the group discussions offered some initial outputs from an ongoing study into paying commercial and industrial users to accept longer power outages as a result of supply faults from overloaded distribution. Large users would receive income for providing system benefits by enabling greater use of existing grid infrastructure without the upgrades necessary to ensure the same supply fault incidence and response. The research had identified barriers in terms of where this activity would conflict with the company's services. An example was given of a large user reluctant to take this option because of agreed times of use with its customers (i.e. when events are scheduled) months or years in advance. This led to a discussion within the group about what electricity services are temporally sensitive, and therefore cannot be shifted.

The value chain for demand reduction was another point of interest in this theme. Questions were raised about how demand reduction can be incentivised across the system and this led to a conversation about how costs and benefits of demand reduction are distributed. For example what direct benefits are there for end users or, do distribution network operators (DNOs) benefit more? One participant stated that the longevity of electricity grid assets may even be increased by fluctuating demand, as opposed to constant loading. This was considered to be worthy of further research.

**System Level Assessments:**
The implications of assessing electricity generation technologies, in terms of cost and $CO_2$ mitigation benefit, began an interesting debate on how the system impacts of different technologies are categorised and the quality of the evidence base to support comparisons. In particular the implication of wind intermittency for back-up thermal power stations was discussed. A Bentek Energy study of the Colorado energy system which has a mix wind and coal fired generation was cited by a participant to suggest wind energy can increase overall $CO_2$ emissions from an electricity system because of part loading fossil fuel plant for back-up (therefore at reduced thermal efficiency). Another participant suggested that this is not the case in the UK where a number of studies that assert wind power might increase grid emissions rely on part loading and intermittency assumptions that are contested. They went on to comment that in their industry experience, while wind is variable, it is predictable to an extent that grid balancers can be well prepared and do not require several thermal plants at part loading. Another participant remarked that a sudden reactor shutdown, such as had happened at Torness nuclear power station the previous week, also represented a challenge for grid balancing.

**Climate Change Impacts on the UK Energy System:**
One of the designated 'carousel' group themes was climate change mitigation and adaptation impacts on the UK energy system. The topic of particular interest to the group participants was the change in energy demand as a result of climate change and uncertainties about what pressures this would put on electricity infrastructure.

The impact of climate change on energy demand was discussed not only in terms of an increase in global average temperature, but the likely increase and 'scattered' nature of extreme weather events. The implications for demand were unclear as participants considered it possible for both higher winter heating loads and much greater summer cooling loads depending upon what happens to weather drivers such as the Gulf Stream and the jet stream. Greater cooling load in the summer was seen as most problematic by one of the participant groups. Hot weather lowers the thermal efficiency of power stations and reduces the volume of electricity grid cables can transport, meaning ramping up supply in summer months is more challenging and puts the system under greater stress. Another group

considered the wider social costs of not being able to meet greater cooling or heating needs affordably i.e. via the impacts of fuel poverty (overheating or cold and damp buildings).

**Political Will and Uncertainties:**
In the discussion groups there was a pervasive sense that the role of government is crucial, at national, supranational (EU) and global levels, for a very low carbon future. A number of facets relating to this were expressed by participants, in terms of the policies driving low carbon energy investment and for setting and realising $CO_2$ emission budgets.

At a national policy level, the UK Government's long term commitment to climate change mitigation was questioned. One participant reported on a recent opinion poll which found that environmental issues such as climate change were not a priority for most MPs. Within two of the discussion groups there was concern about the level of MP understanding of climate change science, and that this might translate into little political will to match the rhetoric of the three main parties. The issue of timescales (discussed below) was seen as one potential cause of the lack of political appetite together with the interventions from the UK Independence Party as a competitor with an openly unscientific but potentially populist perspective on repealing existing climate change targets and low carbon incentives.

One of the discussion groups focused on the range of political uncertainties arising from the current policy landscape, including the possibility of the UK leaving the EU and the potential implications for renewable energy targets and EU wide environmental legislation. The UK's role as a leader in climate change mitigation was seen as being under threat, and there was discussion about whether this position was desirable and at what at cost it should be maintained.

**The UK within the International Context:**
The international context in which the UK energy sits was the topic of the third 'carousel' group. Group participants seemed to agree that the UK is not currently self-determining in energy system decision making. The investors we seek to finance our infrastructure are global, and the UK is less and less of an island in energy market terms. For example, the UK's remaining indigenous oil and gas is not 'earmarked' for domestic consumption and will go to those who will pay.

The international factors discussed covered resource availability, the global impacts of localised $CO_2$ emissions and the UK's role within the international energy technology supply chain. The potential competition for resources included fuel availability and price volatility – with links made to Professor Gregg Butler's presentation showing divergent expert opinions on world uranium reserves – and skilled labour for projects such as nuclear reactors. The need to carry on with energy projects and research was seen as important for retaining skilled capacity by both industry and government attendees.

Seeing the UK as part of a wider global market for energy goods and services led to questions about how the UK will or should position itself. The group considered the options available to the UK to be, as a user (buyer) of technology, a partner with other national development programmes, or as a developer its own technology (as happened with advanced gas cooled reactors).

## RESEARCH DIRECTIONS

In the final participatory part of the day the attendees were divided into groups on the basis of whether they represented industry, government or academia. The groups were asked to identify areas of research likely to be most relevant for nuclear energy's role in a very low carbon future:

| Sector | Future Research Topic |
|---|---|
| **Industry** | Uranium reserves through UK eyes |
| | Small modular reactors (potential to lower capital costs) |
| | Small modular reactors for shipping |
| | Constructability of Gen IV and beyond (supply chain and capability) |
| **Government** | Future Reactors: Fast reactors, small modular reactors, nuclear district heating (strengths, limitations and implications) |
| | Fuel Technology (including uranium and thorium to keep 75GWe open) |
| | Spent fuel management (reprocessing waste management) |
| **Academia** | Assessing energy scenarios, on the basis of feasibility of generation, distribution, demand and looking beyond electricity |
| | The relationship and perceptions of trust between policy makers, scientists and civil society |
| | The financial and economic characterisation of nuclear energy within the structure of decision making of energy systems |
| | The context of nuclear as a contribution to different interactions of what climate change is for different groups/tribes |

The research topics identified by the groups reflect the general trend of the day of looking how nuclear technology can be tailored to meet the challenges of a very low carbon energy system and move beyond electricity generation to heating and transport services. This opens up new research priorities, opportunities for industry and options for policy makers.

An interesting point of contention throughout the day was the impact of wind variability on the future energy system, with different studies and technical assumptions provided by participants to support differing views. This discussion highlighted the need for robust technical assessments of low carbon energy scenarios based on up-to-date peer reviewed evidence.

In discussions about the generic feasibility assessment approach, a number of suggestions and points for further development were identified. A number of participants expressed an interest in the GFA concept due to its differences from a Multi-Attribute or Criteria Decision Analysis, 'score keeping' methodology. Whether comparisons between a technology and the chosen base case can be objective and the need for clarity about market drivers and other assumptions were discussed. The range of attributes, including how to factor in social and political impacts, was also questioned. These discussions emphasised the need to ensure the database of expert published literature which underpins the GFA is comprehensive enough for all technologies to make justified comparisons. It was also a recommendation from the participants that more 'trial runs' with a wider group of experts would help enhance the process and ensure that GFA developed as a robust and useful 'tool'.