UK Energy Research Centre

Scottish Government: Draft Energy Strategy and Just Transition Plan consultation

UKERC Response

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Introduction to UKERC

The UK Energy Research Centre (UKERC) carries out world-class, interdisciplinary research into sustainable future energy systems.

It is a focal point of UK energy research and a gateway between the UK and the international energy research communities.

Our whole systems research informs UK policy development and research strategy.

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Introduction to submission

UKERC undertakes whole system and interdisciplinary research on a range of topics relevant to the Energy Strategy and Just Transition Plan. In what follows we draw upon this research and wider evidence to provide answers to selected questions. As UKERC is a consortium of research institutions that encompasses a range of perspectives it is not possible or desirable to achieve an agreed view on every topic. This submission reflects the views of individual contributors, identified in each section below. This is a particular facet of answers to questions that bring into focus a range of complex ethical and societal considerations. UKERC believes that it is essential to tackle such issues head on, taking a wide and whole system view of the issues, and acknowledging the need for the Scottish and UK governments to make difficult ethical and political choices.

Chapter 1: Introduction and vision

Q1. What are your views on the vision set out for 2030 and 2045? Are there any changes you think should be made?

Authors: Robert Gross and Keith Bell

There are many laudable aims expressed in the draft Energy Strategy and Just Transition Plan (ESJTP), notably that the "*transformation of Scotland's energy system will help us to achieve our net zero and interim climate targets*", "*our biodiversity, habitats and natural environment will have been protected and enhanced as part of the energy transition*", that the energy sector in Scotland "*will be innovative and competitive, will attract investment to Scotland and will enable businesses to set up and grow sustainably*", and "*the costs and benefits of the growth in our clean electricity generation will be shared equitably across society*". The challenge, of course, lies in meeting those aims.

The vision sets out a dramatic expansion in renewables, notably both onshore and offshore wind. The strategy also states that Scotland will continue to export energy internationally, but it is not obvious that expansion in renewable generation can even partially replace the reduction in oil and gas exports. As the consultation notes, Scotland is a significant net exporter of energy producing around 1160 TWh of primary energy in 2019 with nearly 900 TWh exported to other parts of the UK or other countries. Important economic benefits accrue from that production although more than 90% of it is from fossil fuels and is not sustainable in the long term.

It is not entirely clear how the strategy proposes to retain the economic benefits and jobs Scotland currently enjoys as a result of oil and gas production. We agree that it can and must make use of Scotland's rich potential for renewable electricity production, and develop and deploy means of capturing the CO_2 associated with any continued use of fossil fuels. There is no doubt that expanding renewables and exporting electricity and/or hydrogen will create jobs and the economic benefits associated with those jobs. However, reduction of oil and gas production (to 3% of current levels as the strategy proposes) and the need to expand use of electricity *within* Scotland as Scotland largely electrifies sectors currently served by fossil fuels, combined with the energy intensity of fossil stores, means that the volume of energy available for export in 2045 will be much lower than is the case today. That does not mean that Scotland will inevitably suffer economically because of the transition, the picture is far more complicated than that. But if Scotland wishes to continue to be a significant energy exporter, then it will need even greater expansion of renewable generation, or to produce hydrogen from fossil fuels with carbon capture and storage (CCS), or both.

The aspiration for Scotland to continue to be a net exporter of energy also requires that Scotland and the rest of the UK construct the network infrastructure needed to do so. Lack of network capacity already impedes Scottish renewables output. Irrespective of any changes to electricity network charging, increased availability of energy storage or smart demand, an expanded electricity transmission infrastructure is essential. Ambitions for hydrogen and CCUS also require entirely new infrastructure to be created. We return to these issues in the sections below.

The vision expressed in respect of the use of energy is compelling, and it has to be, because a wholesale transition of the use of energy away from unabated use of fossil fuels has to be achieved if legislated targets for greenhouse gas (GHG) emissions reduction are to be met. Important questions need to be asked about how the demand side transition is to be delivered and paid for. Notwithstanding recent rises in the price of fossil fuels, conversion to low carbon heating, transport and manufacturing industries remains a major challenge. Although the gap in long-run costs between fossil fuel-based uses of energy and uses of low carbon energy is much lower than it was (and in some cases renewable sources offer the cheapest form of electricity generation), the need for cheap finance and confidence about the long-term cost remains problematic across many sectors. A re-balancing of how legacy costs of support for development of low carbon electricity are recovered would help, moving away from adding to the cost of using of 'good' forms of energy to penalising use of 'bad' forms. It will also be important to ensure that households and businesses have access to information and trust in the agencies and companies tasked with delivery, that industries are able to secure the skills that will be needed, and that local supply chains ramp up.

There is a huge social benefit to be gained from mitigation of climate change. It is essential that every country on the planet decarbonises with the avoided adverse impacts of climate change being greater in some places than others. Action to decarbonise the energy system will also deliver local benefits, such as through improvement to air quality[1] and through jobs created to carry out retrofit of buildings,[2] expansion of the electricity network and installation of electric vehicle (EV) charging points. To the extent that Scotland's consumption emissions can be reduced through reduced consumption of meat and more active travel, there is the potential for better diets and further improvements to health.

Regulation to oblige high standards in design of buildings, provision of local amenities and support of public transport, plus monitoring and enforcement of rules, is within the gift of the Scottish Government and is long overdue. This will put pressure on the Scottish Government's and local authorities' budgets though the majority of investment in energy efficiency and low carbon heating in buildings will need to come from private investment.[3,4]

The problem of place needs to be addressed. Most of the jobs in a low carbon energy sector will be in different locations from where they've been in the high carbon sector. There may be fewer very high value jobs. As energy system specialists, it is beyond our expertise to comment in detail on how the problem of place might be tackled, but we note the need to avoid being locked into fossil fuel-based practices that will succeed only in deferring social and economic costs.

Overall, we welcome the level of ambition signalled in the strategy, and the explicit goal of ensuring that the transition is as equitable as possible. However, we believe

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[1] CCC. 2020. Sustainable Health Equity: Achieving a Net Zero UK (UCL). https://www.theccc.org.uk/publication/ucl-sustainable-health-equity-achieving-a-net-zero-uk/

[2] UKERC. 2023. Delivering a Sustainable and Equitable Heat Transition. https://ukerc.ac.uk/project/delivering-heat-transition/

[3] CCC. 2020. Sixth Carbon Budget. https://www.theccc.org.uk/publication/sixth-carbon-budget/

[4] Chris Skidmore. 2023. Mission Zero. https://www.gov.uk/government/news/net-zero-review-uk-could-do-more-to-reap-economic-benefits-of-green-growth

that it is important that the challenges inherent in doing this are not understated and that credible, detailed delivery plans are developed and implemented to dramatically expand renewable energy capacity, ensure that there is the network infrastructure needed to do so, unlock investment in energy efficiency and electrification, provide new sources of flexibility and grow a hydrogen sector. All this, whilst managing the decline of oil and gas production. In the sections that follow we comment on many of the more detailed proposals laid out in the consultation. We look forward to contributing evidence and insights as Scotland takes forward action across all aspects of energy production and use.

Chapter 2: Preparing for a just energy transition

Q6. Where do you see the greatest market and supply chain opportunities from the energy transition, both domestically and on an international scale, and how can the Scottish Government best support these?

Authors: Karen Turner, Hannah Corbett, Christian Calvillo Munoz, Sam Cooper, Rob Gross

Economic Opportunities

UKERC and wider economic research indicates that transitioning the Scottish and UK economy to meet net zero emission targets could deliver substantial wider economy benefits. There is significant potential to support jobs in new or growing sectors such as offshore wind and carbon capture, utilisation and storage (CCUS), with near-term opportunities for possibly extended transitory employment gains at infrastructure development stages across the broad and ongoing net zero transition space.

Two main areas seem to present particularly important opportunities for Scotland: CCUS and offshore renewables. Thanks to the availability of potential storage sites in Scottish waters and the availability of skills, expertise and infrastructure in the oil and gas sector. CCUS research[5] shows that a new Scottish CO2 Transport and Storage (T&S) industry linked to the Acorn carbon capture and storage (CCS) project, with capacity to sequester 3.8Mt of emissions from the Scottish cluster and a further 2.6Mt from overseas, could:

- Deliver a sustained uplift in UK GDP of £257m per annum by 2035 and net creation of almost additional 1,100 full-time equivalent (FTE) jobs across the economy, even where labour supply constraints trigger wage competition price pressures.
- Reduce the near- to mid-term public budget implications of intervention to guarantee utilisation of Scottish T&S capacity by 37%, from £171m per annum associated with Scottish cluster requirements to an estimated £108m per annum.

All these wider economy gains are delivered in the context of increases in wage rates, producer costs and consumer prices. If wage pressures are limited, there is potential for a greater sustained GDP uplift (up to £416m per annum) and substantially greater employment gains (up to 3,900 additional jobs) with almost no displacement of jobs across sectors or consumer price index (CPI) pressure. Identifying and exploiting sources of comparative advantage – such as the new export potential associated with enabling Scottish T&S through the Scottish cluster and Acorn CCS project - in the decarbonisation of different regional clusters will be critical.

[5] Turner et al. 2023. The Potential Economic Value of Increasing Scottish CO2 Transport and Storage Capacity to Service Overseas Export Demand. https://strathprints.strath.ac.uk/84117/

Potential market and supply chain opportunities are also linked to improving energy efficiency.[6,7] Benefits include:

- New economic activity, with the likelihood and magnitude of a transitory net GDP impact depending crucially on how actions are funded (i.e., grants, loans or households paying upfront), signalling by government on the extent and length of the programme and the extent to which resources are displaced and consequent price responses.
- Lower energy bills and gains in real income available for households to spend on other goods and services as a result of energy efficiency projects delivered. Sustained net gains in GDP can be expected to evolve over time and, crucially, to increasingly coincide with and uplift gains/offset losses associated with project delivery as more households make energy efficiency improvements. Ultimately, the magnitude and composition of evolving and sustained GDP gains will be dependent on constraints and price/cost responses across the economic system.

Finally, research also suggests that the decarbonisation of heat, via heat pumps can have positive economic impacts, while reducing total energy use, improving our energy security and helping to achieve Net Zero targets.[8]

Industrial decarbonisation

A key finding from a recent UKERC study that built upon the industrial analysis supporting the CCC's 6th carbon budget advice is that the supply chain for technologies to enable industry to transition to low-carbon processes needs to scale-up massively over this coming decade. Many of the technologies exist (e.g. high-temperature heat pumps, electric boilers, hydrogen-fired furnaces) but the supply is not yet mature.[9]

The technologies needed to enable Scottish industry to decarbonise exist in some form (e.g. switching away from fossil fuels to electricity) and are cost effective under a reasonable carbon-price. However, the rate at which the transition to these technologies can occur, is limited by the supply chain for delivering and installing them. This relates to manufacture of the equipment, expertise in specifying and installing it, operational expertise, commercial confidence in the technologies and their operation, and in the infrastructural requirements to support them.

These considerations relate to the enablers for industry to make use of the energy transition, in that they are separate and additional to the more obvious direct supply chain requirements and impacts of the energy transition itself.

The changes present both risks and opportunities. If supply chains are not scaled up quickly enough this will present a bottleneck to industry taking full advantage of the

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6 Turner and Katris. 2022. What does increasing residential energy efficiency do for the economy? https://strathprints.strath.ac.uk/82777/

7 Net Zero Neighbourhoods. https://ukerc.ac.uk/project/net-zero-neighbourhoods/

8 Turner et al, 2023. Unlocking the Benefits of Heat Pumps: The Role of Electricity and Gas Prices. https://ukerc.ac.uk/publications/benefits-heat-pumps-role-electricity-gas-prices/

9 Gailani et al. 2021. Sensitivity analysis of net zero pathways for UK industry. https://ukerc.ac.uk/publications/sensitivity-nzip

energy transition. There is also growth opportunity in supplying these technologies along with the expertise to install and operate them. Barriers that the Scottish government could help address include enhancing the pipeline for training the necessary workforce, and funding for commercial-scale demonstrations.

Interviews with relevant stakeholders, relating to barriers for a specific technology (in this case biomass gasification)[10] revealed that the commercial demonstration phase of technologies can often be where they fall down and do not meet their potential. This can happen when technologies are insufficiently mature for other support mechanisms to be appropriate (in which risk is not shared), but more developed than appropriate for R&D funding support.

Research relating to competitiveness[11] has demonstrated that the overall cost impact of industrial decarbonisation is likely to be minimal at an aggregate level (in the order of a few percent). However, energy / emissions intensive industries such as iron & steel, refining and cement will face greater hurdles and will need additional support / protection to remain competitive if overseas competition does not also face these costs. The most appropriate mechanisms for this support are beyond the scope of this response except to note that any action (or lack of action) will have an impact on the supply chains that depend upon them.

Q7. What more can be done to support the development of sustainable, high quality and local jobs opportunities across the breadth of Scotland as part of the energy transition?

Author: Richard Hanna

It is desirable that green and low carbon energy jobs should be decent jobs "which provide adequate wages, safe working conditions, safeguard workers' rights and social dialogue, and which provide social protection."[12] Higher job quality in green employment is also described in terms of higher wages and access to full-time employment,[13] and permanent rather than temporary jobs.[14,12] The literature suggests that direct employment in renewable energy construction or installation may be linked to temporary work which expires on completion of specific

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[10] Cooper, S., McManus, M., Welfle, A., & Blanco-Sanchez, P. 2019. Bioenergy and waste gasification in the UK. Barriers and research needs. https://researchportal.bath.ac.uk/en/publications/bioenergy-and-waste-gasification-in-the-uk-barriers-and-research-

[11] Cooper et al. In draft.

[12] de Mattos F. 2018. Greener growth, just transition, and green jobs: there's a lot we don't know. https://www.voced.edu.au/content/ngv%3A79770

[13] Jung Y-M. 2015. Is South Korea's green job policy sustainable? https://www.mdpi.com/2071-1050/7/7/8748

[14] MacCallum A.M. 2016. Employment associated with renewable and sustainable energy development in the Kingston region. https://qspace.library.queensu.ca/bitstream/handle/1974/13921/MacCallum_A_Megan_201601_MA.pdf?sequence=1

projects.[14,15,16] Nevertheless, it is likely that achieving net zero will require building new renewables capacity over the next several decades.

Godinho[16] point to OECD research which indicates that in general, lower skilled employees in the energy supply sector are more likely to be affected by job displacement as a result of low carbon energy transitions, and this may be compounded by workers losing benefits from previous work in carbon-intensive sectors.[17,18] In general, stronger national and international labour market standards and regulations are needed to support unemployed workers in decommissioned industries, provide skills training and increase the availability of alternative, decent work in affected regions.[19,16]

Various studies suggest that green jobs in general tend to be more highly skilled compared to higher carbon occupations. A review published by UKERC last year[20] observes that renewable energy or energy efficiency jobs are not always or necessarily more skilled than jobs in higher carbon energy sectors. Most jobs in the operation and maintenance of wind power and solar PV are in highly skilled, professional occupations. However, there is also demand for lower-skilled, manual occupations which comprise significant shares of solar PV installation and offshore wind construction activities.[21,22]

There is therefore a need to co-ordinate the development and supply of training so that it takes full account of the wide range of occupational functions required for manufacturing, building and installing, operating and maintaining renewable energy technologies and infrastructure. Sequential planning will be required to train and coordinate local workforces required for renewables expansion, minimising time gaps between projects and the need for construction workers to relocate.[20]

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[15] Sofroniou N. and Anderson P. (2021) The green factor: Unpacking green job growth. International Labour Review, 160(1), pp. 21-41.
[16] Godinho C. (2022) What do we know about the employment impacts of climate policies? A review of the ex post literature. WIREs Clim Change 13(6): e794.
[17] Chateau J., Bibas R., Lanzi E. (2018) Impacts of green growth policies on labour markets and wage income distribution: A general equilibrium application to climate and energy policies. OECD Environment Working Papers No. 137, Paris, France.
[18] Botta E. (2019) A review of “Transition Management” strategies: Lessons for advancing the green low-carbon transition. OECD Green Growth Papers 2019-04, Paris, France.
[19] IRENA and ILO (2021) Renewable energy and jobs – Annual review 2021. International Renewable Energy Agency, International Labour Organization, Abu Dhabi, Geneva.
[20] Hanna R., Heptonstall P., Gross R. (2022) Green job creation, quality and skills: A review of the evidence on low carbon energy. UKERC Technology and Policy Assessment.
[21] Allan G. and Ross A. (2019) ‘The characteristics of energy employment in a system-wide context’, Energy Economics, 81, pp. 238–258.
[22] Dominish E. et al. (2019) ‘Just Transition: Employment Projections for the 2.0 °C and 1.5 °C Scenarios BT - Achieving the Paris Climate Agreement Goals: Global and Regional 100% Renewable Energy Scenarios with Non-energy GHG Pathways for +1.5°C and +2°C’, in Teske, S. (ed.). Cham: Springer International Publishing, pp. 413–435.

Chapter 3: Energy supply

Scaling up renewable energy

> **Q9. Should the Scottish Government set an increased ambition for offshore wind deployment in Scotland by 2030? If so, what level should the ambition be set at? Please explain your views.**

> **Q10. Should the Scottish Government set an ambition for offshore wind deployment in Scotland by 2045? If so, what level should the ambition be set at? Please explain your views.**

We answer Qs 9 and 10 together.

Authors: Rob Gross and Keith Bell

It should be noted that Scotland's own targets for territorial net zero greenhouse gas emissions do not depend on the level of ambition for development of wind generation expressed in the draft ESJTP; elimination of production of energy from fossil fuels would suffice for that. However, according to the CCC, the meeting of targets for the UK as a whole would benefit from development and utilisation of substantial renewable energy production in Scotland. The CCC also notes (to the extent that appropriate uses of land permits it) the potential role of engineered CO_2 removal, e.g. through bioenergy with carbon capture and storage.[23]

Bids for seabed options in the Scotwind leasing round suggest that there is a huge amount of interest in developing offshore wind generation capacity. However, there are many factors that will affect how much of the initial Scotwind interest translates into development. These include how easy it will be for developers to gain planning permission for both production facilities and network capacity, whether there is a physical route to where buyers of the energy are located, and whether energy produced in Scotland is attractive to buyers relative to alternative sources. All of this suggests that the levels of energy production envisaged in the energy scenarios commissioned by the Scottish Government[24] are just some among many possible scenarios. If circumstances beyond Scotland's border have not been modelled in the development of those scenarios, they will have limited credibility and value.

Direct benefits to Scotland and its communities come from the jobs created and sustained in the development, operation and maintenance of energy production facilities within Scotland. However, the full extent of net future economic benefits to Scotland of energy production within its onshore and offshore territory depends on ownership structures, whether the profits arising from development feed back into the Scottish economy, and local content within the supply chain.

Investment in new production facilities and maintenance of existing ones depends on markets for the energy. Even if energy policy were fully devolved, the Scottish

[23] CCC. 2020. Sixth Carbon Budget. https://www.theccc.org.uk/publication/sixth-carbon-budget/
[24] Scottish Government. 2022. Scottish whole energy system scenarios: context document. https://www.gov.scot/publications/scottish-whole-energy-system-scenarios-context-document/

Government would have limited control over the attractiveness of Scottish sources of energy compared with competitor sources. Although high global prices of fossil fuels and geopolitics have pushed many parts of Europe more strongly in the direction of development and use of renewable forms of energy, global demand for fossil fuels remains higher than it should if the world is to stay within a maximum of a 1.5°C rise in average temperatures relative to pre-industrial levels.[25,26] Scotland's production of energy must transition away from fossil fuels towards renewables yet the infrastructure for the physical export of energy from the latter is currently severely limited and will take huge efforts to begin to compare with that of fossil fuels.

The potential for local content and supply chain development should be evaluated seriously and in detail, including assessment of the nature of Scotland's ports and access to materials and resources including expertise, with an honest appraisal of how Scotland compares to its competitors. It is often suggested that people and skills can be migrated from the oil and gas sector, but it must be asked whether this is likely to happen if that sector is being protected in any way. In any case, investment in expanded manufacturing capacity *somewhere* is essential not just for Scotland's renewable energy ambitions but Europe's. Manufacturers require long-term confidence in markets for goods. Contracting arrangements for low carbon energy at the GB level have a major bearing on that, but so too do matters such as support for development of skills – not just for young people but for older workers who are re-skilling, and for both the Further and Higher Education sectors – which is a devolved matter.

Q14. In line with the growth ambitions set out in this Strategy, how can all the renewable energy sectors above maximise the economic and social benefits flowing to local communities?

Author: Sarah Whitmee

Integrating health in the assessment of the costs and benefits of climate action can reveal benefits that are normally not considered in sectoral planning.[27] In the energy sector these benefits can vary substantially by installation type and location, due to differing electricity generation or savings by location, characteristics of the electrical grid and displaced power plants, along with population patterns.[28] It is therefore crucial to have spatial, environmental and demographic data to inform modelling exercises. Including indirect benefits can have important policy implications, and possibly determine whether investment in climate mitigation or adaptation is economically viable from a broader societal perspective. Forecasting the health cost of inaction and the health co-benefits of climate action allows to reduce pressure on future decision-making, increasing flexibility of subsequent decision-making by

[25] Welsby et al. 2021. Unextractable fossil fuels in a 1.5 °C world. https://www.nature.com/articles/s41586-021-03821-8
[26] IEA. 2021. World Energy Outlook 2021. https://www.iea.org/reports/world-energy-outlook-2021
[27] World Health Organization. 2023. A framework for the quantification and economic valuation of health outcomes originating from health and non-health climate change mitigation and adaptation action. https://www.who.int/publications/i/item/9789240057906
[28] Buonocore et al. 2016. Health and climate benefits of different energy-efficiency and renewable energy choices. https://iopscience.iop.org/article/10.1088/1748-9326/ab49bc/meta.

making the multidimensional value of current decisions explicit in the context of a changing climate.

We recommend that recent work on assessing the impact on mortality of pathways to net zero greenhouse gas emissions in England and Wales[29] is extended to examine impacts of pathways for Scotland. This would explore the potential impact on population health through multiple pathways and allow the potential predicted benefits from mitigation for public health to be quantified and communicated to help accelerate both ambition and action. We recommend that the abatement costs of any policy must be compared against the costs of inaction (business as usual)[27] – including the forecasted impacts of climate change on health and wellbeing.[30]

A full range of benefits may not be currently able to have robust valuation due to lack of data. To capture the range of benefits that can be accrued it may be necessary to use multi criteria analysis (MCA). MCA entails evaluating multiple attributes of policy or intervention outcomes, assigning utility values to them, and combining these assignments to arrive at an overall utility score. MCA can be an extension of a standard cost benefit analysis, adding qualitative dimensions to provide context and highlighting points of engagement needed in creating social tipping points. MCA can help identify factors to consider beyond the economic viability of a policy or investment when determining the course of action to take to address health concerns.[27]

Q15. Our ambition for at least 5 GW of hydrogen production by 2030 and 25 GW by 2045 in Scotland demonstrates the potential for this market. Given the rapid evolution of this sector, what steps should be taken to maximise delivery of this ambition?

Q16. What further government action is needed to drive the pace of renewable hydrogen development in Scotland?

Qs 15 and 16 are answered together.

Authors: Keith Bell and Rob Gross

A large hydrogen sector has obvious attractions. There is existing demand for hydrogen, currently served by ‘grey’ hydrogen made from natural gas without carbon capture and storage. In addition, as we discuss in relation to chapter 5 of the draft ESJTP, hydrogen made by using spare renewable electricity and stored until times when there is a deficit of renewable production relative to demand, promises to be the main vector through which security of energy supply can be achieved. It might also appear to be a means by which Scotland’s rich wind resources can be used, exporting hydrogen made by electrolysis.

[29] Milner et al. 2023. Impact on mortality of pathways to net zero greenhouse gas emissions in England and Wales: a multisectoral modelling study. https://www.thelancet.com/journals/lanplh/article/PIIS2542-5196(22)00310-2/fulltext
[30] Gasparrini et al. 2017. Projections of temperature- related excess mortality under climate change scenarios. https://www.thelancet.com/journals/lanplh/article/PIIS2542-5196(17)30156-0/fulltext

However, the report on decarbonising the power sector published by the Climate Change Committee in February this year[31] warned that, due to supply chain constraints, it is unlikely to be possible to meet the UK's demand for hydrogen in the 2030s solely from supplies manufactured using electrolysis.

The ESJTP acknowledges that oil and production form the North Sea will decline in the coming years. The ESJTP does not specify the extent to which the Scottish Government envisages using natural gas as a feedstock for manufacture of hydrogen and related products and whether its vision for retention of jobs in the North Sea oil and gas sector depends on it.

To be consistent with emissions reduction targets, use of reformation of natural gas for the production of hydrogen depends on carbon capture and storage (CCS). However, even the best process envisaged for CCS fails to capture all the CO_2, extraction of natural gas requires energy that is not currently low carbon, and there is flaring and potential leakage of methane, which is itself a potent greenhouse gas.

Many countries have strategies for the production and export of hydrogen. Investors in hydrogen production for export from Scotland will be wary of competition from these other potential sources. Overall, we therefore suggest that if hydrogen is to play a substantive role in Scotland's energy mix in future more clarity is needed on the roles of green and blue hydrogen, and on the policies that would underpin investment in Scottish hydrogen production.

North Sea oil and gas

Opening remarks

Author: Rob Gross

In our answers to Q20 and those on North Sea oil and gas that follow, UKERC is mindful of the significance of the offshore oil and gas industries to the Scottish economy, as well as the significant UK-wide economic and societal impacts of high fossil fuel prices, and heightened concerns about security of supply across Europe due to the war in Ukraine. We are cognisant of arguments that domestically produced gas is likely to have a lower carbon equivalent footprint than some imports, and that as the UK will be a net importer of oil and gas for some years to come, there may be emissions advantages from domestically produced gas replacing imports.[32]

We note also that these questions give rise to a range of complex trade-offs and argue that the topic is inherently ethical and political, giving rise to questions about Scottish and UK aspirations to show global leadership in the battle against dangerous climate change. We note in this regard the carefully nuanced CCC position on UK-wide climate compatibility checkpoints. We agree with the CCC view that "the best way of reducing the UK's future exposure to these volatile prices is… improving energy efficiency, shifting to a renewables-based power system and

[31] CCC. 2023. Delivering a reliable decarbonised power system. https://www.theccc.org.uk/publication/delivering-a-reliable-decarbonised-power-system/
[32] CCC. 2022. Letter: Climate Compatibility of New Oil and Gas Fields. https://www.theccc.org.uk/publication/letter-climate-compatibility-of-new-oil-and-gas-fields/

electrifying end uses in transport, industry and heating. Any increases in UK extraction of oil and gas would have, at most, a marginal effect on the prices faced by UK consumers in future". The CCC also note that "an end to UK exploration would send a clear signal to investors and consumers that the UK is committed to the 1.5°C global temperature goal. That would also help the UK in its diplomatic efforts to strengthen climate ambition internationally."[33]

This is a topic where views may differ within the UKERC consortium as well as the wider academic community. The detailed arguments presented here reflect the perspectives of the section authors. Nevertheless, UKERC takes a whole system approach to energy issues, and we believe that it is appropriate to take a holistic view of this complex topic that fully acknowledges the ethical dimensions it entails. Narrow questions about Scope 1 and 2 emissions are important but should not displace wider concerns about Scope 3 emissions, or indeed undermine broader goals such as showing global leadership on climate change mitigation.

Q20. Should a rigorous Climate Compatibility Checkpoint (CCC) test be used as part of the process to determine whether or not to allow new oil and gas production?

Authors: Gavin Bridge, Connor Watt and Gisa Weszkalnys

New oil and fossil gas production is not compatible with climate goals when the full life-cycle emissions associated with their extraction, processing and combustion are accounted for. The idea of a climate compatibility checkpoint, therefore, is misplaced. Moreover, the notion of a 'checkpoint' – if understood as a point of calculating compatibility, mischaracterises the nature of decision-making about futures where there are multiple uncertainties. Action in this context should be guided by an ethics (of care, of responsibility) and not reduced to calculation.

We note a number of points that suggest that if a more holistic and principle-based approach is taken to climate policy overall, a climate compatibility checkpoint test that allows production of fossil fuels to increase places global climate goals at risk:

Firstly, research shows that "existing fossil fuel infrastructure already places a 1.5 °C target at risk owing to implied 'committed' future CO_2 emissions."[34] This finding is buttressed by the IPPC's recent Synthesis Report (2023) which finds, with high confidence, that "projected CO2 emissions from existing fossil fuel infrastructure without additional abatement would exceed the remaining carbon budget for 1.5°C (50%)" and that emissions from existing and planned fossil fuel infrastructures alone are "equal to the remaining carbon budget for limiting warming to 2°C with a likelihood of 83%."

[33] CCC. 2022. Letter: Climate Compatibility of New Oil and Gas Fields. https://www.theccc.org.uk/publication/letter-climate-compatibility-of-new-oil-and-gas-fields/
[34] Tong et al. 2019. Committed emissions from existing energy infrastructure jeopardize 1.5 °C climate target. https://www.nature.com/articles/s41586-019-1364-3

Second, that there is sufficient oil and gas production to sustain current demand in a net zero scenario with no need for new oil and gas development.[35]

Third, at least "60% of existing oil and fossil methane gas" globally needs to remain undeveloped to have a 50% chance of limiting temperature rise to 1.5 degrees[36].

Fourth, there is a substantial 'production gap' between planned oil and gas production and production pathways consistent with a 1.5 degree rise,[37] so that global production must decline globally by 3 per cent each year until 2050, with steeper declines for Europe;[38] and a corresponding need (and responsibility on governments) to explicitly plan for the rapid reduction in fossil fuel production that climate targets require.

Fifth, the need to "forgo future production means country producers, fossil energy companies and their investors need to seriously reassess their production outlooks" the implication of this work is that "most regions must reach peak production now or during the next decade, rendering many operational and planned fossil fuel projects unviable".[39]

Finally, the urgency of reducing emissions (to remain within a carbon budget consistent with 1.5 degrees of warming) requires "placing restrictions on fossil fuel exploration and extraction to avoid locking in levels of fossil fuel supply that are inconsistent with climate goals." Examples of these supply side policies include moratoria, bans, or limits on fossil fuel exploration and extraction. Research also shows that "countries with higher financial and institutional capacity should lead the way as they are better equipped for a rapid and sustained decline."[40]

BEIS published a Climate Compatibility Checkpoint in September 2022, based on the assumption that "continued licensing for oil and gas is not inherently incompatible with the UK's climate objectives". Evidence cited above shows that this is not the case. The Climate Compatibility Checkpoint published by BEIS has a number of shortcomings:

First, applied to the point of production, it considers only Scope 1 (direct) and Scope 2 (indirect) emissions, leaving Scope 3 emissions (supply chain and customer use of products) out of the equation.[41] For oil and fossil gas, Scope 3 emissions account for roughly 70 to 90 per cent of lifecycle emissions from oil products and 60 to 85 per

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35 IEA (2021) Net Zero by 2050: A Roadmap for the Global Energy Sector.
36 Welsby et al. 2021. Unextractable fossil fuels in a 1.5° C world. *Nature*, *597*(7875), pp.230-234.
37 UN Production Gap Report (2021)
38 Welsby et al. 2021. Unextractable fossil fuels in a 1.5° C world. https://www.nature.com/articles/s41586-021-03821-8
39 Welsby et al. 2021. Unextractable fossil fuels in a 1.5° C world. Nature, 597(7875), pp.230-234.
40 UN Production Gap Report (2021), citing Muttitt & Kartha, 2020; SEI et al., 2020.
41 Scope 1, 2 and 3 are defined by the Greenhouse Gas Protocol and form the basis for all mandatory greenhouse gas emissions reporting in the UK (and beyond).

cent of those from natural gas.[42] Current offshore policy - the UK's Net Zero Strategy, which restates commitments in the North Sea Transition Deal - focuses on only operational emissions (Scope 1 and 2) and aims to halve them by 2030 (based on 2018 levels). However, global climate responds to absolute concentrations of greenhouse gases, rather than to measures of carbon intensity on a per-barrel basis. Total aggregate emissions is what matters from a climate change perspective, which is why including Scope 3 is essential (even if they are complex to measure).[43] Furthermore, efforts to reduce Scope 1 and 2 emissions on a per-barrel basis – without considering aggregate emissions - can have the paradoxical effect of increasing overall life-cycle emissions by encouraging throughput: a reduction in operational emissions per barrel can be achieved by expanding production from infrastructures with relatively fixed operating emissions, accelerating life-cycle emissions overall.

Second, it only applies to new licensing rounds rather than already existing licences in exploration phase or awaiting consent. Production declines in a mature basin provide an opportunity to phase down oil and gas production in line with the goals of the Paris Agreement. There is increasing evidence that new oil and gas production is not 'Paris compliant' and, furthermore, that imagined solutions via carbon dioxide removal technologies lack the scale, pace and certainty required.

Third, the Climate Compatibility Checkpoint in its current form has no legal force. The information derived from the checkpoint is advisory only and "*ensures Ministers have considered the sector's performance against climate related targets before endorsing a prospective licensing round*" and does not bind the Minister to any particular outcome.[44] There are no plans to put the Checkpoint on a statutory footing. As such, the Checkpoint is an inherently weak and insufficient regulatory instrument.

Fourth, the Checkpoint explicitly omits consideration of broader ethical and moral principles, stating that "*ethical considerations are beyond the scope of the checkpoint, which is focused on factors which are directly climate related*." The attempt here to remove ethical considerations and treat climate change as a narrowly scientific or technical issue is misguided, since climate change is, inherently, an ethical issue, and increasingly out of step with societal expectations.

Discussions held around the COP26 and COP27 - including newly formed organisations such as the Beyond Oil and Gas Alliance (BOGA) and campaigns such as the Fossil Fuel Non-Proliferation Treaty - indicate societal demands for

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[42] The IEA's World Energy Outlook (2018, p.490) reports "[…] the extraction, processing and transporting of oil and gas to end-users represents on average around 20% of the full lifecycle emissions of oil and 25% of the full lifecycle emissions of gas". In its comparison of the emissions intensity of oil and gas production, the IEA (2018: 477) further reports "Indirect emissions of oil are between 10% and 30% of its full lifecycle emissions intensity; indirect emissions of natural gas are between 15% and 40% of its full lifecycle emissions intensity." The category 'indirect emissions' in these quotations refers to "emissions from producing, transporting and processing oil and gas" (i.e. to both Scope 1 and Scope 2).
[43] EY. 2022. Just Transition Review of the Scottish Energy Sector. https://www.energy-system-and-just-transition-independent-analysis.co.uk/chapter1.pdf, see p.48
[44] CMS LAW NOW. 2022. The Climate Change Checkpoint Design. https://cms-lawnow.com/en/ealerts/2022/10/the-climate-change-checkpoint-design

action are shifting, in line with scientific evidence of the need for rapid reductions in extraction and use of fossil fuels. For example, although it proposes to benchmark emissions from UK oil and gas production against global producers, the Checkpoint does not consider regulatory measures taken by a number of countries to disincentivise the continued production of fossil fuels – that is, supply-side rather than demand-side measures to curb greenhouse gas emissions.[45] The UK Government's narrow framing of the Climate Compatibility Checkpoint and its explicit omission of ethical considerations is out of step and exposes investors in new production to the risk of asset stranding.

Q21. If you do think a CCC test should be applied to new production, should that test be applied both to exploration and to fields already consented but not yet in production, as proposed in the strategy?

Authors: Gavin Bridge, Connor Watt and Gisa Weszkalnys

We do not think a Climate Compatibility Checkpoint test should be applied to new production because there should be a presumption against new oil and gas development.

'New production' here should include not only new exploration and future licensing but also extensions to licenses that have not yet been consented or developed (consistent with a presumption of no new development). If there are legal obstacles to this position, consent should be contingent on an accounting of the full life-cycle emissions of the hydrocarbons produced over the projected life of the project. Any evaluation of overall benefit should include an evaluation of the environmental as well as social (including health)[46] costs associated with these life-cycle emissions: this could, for example, include shadow pricing of total emissions (including Scope 3) or requirements for extended producer responsibility such as a 'carbon take back obligation'[47] or the 'geo-zero' storage obligation on oil and gas producers highlighted in the Skidmore Review.[48] It should also consider economic risks, such as those associated with the 'stranding' of economic assets, and the volatility and system-wide risks associated with rapid mark-downs in the value of fossil assets.

Q22. If you do not think a CCC test should be applied to new production, is this because your view is that

(a) Further production should be allowed without any restrictions from a CCC test

[45] C. Higham and A. Koehl 2021. Domestic limits to fossil fuel production and expansion in the G20 (commentary). Grantham Research Institute on Climate Change and the Environment, LSE.
[46] Kotcher et al. 2021. Views of health professionals on climate change and health: a multinational survey study. https://www.thelancet.com/journals/lanplh/article/PIIS2542-5196(21)00053-X/fulltext ; World Health Organization 2014. Gender, climate change and health https://www.who.int/publications/i/item/9789241508186 ; Ramonello et al. The 2022 report of the *Lancet* Countdown on health and climate change: health at the mercy of fossil fuel. https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(22)01540-9/fulltext
[47] Jenkins, S., Kuijper, M., Helferty, H., Girardin, C. and Allen, M., 2022. Extended producer responsibility for fossil fuels. https://iopscience.iop.org/article/10.1088/1748-9326/aca4e8
[48] Mission Zero: Independent Review of Net Zero (2023), see p. 116.

(b) No further production should be allowed [please set out why], and;
(c) Other reasons [please provide views].

(b) New production of oil and gas is not compatible with the requirements of rapid climate change mitigation, borne out by scientific evidence (see above) and acknowledged by the Scottish Parliament's declaration of a climate emergency in 2019. Production declines from existing fields offer a 'glide path' for phasing out oil and gas production. Production from sanctioned fields on the UKCS is estimated by OEUK to decline 75% by 2030 (from 2019) levels, while production from the Scottish North Sea is projected to decline by 90% by 2050 with a compound average rate of decline of 7.8% in this period.[49] Sanctioning new projects will not reverse production declines (because of smaller field sizes) and will lock in future emissions (from Scope 1, 2 and 3). The aggregate effect of sanctioning new fields is to increase life-cycle emissions overall and, by forestalling the end date of production, it requires an even steeper (and more traumatic) decline.[50] Achieving a just transition is possible by not locking in future production and phasing out now.

Q23. If there is to be a rigorous CCC test, what criteria would you use within such a test? In particular [but please also write in any further proposed criteria or wider considerations]

Authors: Gavin Bridge, Connor Watt and Gisa Weszkalnys

As outlined above, we do not think the concept of a climate compatibility checkpoint is appropriate in the context of new hydrocarbon production, because fossil oil and gas when consumed will contribute to the accumulation of atmospheric GHG. The notion of 'climate compatibility' is made possible only by ignoring Scope 3 emissions.

While 'climate compatibility' is a misnomer, it does acknowledge (albeit in a flawed way) the need to complement demand side policies (that focus on emission reduction) with domestic supply-side policies that restrict production. As we highlight above, research shows both are necessary if there is to be a chance of remaining within the carbon budget.

If the political process of negotiating a Just Transition requires a process whereby the full climate consequences of oil and gas production can be evaluated, then that process should be based on a full accounting of Scope 3 emissions together with the wider social and environmental costs of hydrocarbon consumption.[51] Importantly, this is not a check of 'climate compatibility': rather it is a physical accounting process

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49 EY. 2022. Just Transition Review of the Scottish Energy Sector.https://www.energy-system-and-just-transition-independent-analysis.co.uk/chapter1.pdf see pages 5 and 82
50 Kemfert et al., 2022. The expansion of natural gas infrastructure puts energy transitions at risk. https://www.nature.com/articles/s41560-022-01060-3
51 Kotcher et al. 2021. Views of health professionals on climate change and health: a multinational survey study. https://www.thelancet.com/journals/lanplh/article/PIIS2542-5196(21)00053-X/fulltext ; World Health Organization 2014. Gender, climate change and health https://www.who.int/publications/i/item/9789241508186 ; Ramonello et al. The 2022 report of the *Lancet* Countdown on health and climate change: health at the mercy of fossil fuel. https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(22)01540-9/fulltext

that evaluates the full suite of environmental and social consequences of production-consumption.

In the context of understanding the impact of oil and gas production in the Scottish North Sea specifically on the global goals of the Paris Agreement, should a CCC test reflect –

(a) the emissions impact from the production side of oil and gas activity only;
(b) the emissions impact associated with both the production and consumption aspects of oil and gas activity (i.e. also cover the global emissions associated with the use of oil and gas, even if the fossil fuel is produced in the Scottish North Sea but exported so that use occurs in another country) – as proposed in the Strategy;
(c) some other position [please describe].

(c) As outlined above, any evaluation of the impacts of new oil and gas production needs to account for its full environmental and social impacts. This should include the global emissions from Scottish production (Scope 3) but should also extend to the full social and environmental consequences of its production.

Should a CCC test take account of energy security of the rest of the UK or European partners as well as Scotland? If so, what factors would you include in the assessment, for example should this include the cost of alternative energy supplies?

Energy security concerns should be addressed, in the first place, through intensified development of domestic renewable energy production and storage and through energy efficiency improvements. As recommended by the Climate Change Committee's Sixth Carbon Budget Report, there is urgent need (and scope) for a reduction of fossil fuel demand through the development of a low-carbon economy and a reliable and resilient decarbonised electricity supply system at a regional and national level.[52] Physical supply security during transition is most likely to be best achieved via diversification, rather than developing new domestic supplies which lock in new fossil production for long periods. Concerns about potentially higher emission intensities of oil and gas sourced outside the UK need to be acknowledged, although (a) this is a long-standing phenomenon that already arises from oil and gas trade (which is based on price and not on emissions) rather than solely as a consequence of winding down domestic production; and (b) higher emission intensities in the short-term (which account for only Scope 1 and Scope 2 emissions) can be justified in the interests of rapidly phasing out both supply and demand (i.e. Scope 1, 2 and 3 emissions).

Concerns about energy security should be directed to existing patterns of energy use and accelerating action on energy efficiency by, for example, improving leaky buildings while also ensuring the poorest have access to affordable energy (as recommended by UKERC Annual Policy Review).[53] The British Energy Security

[52] Committee on Climate Change 2020. Policies for the Sixth Carbon Budget and Net Zero. https://www.theccc.org.uk/wp-content/uploads/2020/12/Policies-for-the-Sixth-Carbon-Budget-and-Net-Zero.pdf
[53] Webb, J. 2022. Affordability of Energy for Households in Britain. UKERC Review of Energy Policy.

Strategy (2022) focused primarily on new sources of supply, but research identifies how "*developing new sources of supply will take years and cannot provide short-term help to struggling households*." It also recognises how "*failure to act on demand-side measures harms health and welfare…(while) subsidies without demand side policies contribute to lock-in to fossil fuels*."[54]

Recent UKERC research also points to the importance of planning for the phase down of gas consumption – a strategy of 'gas by design', the importance of which has been reinforced by the recent energy price crisis.[55] There is some evidence among industrial consumers that high energy prices over the last year is accelerating action to reduce the dependency of businesses on fossil fuels and promote electricity as a low carbon source of energy.[56] In other words, current projections about future demand for fossil energies may be revised to see a more rapid winding down of consumption, particularly if underpinned by concerted action on electrification, efficiency and demand reduction.

Should a CCC test assess the proposed project's innovation and decarbonisation plans to encourage a reduction in emissions from the extraction and production of oil and gas?

As identified above, there should be a presumption against new development. Existing production should be incentivised to reduce full life-cycle emissions i.e., including Scope 3 and not only operational emissions (Scope 1 and 2).

Emissions reduction via electrification of existing assets is insufficient on its own, yet also essential as it is required to create some headroom for emissions which will arise from consuming the oil and gas produced. However, focusing only on reducing Scope 1 and 2 can incentivize an increase in overall life-cycle emissions: a reduction in operational emissions per barrel can be achieved by expanding production from infrastructures with relatively fixed operating emissions, accelerating life-cycle emissions overall.

In carrying out a CCC test, should oil be assessed separately to gas?

As outlined above, we do not think the concept of a climate compatibility checkpoint is adequate in the context of new hydrocarbon production, because oil and gas when consumed will contribute to the accumulation of atmospheric GHG. The notion of 'climate compatibility' is made possible only by ignoring Scope 3 emissions.

Oil and gas should not be assessed separately. The discursive separation of natural gas from other fossil fuels and its promotion as a "transition fuel" is misleading. It downplays economic interests with a stake in continued production, transport and use of natural gas, minimises natural gas's role as a causal factor in climate change

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[54] See Webb, J. 2022, who also notes "The UK is unique in Europe in that its response to the energy crisis has focused almost entirely on supply-side measures and subsidies" UKERC Review of Energy Policy.

[55] Bradshaw, M. 2022. Crisis – Which Crisis? Building Gas Security and Electricity Market Resilience. UKERC Review of Energy Policy.

[56] Taylor et al. 2022. Impacts of the Energy Crisis on Business and Industry. UKERC Review of Energy Policy.

(including methane emissions in the supply chain). It may lead to substantial carbon lock in (due to infrastructural, institutional and behavioural factors) that crowds out investment in renewables and creates a risk of stranded assets.[57]

Q24. As part of decisions on any new production, do you think that an assessment should be made on whether a project demonstrates clear economic and social benefit to Scotland? If so, how should economic and social benefit be determined?

Authors: Gavin Bridge, Connor Watt and Gisa Weszkalnys

Yes. This assessment should be in the spirit of a "just" transition, which requires moving beyond a narrow conception of economic and social benefit (in terms of, for example, jobs and revenues), to include a comprehensive and holistic evaluation. Specifically, it has to include an evaluation of the interlinked socio-economic (including health)[58] and environmental costs associated with hydrocarbon production through its full life-cycle, particularly in the form of climate change.

Q25. Should there be a presumption against new exploration for oil and gas?

Authors: Gavin Bridge, Connor Watt and Gisa Weszkalnys

For the reasons set out above, a presumption against new exploration is more likely to be broadly compatible with UK-wide and Scottish aspirations to move towards net zero emissions. It is easier to align a presumption against new exploration with a 'glide path' associated with progressive emissions reduction. Doing so would ensure efforts focus on the transition away from oil and gas and avoid the risk of stranded assets, as we explain more fully in our answer to Q26.

Q26. If you do think there should be a presumption against new exploration, are there any exceptional circumstances under which you consider that exploration could be permitted?

Authors: Gavin Bridge, Connor Watt and Gisa Weszkalnys

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[57] See, for example, Kemfert et al. 2022. The expansion of natural gas infrastructure puts energy transitions at risk. *Nature Energy* 7, 582-587 ; https://www.theguardian.com/environment/2022/nov/11/gas-producers-using-cop27-to-rebrand-gas-as-transitional-fuel-experts-warn; and C. Gürsan and V. de Gooyert 2021. The systematic impact of a transition fuel: Does natural gas help or hinder the energy transition? *Renewable and Sustainable Energy Review* 138. Looking specifically at the case of Poland, Zych et al. (2023) point to the unprofitability of investment in gas infrastructures as 'transitional' measure in certain circumstances. Zych et al. 2023 The cost of using gas as a transition fuel in the transition to low-carbon energy: The case study of Poland and selected European countries. *Energies* 16(2), 994.

[58] Kotcher et al. 2021. Views of health professionals on climate change and health: a multinational survey study. https://www.thelancet.com/journals/lanplh/article/PIIS2542-5196(21)00053-X/fulltext; World Health Organization 2014. Gender, climate change and health https://www.who.int/publications/i/item/9789241508186; Ramonello et al. The 2022 report of the Lancet Countdown on health and climate change: health at the mercy of fossil fuel. https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(22)01540-9/fulltext

Arguments that domestic exploration should be permitted as a hedge against rising prices misunderstand the nature of international oil and gas markets. Recent experience shows that domestic gas supplies (account for around half UK consumption) have not provided price security.[59] Physical supply security during transition can be best achieved via diversification, rather than developing new domestic supplies which risk lock-in to new fossil production for long periods.

Arguments that domestic exploration and/or production of oil provides supply security ignores the strong export focus of most offshore oil production. There is no requirement that oil produced from the UKCS flows to UK consumers and most of it does not. In 2020 over a quarter of UK oil production was exported to China. When re-fuelling at the petrol station, it is more likely to be petrol or diesel refined from crude oil extracted in Norway or the United States than it is from North Sea oil.[60]

Arguments that domestic production can be kept on 'standby' or provide a stopgap in the face of short-term supply issues fail to consider the timeframes of ordinary oil and gas production. Existing installations cannot simply be switched on and off, and new projects take considerable time to materialise, including a pronounced hiatus between exploration and production. Promoting such speculative investments based on security considerations risks increased exposure to stranded assets.

However, it may be prudent to include a contingency around long-term oil and gas storage linked to war/emergency, and this is an important matter for the UK and Scottish Parliaments to decide.

[59] See, for example, Bradshaw, M. 2022. Energy crisis: why the UK will be at the mercy of international gas prices for years to come (theconversation.com)
[60] See, for example, Digest of UK Energy Statistics (2022), Chapter 3 (Petroleum) and summary analysis using these data, such as Bridge et al. (2022) here.

Chapter 4: Energy demand

Heat in buildings

Q27. What further government action is needed to drive energy efficiency and zero emissions heat deployment across Scotland?

Authors: Jan Webb, Katherine Sugar, Jess Britton, Helen Poulter and Rob Gross

UKERC welcomes the ambition to decarbonise heat in buildings, and to combine renovation of buildings to reduce the need for heat with zero emission heating systems. We endorse the emphasis on energy efficiency which should contribute to avoiding some of the costs of decarbonising supply and reinforcing power networks. Demand reduction offers the potential for households, community and public facilities and businesses to benefit through lower energy bills and improved comfort. We also recognise the value of the considerable investment in Local Heat and Energy Efficiency Strategies (LHEES). LHEES and delivery plans can provide a critical part of the framework to accelerate building retrofit and heat decarbonisation.

The relevant section in the draft ESJTP largely summarises the Heat in Buildings Strategy (2021). The ESJTP adds a statement that hydrogen is not expected to be central to decarbonisation of domestic heat, although some niche applications may be developed. This is useful recognition that uncertainty about the future of hydrogen and the gas grid should not delay urgent action using existing solutions that are already established and available.

We also welcome the recognition that an unprecedented level of leadership and co-ordination will be needed to secure full awareness and understanding of the changes required to maximise energy efficiency in buildings and to decarbonise the energy required to meet the remaining needs. This is required both now and over the long-term.

The establishment of a Public Energy Agency, Heat and Energy Efficiency Scotland (EES), currently in a virtual form, is the main institutional change expected to provide that leadership and coordination. Initial work is focused on a public understanding and engagement strategy, providing project expertise and co-ordinating investment. Around £1.8bn is committed over the course of the parliament to support the work.

As the development of the new agency is very recent, it is not yet possible to assess the adequacy of the envisaged solution. However, given the scale of work (with action needed by almost every building owner in Scotland), and importance of LHEES in heat decarbonisation, Heat and Energy Efficiency Scotland should publish, as a priority, details of its approach to information provision and public engagement, and how this will support and integrate with LHEES and delivery plans.

Progress thus far – since establishment of EES and LHEES Pilots - has been slow and small scale, encountering multiple issues ranging from materials' procurement to workforce availability, budgets, data, private investment and owner consent in multi-use, multi-ownership buildings.[61,62,63,64] The draft does not state explicitly why we should now expect progress to be radically accelerated. This is particularly worrying in the context of the recent Climate Change Committee criticisms of the credibility of Scotland's climate policy to meet stated aims[65], and the Committee's emphasis on necessity for action commensurate with the urgency and scale of policy commitments. The criticisms are highly relevant to heat decarbonisation, where there has been little change in sectoral emissions since the first Climate Change (Scotland) Act in 2009.

The Scottish Government, and/or Heat and Energy Efficiency Scotland, should undertake a full review of LHEES and Delivery Plans shortly after the 31 December 2023 publication deadline. This should include: an assessment of how the identification of strategic zones and delivery areas could inform the design of Scottish Government policies; a review of project pipeline development (and how coordination or investment portfolio development should be managed); and a review of how the delivery plans can be mobilised to crowd in finance for net zero. Given the resourcing and skills constraints experienced by local governments, this should include engagement with local governments on barriers and enablers to high quality LHEES and delivery.

The likely electrification of a significant proportion of heat demand will create substantial demands on electricity distribution networks, as well as scope for demand flexibility. Whilst LHEES does not currently incorporate wider energy planning (beyond heat and energy efficiency) plans are likely to have a material impact on distribution networks through identification of priority areas for electrified heat. Research suggests that approaches to incorporating local flexibility are less developed in Scotland than in the rest of Great Britain[66]. The Scottish Government

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[61] Bush R, McCrone D, Webb J, Wakelin J, Usmani L & Sagar D. 2018. Energy Efficient Scotland – Phase 1 pilots evaluation final report. https://heatandthecity.org.uk/wpcontent/uploads/2018/11/EES-Pilot-Evaluation-Phase-1-Final-Report1.pdf
[62] Sugar, K., Webb, J., & Wade, F. 2022. Energy Efficient Scotland Transition Programme Survey Evaluation. https://www.gov.scot/binaries/content/documents/govscot/publications/research-and-analysis/2022/08/energy-efficient-scotland-transition-programme-survey-evaluation/documents/energy-efficient-scotland-transition-programme-survey-evaluation/energy-efficient-scotland-transition-programme-survey-evaluation/govscot%3Adocument/energy-efficient-scotland-transition-programme-survey-evaluation.pdf
[63] Wade, F. Webb, J., & Creamer, E. 2020. Energy Efficient Scotland Phase 2 Pilots: Final Social Evaluation Report. https://www.gov.scot/binaries/content/documents/govscot/publications/research-and-analysis/2020/10/energy-efficient-scotland-phase-2-pilots-final-social-evaluation-report/documents/energy-efficient-scotland-phase-2-pilots-final-social-evaluation-report/energy-efficient-scotland-phase-2-pilots-final-social-evaluation-report/govscot%3Adocument/energy-efficient-scotland-phase-2-pilots-final-social-evaluation-report.pdf
[64] Wade, F., & Webb, J. 2020. LHEES Phase 2 Pilots: Evaluation Report. https://www.gov.scot/binaries/content/documents/govscot/publications/research-and-analysis/2020/10/local-heat-energy-efficiency-strategies-lhees-phase-2-pilots-evaluation/documents/lhees-phase-2-pilots-evaluation-report/lhees-phase-2-pilots-evaluation-report/govscot%3Adocument/lhees-phase-2-pilots-evaluation-report.pdf
[65] https://www.theccc.org.uk/2022/12/07/scotlands-climate-targets-are-in-danger-of-becoming-meaningless/
[66] Britton, J. and Webb, J. (2022) Institutional Landscapes for Local Energy Systems: Mapping England, Scotland and Wales. https://ukerc.ac.uk/publications/institutional-landscapes-for-local-energy-systems-mapping-england-scotland-and-wales/

should therefore work more closely with Ofgem to incorporate LHEES as material considerations in DNO business planning and investment during the 2023-2028 price controls.

Although Scottish Government have been working closely with the energy networks to create ambitious business plans for the new price control period, the lack of clarity about the future direction of heat means that these plans, and therefore Ofgem, must deal with high levels of uncertainty, which could result in unfavourable outcomes for customers. For the new price control, Ofgem has included uncertainty mechanisms (volume drivers, re-openers and price control deliverables) to allow the networks to access funding should certain types of investment be needed and so protecting customers against excess costs. However, as none of these mechanisms have yet been triggered, it is too early to state whether they will be responsive to Scottish heat policy and implementation, or whether they will hinder progress.

For the energy network companies to plan future investments, Scottish Government need to provide clarity on the expected scale, pace and geography of energy efficiency measures and heat decarbonisation pathways. Decisions around capacity investment for the electricity networks and extending and refurbishing the gas network are reliant on energy efficiency and technology specifics; hence alleviating some of the uncertainty for the energy network companies could enable more 'no regrets' investment ahead of need and a more seamless, less costly transition. We draw attention to the Net Zero South Wales project[67] which recognised the place-based nature of heat decarbonisation and the benefits for network planning, and therefore for customers, of clarifying which pathway(s) heat decarbonisation would be expected to take. We suggest that Scottish Government should continue to coordinate with the gas and electricity networks, both at distribution and transmission level to ensure that the energy network businesses develop robust scenario modelling for heat decarbonisation across vectors, so decreasing the levels of uncertainty in the system.

We also recommend that Scottish Government continue to work closely with the regulator to identify the possible regulatory challenges of some heat decarbonisation solutions. New technologies could require new customer protections which will necessitate liaison with Ofgem and the Competition and Markets Authority to ensure codes are fit for purpose.

Further Government Actions

- Explicit statement of the carbon saving targets expected from implementing each component of the Heat in Buildings Strategy (HiBS) (as in 2020 Climate Change Plan), to help prioritise actions.
- Clarity about the envisaged sources of 'zero direct emissions' heat and information about how decisions will be made about potential zoning of areas for different heating systems, including heat networks.

[67] Regen, WWU, and WPD. 2020. "Net Zero South Wales 2050. Data Companion Report." https://www.regen.co.uk/wp-content/uploads/Net-Zero-South-Wales-Final.pdf

- Explicit division of responsibilities between national and local governments, as well as industry and third sector.
- A timetabled programme of work to meet the targets, beyond Home Energy Scotland loans and grants, to help minimise delivery bottlenecks and to set industry and property owner expectations.
- Clarification of the intended link between the HiBS, the promised Heat in Buildings Bill and Local Heat and Energy Efficiency Strategies (LHEES). How will these work quickly and in coordination to secure faster progress, monitoring and review?
- A Strategy monitoring and evaluation plan including commitments to adopt improvements quickly. The plan should link to the Climate Change Plan Monitoring Framework to track progress against carbon reduction targets.
- Action to adapt EPCs – or to adopt another standard - to ensure that building assessments are fit for purpose, including assessing actual energy performance of buildings, and prioritising highest standards of retrofit, not a lowest common denominator checklist. This should include training and accreditation of Assessors, including for highest efficiency ratings. A high standard retrofit model is for example set out by the Passivhaus Trust guide to EnerPHIT which includes routes to certification including staged retrofit to suit owners' timetables and budgets.[68]
- A unified system for enforcement of building retrofit and zero emission heat standards, through for example resources to recruit and train adequate, skilled building control officers in local authorities.

Suggested Actions - Heat and Energy Efficiency Scotland

- Working closely with the building trade associations (and sector skills councils or other relevant bodies), including heating engineers, gas fitters, joiners and electricians, the Agency should coordinate a major training/skills programme in net-zero retrofit and construction, which will enable the benefits of a wider just transition for Scotland through the delivery of new jobs, apprenticeships and work placements. This is part and parcel of necessary reform of regulation, organisational culture and the provision of vocational and technical training (see Killip, 2020 for evaluation of the German example and success factors[69]).
- All trades in building Repair, Maintenance and Improvement would then work with customers to promote knowledge about net zero emission buildings, what action is required by when, what is on offer and how to get access to grants and loans. This would give greater momentum to the programme at sectoral scale, rather than relying on the initiative of building owners (see Wade et al, 2017 for example[70]).
- Such a new approach to training and skills will require support through a statutory framework and use of public procurement to drive change. Public

[68] Passive House Institute. Certification process. https://passivehouse.com/03_certification/02_certification_buildings/06_process/06_process.html
[69] Killip, G. 2020. A reform agenda for UK construction education and practice. Buildings and Cities, 1(1), 525–537. DOI: http://doi.org/10.5334/bc.43
[70] Wade, F., Shipworth, M. & Hitchings, R. (2017). How installers select and explain domestic heating controls. Building Research & Information, 45(4), pp.371-383. DOI: https://doi.org/10.1080/09613218.2016.1159484

procurement could utilise local businesses and supply chain, particularly through Scotland's small-medium enterprises, to help contribute to community wealth in places. The approach to procurement, LHEES and supply chain development should also be integrated with Scotland's evolving approach to Community Wealth Building, including the current consultation on community wealth building legislation.[71]

- Consider lessons from UK Government's recent consultation on a new approach to energy performance of non-domestic buildings in England and Wales. This proposes introduction of energy performance benchmarking and disclosure requirements.[72]

On Heat Network Targets and Developments

- We welcome the legislation designed to license and regulate the nascent heat network sector in Scotland. Heat networks are heat source agnostic and an established socio-technical solution to make effective use of waste heat, which currently pollutes the environment rather than providing cost and carbon savings.[73] Meeting the extremely ambitious development targets will however (minimally) require cross-sector coordinated heat planning and zoning to be concluded rapidly, with an obligation to connect for key building types or heat loads. This will ensure financial viability, and de-risk investment. Without these steps, there is no obvious route to ensuring that heat network infrastructure will be developed in places with high density and diversity of heat demand, where it provides the required economies of scale to provide efficiency and carbon savings.[74] Scottish Government needs to work with UK Government to ensure that such a connection requirement is implemented in line with current zoning plans in England (formerly BEIS now DESNZ).
- Use of licensed concession zones with a requirement to connect for specific building owners would in turn incentivise heat network developers to invest in future proofing systems and to plan for future expansion to capture the value of maximising heat demand connected to a network, including affordability of heating and hot water.
- Progress will require customer protection measures; Scottish Government is indicating the intention to coordinate with Ofgem for future regulation and customer protection. Standards adopted need to include transparency over heat prices relative to company profits, and published standards for heat network business accounting. Protections should also include a supplier of last resort if the contractor/system operator failed. This is typically either a local authority or a national government agency.

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[71] Scottish Government. Building community wealth: consultation. https://www.gov.scot/publications/building-community-wealth-scotland-consultation-paper/documents/

[72] DESNZ & BEIS. Introducing a performance-based policy framework in large commercial and industrial buildings. https://www.gov.uk/government/consultations/introducing-a-performance-based-policy-framework-in-large-commercial-and-industrial-buildings

[73] https://www.whyenergyefficiency.com and https://www.iea.org/reports/district-heating

[74] Hawkey et al. 2016. Sustainable Urban Energy Policy: Heat and the City. https://www.routledge.com/Sustainable-Urban-Energy-Policy-Heat-and-the-city/Hawkey-Webb-Lovell-McCrone-Tingey-Winskel/p/book/9781138826120

Energy for industry

Q36. What are the key actions you would like to see the Scottish Government take in the next 5 years to support the development of CCUS in Scotland?

Authors: Ahmed Gailani and Imogen Rattle

Scottish manufacturing industry emits around 7 $MtCO_2e$ in 2017 which comes mainly from chemicals, refining, and cement sites as shown in Figure 1. We used the Net Zero Industry Pathways (NZIP) model, which was used to inform the Committee on Climate Change analysis for the 6th carbon budget, to explore the emissions pathway by 2050 and therefore uncover the role of CCUS to decarbonise those emissions in Scotland.

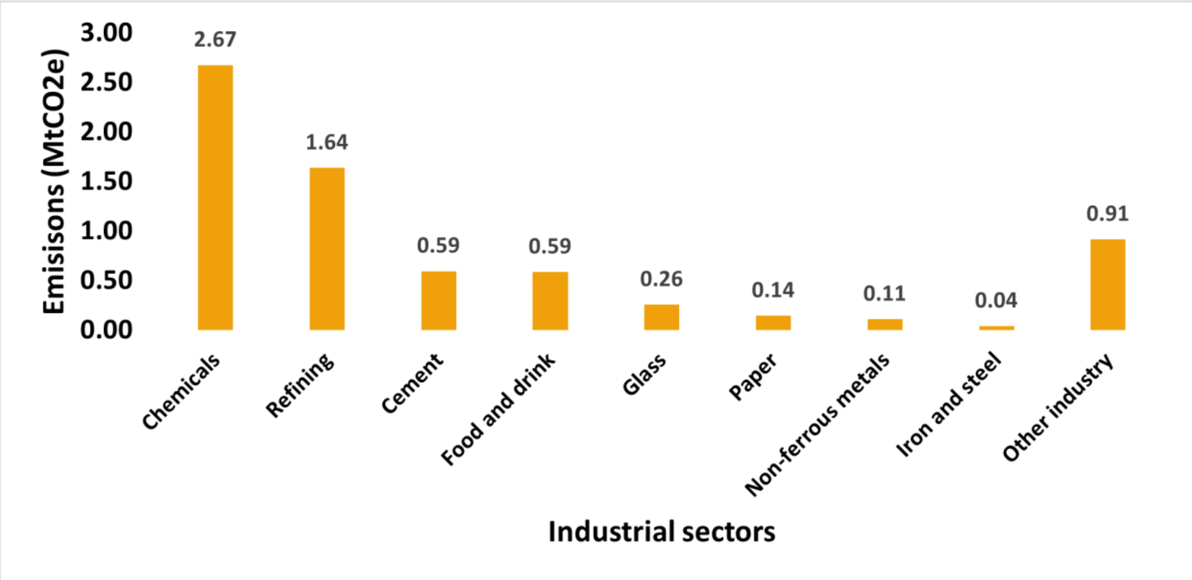

Figure 1 Emissions baseline for Scottish manufacturing sector in 2017, adopted from the net-zero industrial pathways model[75] .

As shown in Figure 2, CCUS technologies are implemented in 2035 in the model and can decarbonise nearly 23% of the baseline emissions by 2050. However, 50% of emission saving is expected to come from resource efficiency and energy efficiency (REEE) measures with other savings expected from deploying electrification and hydrogen technologies. While CCUS has an important role to play especially for industrial sites located in clusters and for sites with high process emissions, the Scottish government may consider supporting wider set of measures to decarbonise the sector.

[75] Element Energy 2020. Deep-Decarbonisation Pathways for UK Industry. https://www.theccc.org.uk/wp-content/uploads/2020/12/Element-Energy-Deep-Decarbonisation-Pathways-for-UK-Industry.pdf

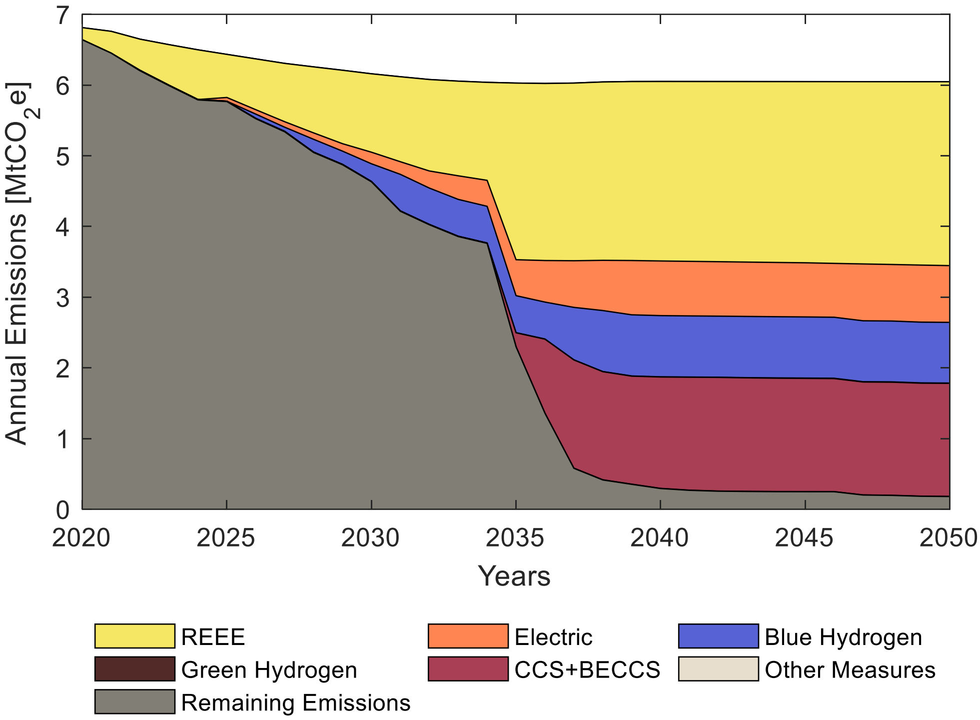

Figure 2 Emissions pathway (balanced scenarios) for Scottish manufacturing industry produced by NZIP model.

It is instructive here to consider the lessons learned from previous CCS projects. A review of 39 successful and unsuccessful carbon capture projects in the United States[76] finds that credibility of revenues and incentives, capital cost and technological readiness are the four main attributes that explain variation in CCS project outcomes. In terms of credibility of revenues, projects that can demonstrate credible revenue streams are, understandably, more likely to succeed. In the case of the US, credible revenue streams have historically been sale of captured CO2 for use in enhanced oil recovery or upfront cash grants from federal government. The same study also notes that projects that are successful rely less on government incentives than those that fail. This is because projects that receive government incentives are often flagship, high-risk, demonstration projects that are vulnerable to political veto. Projects with larger capital costs are more likely to fail, again because they are often more complex and high risk. In terms of technological readiness, use of mature technologies improves the chance of project success by reducing technical and system integration risks. However, political institutions and social dynamics vary across countries, so caution about Scottish relevance is needed, and the findings outlined above may not transfer directly to Scotland.

A conference paper reviewing lessons from European CCS policy in the period 2010-2015[77] argues that the failure of CCS policy in this period was due to three

[76] Abdulla et al. 2021. Explaining successful and failed investments in US carbon capture and storage using empirical and expert assessments. https://iopscience.iop.org/article/10.1088/1748-9326/abd19e
[77] Billson and Pourkashanian. 2017. The Evolution of European CCS Policy. https://www.sciencedirect.com/science/article/pii/S1876610217319057

main factors: an industry that was weak in communicating why CCS was important; government that were not willing to fund the high costs of the first CCS projects; and weak market-based structures that forced industry to rely on government subsidy, thus leaving them vulnerable to political changes.

Drawing from these analyses, key actions for the Scottish government if it wishes to support CCS deployment, appear to be:

- To communicate and engage with the public about the role it believes CCS will play in system wide decarbonisation.
- To support development of business models for CCS that provide credibility of revenues.
- To focus on incentivising lower cost, lower risk projects implementing mature technologies.
- To acknowledge that political factors constitute a key risk for CCS projects, and therefore consider how policy might mitigate this risk.

Q37. How can the Scottish Government and industry best work together to remove emissions from industry in Scotland?

Author: Imogen Rattle

It is unlikely that government and industry will be able to deliver industrial decarbonisation in isolation. The low carbon transition will require cross-sector partnerships. Decisions on the preferred energy sources for space heating and transport will determine how much green hydrogen and low carbon electricity is available for industry, and vice versa. The associated infrastructures will be sized according to total demand, not industry demand. We suggest the Scottish Government and industry will need to work with local authorities and regulators and with stakeholders across sectors in order to remove emissions from industry.

One way of achieving could be through Local Energy Plans. We note that the present Local Heat and Energy Efficiency Strategies are focussed on heat and energy efficiency.[78] Expanding these to incorporate other sectors would provide a venue to consider industrial emission reduction in the local context.

Q38. What are the opportunities and challenges to CCUS deployment in Scotland?

Author: Ahmed Gailani and Imogen Rattle

Sites located at the Grangemouth cluster represent 61% of the total sites and hence CCUS technologies can be deployed with infrastructure shared between sites to reduce costs. However, careful planning is needed for the remaining 39% dispersed sites.

The challenges for CCUS deployment include the high investment cost needed as shown in Figure 3. It is estimated that the CCUS technologies needed to decarbonise

[78] Local energy Scotland. Local energy plans. Available from: https://localenergy.scot/hub/local-energy-plans/

some Scottish industrial sites will cost nearly £226m in 2050 for the decarbonisation pathway of Figure 2. Nevertheless, CCUS technologies require high energy consumption as shown in Figure 3 where an extra 633 GWh, 375 GWh, and 335 GWh of biomass, electricity and hydrogen are needed respectively. Therefore, to enable competitive CCUS technologies, the Scottish government may support CCUS technologies with low technology readiness level but require much lower energy consumption such as molten carbonate fuels cells.

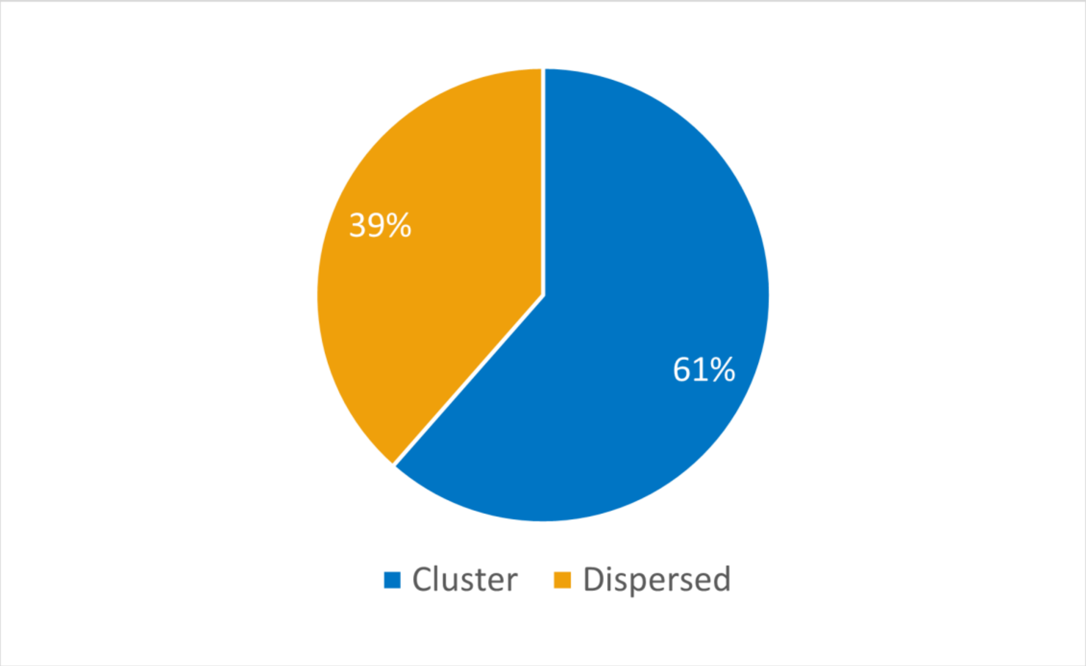

Figure 3 Percentage of sites located in Cluster and Dispersed for the Scottish industry (dispersed sites located more than 25 km radius of Grangemouth cluster).

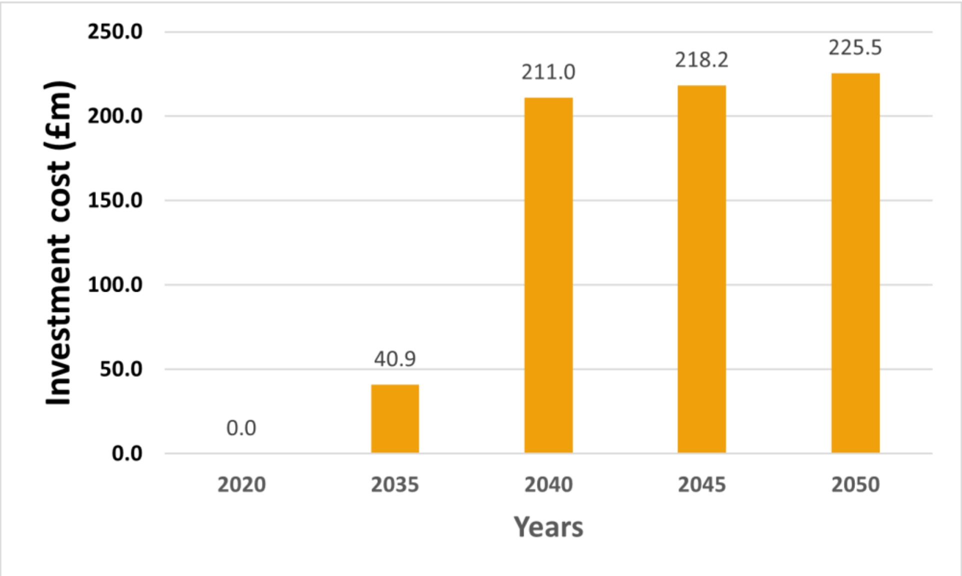

Figure 4 Investment cost needed for CCUS technologies in the decarbonisation pathway of Figure 1.

The literature suggests the following features are particularly advantageous for CCS deployment:

- Proximity to suitable geological storage since it minimises transport costs and improves technical feasibility. It is particularly beneficial for project economics if the subsurface geology is already well characterised[79,80,81,82,83]
- Access to existing pipeline infrastructure[79,82,84,85]
- Access to large volumes of renewable energy[85,86]
- The sectors involved. In the majority of cases the CO2 released by industry is not pure. The composition of the resulting flue gas directly influences the capturing costs: a high purity CO2 stream reduces the cost per tonne of CO2 avoided.[87] Cement, lime production, ethanol manufacturing and ammonia production[87,88,89,90,91] have been identified as promising sectors for this reason.

Some challenges of CCS deployment are specific to the sectors involved. The number of points of emissions is significant. The more flue-gas stacks a site has, the greater the number of carbon capture points needed, increasing the overall costs of operations. The refining sector had been identified as more complex in this respect.[87] This may present challenges when decarbonising the refineries sector, which is the second largest source of Scottish industrial emissions (see Figure 1).

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79 Brownsort, P., Methodologies for cluster development and best practices for data collection in the promising regions. 2019, Strategy CCUS.
80 Friedmann, S.J., M. Agrawal, and A. Bhardwaj. Evaluating Net-Zero Industrial Hubs in the United States: A Case Study. 2021; Available from: https://www.energypolicy.columbia.ed u/sites/default/files/fileuploads/Houston,%20final%20design,%206.29.21.pdf.
81 Meckel, T.A., et al., Carbon capture, utilization, and storage hub development on the Gulf Coast. Greenhouse Gases: Science and Technology, 2021. 11(4): p. 619-632.
82 McConnell, C., Carbon Capture, Utilization and Storage – Lynchpin for the Energy Transition, in UH Energy White Paper Series. 2021, University of Houston.
83 Element Energy, Deployment of an industrial Carbon Capture and Storage cluster in Europe: A funding pathway. 2017, Element energy.
84 NZKG. Hydrogen hub Amsterdam North Sea Canal Area. No Date 1 March 2022]; Available from: https://www.portofamsterdam.com/sites/default/files/2021-10/Hydrogen%20Hub%20NZKG_uk_v06_LR%2005-10.pdf
85 Notermans, I., et al., Hydrogen for the Port of Rotterdam in an International Context. 2020, DRIFT, Erasmus University: Rotterdam.
86 Accenture. Industrial clusters Working together to achieve net zero. 2021 01 March 2022]; Available from: https://www.accenture.com/_acnmedia/PDF-147/Accenture-WEF-Industrial-Clusters-Report.pdf.
87 Pilorgé, H., et al., Cost analysis of carbon capture and sequestration of process emissions from the US Industrial Sector. Environmental Science Technology, 2020. 54(12): p. 7524-7532.
88 Global CCS Institute, The global status of CCS 2021: accelerating to Net Zero. 2021: Melbourne, Australia.
89 TCE: Europe: Services deal for Rotterdam bio-based cluster. TCE The Chemical Engineer, 2013(868): p. 14.
90 Hills, T.P., et al., LEILAC: Low Cost CO2 Capture for the Cement and Lime Industries. Energy Procedia, 2017. 114: p. 6166-6170.
91 Waxman, A.R., et al., Leveraging scale economies and policy incentives: Carbon capture, utilization & storage in Gulf clusters. Energy Policy, 2021. 156: p. 112452.

Q39. Given Scotland's key CCUS resources, Scotland has the potential to work towards being at the centre of a European hub for the importation and storage of CO2 from Europe. What are your views on this?

Author: Imogen Rattle

The success or failure of this proposal appears subject to two main considerations. The first is whether Scotland can provide a more politically and economically attractive destination for CO2 storage than other European countries, given the lack of onshore pipeline connections to the European mainland, Scotland's present position outside the EU, and the greater experience with CCUS projects that countries such as Norway and the Netherlands possess.

The second, linked, consideration is the timescales involved and whether the Scottish Government believes carbon capture and storage will be an ongoing requirement or a transitional technology, while longer term solutions are developed. Here, we highlight the Dutch SDE++ scheme that provides subsidy support for the deployment of industrial CCS[92] but only until 2035 to incentivise the development of alternatives, as set out in the Dutch National Climate Agreement.[93] If European countries continue to require carbon capture in the long term, there will be value in developing Scotland's CCUS resources. If European countries reduce subsidies for industrial carbon capture and/or develop alternative technologies, there is a risk these same resources become stranded assets.

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[92] Andreas, J. The Industrial CCS Support Framework in the Netherlands. 2021; Available from: https://network.bellona.org/content/uploads/sites/3/2021/07/The-Industrial-CCS-Support-Framework-in-the-Netherlands.pdf.
[93] Dutch Central Government. National Climate Agreement - The Netherlands. 2019; Available from: https://www.klimaatakkoord.nl/binaries/klimaatakkoord/documenten/publicaties/2019/06/28/national-climate-agreement-the-netherlands/20190628+National+Climate+Agreement+The+Netherlands.pdf.

Chapter 5: Creating the conditions for a net zero energy system

Q40. What additional action could the Scottish Government or UK Government take to support security of supply in a net zero energy system?

Author: Keith Bell and Rob Gross

What is security of supply?

Security of supply entails reliable supplies of energy and supply being resilient against disturbances that affect the energy system.[94] As noted in UKERC's 2022 Review of Energy Policy,[95] over the medium to long term, increased renewable electricity generation could minimise dependency on imports of gas. However, action is needed to ensure that it is possible to utilise inherently variable renewable generation options such as wind and solar, both on and offshore. This means having enough network capacity, being able to maintain electricity system stability without the need to run unabated gas-fired plant, and an ability to store energy at times of surplus output for periods when renewable generation is low.[96]

Balancing supply and demand

As we have discussed earlier in our response, the means to manufacture hydrogen via electrolysis, store it and then use to generate electricity currently looks the most promising means of providing long-term energy storage and resolving periodic surpluses and deficits of electricity production relative to demand.[97] More generally, the ability to meet residual demand[98] depends on access to stores of energy: fuels such as natural gas, hydrogen, biomass or nuclear fuels, or other forms of storage that permit timely conversion to energy such as reservoirs of water for hydropower. Which sources should be used depends on how readily they can be accessed and at what cost, both financially and environmentally. For example, in accordance with UK Government policy,[99] by 2035, the bulk of use of natural gas for the production of electricity should be with CCS. Use of biomass for production of energy must be

[94] ClimateXChange. 2022. Security of Scottish electricity supply - gauging the perceptions of industry stakeholders. https://www.climatexchange.org.uk/research/projects/security-of-scottish-electricity-supply-gauging-the-perceptions-of-industry-stakeholders/
[95] Gross et al. 2022. Review of Energy Policy. https://ukerc.ac.uk/publications/rep22/
[96] Gross et al. 2022. BEIS Review of Electricity Market Arrangements. https://ukerc.ac.uk/publications/beis-rema/
[97] CCC. 2023. Delivering a reliable decarbonised power system. https://www.theccc.org.uk/publication/delivering-a-reliable-decarbonised-power-system/
[98] Residual demand is the difference, at any moment in time, between demand for energy and the energy available from variable, renewable resources. (Some authors also include energy produced from relatively inflexible low carbon sources, such as nuclear power stations, in the available production).
[99] BEIS.2021. Plans unveiled to decarbonise UK power system by 2035. https://www.gov.uk/government/news/plans-unveiled-to-decarbonise-uk-power-system-by-2035

within the limits of sustainable production and strictly prioritised, such as in achieving negative emissions.[100]

The advantage of hydrogen as an energy vector is that it can be stored, and its manufacture can make use of surplus available renewable energy at times when it exceeds demand and the ability of the network to export it. However, the CCC's recent report on "Delivering a reliable decarbonised power system"[101] cast doubt on Britain's ability to have enough 'green' hydrogen production capacity to meet demand for hydrogen in the medium term. The CCC report makes a number of recommendations oriented towards ensuring that a market for low carbon hydrogen and associated infrastructure are in place to support the reliable supply of electricity.

Dedicated electricity market and regulatory arrangements are likely to be required for long-term storage that, unlike short-term storage that cycles energy in and out of the store on a daily or more frequent basis, is unable to earn significant revenues from 'energy arbitrage'. Small scale storage also benefits from revenues from the provision of services to the system operator. These may be substantial relative to investment in a relatively small battery installation but small in comparison to a large, long-term storage solution. Large scale storage may also have other characteristics that mean it is difficult for solely 'merchant' revenues to provide prospective investors with sufficient confidence to develop projects in the absence of additional incentives. These include the size and capital intensity of individual schemes, long payback periods, limited geographical opportunities/suitable sites, possible deployment of earlier stage technologies and uncertainty about future electricity market price formation.

For all these reasons there may be a case for 'off-market' interventions such as the cap-and-floor schemes offered to interconnectors, and/or dedicated revenues through the Capacity Mechanism, or other direct interventions. Scotland's geography may offer opportunities for new sources of long-term storage, notably new pumped hydro. It will be important for the Scottish Government to work with the UK Government, Ofgem and the System Operator to define an appropriate incentive regime if long-duration storage is to become a reality.

While there is already significant curtailment of wind farm production in Scotland and Scotland looks like a promising place to build electrolyser capacity, it should be noted that suitable sites for geological storage of hydrogen at large scale are quite distant from Scotland.[102,103] Given that demand for energy within Scotland is limited, maximisation of utilisation of Scotland's renewable energy resources therefore depends on network capacity, whether for electricity or for hydrogen. Surpluses of production within Scotland could then be utilised via exports, and deficits can be met, to the extent necessary, via imports from reliable sources. As the draft ESJTP notes,

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[100] CCC. 2020. Sixth Carbon Budget. https://www.theccc.org.uk/publication/sixth-carbon-budget/

[101] CCC. 2023. Delivering a reliable decarbonised power system. https://www.theccc.org.uk/publication/delivering-a-reliable-decarbonised-power-system/

[102] ClimateXChange. 2023. Redirecting excess renewable energy to produce hydrogen. https://www.climatexchange.org.uk/research/projects/redirecting-excess-renewable-energy-to-produce-hydrogen/

[103] Julien Mouli-Castillo, Niklas Heinemann, Katriona Edlmann, Mapping geological hydrogen storage capacity and regional heating demands: An applied UK case study (2021). Applied Energy, 283, 116348

Scotland benefits from being part of GB-wide electricity and gas markets that allow energy to be exchanged between different regions within Britain. International exchanges are also facilitated by gas and electricity interconnectors and by LNG terminals in Wales and England.

The development of network capacity depends on a number of factors, in particular: the structures and processes within which the parties responsible for developing the network identify need and gain approval for the investment (which, in turn, depends both on the regulator, Ofgem, and relevant company boards); the gaining of planning consents; and the capacity of the supply chain to deliver in a timely way. Scotland is far from unique in facing risks to its energy system ambitions from lack of network capacity and in being subject to forces outside of its direct control[104]. The same is true for the UK as a whole and for many other countries. In principle the granting of planning permission for onshore developments is within the Scottish Government's gift (rules and responsibilities for offshore developments are more complicated). Scottish government therefore needs to find a way to reconcile local environmental impacts and opinion with the need for reliable, low cost and low carbon supplies of energy. This cannot be achieved without a significant amount of new infrastructure. The Scottish government shares this challenge with the rest of UK and many countries around the world.

It might appear that an extensive "North Sea Grid" would avoid – or, at least, much reduce – the need for highly contested decisions on onshore network developments. However, energy would still need to reach onshore demand centres and so offshore networks cannot entirely obviate the need for onshore infrastructure. In addition, the technologies and regulatory arrangements for offshore networks are still under development[105], despite many years of discussion. Finally, at least anecdotally, there is evidence that the supply chains for manufacture and deployment of relevant technologies – cables and HVDC converter stations, especially – for offshore electricity networks are particularly constrained.

Security of supply, "flexibility" and affordability

Supplies of energy might be physically available but would be of little use if they are unaffordable. "Affordability" of energy depends not just on the price of energy but on how much is required to meet a user's needs, what that user's income is and what other expenditure they are faced with.

Energy efficiency can reduce the total cost of energy faced by an energy user but many of the means of achieving that efficiency must be paid for. Policy decisions can have a direct effect on that. Otherwise, much attention in energy policy is given to reducing the price. That, in turn, means that policy at least historically has tended to be concerned with promotion of competition and market arrangements.

As the draft ESJTP notes, the UK Government is currently undertaking a review of electricity market arrangements (Review of Electricity Market Arrangements, or

[104] We note the work of the UK Government's Electricity Networks Commissioner in identify ways in which the development of electricity transmission network capacity can be speeded up. We understand that the Scottish Government is represented on the Commissioner's advisory group.
[105] Bell, Houghton and Xu. 2015. Considerations in design of an offshore network, https://strathprints.strath.ac.uk/53592/

REMA[106]). The UK Government's stated aim in REMA is to "focus on the enduring market arrangements needed to deliver a fully decarbonised and cost-effective electricity system by 2035, subject to security of supply".[107]

The main focus in much debate around REMA has been the means by which electricity wholesale prices and the total costs faced by electricity users can be minimised. What arrangements will lead to best utilisation of network capacity and lead to an optimal balance between costs arising from lack of network capacity, such as the need to use 'low merit', marginal sources of energy, and the costs of building and maintaining the network?

That then leads to further areas of debate:

- 'Decoupling' of contracting or trading with zero marginal cost electricity generation from generation that has a high marginal cost: where the long-run average costs of production of energy (such as from wind and solar power) are much lower than the long-run costs of marginal sources of energy (such as from gas-fired electricity generation), what market or contracting structures can ensure that the benefits of those low costs can be passed on to consumers?
- "Flexibility", i.e. the ability of different sources of energy or users of energy to adjust the time and/or location of their actions to complement what is available from other sources: this is often cited as a means of reducing the total cost of energy by reducing the need for generation and network capacity and the utilisation of marginal sources of energy.[108] What market arrangements are best suited to encouraging investment in flexible resources and their utilisation?

It is very easy to say, as the draft ESJTP does, that "The UK Government must design and implement changes to the wholesale market … in a way that maximises the benefit to consumers and does not disadvantage generators who are not making excessive profits". It is, in our view, difficult to decide what that means in practice.

Locational marginal pricing (LPM) has been proposed as one means to enhance incentives for both flexibility and efficient utilisation of network capacity.[109,110] LMP would, in effect, split the market based on location and the status of generation and demand relative to the capacity of the network to send power out from or into that location. It would potentially benefit energy users in Scotland as, with limited network capacity, the wholesale market price seen within Scotland at times when wind power is plentiful would be driven by the cost of wind and not by the cost of any marginal

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106 BEIS. 2022. Review of Electricity Market Arrangements. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1098100/review-electricity-market-arrangements.pdf
107 Gross et al. 2022. BEIS Review of Electricity Market Arrangements. https://ukerc.ac.uk/publications/beis-rema/
108 Gill, Bell and MacIver, Exploring Market Change in the GB Electricity System : the Potential Impact of Locational Marginal Pricing, https://strathprints.strath.ac.uk/83869/
109 NGESO: Net Zero Market Reform, Phase 3 Assessment and Conclusions, May 2022 https://www.nationalgrideso.com/document/258871/download
110 Energy Systems Catapult, Locational energy pricing in the GB power market, October 2021, https://es.catapult.org.uk/report/locational-energy-pricing-in-the-gb-power-market/

generation needed to meet the last unit of total GB demand. This would appear to meet the call in the draft ESJTP for market reform that “maximises the benefit to consumers” in Scotland. However, as is discussed in Gill et al. (2023),[111] the direct wholesale market revenues of wind generators in Scotland would be reduced though other contracting arrangements, such as particular forms of contracts for difference awarded through the UK Government, have the potential to offset such losses. Whilst not directly focused on the impacts of LMP, UKERC research has investigated the impact on investor risk of uncertainty over future electricity market price formation with large variable renewable shares (so called capture price), and the prospect of significant curtailment of renewable output[112]. The research finds that a hypothetical offshore wind developer would face cost of capital impacts of up to around 5 percentage points as a result of these risks. UKERC’s report notes that each percentage point increase in risk adjusted rate of return translates into a £1bn per year increase in costs across the offshore wind fleet envisaged in many scenarios for 2035. This is a UK-wide figure but illustrates the scale of the impact of increasing risk for overall consumer costs[113].

It follows from analysis of this nature that the apparent immediate benefits of LMP to consumers in Scotland might – depending on the full package of market reforms – be offset by rises in the cost of wind energy arising from their increased risk and the associated impact on cost of capital. Another possibility is that investment in new wind generation in Scotland might be far lower than the levels envisaged in the ESJTP. Without other, counter-balancing arrangements, this would mean that the Scottish Government’s ambitions for wind generation capacity in Scotland would not be realised. Depending on the extent to which potential locations for the development of low carbon generation elsewhere in GB are utilised (and what the associated costs are), it might also mean that UK Government targets also fail to be met.

It might be noted in this context that the assertion from the Just Transition Commission, quoted in the draft ESJTP, that “The current transmission charging scheme militates against investment in Scottish solutions and inflates costs for Scottish communities” is not supported by the evidence that there is significant interest in generation development in Scotland[114] and that locational Transmission Network Use of System (TNUoS) charges for the demand side in Scotland are lower than for anywhere else in Britain.[115]

It is important to note that the business case for investment in electricity storage capacity in Scotland is also affected by a lack of network capacity, because this limits the potential for storage operators to benefit from high price periods driven by

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[111] Gill, Bell and MacIver, Exploring Market Change in the GB Electricity System : the Potential Impact of Locational Marginal Pricing, https://strathprints.strath.ac.uk/83869/
[112] Blyth et al. 2021. Risk and investment in zero-carbon electricity markets. https://ukerc.ac.uk/publications/zero-carbon-electricity/
[113] Blyth et al. 2023. Transition Risk: Investment signals in a decarbonising electricity system. https://ukerc.ac.uk/publications/transition-risk-investment-signals/
[114] National Grid ESO. Transmission Entry Capacity (TEC) Register. https://data.nationalgrideso.com/connection-registers/transmission-entry-capacity-tec-register
[115] National Grid ESO. Transmission Network Use of System (TNUoS) Charges. https://www.nationalgrideso.com/industry-information/charging/transmission-network-use-system-tnuos-charges

demand in England. Significant curtailment of wind generation may appear to offer the potential for storage operators to access cheap energy to charge stores, but Scottish demand is still limited relative to potential renewable supply. New storage capacity may improve utilisation of renewable resource in Scotland, but it is not a substitute for adequate transmission network capacity both within Scotland and beyond.

In summary, we agree with the Scottish Government that there is an urgent need for new electricity transmission capacity between Scotland and England. Delivering such capacity depends on a number of factors, of which only one – planning consents within Scotland – is significantly within the Scottish Government's control. However, there is also the opportunity for the Scottish Government to engage constructively in debate around REMA. The debate about LMP is of particular importance to the Scottish Government. The Scottish Government therefore needs to take a clear view of the relative priority given to any potential for LMP to reduce wholesale prices, and/or encourage investment in hydrogen production or energy storage, against the potential negative impacts on investment in wind generation.

Resilience

A resilient supply of energy is one in which interruptions to supply due to disturbances, such as severe weather, equipment faults or deliberate interference, are prevented, contained and recovered from.[116]

Although most energy users' experiences of interruptions to energy supply are seen at a local level – local garage forecourts are closed, or local gas or electricity network connections are out of service – each part of the energy system – gas, electricity and liquid or solid fuels – must be seen as system and, further, as an integrated system of systems. The need to consider them in this way is especially evident in the electricity system, a tightly coupled, dynamic, non-linear and very large set of components that can interact with each other very quickly, in timescales of seconds or even milliseconds (see, for example[117]).

As noted in Nedd and Bell[118] in 2021 key electricity sector stakeholders harboured "doubts about current and future power system operability for both the British system and the Scottish power system within it, with operability expected to become more challenging between now and 2030". There was also "a feeling of concern around the trend of the Scottish power system's ability to prevent, contain and recover from interruptions to supply arising from disturbances, i.e. its resilience." That report made a number of recommendations for UK and Scottish Government action including to "ensure vulnerable groups and regions are not disadvantaged in the prioritisation required in the process of restoring the electricity system following a national black out, as laid out in the new system restoration standard" and "consider the

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[116] Cox, Bell and Brush. 2022. Response to JCNSSI Inquiry: Critical national infrastructure and climate adaptation. https://ukerc.ac.uk/publications/critical-infrastructure-climate/

[117] MacIver, C., Bell, K., & Nedd, M. (2021). An analysis of the August 9th 2019 GB transmission system frequency incident. Electric Power Systems Research. https://doi.org/10.1016/j.epsr.2021.107444

[118] Nedd and Bell. 2021. Security of Scottish electricity supply: gauging the perceptions of industry stakeholders. https://www.climatexchange.org.uk/research/projects/security-of-scottish-electricity-supply-gauging-the-perceptions-of-industry-stakeholders/

introduction of a regional capacity market or a similar mechanism that might, for example, stipulate the type, power and energy capacities of production or import capability".

Like the Scottish Government, we welcome the Electricity System Restoration Standard that was proposed by BEIS in April 2021. This requires that at least 60% of demand can be restored in each region of GB (including Scotland) within 24 hours of a GB wide blackout, and that all demand can be restored within 5 days. However, we note that the electricity sector's compliance with the standard is not required until 31st December 2026.[119] We have some concerns about restoration times were the GB system or a region of it to suffer a collapse before then.

We note that the draft ESJTP says that "Responsibility for the security and resilience of infrastructure lies solely with UK Government." However, *Keeping Scotland Ready* [120] notes that, while responsibility for energy infrastructure is reserved to the UK Government, responsibility for the following sectors is devolved: Government – Scottish Government, Scottish Parliament, NDPBs and other agencies, Local Authorities; Health; Food; Water – Drinking Water, Waste Water; Transport – Roads and Bridges; Emergency Services – Police, Fire and Ambulance; and Chemicals. All of these would be affected by losses of energy supply.

It is important to note that resilience against loss of energy should not solely be the responsibility of energy networks companies or energy producers. The most cost-effective way of ensuring that the adverse impacts of loss of energy are mitigated might be through action by the energy user or at their site. For example, the provision of standby electricity generation or battery storage (with enough fuel or energy to cover a reasonable worst case duration of interruption to external electricity supply), may be a cheaper way of ensuring continuity of electricity supply for essential services than, say, redundancy of network connection. We therefore agree with *Keeping Scotland Ready*'s promises of "a move from silo working to a holistic approach to critical infrastructure resilience; a move from a culture of secrecy to a culture of sharing information appropriately between partners; improved relationships with critical infrastructure owners and operators; and enhanced engagement with essential services owners and operators during disruptive events, resulting in improved response arrangements".

We welcome the promise made in the draft ESJTP to "improve our response to climate related events by facilitating the local authority roll out of the Persons at Risk Distribution (PARD) system across Scotland, which helps local authorities and the NHS to identify vulnerable individuals during an emergency" and look forward to seeing evidence of progress. It was noted in Cox and Bell (2022)[121] that "While arrangements such as Local Resilience Forums [and Partnerships] promise to

[119] BEIS & DESNZ. 2021. Introducing a new 'Electricity System Restoration Standard': policy statement. https://www.gov.uk/government/publications/introducing-a-new-electricity-system-restoration-standard/introducing-a-new-electricity-system-restoration-standard-policy-statement
[120] Ready Scotland. Keeping Scotland Running: Resilient Essential Services. Scottish Government's Strategic Framework 2020-2023, https://ready.scot/how-scotland-prepares/preparing-scotland-guidance/keeping-scotland-running
[121] Cox and Bell. 2022. JCNSSI Inquiry: Critical national infrastructure and climate adaptation. https://ukerc.ac.uk/publications/critical-infrastructure-climate/

provide much needed coordinated preparation and response, their effectiveness needs to be demonstrated."

Q41. What other actions should the Scottish Government (or others) undertake to ensure our energy system is resilient to the impacts of climate change?

Author: Keith Bell

Both the CCC's 3rd Climate Change Risk Assessment[122] and its recent report on "Delivering a reliable decarbonised power system" noted that climate change can be expected to have significant impacts on the energy system, not least in respect of heatwaves, flooding and drought. Although the climate science is uncertain on whether the UK will see significant changes to wind strength and wind regimes or increased storminess and occurrence of storm events, both reports noted that, as the UK reduces its total GHG emissions associated with production of energy and electrifies much of the end use, dependency on electricity will increase and, without appropriate action, the impacts of losses of electricity supply would be greater than today.

The CCC has made a number of recommendations to the UK Government in respect of the electricity system's resilience to climate change.[123] These include: "Commission further research to improve understanding of how climate change is altering key weather hazards that will impact the energy system"; "Coordinate a systematic assessment of risks posed from cascading impacts across multiple sectors due to failures of the decarbonised energy system as part of the next round of the Adaptation Reporting Power"; and "Require all energy system organisations to report under the Adaptation Reporting Power".

As the draft ESJTP noted, Storm Arwen highlighted a number of issues with both the network companies' actions before, during and after the storm and other key stakeholders' actions. We understand that the network companies are making increasing use of geospatial data to target strengthening of network assets; this should be continued with good data and evidence used to justify investments to Ofgem. While Ofgem's report into the storm noted some good performance by network companies, e.g. robustness of some companies' websites, other aspects, such as estimates of restoration times, were criticised.[124] Both Ofgem and the Energy Emergencies Executive Committee (E3C) have made a number of recommendations as results of their reviews.[125]

We believe action should also be taken to review communication service providers' performance, the effectiveness of Local Resilience Partnerships (Ofgem noted that "there is a need to make improvements with regards to the roles and responsibilities between DNOs and Local Resilience Forums (LRFs) and communications around

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[122] UK Climate Risk. Independent Assessment of UK Climate Risk (CCRA3). https://www.ukclimaterisk.org/
[123] CCC. 2023. Delivering a reliable decarbonised power system. https://www.theccc.org.uk/publication/delivering-a-reliable-decarbonised-power-system/
[124] Ofgem. 2022. Storm Arwen Report. https://www.ofgem.gov.uk/publications/storm-arwen-report
[125] BEIS & DESNZ. 2021. Storm Arwen electricity distribution disruption review. https://www.gov.uk/government/publications/storm-arwen-electricity-distribution-disruption-review

the welfare support") and the extent to which they and local health and community services can identify and support the most vulnerable energy users. The Scottish Government is likely to be the party best placed to take a lead on that and to push to ensure that appropriate action is taken to enable improved performance before, during and after the next major storm.

Chapter 6: Route map to 2045

Q43. What, if any, additional action could be taken to deliver the vision and ensure Scotland captures maximum social, economic and environmental benefits from the transition?

Author: Sarah Whitmee

Due to the significant health co-benefits that can be achieved through well designed actions to mitigate greenhouse gas emissions across all sectors, we recommend the explicit recognition of transitioning towards a *healthy* net zero future within the vision for Scotland. We recommend a 'health in all climate policies' approach. This is supported by the IPCC AR6 WG III which identified three significant pathways to health co-benefits from mitigation activities: as (1) energy, (2) land and (3) urban infrastructure sectors. Cleaner energy improves air quality; sustainable food systems produce healthier, lower-carbon diets; and sustainable urban planning promotes active mobility.[126,127] From the health perspective, these mitigation options are additionally likely to yield significant benefits to mental health and well-being, and impact positively on various social determinants of health, including social cohesion and equity. The 'health in all climate policies' approach is projected to show benefits of c.200 avoided deaths per 100,000 people in the UK in 2040 (through reductions in air pollution, transition to more nutritious diets rich in fruit and vegetables and increases in active travel such as walking and cycling).[128] The economic benefits of these health gains can be quantified and we recommend the use of a framework such as the WHO Climate-Health Economic Framework which could be utilised to link science, policy and practice for a comprehensive assessment of climate mitigation and adaptation investments and their impact on human health to inform decision-making.[129].

Vulnerability to the impacts of climate change is closely linked to gender inequality and so addressing this inequality can promote increased resilience for disadvantaged populations while making progress on global development and climate goals.[130]. Key to a just transition will be to ensure that the co-benefits delivered by climate mitigation action are fully accessible to all, including women and minority groups. For example, a transition to renewable energies and expansion of solar and wind power plants is urgently needed for decarbonisation. Yet, delivering

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[126] Willets E, Campbell-Lendrum D. 2022. WHO Review of IPCC Evidence 2022: climate change, health, and well-being. https://cdn.who.int/media/docs/default-source/climate-change/who-review-of-ipcc-evidence-2022-adv-version.pdf
[127] IPCC. 2022. Climate Change 2022: Mitigation of Climate Change. https://www.ipcc.ch/report/ar6/wg3/
[128] Hamilton, et al. 2021. The public health implications of the Paris Agreement: a modelling study. https://www.thelancet.com/journals/lanplh/article/PIIS2542-5196(20)30249-7/fulltext
[129] World Health Organization. 2023. A framework for the quantification and economic valuation of health outcomes originating from health and non-health climate change mitigation and adaptation action. https://www.who.int/publications/i/item/9789240057906
[130] Jameel, et al. 2022. Climate–poverty connections: Opportunities for synergistic solutions at the intersection of planetary and human well-being. https://policycommons.net/artifacts/2482293/drawdown20lift_climate20poverty20connections20report_march2020222/3504513/

sustainable energy sources may impact vulnerable communities (i.e. those on low incomes)[131] unless every policy is designed with the active participation of all the communities that will be affected by it.

[131] Levenda et al. 2021. Renewable energy for whom? A global systematic review of the environmental justice implications of renewable energy technologies. https://www.sciencedirect.com/science/article/pii/S2214629620304126