Strengthening the UK's innovation ecosystem to meet net zero targets and advance competitiveness

Bringing together evidence from researchers and policy makers

Workshop report

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Introduction

In June 2022, the Centre for Science and Policy and Laura Diaz Anadon, Professor of Climate Change Policy at the University of Cambridge and Director of CEENRG, delivered a policy workshop on strengthening the UK's innovation ecosystem in the energy space to meet the government's net zero target. This event brought together senior policy and academic experts from the UK, Europe, and the US to share and analyse the most up to date evidence, identify policy implications, and propose next steps.

In June 2019 the UK Parliament passed legislation to amend the *Climate Change Act 2008* to introduce a target to reduce greenhouse gas emissions by at least 100% compared to 1990 levels. If met, this would mean the UK will end its contribution to global carbon emissions by 2050. However, the UK is not currently on track to meet this target.[1] The development and deployment of new technologies – at scale and at pace – that can move us away from a reliance on fossil fuels and towards sustainable sources of energy is a core part of the journey to net zero. The Net Zero Innovation Portfolio – which provides £1bn in funding for low carbon technologies and systems – is part of the government's plan to realise 'investment-led recovery' and put the UK at the cutting edge of global markets for clean technology.[2] The UK currently suffers from slow productivity growth compared to other countries.[3] To address this, over the past decade, there have been various proposals and efforts to enhance innovation and productivity across a range of sectors, including the creation of the Catapult Network in 2011 and the Advanced Research and Innovation Agency (ARIA), which is getting started in 2022.

The purpose of the workshop was to discuss key steps the UK could take to strengthen its innovation ecosystem to jointly address the country's climate, productivity, and fairness goals at a crucial moment in time for the climate and for the UK's role in the world. The workshop brought together 25 leading practitioners and scholars in the field of energy and innovation

[1] Climate Change Committee. (2022). Climate Change Committee: Progress in Reducing Emissions, 2022 Report to Parliament.

[2] https://www.gov.uk/government/collections/net-zero-innovation-portfolio.

[3] https://www.ons.gov.uk/economy/economicoutputandproductivity/productivitymeasures/bulletins/internationalcomparisonsofproductivityfinalestimates/2020.

policy. It aimed to leverage relatively recent domestic and international experience and evidence on the role of government and different types of government agencies and initiatives in supporting innovations in clean technology (cleantech). It was funded by the UK Economic and Social Sciences Research Council (ESRC) Impact Acceleration Account (IAA) at the University of Cambridge.

Executive summary

The purpose of the discussion was to draw upon recent evidence and experiences to explore how the UK can accelerate innovation in the energy sector to meet net zero targets and put itself at the forefront of global clean technology markets. The discussion centred around three focal questions, each of which addresses a possible mechanism for stimulating the development and commercialisation of new clean energy technologies.

Does the UK need national laboratories?

National laboratories – research and development institutions with a public mission and purpose, working in specialist areas of scientific and technical expertise – already exist in the UK but are limited in number, particularly AW when it comes to specialising in energy-related challenges. Participants discussed features of the US National Laboratory ecosystem which could be integrated in the UK, the potential for national laboratories to collaborate with and fund start-ups, and the case study of institutional and programme-based funding for national laboratories in Germany in places like the Fraunhofer and Max Plank Institutes.

Participants raised the concern that the absence of disruptive innovation laboratories – institutions that encourage high risk, high return research – constitutes a gap in the UK's innovation pipeline. The Whittle Laboratory at the University of Cambridge was mentioned as an example of one such institution, with one speaker discussing the merits of its non-siloed, multidisciplinary structure and its flexible, collaborative organisational culture.

At present, when compared to countries like Germany, Korea, and China, the UK has a very small number of (mostly) small-scale national laboratory-like institutions in the energy space. Institutions in this category, which have seen quite a lot of instability over time, currently include two Catapults, to some extent Harwell, and the Faraday Institution. Data available for Germany, China and South Korea show that the share of public energy R&D in public research institutions (as opposed to firms or universities) has been stable or increased over the past 20 years, representing around 40-50% of public energy R&D in those countries.[4] While the equivalent numbers are not available for the UK, the landscape suggests it is likely much smaller.

Participants stressed the importance of several features of US national labs which helped make them leading institutions for scientific innovation: mission-orientated to deliver on climate mitigation, energy security and competitiveness; large scale; researcher autonomy to engage in entrepreneurship; physical facilities available to external actors; a strong technology transfer mandate; having some flexible funding; and a wide range of linkages with universities and the private sector.[5]

Participants discussed the importance of relationships between start-ups and national laboratories. Start-ups play a crucial role when it comes to disruptive innovation and are therefore strong partners for governments in the climate-tech context. For start-ups, collaboration with public entities can mitigate against the risk of the power imbalance which is characteristic of private sector collaboration. Government agencies and labs might offer a variety of resources to start-ups, such as expertise and networks, infrastructure, licensing opportunities and a quality check, to encourage investment.[6]

Participants considered the system of institutional and programme-based funding for national laboratories, using Germany as a case study. Germany is very active in directing innovation and has invested significant amounts of public funding into research and development in the last decade. Participants debated the pros and cons of different national research models and brought up the issue of the trade-off between competition and collaboration. Although participants acknowledged that centralised research models might require a high degree of management effort to collaborate effectively on a national mission, there was a general

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[4] Energy innovation funding and institutions in major economies | Nature Energy (see supplementary information)

[5] Doblinger, C., Surana, K., & Anadon, L. D. (2019). Governments as partners: The role of alliances in US cleantech startup innovation. *Research Policy*, *48*(6), 1458-1475.; Surana, K., Doblinger, C., & Anadon, L. (2020). Collaboration Between Start-Ups and Federal Agencies: A Surprising Solution for Energy Innovation. Information Technology and Innovation Foundation.

[6] Doblinger, C., Surana, K., & Anadon, L. D. (2019). Governments as partners: The role of alliances in US cleantech startup innovation. *Research Policy*, *48*(6), 1458-1475.; Surana, K., Doblinger, C., & Anadon, L. (2020). Collaboration Between Start-Ups and Federal Agencies: A Surprising Solution for Energy Innovation. Information Technology and Innovation Foundation.

optimism that we are shifting towards a culture of collaboration and mission-orientation when it comes to reaching net zero targets. A general trend in innovation policy over the past 10 years has been one of mission orientation. Participants discussed key approaches that have been helpful in Germany, including the need to achieve a broad activation of society (e.g., through thematic regional dialogues), the creation of strategy processes to formulate goals, coordinated mission management and flexibility, and a reflective and experimental learning approach to public innovation institutions.[7]

What would an ARPA-like agency for the UK look like?

The second roundtable focused on the design features of the proposed ARPA-style research agency in the UK – ARIA. ARPA-E (the Advanced Research Projects Agency for Energy) is a US-based funding agency launched in 2009 focused on facilitating high-risk, high-reward R&D in the energy sector. The concept of a UK-based agency built on this model (provisionally referred to as the Advanced Research and Invention Agency, or ARIA) first appeared in the 2019 Conservative Party Manifesto.

The session began with a discussion of what an ARPA-style agency for the UK would look like, and what would distinguish it from extant agencies such as BEIS and national laboratories. Two prominent points of difference emerged, one focused on the structure and mission of ARIA and the other on its metrics of success (click here for an article on the ARPA funding model).

The second part of the session moved to a discussion of whether the Department for Business, Energy, and Industrial Strategy (BEIS) – already resembles an ARPA-like agency. Several participants were sceptical that BEIS could achieve the same results as an ARPA-style agency given its relatively static structure. It is yet to be seen exactly how ARIA will work with BEIS, and other government departments, although it has now been clarified that it is a non-departmental public body ‘sponsored’ by BEIS.[8] One key area of discussion was the extent to which ARIA and BEIS will leverage public procurement to drive innovation.

[7] https://publica-rest.fraunhofer.de/server/api/core/bitstreams/e5ca6ed6-4d37-4c8f-b818-77309dc1d5e8/content
[8] Advanced Research and Invention Agency - GOV.UK (www.gov.uk)

The structure of an ARPA-style agency was neatly described as having divided into three core elements: mission, methods, and mindset. ARPA agencies should be focused on a clear mission around which its projects are centred, work with a flat-hierarchical structure and time-bound approach to projects, and hire people who combine a high level of scientific expertise with a commercial mindset. One concern that emerged during discussion was the lack of external pressure to innovate quickly when it comes to the climate crisis and the lack of clarity regarding the extent to which ARIA will have a critical mass of people and funds to advance net zero goals given that it does not have a climate or energy mandate and it is open to all areas.

What other options should be considered?

Participants explored what options the UK might consider for fostering innovation, besides the possibility of creating national laboratories with an energy focus and tasking ARIA with a significant energy mission.

Participants considered the importance of integrating sub-national, or regional perspectives on climate and energy innovation. Regional differences such as local environmental challenges and climate impacts can create a variety of foci for innovation. Several suggestions emerged, which included the importance of ensuring energy innovation is compatible with local economic development, strategizing on regional specialisation, creating a market for clean energy, developing the relevant workforce, and creating links with private sector investors to commercialise new technologies (click here for more).

A second strand of discussion focused on the principles the government should apply to achieve its net zero target. Suggestions included the strategic importance of creating market incentives for achieving net zero targets, tracking relationships between innovation funding and policy outcomes, fighting the urge to centralise while creating critical mass of resources in the regions, and creating stronger links between research and place. One point that drew particular attention was the trade-offs that can emerge between political, economic, and technological goals, and the potential for cases to arise in which adopting solutions to climate problems requires decoupling these goals.

Finally, participants discussed the potential of innovative funding mechanisms, focusing on the Strategic Innovation Fund (SIF) as a case study.[9] The SIF is a funding mechanism delivered by a partnership between Ofgem and Innovate UK to support energy innovation projects, paid for by taking a cut from consumers' energy bills. One core aspect of the SIF that was stressed during discussion was its agility, both in terms of setting targets and delivering projects, as well as a strong commercial pillar which focuses on securing a route to market for its products. Several challenges for the SIF and other novel funding mechanisms for the energy sector were raised, including the high-risk target market for products, the problem of deciding what counts as 'innovation', and the challenge for academics to use the SIF to access long-term, secure funding.

Key takeaways

The complexity of accelerating the UK's innovation ecosystem to reach Net Zero targets is considerable. Three key takeaways emerged at the end of the discussion.

- Participants were keen to stress the **urgency with which we need to reform and restructure UK institutions** if we want to achieve net zero targets. Several UK-specific problems were raised, amongst them the lack of clear incentives for energy innovation, gaps in functions provided to the UK's innovation ecosystem by national laboratories, the problem of encouraging innovation in traditionally less innovative sectors, and the volatility in policy efforts to date.
- Participants discussed the importance of allowing space for **researcher autonomy and flexibility, avoiding conservativism, and finding metrics to track milestones and outcomes**. This involves higher levels of flexible funding, support for technology transfer and interaction with firms, investment in facilities to allow researchers in firms and other institutions to interact, and streamlined processes to support R&D in particular in SMEs, which have more constraints than other firms.
- Participants raised the importance of introducing place-based policy, and the concern that at present the UK biases spending towards the South-East and fails to recognise regional variation in the distribution of new and at-risk sectors. Given the low R&D intensity (1.74% of GDP as of 2019) and the need to significantly increase this level of investment, participants felt that R&D support should not be a zero-sum game in which

[9] Strategic Innovation Fund (SIF) | Ofgem

one region loses for another to gain. Public R&D investments should grow to address the productivity challenge and energy goals for the foreseeable future. One ameliorative proposal was the potential for much closer collaboration between national and local government, along with an increase in regional autonomy.

Does the UK need national laboratories?

The first roundtable focused on the importance of national laboratories. National laboratories are specialist institutions responsible for conducting research and development and tackling difficult problems beyond the capabilities of private industry or individual universities. According to the Association for Innovation, Research and Technology (AIRTO), national laboratories provide government and businesses with expert advice, which is especially important in the event of crisis. Additionally, they accelerate research and innovation across the country and provide the public with access to important information and expertise. National laboratories are typically funded by central governments.

The UK has over 25 national laboratories, with each having their individual public mission. Of particular national importance are the scientific and technology areas of defence and security, health, agriculture, and food science as well as energy and climate remediation. In these areas, national laboratories could support a sustained collaborative R&D effort by being a focal point for efforts.

Examples of national laboratories that have activities in energy include the Energy Systems Catapult and the National Physical Laboratory (NPL). The Faraday Institution, for instance, focuses on electrochemical energy storage research, skills development, market analysis and early-stage commercialisation. By growing economic value for industry, enabling the transition to a fully electric UK, and creating new scientific knowledge, the Faraday Institution's impact is manifold.

Disruptive Innovation Laboratories

The UK – although it boasts an effective network of applied R&D centres and some of the best universities in the world – is confronted with a gap in its innovation pipeline: disruptive innovation laboratories (institutions that reward high risk, high return breakthroughs). The first speaker discussed the Whittle Laboratory (in the Department of Engineering at the University of Cambridge) as an example of a UK-based research institution that displays some of the attributes of a disruptive innovation laboratory.

Case Study: The Whittle Laboratory

Established in 1973, the Whittle Lab was founded by a group that understood both academia and industry, and the need to link the two. Its founders understood the significance of the emerging age of mass air travel and worked to ensure that the UK could own its technology through the creation of a national laboratory that focuses on improving the aerothermal performance of turbomachines. The Whittle currently accounts for close to 10% of the University of Cambridge's industrial income and is an award-winning academic centre. Today, their challenge is to decarbonise aviation. Through a series of trials, the Whittle Lab has underscored the value of people, tools, culture, and environment in achieving its aims.

- **People**
  A multidisciplinary, non-siloed team that can tackle new challenges.

- **Tools**
  The ability to develop and own not only new technologies, but the tools that are used to develop these.

- **Culture**
  An organisational culture that encourages and rewards rapid and creative reframing of the target problem, and gives researchers the autonomy to reframe the problem in an agile way – ensuring the time and funding to engage in this process.

- **Environment**
  An environment that facilitates awareness of the target problem, collaborative work (that is not forestalled by hard disciplinary silos) and open access to tools.

The landscape of national laboratories

In contrast to countries like China, Korea or Germany, the UK currently has a very limited range of national labs in the energy space. The landscape of national laboratories in the UK has been dynamic and changed throughout the last 25 years. Whereas China is increasing the number of national labs and reforming their programmes to establish an efficient mechanism for breakthroughs in core technologies, including energy, at least in the energy space in the UK there seems to be is less reliance on public research institutions. Of the public funding overall, at most 1/3 goes to government research and innovation in the UK. In terms of public energy R&D the fraction is likely lower. In Germany, Korea and China, public energy R&D is being done in national research institutes, which increased or maintained reliance on public labs over the past 10 years, as shown in Figure 1.

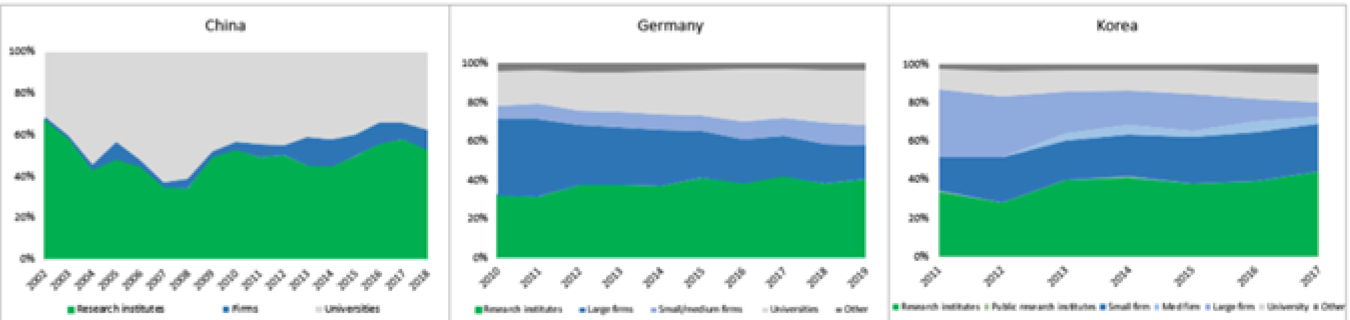

Figure 1. Percentage of total public energy RD&D funding by performer for China, Germany and South Korea. Green denotes the percentage of the effort conducted at public research institutes. Blue the percentage of the funding spent by private firms, with light blue indicating the amount of the effort performed by smaller firms for Germany and South Korea (this small vs large firm distinction was not available for China). Grey denotes the percentage of RD&D performed at universities.

Source: Energy innovation funding and institutions in major economies.

This international comparison reveals different ecosystems of public programmes. While the United States has an ecosystem of public programmes with 17 national laboratories, the UK ecosystem shows a different and arguably sparser and more volatile ecosystem (with institutions like the Carbon Trust and the Energy Technologies Institute not lasting much in their original design). National labs and facilities are largely missing compared to other countries. The example of the use of the currently-under-construction Cavendish 3.0 to provide user facilities to users outside of the University of Cambridge could be taken as a recognition that such as function—which is at least partly fulfilled by places like NREL, Sandia and Lawrence Berkeley in the US—has been missing in the UK. The Whittle Lab (see Case Study on p11), was mentioned as an entity that could occupy a space between a National Lab, a Bell Labs, and some ARPA features.

Participants highlighted key features of the US national labs:

- ### Lab mission and direction, research organisation and technology

  Balancing the lab's mission with advanced competitiveness in energy innovation and leveraging features of competition between labs.

- ### Researcher autonomy, flexibility, and accountability

  Allowing more flexibility to researchers, for example through two-year sabbaticals in start-ups.

- ### User facilities

  Ensuring the relevant facilities are available to researchers.

- ### Technology transfer mandate and funding

  Harnessing the benefits resulting from strong collaboration in technology transfer, especially between small firms, start-ups, and national labs.

- ### The ecosystem

  Recognising the importance of linkages partnerships between universities, the private sector, other public programmes, and the international community.

Start-ups collaborating with government institutions

Participants discussed which types of partnerships with government or public entities are most helpful for start-ups. Start-ups play an important role when it comes to the introduction of novel, disruptive clean technologies and therefore are indispensable for achieving the net zero emission targets. However, start-ups are often financially constrained and lack resources or information needed to advance their technologies towards commercialisation. Gaining access to such complementary resources through external partnerships is often critical for the success of start-up innovation.

Research shows that not all start-up partnerships are equal. Collaborations in the form of joint technology development or licencing with government agencies have the strongest impact on follow-on patenting or financing for participating clean-tech start-ups in the US compared to collaborations with universities or private sector firms.

As can be seen in Figure 2 below, one additional collaboration with a governmental agency increases subsequent patenting by clean-tech start-ups by 74%.[10] Similarly, whenever a clean-tech start-up obtains a license from an agency, its likelihood of receiving follow-on financing from private sector firms increased by 155%.

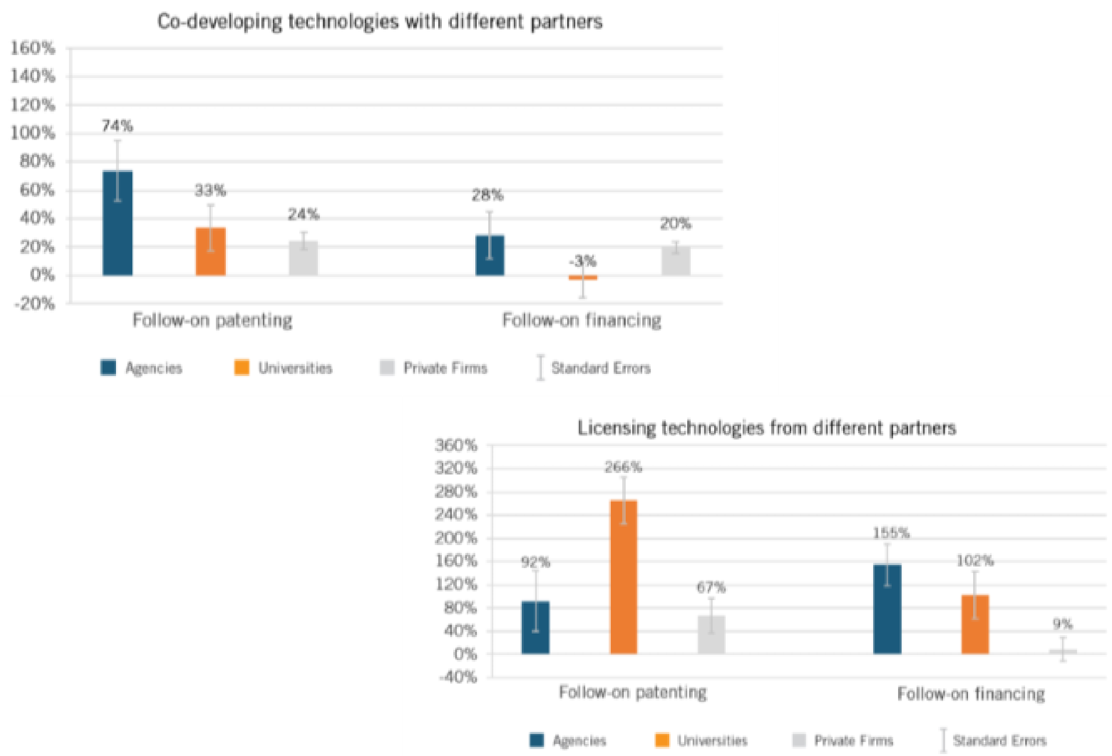

Figure 2. Impact of collaboration between clean-tech start-ups and different types of organisations on start-up success in the United States.

Source: Surana, K., Doblinger, C., & Anadon, L. (2020). Collaboration Between Start-Ups and Federal Agencies: A Surprising Solution for Energy Innovation. Information Technology and Innovation Foundation.

[10] Collaboration Between Start-Ups and Federal Agencies: A Surprising Solution for Energy Innovation (itif.org).

With better aligned motivations, government agencies and labs are stronger partners for start-ups than universities or private firms, as they have a long-term perspective and the physical infrastructure that the start-ups can access. Compared with the collaboration with private companies or universities, it gets clear how critical complimentary resources of government agencies are for start-ups.

Government collaboration with private companies is also relevant to start-ups but power imbalances as well as opportunistic shark behaviour might arise. The downside of the collaboration with universities are the potential conflict of interest as well as the limits to commercialisation of nationally funded research.

Additionally, government agencies and labs also offer the right resources:

- ### Expertise and networks

  Governments provide a critical mass of employees, which have unique insights on technology development and the complimentary technologies that can benefit start-ups. This is particularly true for technologies in the energy system, or future developments.

- ### Infrastructure

  Government agencies offer physical infrastructures and facilities for experimentation, demonstration, and testing facilities. Good examples are the US Department of Energy which has over 200 facilities available for external users and the US Department of Defense, which also provides extensive shared infrastructure and test beds.

- ### Inventions available for licensing

  Government agencies offer the opportunity to obtain licenses to federal RD&D patents for start-ups and to put the inventions to use in commercial applications.

Investors perceive government collaboration as a quality check

The licensing has a tremendous effect and impact on investors. As the investors regard public licenses as a quality check, they are more likely to invest in start-ups after they have taken a public license.

One participant mentioned that the partnerships between start-ups and other organisations might differ depending on the culture. They mentioned the example of power imbalances, which might not necessarily only occur with other firms, but sometimes also with national laboratories, as they have observed in France.

The role of public research in a new generation of innovation policy

At the end of the first roundtable, participants discussed the system of institutional and programme-based funding in Germany. Germany was provided as a case study of a state taking responsibility as policy for transformation and technology sovereignty need proactive orchestration, critical mass, and speed. With the Pact for Research and Innovation and a steady annual budget increase, the German government has shown a strong commitment to public funding of public research during the last decade.[11] Public research is divided across various organisations with different positioning. Whereas the Fraunhofer Society[12] is focusing on applied research, the Helmholtz Association of German Research Centres[13] concentrates on the alignment with research programmes and research infrastructure, the Leibniz Association[14] addresses knowledge and application oriented basic research, and the Max Planck Society[15] is conducting basic research.

[11] https://www.bundesbericht-forschung-innovation.de/files/BMBF_BuFI-2020_Short-version.pdf

[12] About Fraunhofer

[13] About us - Helmholtz - Association of German Research Centres

[14] Leibniz Association: Leibniz Association (leibniz-gemeinschaft.de)

[15] Homepage - Max Planck Society (mpg.de)

As a system perspective is needed for the cross-sectoral integration of different technologies, the government is very active in directing innovation and securing technological capabilities in these research institutes to mobilise Research and Innovation (R&I) for transformation, mission policies, industrial policy as well as technology sovereignty.

The project of H2 strategy national action plan fuel cell is one example how large public research lab networks combine forces with the state. 9 German States, 18 Fraunhofer Institutes and 40 industrial partners are working towards the aim of developing and launching industrial technologies for the economic application of fuel cells in cargo transportation. As this project has a public good character, long term economic implementation and individual labs are overwhelmed by the task, the state must step in. It has the capacities to manage the project and integrate the different technologies. Private research and fragmented University based research could contribute but would not have the capabilities to orchestrate such a mission.

Participants debated the advantages and disadvantages of national research models. National centralised research models might have the disadvantage of increased management demands in order to get all the relevant institutes to collaborate on a national mission effectively. Balancing competitive versus collaborative spirit and the tensions arising between the organisations might risk decelerating progress. However, it was suggested that the importance of common aims, in terms of speed and capacity, should not be underestimated. It was also suggested that there was a cultural shift towards a greater willingness to work towards a common goal across organisations.

What Should An ARPA-Like Agency Look Like?

The Advanced Research Projects Agency (ARPA) is an American funding body set up by President Dwight D Eisenhower in 1958 in response to the Soviet Union's launch of the first Sputnik satellite. Its mission is to invest in the development of breakthrough technologies for national security. ARPA became DARPA when 'Defense' was added to the title in 1972. More recently (in 2009), the Advanced Research Projects – Energy (ARPA-E) was set up as part of the United States Department of Energy (DOE) to fund the research and development of advanced energy technologies. DARPA and ARPA-E share the vision of investing funding into high-risk, high-reward scientific research.

The possibility of a UK version of ARPA was put high on the government agenda by Dominic Cummings during his time as Chief Advisor to the Prime Minister. The Advanced Research and Invention Agency (ARIA) was devised in February 2021 as part of government plans to cement the UK's position as a global science superpower.[16] It will be tasked with funding high-risk, high-reward research to facilitate the development of breakthrough technologies in emerging fields. (ARIA's founding Director and Chairman were announced in July 2022, shortly after the workshop took place). The creation of an ARPA-like agency in the UK answers the demand for breakthrough climate solutions as we work toward achieving the government's Net Zero target by 2050.[17]

The ARPA model for breakthrough mission-oriented research funding

The roundtable began with a discussion of the structure of ARPA-E in the US. ARPA-E is divided into chunks or 'programmes' each of which has a specific technology goal. Programmes have a lifespan of about three years before they are retired and replaced by a successor programme. The ARPA paradigm is geared towards projects that answer a specific challenge against the background of a nascent technology and friction in the market of ideas.[18] The dynamic structure

[16] UK to launch new research agency to support high risk, high reward science - GOV.UK (www.gov.uk)

[17] Net Zero Strategy: Build Back Greener - GOV.UK (www.gov.uk)

[18] Azoulay, P., Fuchs, E., Goldstein, A. P., & Kearney, M. (2019). Funding breakthrough research: promises and challenges of the "ARPA Model". *Innovation policy and the economy*, *19*(1), 69-96.

of an ARPA agency requires a low-hierarchical structure and a flexible, time-bound approach to hiring, project management, and bottom-up programme designs. Notably, programme directors have significant discretion in the choice of projects to fund.

There are several challenges for ARPA-like funding agencies, but the problem of accurately measuring success emerged as the most salient; standard programme evaluation tools are insufficient for measuring innovation-policy outcomes, particularly over long term. To mitigate these challenges, agencies should adopt an adaptive learning strategy whilst keeping government funding for innovation stable and predictable. Qualitative insights, changes of direction and failures, for instance, were mentioned as important learning metrics.

One participant was sceptical that the ARPA paradigm of 'buying a million lottery tickets and hoping one will win' could translate to the UK context; one criticism of the proposal to set up an ARPA-style funding agency in the UK is that these programmes only work at scale. This might be balanced, however, by the expectation that the initial investments of ARIA would have high potential payoff because they would be funding a previously overlooked group of innovators.

Does the UK already have an ARPA-style unit for net zero?

Government funding for energy innovation in the UK has increased significantly in recent years. For example, the Department for Business, Energy, and Industrial Strategy (BEIS) Net Zero Innovation Portfolio fund targets net zero innovation opportunities to facilitate the development of low-carbon technologies. The programme has grown from £180m at its inception in 2010 to over £1bn in 2021. It has supported over 400 projects with the average initial funding of about £200-300k per project, potentially going up to £2m over time.

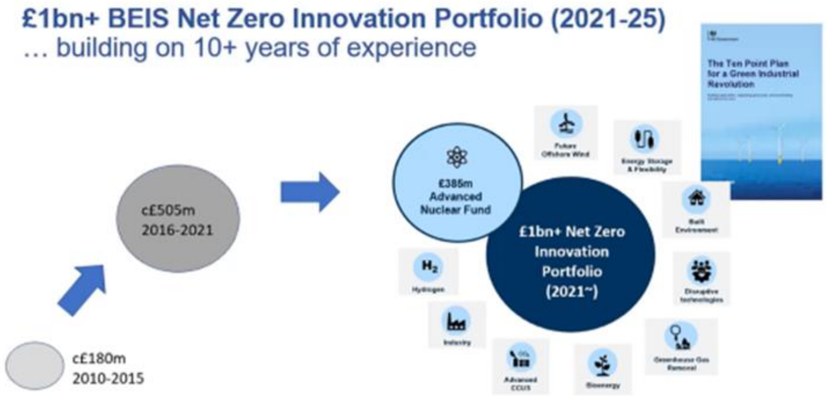

Figure 4. BEIS Net Zero Energy Innovation Programmes, 2022.

Source: BEIS presentation to CSaP, 2022.

Although public energy RD&D funding for achieving net zero in the UK has increased significantly over the past 20 or so years, time was identified as a key constraint. Given the amount of time it takes for the results of R&D to enter the market, some participants mentioned that the next energy innovation budget cycle (2025/2030) might be the last. One speaker pointed out that some analysts may think that there will not be time after 2030 to invent radically new net zero technologies and that this may mean the UK should shift its focus to climate change mitigation with the deployment of existing technologies.

Workshop participants, however, emphasised that this view is mistaken for various reasons. Firstly, research shows that public R&D is also essential alongside deployment, to both improve the existing technologies, develop domestic capacity for deployment and (in some cases) manufacturing, and to avoid locking-in first generation technologies that could be improved upon. Secondly, because in some technology areas and industrial sectors the path between research and deployment can be shorter than multiple decades, particularly when innovation does not require infrastructure or consumer changes. Thirdly, because the social returns from public R&D can occur through knowledge spill overs and research shows they should be increased, not decreased. And finally, because net zero technologies represent one of the largest (if not the largest) growth sector in the global economy and withdrawing when others are increasing support would put the UK economy and UK science at a severe disadvantage when others are doubling down on investments.

To accelerate the pace of energy innovation, the government should encourage coordination across the various government departments and agencies that fund energy innovation. Because

BEIS is a central government department, rather than an agency, they have much stronger policy feedback loops; lessons learned in the process of tracking R&D projects and evaluating outcomes can enter quickly into policy and vice versa. BEIS employees usually have an academic background in science or engineering and/or a project management qualification. The accumulation and regular refreshing of organisational and policy knowledge this achieves, along with the longevity of the programmes and a fair degree of autonomy in setting programme structures, can facilitate a frequent change in tack of BEIS programmes.

Participants were curious about whether the government is considering public procurement of the products of the BEIS programme. Although there is no coherent policy of large-scale public procurement, there are programmes that subsidise private purchases of BEIS products, as well as funding for public sector organisations to drive down their emissions. Several participants were sceptical that BEIS is analogous to ARPA in the way in which it operates and (therefore) the types of research and innovation it has historically funded. Some of the reasons raised by some participants include that it has less of a focus on high-risk, high-reward areas, no systematic efforts towards creating a community of researchers working on competing solutions to major problems, and a lack of ability to implement short-term changes in project milestones and directions. ARPA-like agencies in the US have also taken on additional roles such as organising innovation summits to showcase the work of recipients, some demonstration arrangements, and (in the case of defence) a formal link to public procurement.

Ingredients of an 'ARPA-like' agency

The third discussion centred around what set of ingredients are needed to create an 'ARPA-like agency' like ARIA. These were split into three sub-categories: mission, methods, and mindset.

- ### Mission

  An ARPA-like agency should be focused on a clear and simple mission, which emerges in the context of a larger policy problem. This might, for example, be the mission of developing low-carbon technologies within the context of working towards the government's objective of achieving net zero by 2050.

- ### Methods

  ARPA agencies tend to work best with a low-hierarchical or 'flat' organisational structure and a time-bound approach to hiring and projects. Flexible hiring practices and discretion in project selection foster a high degree of internal accountability and competition that encourages disruptive innovation that helps create new approaches to a problem, not just new solutions.

- ### Mindset

  ARPA-like agencies work best when they encourage a culture of fearless agency and intellectual honesty. This might involve a focus on hiring 'and' people as programme directors, i.e., people who combine scientific expertise with business acumen.

One participant was concerned that the climate crisis is distinct from national crises such as the COVID-19 pandemic due to the lack of external pressure to innovate quickly. Another participant consolidated this point, emphasising that innovations are unlikely to be deployed without the relevant demand in place. Others mentioned that the research is clear and robust regarding the crucial role that fiscal and regulatory policies have had fostering demand for key energy technologies (i.e., on and offshore wind, solar PV, lithium-ion batteries, and solid-state lighting) and that creating demand is an essential component to ensure that net zero goals are met. To make the most out of innovation the broader system needs to be organised in the right way; in the context of the climate crisis this might involve the establishment of a green investment bank, the creation of demand for low-carbon steel, and so on. As one participant pointed out, the development of vaccinations during the COVID-19 pandemic – much like the code breaking at Bletchley Park during WWII–– showed that we can speed up innovation when we must. One participant pointed out that the successful diffusion of expertise at Bletchley Park teaches us an important lesson about rapid progress: innovation works fastest when we break down silos and disciplinary boundaries. While the response to the 2009 financial crisis, which was not specific to energy, boosted public energy RD&D for fossil and renewables and not for 'new clean technologies', Mission Innovation efforts did lead to an increase in net zero research, and the oil crisis of the 1970s led to increases in public energy RD&D funding in renewables, as well as other fossil fuel substitutes. It is possible that the ongoing energy-related crisis will also help focus and increase efforts.

What other options should be considered?

The final roundtable focused on what other options besides creating national laboratories with an energy focus and tasking ARIA with a significant energy mission should be considered to strengthen the UK's energy innovation ecosystem. Discussions centred on three key ideas: the importance of integrating sub-national perspectives of climate and energy innovation, the trade-offs between political, economic, and technological goals, and the potential for the UK to benefit from more innovative funding mechanisms.

Sub-national perspectives on climate and energy innovation

The final roundtable began with a discussion of the importance of the geography of climate and energy innovation ecosystems. In the US, for example, innovation tends to cluster around DOE labs and universities, as seen in Figure 5. However, the presence of national labs or universities alone does not necessarily lead to a propagation of *clean* energy firms.

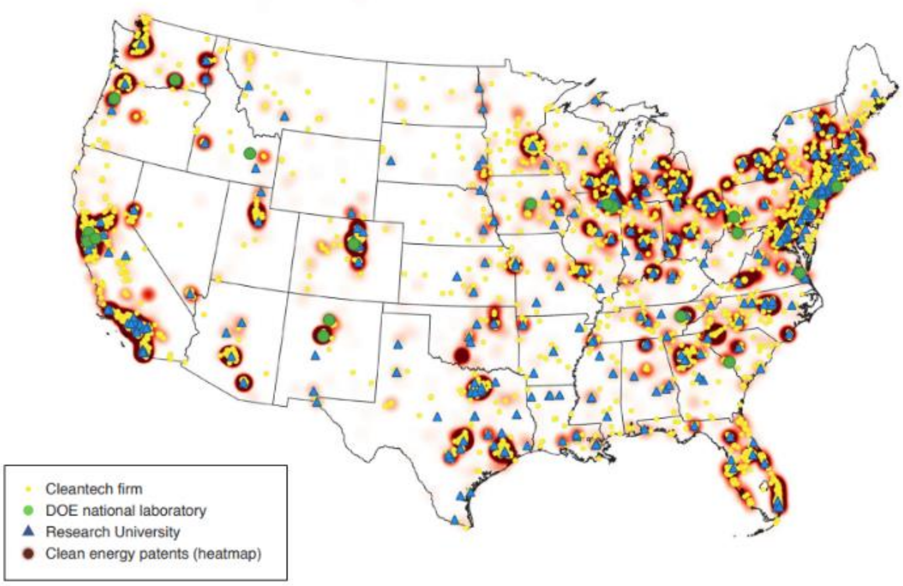

Figure 5. Dispersion of clean energy innovation activity across the USABEI

Source: Surana, Kavita et al. "Regional Clean Energy Innovation**".** 2020, https://cgs.umd.edu/sites/default/files/2020-05/Final_Regional%20Innovation%20Report_2.20.20.pdf

Regional differences can create a variety of different foci for innovation, including local environmental challenges and climate impacts, regional access to resources, and varying economic benefits across regions. How do we leverage these regional foci to get technologies out of the lab, onto the market, and to scale?

- ### Integrate goals and outcomes

  For many countries and regions, promoting biotech and healthcare innovation is a part of economic development efforts. The same is not always the case for energy innovation. To integrate climate and energy innovation as an economic development priority, we need to break down (national and regional) silos in energy and economic development agencies by aligning climate, energy, and economic goals. To be compatible with economic development, energy innovation programmes need to reflect a set of key economic priorities: maintaining affordability, creating employment, and encouraging investment and exports. The speaker drew on a case study from Colorado, which has a very active climate an innovation ecosystem. Colorado has a specific agency – the Renewable and Clean Energy Initiative – that funds climate and energy innovation start-ups.

- ### Strategize on sectoral, technological, and regional specialisation and complexity

  For the UK or anywhere else trying to strengthen their energy innovation ecosystem, the key question is which sectors, technologies, and regions will be the most effective to spend money on, to develop, and to commercialise.

- ### Create demand pull (national and subnational)

  Generating greater market demand for clean energy can incentivise research and development. This can be done by creating national and regional targets, using advance market commitments, signalling effects, cheap financing, fiscal incentives, regulations, and procurement.

o Develop the workforce

Innovation can be promoted locally by providing training, incubators, and accelerators for local researchers and start-up teams, supporting their skills development and technology commercialisation. For example, in Colorado the NREL (National Renewable Energy Laboratory) administered a number of privately funded incubator programmes such as the Wells Fargo Innovation Incubator and the Shell Gamer Changer Accelerator.

o Engage the private sector and strengthen public-private networks

The private sector is key to advancing climate and energy innovation. Private sector actors are frequently the first adopters of novel clean technologies, can provide a niche market for climate-related innovations, and are increasingly acting as investors by providing venture capital that is needed to quickly commercialise and scale new technologies. Therefore, policy makers should focus on establishing links between technology innovators and the private sector.[19]

Examples of US network-building and coalitions in the climate and energy field

Privately funded incubator programmes

- Wells Fargo Innovation Incubator
- Shell Game Changer Accelerator

Regional partnerships

- Regional Innovation Engines
- Innosphere
- CSU Energy Institute
- Maryland Energy Innovation Accelerator

Industry associations as anchors

- Colorado Cleantech Industry Association

Forums

- Industry Growth Forum (NREL)
- ARPA-E summit

Coalitions

- First Mover Coalition

What principles should the government apply to achieve net zero?

The Government Office for Science has existed in some form for around 20 years. It serves two core functions: providing scientific advice on specific policy areas and ensuring capabilities exist across the UK Government to draw on the best science and evidence. More recently, the government established the Office for Science and Technology Strategy as part of the Cabinet Office. The aim in making these recent changes is to introduce science and technology scientific evidence into the 'policy balance,' or the set of considerations that factor into policy decisions. As one participant pointed out, for the last 20 to 30 years, UK policymaking has been dominated by the balance between politics and economics. But the context is changing in the UK as the Government grapples with setting strategic priorities for science and technology as the third "pillar" in this balance. What are some of the principles the Government should apply when thinking about how it funds and stimulates innovation for net zero? The second speaker listed four key priorities in this area.

- ### Separate strategy and delivery

  The Government should be setting strategy and leaving expert delivery to others. This is precisely the role of the net zero target. The Government has a set a big milestone – net zero emissions by 2050 – and the next stage is to shape society to deliver that target. The market will not minimise carbon emissions by itself. There must be price or regulatory incentives to secure net zero emissions, and those incentives are strategically created by Government policy.

[19] In the UK context, one participant pointed out that some BEIS programmes already combine grant funding for research and innovation with team training and incubation support for business plans.

- ### Create feedback loops between policy outcomes and policy design

  Government needs to track, understand, and consider the systemic relationships between policies and outcomes that they aim for. In the context of the Net Zero strategy, the Government has set out several policy outcomes they hope to achieve. To ensure that these are achieved, appropriate metrics of success need to be established and monitored so that policy can be finetuned to result in better outcomes.

- ### Fight the urge to centralise

  The recent urge to centralise in the UK has risks attached to it. As one participant pointed out, the UK differs in this respect from countries like Germany where there is a much higher degree of regional autonomy and power, including in terms of budget. This dispersion of power makes it easier to mobilise regions to achieve governmental objectives. However, regional autonomy alone is not sufficient; it should be complemented with a critical mass of resources available to regions to act on these objectives.

- ### Create a stronger link between research and place

  A recent report for NESTA – The Missing 4 Billion – outlines how the UK biases research and development spending towards the South-East. One speaker pointed out that net zero is a social as well as a technological problem, and that if we fail to address the various social challenges that are involved in achieving net zero, then we will be resolving technological problems in vain. Many relevant social and technological challenges are place-based in nature and closely tied to local contexts. For example, peatland restoration is a viable net zero strategy in the Fens in Cambridgeshire but not in Central London. Therefore, research that aims to address the social and technological challenges of achieving net zero should be stronger linked with local contexts and needs.

Participants raised the question of how scientific evidence is absorbed and put into use in policy making. One participant pointed out that a major problem in the UK is that our civil service is heavily dominated by non-STEM graduates that lack science and technology literacy needed in decision-making in this field.[20] A first step to address the problem is to introduce a higher number of STEM-literate employees into government, and (the Science Capability Review places a big emphasis on this).

Another area of concern was the trade-off between climate and economic goals in the Government. Policy makers, one participant pointed out, are often selling their constituents a bargain: by investing in global climate problems, we might not grow our GDP. But are there areas where adopting solutions to climate problems does not lead to the trade-off between requires decoupling these two sets of goals? Such areas might, for example, include international collaboration on technological innovation to reduce carbon emissions. Given that many of the most pressing climate problems cross national borders, they are best addressed on an international basis. However, as another participant noted, benefits from international collaboration on climate and energy innovation should be balanced with considerations of national security and technology sovereignty.

Innovative Funding Mechanisms

Participants discussed the Strategic Innovation Fund (SIF), a funding mechanism for the UK gas and electricity networks delivered by a partnership between Ofgem and Innovate UK. The SIF expects to deploy £450m of funding – paid for by consumers through small increases in their energy bills – over the next 5 years to innovative projects that will reduce carbon emissions at the lowest cost to consumers. Projects are progressively funded in three phases – discovery, alpha, and beta – incrementally scaling in both time and value. All projects should eventually scale up to be multi-year, multi-million, nationally significant demonstration projects. The SIF does not restrict its funding to technological innovation: commercial, legal, and other forms of innovation are also eligible. All projects must be led by energy networks, and foreground IP developed in these projects should be accessible to all UK energy networks.

At present, there are three core pillars to the programme: strategic alignment, agile challenges, and commercialisation.

The core pillar involves ensuring that Ofgem and Innovate UK are running the programme in an

[20] STEM professionals in the UK civil service - an international comparative study (cam.ac.uk)

agile manner, both in terms of defining objectives and delivering innovation projects. One aspect of agility is the continual revision of policy commitments; coordinators engage with academic centres across the UK to define what the key objectives are for each year of the programme. The goal of preparing for a net zero power system, for example, answers to the governmental plan to decarbonise the electricity system by 2035. Although the programme is outcome-oriented, energy networks and partners have the freedom to define how they plan to achieve these outcomes.

Another core pillar is the strategic alignment with the innovation ecosystem both nationally and internationally, which is crucial to support the delivery aspect of the programme. For example, Ofgem and Innovate UK are currently looking at how they can partner with BEIS' Heat Pump Ready Programme. Finally, the commercialisation pillar to the programme involves forming strong investor relations and an international route to market. This allows investors to form a relationship with companies funded by the SIF early on to ensure that the procurement frameworks are in place as energy networks reach the end of their demonstration projects.

The programme has now been running for a year and coordinators are thinking about developing it beyond these initial pillars. Potential strategic priorities for the future that were mentioned in the workshop include:

- ### Regulatory Change

  Further down the line it is useful to ensure there is a responsive regulatory change environment, for example by partnering with regulators to get sponsorship for each project and challenge.

- ### Communications and Outreach

  Reforming the UK Energy Innovation Conference (now called the Energy Innovation Summit) and running a podcast.

- ### Data Science

  Developing baseline standards for how SIF-funded projects approach data management and publication. Additionally, the programme itself harnessing data science techniques to analyse, evaluate and disseminate information on the programme portfolio.

- Finance and Investment

  This might include partnerships with UK public institutions such as the Green Finance Institute and the British Infrastructure Bank; novel funding mechanisms including consumer equity.

- Agile, Aligned and Goal-Oriented Innovation

- Public-Private Partnerships

Several challenges have emerged from the programme, with the agile programme having to respond to challenges by revising the programme.

- It is difficult to finance high-risk, long payback assets and infrastructure, which are not necessarily considered innovation, for innovation trials. E.g., one UKRI programme funds the delivery of hydrogen heavy goods vehicles. Alongside that, Ofgem and Innovate UK would like to use the SIF to fund gas network innovation for hydrogen but building a multi-million-pound hydrogen pipeline is not necessarily considered innovation and there are questions over whether infrastructure owners should cover these costs directly.
- The challenge of shifting to a culture of innovation in traditionally less innovative, conservative sectors such as the regulated utility sector.
- Early-stage gaps in support for small businesses and spin outs to begin working on innovation for regulated utilities. It was pointed out that there are only around sixteen companies that are potential customers for energy network innovation of the regulated asset base in the UK. The target market for energy network innovation is therefore high risk: if a product does not land with those four consumers, then there is a potential for a vast misuse of resources.
- With discovery-alpha-beta funding, where the first phase is three months and the second six months, it becomes challenging for academia to use the SIF to access the long term, secure funding on which they tend to rely to support research. To this extent it would be useful to see the ESPRC or other research programmes working in parallel and

shape their programmes around similar objectives to those the SIF is looking to achieve.

There was discussion about the role and dynamics of participation of gas and electricity networks in the programme. When it comes to net zero, the gas networks need to significantly scale down and the electricity networks needs to significantly scale up. In response, it was mentioned that Ofgem and Innovate UK are currently working to test some gas network innovation options as part of the 2025 Hydrogen for Heat programme. This programme will demonstrate not only what works but also what does not work.

Participants were curious about what metrics Ofgem and Innovate UK use to measure the success of the programme. The baseline evidence for the success of the SIF is the cost savings to consumers and overall carbon emission reductions. However, as one participant pointed out, it can be difficult to find where these benefits are being realised within the system because companies do not necessarily pass savings on to consumers. From a business perspective, the key metric of success is the number of products and services that are sold on the market. Although until present programme coordinators have tended to focus on attracting investment and matching funding contributions, looking into the future, they are more interested in finding products that scale.

It was suggested that the benefits of innovation programmes are often realised within the supply market or within generators; it is not always the case that the utilities companies are procuring or tending the products. Although the SIF has not yet reached its commercialisation stage, it is currently looking at how to stimulate procurement in these ways.

Conclusion

As several speakers commented, these are complex and incredibly urgent questions to tackle. Developing stronger links between academia and government is a good starting point to ensure that evidence is incorporated into policy practice. As one participant noted, although the linear model of innovation – according to which innovation is a streamlined process that begins with basic science, before moving onto applied research, technological development and, eventually, innovation – has long been shown as an inaccurate picture of how innovation works, it is still dominant in many policy makers' minds. We need to work with more complex interactive models of innovation to understand how to increase the UK's capacity for clean energy innovation. We also need to recognise the importance of more dynamic, reciprocal interactions between policy research and policy making. Participants formulated the following three points that emerged as the most salient in the discussion on strengthening the UK's innovation ecosystem to meet net zero targets:

Urgency

Although there was a consensus among participants that we are seeing increasingly more discussion, activity, and funding in the climate space, there was also a recognition that the current set of institutions in the UK's innovation ecosystem is insufficient if we want to achieve net zero targets. In discussions on what exactly the UK institutions might be lacking, several ideas emerged, including: incentives for energy innovation, hiring, mission orientation, autonomy, and culture of innovation. Participants agreed that the UK is falling short in terms of innovation incentives if we do not have an ARPA-style climate-oriented funding agency, and that several of the functions that can be successfully performed by national laboratories are not being fulfilled by such institutions in the UK at present. Participants also highlighted the problem of encouraging innovation in traditionally less innovative sectors, and the problem of granting autonomy to researchers. With these institutional gaps identified, participants were keen to stress the urgency with which we need to reform and restructure UK institutions if we want to achieve net zero targets.

- ### Flexibility

Participants generally agreed that there is a clear need for flexibility and researcher autonomy if we want to encourage clean energy innovation. This can be encouraged, for example, by low-hierarchical challenge-oriented funding structures based on the model of ARPA-E. This flexibility, however, must be paired with clearly defined metrics of success, and the Government should develop mechanisms to track innovation milestones and outcomes.

- ### Place-based policy

Finally, there was a concern that the UK biases spending towards the South-East. Not only does this approach fail to address the social challenges involved in achieving net zero – uncertainty surrounding the performance of heat pumps and electric heating technology, for instance, as well as the cost of zero-emission heating systems – it also fails to recognise that regional variation can generate a concomitant variation in foci for innovation. Regional variation in the distribution of new and at-risk sectors generate different sets of opportunities and challenges for different parts of the UK. A closer collaboration between national and local government, along with an increase in regional autonomy, will be necessary to achieve net zero targets.

Participants

Chair - Dr Rob Doubleday, Executive Director, CSaP, University of Cambridge

Peter Bennett, The Peter Bennett Foundation

Matthew Billson, Deputy Director & Head of Energy Innovation Strategy, Department for Business, Energy & Industrial Strategy (BEIS)

Matthew Burnett, Head of Science and Technology, Onward UK

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Tomas Coates Ulrichsen, Director, UCI Policy Evidence Unit, Institute for Manufacturing, University of Cambridge

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