ERA Big Ideas

Overview

As ERA reaches the end of its £60 million capital build programme, which has focused on the development of 23 test and demonstration facilities, it has been through a process of examining how to apply its academic capability and facilities to a series of major research, development and demonstration challenges which face the UK as it accelerates the delivery of low-carbon solutions towards 2050. This has resulted in a series of 'Big Ideas' focussed on:

- Implementation and demonstration of next-generation fuels;
- Medium-term, large-scale, energy storage;
- Integrating the circular economy with zero carbon and CCUS acceleration;
- Grid-scale electricity system modelling for future-proofing infrastructure;
- A National Centre for Decarbonisation of Heat, NCDH, and
- Behavioural transition for a low-carbon future.

ERA has created a number of platforms for the development of these Big Ideas which include the Tyseley Energy Park, the Trent Basin housing development in Nottingham and the Keele campus. ERA is also actively pursuing the creation of new activities associated with the redevelopment of the Ratcliffe-on-Soar coal-fired power station near Nottingham. In each case the aim is to support a transition, in close alliance with industry and the public sector, which also links to the underpinning research expertise.

Implementation and demonstration of next-generation fuels

As decarbonising the energy system and especially transport are becoming increasingly pressing issues, we are planning to establish an applied research centre for alternative fuels. This will focus work on a broad range of 'alternative' and renewable energy based fuels for a variety of different transport and power generating applications, including bio-fuels, alternative aviation fuels, hydrogen, synthetic natural gas, ammonia, etc... There is interest from Cadent Gas, Siemens, Engie, Rolls-Royce, EDF Energy and ITM Power, plus Tyseley Energy Park, Uniper, Unilever, John Lewis, GKN Aerospace and others. This idea is aligned with the desire within the UKRI Infrastructure Roadmap for an 'Alternative Fuels R&D Centre'.

This centre would build on existing projects on hydrogen use in trains (Birmingham), hydrogen and synthetic fuel use in heavy-duty and off-road vehicles, aircraft, shipping and passenger vehicles (Birmingham), the use of hydrogen in the domestic gas network (Keele and Cadent Gas' HyDeploy Project), hydrogen production (Cranfield recently won the HyPer2 £7.5m pilot plant demonstration project), two Centres for Doctoral Training and R&D around 'green' fuels, hydrogen storage and distribution at the universities of Birmingham and Nottingham, and the cooperation between Aston University, the University of Birmingham and The Fraunhofer Society on steam methane reforming and hydrogen production from biowaste.

Research and demonstration topics would include the following:

- Development of UK infrastructure for testing and validation of biofuels for the road transport and aviation sectors which addresses current challenges in fuel consistency, impurities and fast feedback on engine performance and engine behaviour;
- Sustainable ('green') production of hydrogen from renewable electricity, solar energy, biomass, wastes and a variety of other sources;
- Production of carbon-neutral methane (synthetic natural gas, SNG) from green hydrogen and biomass-derived CO_2;
- Substitution of natural gas by SNG in transport and power generating applications;
- Substitution of liquid transport fuels (incl. LNG) by liquefied SNG (LSNG), synthetic diesel, ammonia and methanol for all long-haul, heavy-duty freight transport, including road, shipping and aircraft;

- Optimisation of carbon capture and utilisation (CCU) technologies to provide CO_2 to the above processes at lower (energy) cost and environmental impact
- Development of 'closed carbon' energy systems where carbon is used for its high energy density but not released to the atmosphere (using Sabatier synthesis, oxy-fuel, and exhaust gas recycling technologies) for power generation and other stationary applications;
- Establishment of environmental and financial impact models to assess the consequences of transport-related urban and regional air pollution on public finances, damage induced by climate change and urban air quality, and public health;
- Infrastructure development for alternative, 'green' fuels, including optimisation of fuel choice with respect to application and business cases, linking the various transportation modes and networks (airports, rail network(s), logistics, waterways); and
- Develop whole-system models for system and infrastructure efficiency and cost evaluation, but also overall optimisation and predictive control of energy supply, demand and delivery from renewable, carbon-free sources.

The fuels development programme would be linked to the sites ERA has at both the Tyseley Energy Park, located in an industrial zone in Birmingham which could enhance its opportunity as a hub for low-carbon fuel/energy, and Ratcliffe-on-Soar in the East Midlands, which is the site of a current power station, next to the M1 and adjacent to East Midlands Airport, the largest freight carrier airport outside London. The aim would be to use these sites to accelerate the transition of new fuels to market. It is envisaged that this work will be done in collaboration with various public sector bodies, including Highways England and the relevant LEPs and councils in the region.

Medium-term, large-scale energy storage

It is increasingly recognised that in order to to balance a large wind energy component and enhanced solar PV generation on the grid, much more energy storage will be required. At present the variability of wind and solar generation, and electricity demand is being managed through gas-fired power generation. A reduction in the dependence on gas will need greater energy storage. Short-term, fast-response requirements may well be managed through the use of lithium-ion battery systems, but there is an increasing need for large-scale, medium-duration energy storage solutions. The ERA universities helped pioneer the large-scale energy storage technology which utilises liquid air (liquid air energy storage – LAES) which is now being scaled-up to 50MW/250MWh by Highview Power. This is a technology which bridges from short to medium term. An attractive alternative is the use of compressed air (compressed air energy storage – CAES) as an energy storage medium. There are a couple ways of creating CAES facilities: i) use of a geological site, e.g. repurposing a salt cavern; or ii) using high-pressure tanks to store the compressed air above ground.

For thermal energy, hot and cold energy systems, it is often most efficient to store the energy thermally rather than electrically. This can be done in materials in which the internal energy, temperature, of the system is increased (e.g. water), or using the transition of a material from one phase to another (e.g. solid to liquid) to store energy, a phase change material (PCM). Large-scale thermal energy storage using PCMs remains to be demonstrated in the UK, although ERA has pioneered the use of PCMs for the capture of thermal energy from curtailed wind power in China.

The *idea* is to develop research and demonstration of medium-duration energy storage (including electrical, chemical, thermal (including geothermal), biological and mechanical) which currently Aston, Birmingham, Loughborough, Nottingham and Warwick are all working on. The partnership recognises the need to develop grid-scale energy storage systems and one of the most promising areas – CAES – has been discussed with EDF Energy and others (e.g. EPRI) with the possibility of utilising a salt cavern as a demonstrator facility. Another idea being discussed is the potential use of the Ratcliffe-on-Soar site for a large-scale energy storage demonstration linked to the electricity grid and utilising the existing grid infrastructure. The use of Tyseley Energy Park, with its large volumes of waste heat from the energy-from-waste (EfW) plants, is a potential site for a large-scale thermal energy storage

demonstrator. In all cases these demonstrators would be integrated into the local energy networks (heat or electricity).

Integrating the circular economy with zero carbon and CCUS

ERA has recently concluded a Policy Commission on Energy from Waste and the Circular Economy, chaired by Lord Teverson. The output provides a way forward to increase the 'circularity' of our waste, to increase the carbon efficiency of incineration and utilise CO_2 emitted in the process to form new by-products. The findings are particularly important for former industrial sites in the Midlands which have inefficiently burnt wastes or have produced carbon-intensive energy, but are applicable to a wider area.

In summary ERA proposes the development of a network of new 'Resource Recovery Clusters' (RRCs), developed on post-industrial sites, which could produce significant environmental and economic benefits. The RRCs would combine a spread of EfW and recycling technologies with businesses that can consume the cheap electricity, heat, fuels, CO_2 and material outputs, so greatly reducing carbon intensity and improving circularity. The Midlands has many post-industrial sites and former coal-fired power stations that could become RRCs. Potential sites in the Midlands include Tyseley Energy Park and sites for former coal-fired power stations, such as Ratcliffe-on-Soar, High Marnham, Cottam and West Burton. Each RRC would reflect its local conditions and so each would be different, but in principle all would include a range of recycling (MRF, mechanical plastics recycling and other specialist facilities), EfW (incinerator, gasifier, pyrolyser, anaerobic digestor), manufacturing, horticultural and other businesses to maximise recycling and minimise emissions. All the businesses could be connected to the RRC's heat, electricity, gas and CO_2 networks, and each could consume another's physical outputs.

This *idea* chimes with existing work by BEIS and DIT, known as the Load Creation Model, designed to lure and anchor inward investment by providing secure, economic and low-carbon energy supplies:

a) Whilst the Policy Commission report outlines key interventions needed to realise its ambitions, the following are the key research and innovation opportunities which arise from it that ERA could play a role in: Providing supporting R&I to develop the proposed RRCs. R&I would support:
   i) The overall development of a series of RRCs identifying suitable locations and how a network of RRCs could support the wider region;
   ii) The development of individual RRCs (such as by mapping of areas around current and future proposed incinerators to maximise efficiency). These sites are well positioned to provide a range of place-based solutions including low-carbon fuels for road and rail, low-carbon steam, processing household waste, using biomass for energy production and linking to CCUS opportunities; and
   iii) Individual technologies to be deployed within clusters. This may include increasing the utilisation of heat in both existing and new EfW plant; the roll-out of 2nd generation EfW technologies such as anaerobic digestion, pyrolysis and gasification, considering issues such as yield improvement, digestate upgrading and centralised gas injection; full-scale demonstrators.

b) Research into methods of small-scale, circular, carbon capture that economically capture a large proportion of CO_2 and allow its conversion into useful products – particularly important for areas such as the Midlands that are remote from depleted oil and gas reservoirs with the potential for carbon sequestration. Within the CCUS agenda, ERA is interested in developing the utilisation of captured CO_2 from EfW plants or industry clusters, producing products or offering exploitation in agriculture. The research undertaken within the ERA institutions is mainly around the production of new fuels and materials (e.g. carbon, fertilizers, etc.). This ties in with budget announcements on CCUS and the need to decarbonise industrial clusters and the utilisation of CO_2 from new EfW facilities. Within the ERA partnership, work has been undertaken on the production and utilisation of biochar activity at EBRI (Aston), expertise exists in soil sciences and carbon storage (BGS, Nottingham - Sutton Bonnington) and rigs are

available (Cranfield). There is also interest in understanding how 'indoor agriculture / vertical farming' may present an opportunity.

Grid-scale electricity system modelling for future-proofing infrastructure

As the UK's energy system develops to meet net-zero greenhouse gas emissions by 2050, there are significant challenges on how to operate, protect and control the UK's energy supply system (with an annual investment of around £12 billion in 2018) on a real-time basis. Utilities in the US, China and South Korea use real-time digital simulation to provide a high-fidelity model of the high-voltage section of their networks. However, currently there is no national-scale real-time energy system research facility in the UK. The national power cut on 9th Aug 2019 (with an estimated economic loss of ~£20m) indicated that such a national-scale simulator is a necessity to ensure implementing the net-zero target by 2050, speed-up the UK's massive deployment of renewable energy, electric vehicles and smart energy controls, and position the UK as a world leader in energy system integration.

ERA proposes the development of a national-level, real-time 'whole energy system simulator' (WESS) aimed at improving the understanding of the fundamental risks associated with the UK's energy system, thereby improving security of supply and moving towards a low-carbon energy network, and a national research facility platform WESS is considered to be the most appropriate approach. WESS would develop a cutting-edge comprehensive model of the whole electricity network from top to bottom, including all generating, network and user dynamics, which would operate in real time thereby facilitating both human and physical plant interaction. No such facility exists worldwide but the need is pressing due to the enormous complexity and risks of supply networks, renewable generation sources, smart grid controls at all voltage levels and energy storage devices, as well as the massive integration of EVs.

Technologically it would put the UK in a world-leading position in the design and operation of clean energy systems, bringing together transmission and distribution networks as an integrated whole. It would enable us to exploit investments in our national supercomputing expertise that should give us a head start with the huge computational task that lies behind the WESS facility. It would also further develop techniques for handling the enormous database challenge that is additionally complicated by multi-party commercial confidentiality requirements.

Research challenges include:

- Comprehensive modelling of full-scale national electricity systems with high penetration of renewable energy representing a prerequisite for subsequent analysis of integrated energy networks including gas and thermal systems;
- Modelling and interfacing of market operations into the energy system;
- Faster than real-time digital computation techniques and hardware/software architecture, including high-performance database structures;
- Accurate and reliable interface techniques/technologies between different energy networks; and
- Reception of real-life data as a national live testing lab to speed-up translational smart solutions towards industry products.

Interested parties so far include: National Grid Electricity Transmission, National Grid ESO, Scottish Power Energy Networks and ERA. They all have actively contributed to the development of the idea.

A National Centre for Decarbonisation of Heat, NCDH

In the UK, over a third of our greenhouse gas emissions are generated from heating. At the same time, reducing heat emissions is one of the most difficult areas to abate, due to the wide range of technical, commercial and systemic challenges. For the UK to achieve its net-zero emissions target by 2050, our existing building stock would need to be fully decarbonised, including retrofit measures being applied to over 10 million homes currently at E-G rating. A new wave of place-based building energy

improvement and retrofit projects to enable regions to invest strategically, and the 'upskilling' of heating technicians and installers, will be critical for success.

A new National Centre for Decarbonisation of Heat (NCDH) could be at the heart of this transition, driving the national framework and bringing forward new capabilities in digital manufacturing, building & consumer integration, standards and skills, whilst incubating innovation to capture new business opportunities from this new industry. As well as creating world-class new facilities, capabilities and skills, the NDCH will take a synergistic approach to tackling the heat challenge, with support flowing through from consumer-centric product and service designs, advanced digital production and building integration, to the incubation of new businesses, skills and standards.

The NCDH would co-locate the innovation, incubation, demonstration, system integration, skills and manufacturing support to accelerate the journey of disruptive and next-generation technologies to market on a timescale such that they can provide solutions required by the 2050 (or 2030) target. The Business Incubator would build on the Energy Systems Catapult (ESC) Innovator Support & International Platforms that has already helped 19 SMEs on their commercialisation journey since their inception two years ago. Expanding this approach with the physical capabilities of the NCDH would ensure that the UK captures the wider economic benefits domestically and internationally. ESC is soon to release a feasibility study showing the need for a physical energy incubator in the UK, called 'D4E' and the benefits of locating it in the Midlands.

Through ERA, the Midlands region has developed digital manufacturing capability via the Smart Manufacturing Accelerator programme. Based at the Manufacturing Technology Centre (MTC) at Ansty Park, Coventry, this has created a suite of Industry 4.0 manufacturing approaches culminating in a 'Factory in a Box', FiaB. The FiaB approach provides state-of-the-art, robotically-operated, smart, digitally-integrated, rapidly-deployable and highly flexible manufacturing capability. This is set to transform how sectors can reposition themselves on a rapid timescale in response to rapidly changing markets. The benefits have already been realised in the North West region, with the Liverpool LEP investing £15m to support the pharmaceutical and fast-moving consumer goods sectors. This approach can be applied to support the scale-up of manufacturing for the thermal energy transition.

To achieve the decarbonisation of the UK's building stock not only requires new manufacturing solutions, innovation and integrated solutions, but also new skills and expertise in the workforce to implement it. Heat decarbonisation will require heating technicians and installers to be upskilled in areas including heat pumps, hydrogen boilers, smart system controls, digital platforms, building integration, energy efficiency implementation, retrofit coordination and surveying, building performance assessment and monitoring. The ESC is already developing proposals to address this need in collaboration with a wide range of partners (e.g. BEAMA, TrustMark) with existing skills and training capabilities that could be adapted through a new academy.

Successful heat decarbonisation needs to take a whole systems approach, focusing on building systems level integration of new solutions and bringing the consumer to the heart of future products and services. The NCBH could do this through building on the BEIS-funded 'Smart Systems and Heat' programme Living Lab for consumer-centric heat service propositions as well as ESC's Systems Integration and Consumer Insights assets and capabilities. The NCBH would create a 'Centre of Excellence in building and consumer integration', ensuring that new products and services are designed as interconnected solutions aligned with building components, building fabric, digital platforms and the consumer. It would also ensure that new software, control systems, AI and machine learning requirements are factored into the other NCBH capabilities such as digital manufacturing, business incubation and standards. Factoring-in future business models, consumer service propositions and whole system integration at the building level, would be essential for the NCBH to accelerate the adoption of low-carbon heating.

As the NCBH and the low-carbon heating market evolves, it would be beneficial and indeed necessary to create the right standards for the growing industry. In this space, the NCBH could play a key role in coordinating the relevant standards organisations (e.g. BSI, BEMA, IEEE, etc.) to facilitate appropriate standards, at the right time and with the right verification support structure.

National datasets indicate that the Midlands region has the second highest number (after London) of Low-Carbon Environmental Goods and Services (LCEGS) companies, with more than 10,000 companies and 56,000 people working in the energy sector supply chain and cleantech sector. Some of the largest and most important energy businesses in the UK are located in the region. Annually >£2.5 billion of capital investment delivers energy technologies and infrastructure (excluding buildings and transport) across the Midlands. Additionally, ESC, a national resource and centre of expertise in heat decarbonisation and digital energy, is based in the centre of Birmingham less than 5 miles from the Tyseley Energy Park and within 20 miles of that is the MTC. In 2019 the GBSLEP invested £7 million in developing a low-carbon innovation hub at TEP (and a low-carbon refuelling hub). This is part of a £19.4 million project to develop innovation and incubation facilities within the Energy Innovation Zone.

Behavioural transition for a low-carbon future

ERA wants to initiate a national approach to consumer behaviour change of net-zero actions. Heat, green mobility and housing retrofit are clear focus areas. The transition to clean energy will require major behavioural change. In particular, the level of intervention required to decarbonise domestic heating is unprecedented and, to a large extent, will need to be consumer-led. For domestic heating, the original change to natural gas occurred over a relatively short period of time. By understanding behaviours, and identifying and developing approaches available that provide similar levels of service at a similar cost with minimal negative effects, rapid and natural consumer uptake will occur.

An important aspect of this approach is information on options, implications, user experiences and even technical details, to be offered to consumers to enable them to make educated choices.

ERA would look at: how any potential change would be received by consumers, and how it can work to change perceptions and behaviours; the importance of feedback; links to social science disciplines; health & safety aspects; etc. Also, a key focus would be on aiming to *reduce* demand/consumption, and re-evaluating public expectations. The need for 'user-desirable solutions' in order to shape markets proactively is clearly recognised. ERA would also consider a 'wellbeing' angle, e.g. promoting just solutions by addressing energy (in)equity, intergenerational equity associated with climate change, international law, etc, and there is a potential to link to the CREDS programme (led by the University of Oxford).

ERA also has potential opportunities to test and understand the challenges involved in such a behavioural transition, through its engagement with the cities of Birmingham and Nottingham, and the Trent Basin community programme. There is significant interest from industrial partners e.g. Engie, EDF Energy, Siemens and ESC, which have community demonstrator programmes. The University of Birmingham is building an extensive online repository of publicly-accessible information (MOOCs, flyers, web pages, short courses, etc.) on a variety of technical topics that could be expanded and added to the activities proposed in order to support the drive towards behavioural change. This programme would ideally sit alongside the NCBH, detailed above, if the focus was the decarbonisation of domestic heat.

Summary

Whilst all of the above ideas are presented as stand-alone concepts, there are obviously various synergies between the ideas, particularly in terms of locations and partners, but also in terms of technical focus. By instigating a programme of connected projects, utilising already developed facilities and a firmly established partnership, such as ERA, would allow these projects to move ahead at pace and with a strong governance framework. For each idea ERA would envisage significant further development of the idea by engaging academic, public sector and industrial partners to co-create detailed business cases with sufficient co-investment across the programme to make the projects attractive.