National Engineering Policy Centre

Royal Academy of Engineering

Net Zero Review

Submission from the National Engineering Policy Centre
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This response

This response has been produced by the National Engineering Policy Centre (NEPC). The NEPC brings engineering thinking to the heart of policymaking, creating positive impacts for society. We are a partnership of 43 professional engineering organisations that cover the breadth and depth of our profession, led by the Royal Academy of Engineering. Together we provide insights, advice, and practical policy recommendations on complex national and global challenges.

This response draws from the NEPC's existing programme of policy work on decarbonisation and which has addressed the opportunities and challenges associated with, for example, realising the role of hydrogen in a net zero energy system, decarbonising construction and our built environment and set out a framework for identifying low regrets decarbonisation policies. In addition to drawing on this work, this response draws from input from a range of Fellows of the Royal Academy of Engineering and input from the NEPC's Net Zero working which has representation of 10 Professional Engineering Institutions (PEIs) and Fellows of the British Academy.

This response focuses on the overarching questions (Questions 1-7) as laid out in the Net Zero Review and, in addition, addresses Question 29.

Further information and support

The NEPC would be very happy to work with the review team to provide follow-up engagement for further exploration of any of the areas outlined in this response.

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Key messages

1. While achieving net zero by 2050 is clearly a massive undertaking, global economies and individual businesses risk material failure if decarbonisation is not delivered. There is no trade-off between economic growth and decarbonisation and, provided appropriate choices are made, decarbonisation can lead directly to new high-quality jobs and markets, revitalised and high-value supply chains, new economic models, the commercialisation of new technologies and services, and a range of co-benefits including greater economic and infrastructure resilience.

2. Government can act now with immediate investment in low-regrets measures to reduce carbon emissions that support economic growth, through creating new jobs, markets and UK-based supply chains. Immediate actions that the government can take:

   - Scaling up deployment of proven technologies as fast as possible such as:
     - Upgrading the electricity grid to deal with greater electrification and renewables
     - Scaling up energy storage capabilities
     - Upgrading electric charging infrastructure
   - Demonstration of low carbon technologies so they are ready to be deployed in the future such as investment in research, demonstration and testing of low carbon technologies such as hydrogen and CCS
   - Improving efficiencies in resource and energy use across domestic, commercial, transport and industrial applications such as:
     - Driving decarbonisation using new building standards
     - Retrofitting existing buildings
     - Mandating hydrogen ready appliances
   - Demand reduction such as:
     - Rolling out smart meters
     - Public engagement on demand reduction.

3. Actions such as these can provide clarity and certainty to businesses and consumers in the short term, however, these alone will not achieve net zero. Consistent policies and clearly sequenced priorities are needed. Based on NEPC work, this response provides examples of clearly sequenced policies for key areas of the economy such as the construction sector and for the role of hydrogen in the future energy system. The clarity that clear and consistent priorities would provide will itself support businesses and consumers.

4. Rapid decarbonisation and its growth opportunities depend on high-quality research and development (R&D). While support for the science base is necessary, support for high value late-stage R&D will also be crucial. For low carbon solutions and technologies, there is a need for more physical and digital infrastructure to support late-stage R&D by accelerating and de-risking the testing, certification, development and deployment of new products, processes, services and technologies safely and effectively. Government should:

   - Implement recommendations from the Dowling Review of business-university research collaborations and learn from successful recent and existing schemes which should be restarted or expanded, including the Catalysts, CASE studentships and the KTPs
   - Commit to and deploy outcomes-based procurement to transform companies' investment in R&D in the UK, stimulate innovation, business growth and adoption across supply chains
   - Target support for late-stage R&D including through co-designed, industry-led programmes building on the success of examples such as the Aerospace Technology Institute

- Strengthen and scale existing initiatives and infrastructures that support late-stage R&D, including with the uplift in Innovate UK's budget and by promoting and supporting strategic innovation infrastructures such as the National Physical Laboratory (NPL) and Catapult Centres
- Signal to the world the UK is the place for businesses to undertake late-stage R&D and unleash net zero innovation with clear signposting of the UK offer.

5. Widespread scale up and implementation of innovative net zero solutions requires the requisite skills within the economy but just as the demand for engineering skills is increasing within the key sectors of the future clean economy, the supply of engineering skills in the UK is failing to keep up with demand. New ways of learning and training must be developed locally and supported by individuals, employers, education and training providers. To address this government needs to:

   - Implement the recommendations from the Green Jobs Taskforce
   - Invest in a long-term STEM education and skills strategy that, among other things, provides a guarantee that all pupils receive high quality, up-to-date STEM careers advice and guidance, supported by additional funding of £40 million annually
   - Support and invest in stakeholders active within Local Skills Improvement Plans to develop new opportunities for micro-learning in support of upskilling and reskilling of local workforces in growth sectors supporting net zero
   - Support innovations in skills development such as 'micro credentials', new 'bite-sized' learning opportunities that can be studied flexibly and are designed to be accessible and inclusive.

6. Overall, the UK's Environmental Goods and Services Sector (EGSS) should be seen as renowned for its high-quality expertise. The sector's contributors are drawn from various standard industry classifications and, as a result, it has struggled to be seen and heard as a coherent whole by government. However, the growth opportunities in the UK and overseas are clear and much could be achieved with deeper promotion of the EGSS and recognition of its high-quality expertise and contribution to growth.

7. Some other specific opportunities identified in this response are:

   - The electricity system requires urgent innovation across electricity generation, the electricity network, whole system flexibility and in enabling decentralisation and digitalisation. The innovations required address challenges that are common to power systems globally which means there are significant commercial opportunities for countries that tackle these innovations early.
   - There is an opportunity to support rapid growth of a major UK manufacturing industry in low-carbon products and materials.
   - New infrastructure and programmes of retrofit needed to decarbonise can be a stimulus to modernise and decarbonise the construction sector, as well as to further grow the services around infrastructure and the built environment – both of which are an export opportunity.

Question 1: How does net zero enable us to meet our economic growth target of 2.5% a year?

8. Achieving net zero by 2050 is a massive and unique policy goal because of the scale of transformation needed, the breadth of policy areas it links to, and the number of stakeholders which must work towards a shared goal. But there is no trade-off between economic growth and decarbonisation. Global economies and individual businesses risk material failure if decarbonisation is not delivered, an argument made widely, including within authoritative expert reports commissioned by the UK Government over many years.

9. As is argued throughout this response, provided appropriate choices are made, decarbonisation can lead directly to new, high-quality jobs and markets, revitalised and high-value supply chains, new economic models, the commercialisation of new technologies and services, and a range of co-benefits including, via a range of infrastructure and retrofit activities, greater economic and infrastructure resilience. The growth opportunities associated with net zero are widely accepted by the OECD, UNEP, the World Economic Forum and much of the business and finance sector. To that end, the case for supporting a vibrant green economy that delivers growth is already made in the UK, which is well positioned to capitalise on these opportunities.

10. Across the UK there are already over 410,000 jobs in low carbon businesses and their supply chains, with turnover estimated at £42.6 billion in 2019, and the value of goods and services exported by UK low carbon businesses exceeding £7 billion[1]. The UK government's Ten Point Plan for a Green Industrial Revolution, published in 2021, set out to support up to 250,000 green jobs in 2030, by seeking to develop long-term advantage for the UK in new low carbon sectors.[2] Investments in these sectors were expected to drive funding and jobs across the UK, from electric vehicle manufacture in the midlands, to construction and installation of offshore wind farms around the coast and the retrofitting of homes across the country.

11. The current energy and cost-of-living crisis is an opportunity to lock-in growth areas which will also decarbonise our economy. Rather than lock into a high-carbon future, falling short on legislated commitments and failing to show global leadership, government can instead choose to make bold moves towards a prosperous, low-carbon and more resilient UK economy. This can generate an economic stimulus that sets the UK on a confident trajectory towards meeting net zero and create a thriving low-carbon economy.

12. Good businesses do not mind firm but fair legislation, not least because it helps to protect them from those who would seek to undercut them within their sectors while unenforced legislation is effectively a tax on compliant businesses which itself hinders growth in the areas that need to be encouraged. Many welcome steps are already being made to decarbonise key sectors and there is both a strong understanding of what is needed and strong buy-in across business, research and investor communities.[3] This is a platform for a green and resilient UK economy, and it should not be put at risk but enabled by strong, consistent and clearly sequenced policies.

13. The UK's path to net zero, and its ability to decarbonise at sufficient speed and scale, is contingent on key decisions made by the government now, and in the years that immediately

[1] Expert report: every UK job has the potential to be green, Independent Green Jobs Taskforce issues, 2021
[2] The ten point plan for a green industrial revolution, Department for Business, Energy and Industrial Strategy, 2020
[3] For example, 60% of FTSE 100 companies signed up to the UK's 'Race to Zero' campaign while the UK's top five business groups have called for a just transition to net zero.

follow. Government should demonstrate immediate action on low regrets options, things that can be done now that can put the UK on track to net zero while producing growth. Smart choices made now can rapidly decarbonise the UK economy but also support UK job creation and competitiveness, secure other environmental benefits in respect of local air quality and human and ecological health, and avoid adverse environmental and social impacts, for example ensuring that low income and disadvantaged households are not disproportionally negatively affected.

14. We expand further on low regrets options in Questions 3 and 4. These measures enable pathways to low-carbon medium- and long-term opportunities such as domestic production and supply chains for new infrastructure, workforces equipped to retrofit our building stock and low-carbon hydrogen and associated value chains and skills.[4]

15. In the longer term, consistent and well sequenced policies are essential if investment is to be encouraged, supply chains and markets are to be successfully established, and returns on funding realised. Examples of the necessary sequencing of polices for specific sectors are provided in Question 4.

16. Meeting net zero will require new or retrofitted infrastructure, programmes of buildings retrofit and new and revitalised industrial supply chains. This is an opportunity for investment and economic growth, to progress the levelling-up agenda, to modernise (and decarbonise) the construction sector and should also be treated as an opportunity to embed climate resilience alongside decarbonisation and economic renewal. This can ensure that the UK is as resilient as possible to a warming climate.

17. Overall, the UK's Environmental Goods and Services Sector (EGSS)[5], which was worth £200 billion and employing 1.2 million people in 2021[6], should be seen as renowned for its high-quality expertise. The sector's contributors are drawn from various standard industry classifications and, as a result, it has sometimes struggled to be seen and heard as a coherent whole by government. However, the growth opportunities in the UK and overseas are clear and much could be achieved with deeper promotion of the EGSS and recognition of its high-quality expertise and contribution to growth. Government has the opportunity to further support and promote of the UK's EGSS as part of 'Global Britain'.

18. Some contributors to this response highlighted that they saw the Commission on Environmental Markets and Economic Performance (CEMEP) that reported in November 2007 as a successful vehicle for galvanising the EGSS sector around growth opportunities. There could be merit in a new Commission that sets out and quantifies the opportunities for green economic growth for the UK sector, globally. Opportunities include:

    - ongoing growth in environmental goods and services
    - specific engineering opportunities in offshore technologies, renewables energy and energy system innovation, civil and environmental engineering, electric automotive and in bankability appraisals[7] for global investment

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[4] Rapid 'low regrets' decision making for net zero policy, National Engineering Policy Centre, 2021
[5] UK environmental goods and services sector (EGSS):2019, Office for national statistics, 2022
[6] UK low carbon environmental goods and services sector, KMatrix, 2021
[7] Required for private sector financing during investment appraisal, bankability means that a project provides clear incentives for lenders to consider financing it i.e. that equity and loan commitments are adequate to service the capital and operational requirements of the project. Assessments of a project's bankability draw

- UK higher education provision, innovation and export, especially in postgraduate specialisms where the UK has a prime position
- policy and regulatory leadership, including green finance, policy development and regulatory design
- corporate sustainability, circular economy, resource efficiency advocacy and services support
- climate adaptation.

19. Finally, as outlined at length in Questions 2 and 29, rapid decarbonisation and the growth opportunities that flow from it will depend significantly on a high-quality research and development (R&D) ecosystem and on the rapid and continuing development of the skills base. In part because climate mitigation is a global concern, there are potentially significant market opportunities for first movers. Engineering and technology that exploits UK research will be the determinant of whether the UK realises the substantial socio-economic benefits of exploiting R&D.

20. While support for the science base is necessary, it is not sufficient – support for late-stage R&D activities to accelerate technology, prove and de-risk rapid the deployment of low carbon solutions and technologies will be crucial. Less risk averse public procurement and increased support for high-value late-stage R&D, including more physical and digital infrastructure to accelerate and de-risk the testing, certification, development and deployment of new low carbon solutions and technologies safely and effectively are needed. We set out a more detailed set of recommendations on this aspect of the challenge/opportunity in Question 29.

Question 2: What challenges and obstacles have you identified to decarbonisation?

21. Achieving net zero requires action across all economic sectors. Replacing or retrofitting all major emissions sources is a deployment challenge of unprecedented scale and pace and with individual infrastructure projects typically planned, developed and built over decades, the concurrent and cross-sectoral engineering challenge must not be underestimated. Government must take a joined-up systems approach which will require collaboration with a range of stakeholders including other political parties, devolved and local administrations, industry leaders and financial communities. The National Engineering Policy Centre has set out the nature of this challenge[8,9], what is needed to decarbonise specific sectors, such as construction[10], and has set out in depth the opportunities and challenges that need to be address from new technologies such as hydrogen technologies to be deployed at scale[11].

22. Key highlights are summarised throughout this response but one of the clearest messages is that the UK must play a strong international leadership role by creating a sustainable and inclusive economy or it will leave the nation less commercially competitive. This will entail very substantial capital investment which requires a stable and consistent environment which brings down and maintains a low cost of capital and encourages private investment.

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heavily on future income and expenditure estimates and so requires evidence-based prediction of future costs and benefits.

[8] Net Zero: A systems perspective on the climate challenge, National Engineering Policy Centre, 2020
[9] Beyond Covid-19: laying the foundations for a net zero recovery, National Engineering Policy Centre, 2020
[10] Decarbonising Construction: building a new net zero industry, National Engineering Policy Centre, 2021
[11] The role of hydrogen in a net zero energy system, National Engineering Policy Centre, 2022

Governance

23. There is a significant gap between how we currently govern and control carbon emissions and the transformation required across several vital, interconnected systems of infrastructure, regulation, finance and human behaviour. The change required must occur at unprecedented speed and be maintained over a far longer timescale than current policy horizons of governments and potential impact on vulnerable communities means this is a significant governance challenge requiring scrutiny mechanisms which ensure policies are both sufficient and fair. This will require frank consideration of who bears costs and who benefits and should be informed by deliberative engagement with stakeholders and the public.[12]

24. While the UK's system of legislative governance, built around the CCC, is world leading, there is no formal system of governance for translating high-level targets to national and local levels. A model which provides a credible and comprehensive plan accounting for all emitting sectors is urgently needed. The NEPC set out key requirements from a net zero governance system in its response to the BEIS Select Committee Inquiry into net zero governance[13].

Decisions under uncertainty

25. Deployment, replacement and retrofit of infrastructure, buildings and industrial systems needs to happen at pace and at scale. There are profound opportunities associated with this. However, it also requires difficult decisions with incomplete information and planning must be flexible to adapt to changing circumstances and drivers. To help with this, the NEPC has set out a framework[14] for identifying low regrets policy decisions, including some examples which will be outlined in Question 3 and 4.

Demand reduction and enabling decisions

26. The UK has taken significant steps toward decarbonisation in some sectors but these have been predominantly 'in the background', for example via sources of energy generation and fuel-switching within transport fleets – all possible without significant requirements placed on individuals or households to make specific choices or changes to behaviours. If, however, we are to address significant carbon-intensive areas, such as heat and energy consumption in buildings, this is no longer possible. Further decarbonisation in line with the net zero target will heavily rely on substantial behavioural and societal changes.

27. An estimated 43% of emissions reduction required to reach net zero by 2050 will come from measures combining low-carbon technologies with societal or behavioural changes and 16% through largely societal or behaviour changes[15]. An enabling environment that provides low carbon personal choice is required. There is a rich evidence base showing that policy and

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[12] For a recently published review of public engagement conducted by the Defra Social Science Exert Group of the Defra Science Advisory Council see Review of Public Engagement, Defra Science Advisory Council, 2022

[13] National Engineering Policy Centre Response to BEIS Select Committee Inquiry into Net zero Governance, BEIS Select Committee Inquiry into Net Zero Governance, 2021

[14] Rapid 'low regrets' decision making for net zero policy, National Engineering Policy Centre, 2021

[15] The sixth carbon budget: the UK's path to net zero, Climate Change Committee, 2020 Figure B2.2, Role of societal and behavioural changes in the Balanced Net Zero Pathway (2035).

technological interventions for decarbonisation are de-risked and improved by deliberative and inclusive public engagement. In this context, exercises such as Climate Assembly UK can engage a diverse set of stakeholders in the generate shared insights, such as informing on perceptions on heat decarbonisation.[16] Necessary, although not sufficient for good public engagement with decarbonisation and low carbon decisions is ensuring the provision of independent, trustworthy information to enable individuals and businesses to make informed and confident choices, whether on home retrofit and energy efficiencies or on procurement and supply chains.

Electricity System

28. The target of a fully decarbonised electricity system by 2035 must be maintained and to achieve this a comprehensive long-term delivery strategy for achieving 95% low-carbon electricity by 2030 is required. To achieve this, expanding renewable generation capacity and speeding up its development must be recognised as a top priority. Market arrangements need to be designed to increase the pace and breadth of investment in renewable generation. To enable further penetration of intermittent renewable generation, increased system flexibility, efficient locational signals for network upgrades, system operability and to manage price volatility the following challenges need to be addressed:

- Electricity supply:
  - The lengthy renewable deployment policy processes of offshore site allocation, planning and route to market have been a major barrier to greater and quicker renewable generation deployment.[17] The government has rightly recognised this barrier and committed to cutting the approval time from 4 years to 1 year.[18] This should be fast tracked to speed up the pipeline for new renewable projects.
  - Potential key supply chain bottlenecks for offshore wind must be addressed through investment in ports, vessel capacity, manufacturing capacity and floating wind.[19]
  - As the proportion of intermittent renewable sources of generation grows, ensuring sufficient flexible generation capacity is key to ensure the safe and reliable operation of the electricity system. This requires a clear strategy for replacing unabated gas with low-carbon options for flexible generation such as hydrogen or gas with carbon capture and storage.[20]

- Electricity network:
  - Government rightly recognised that the current policy does not allow coordinated infrastructure between offshore projects and launched the Offshore transmission network review[21]. 'Status quo' development of the UK's North Sea wind resource will lead to a patchwork of direct links from individual wind farms to the onshore network. A coordinated design would reduce the overall cost of connecting winds farms to the GB power system, and could create export opportunities by directly connecting that network to the continental grid, at a significantly lower cost than if cross-border interconnectors were developed separately.[22] Prompt action is also

[16] In this case, over 80% of members 'strongly agreed' or 'agreed' that each of hydrogen (83%), heat pumps (80%), and heat networks (80%) should be part of how the UK reaches net zero (see The Path to Net Zero, Climate Assembly UK, 2020).
[17] 2022 Progress Report to Parliament, Climate Change Committee, 2022
[18] British energy security strategy, Department for Business, Energy and Industrial Strategy, 2022
[19] 2022 Progress Report to Parliament, Climate Change Committee, 2022
[20] 2022 Progress Report to Parliament, Climate Change Committee, 2022
[21] Offshore transmission network review, Department for Business, Energy and Industrial Strategy, 2022
[22] Offshore wind in the north seas from ambition to delivery, Skillings and Strbac, 2021

needed for the necessary regulatory and legislative changes to establish a framework that will allow effective coordination between offshore wind farms and the onshore network to enable offshore grid infrastructure to be built in a cost-effective way.[23]

    - With centres of electricity demand focused in the South and a large volume of intermittent wind generation expected to be located in the North, increasing amounts of highly variable North-South power flows are expected in the future. This creates onshore grid thermal constraints. Bottlenecks in network capacity must be addressed in time to support increasing renewable electricity generation and demand. Frameworks are needed to identify and address network requirements for a net zero electricity network and direct investment in the necessary network upgrades.
    - The increasing deployment of renewables will pose challenges to key system services which maintain the reliable operation of the electricity system (these include frequency and inertia, voltage and reactive power, short circuit level, and system restoration). Existing and emerging technological solutions will be required for the operation of a net zero electricity system. Regulatory frameworks, commercial models and late-stage R&D are all needed for successful implementation.[24]

- Flexibility:
    - Whole system flexibility will become increasingly critical to manage peaks of energy demand and generation distribution to keep the electricity system balanced. Sources of flexibility such as demand-side flexibility, interconnectors and Long Duration Electricity Storage can achieve whole-system optimisation, bring cost reduction in network and generation investment, and improve whole system flexibility.[25] The value of such flexibility (including demand-side flexibility) is large. For example, long duration electricity storage is able to provide system services, maximise the value of renewable electricity, and reducing the future capital expenditure of building new high-cost firm low carbon generation (e.g. gas with carbon capture and storage) to meet the system demand when renewable generation is low. However, the current market design does not recognise the value and benefits of system flexibility.[26]

- Decentralisation and Digitalisation:
    - Decarbonisation and decentralisation are already transforming the energy sector, offering new opportunities to deliver a more productive, efficient and cost-reflective energy system. However, this is a fundamental shift from centralised command and control-based structures to more interactive behaviours, networked actions, collaborative solutions and layering of interventions. The management of this new system, by multiple actors at different levels, will require the exchange and interoperability of data. Digitalisation of the energy system is therefore a critical component to enabling a smart and flexible energy system and in reaching the 2035 target of full decarbonisation. As detailed further in Question 3, BEIS, Ofgem and industry must take on recommendations made by the Energy Digitalisation Taskforce in order to realise a decarbonised, digital energy system.[27]

[23] Roadmap to net zero: a manifesto for a fully decarbonised power system by 2035, Renewable UK, 2022
[24] Operability of highly renewable electricity systems, National Infrastructure Commission, 2021
[25] Flexibility in Great Britain, The Carbon Trust, 2021
[26] Whole-System Value of Long-Duration Energy Storage in a Net-Zero Emission Energy System for Great Britain, Imperial College London, 2021
[27] Delivering a Digitalised Energy System, Energy Digitalisation Taskforce, 2022

29. To manage the much-needed changes detailed above, the regulatory framework needs to change to include more than economics and a focus on individual assets and needs to embody a mechanism for holistic whole-system oversight - broadly a system architect function as proposed in the Future System Operator role. Previous work from the Future Power Systems Architecture programme[28] should be reconsidered as a source of insight and ideas here.

30. In some of the above areas, there is strong reason to believe that the challenges and objectives that need to be achieved are well understood by the relevant bodies. This is evidenced by a host of recent and active reviews and consultations.[29] While encouraging, these reviews and consultations will need to be backed up by urgent action to implement the necessary steps. It should also be recognised that these challenges of system operation posed by decarbonising electricity generation and addressing the subsequent issues of system operation require significant levels of innovation in technology and in the frameworks employed across regulation, delivery and operation. Such innovations address challenges of system operation that are common to power systems globally. There are therefore significant commercial opportunities for countries that tackle these innovations early.

Hydrogen

31. Hydrogen is a highly versatile energy vector that could be used in many hard-to-decarbonise sectors where other energy vectors, such as electricity, may not be suitable, for example in certain industrial direct-firing processes. As such, hydrogen has an essential role in the net zero transition. While the government has set out high expectations for the role of hydrogen and is currently aiming for 10 gigawatts of low-carbon hydrogen production capacity by 2030,[30] it must now build on this ambition by providing the leadership needed to bring confidence to invest in hydrogen, if not then the UK will lose competitive advantage globally. There is a significant gap between current levels of low-carbon hydrogen production and the projected levels needed to meet the UK's carbon budgets and achieve the target of net zero emissions by 2050. To succeed, the government's commitment to hydrogen will require rapid development of a new low-carbon hydrogen production capacity, which is essentially starting from scratch. The NEPC has set out the opportunities presented from production and use of low-carbon hydrogen in key sectors of the economy.[31]

32. Scaling up low-carbon hydrogen production in such a short time frame bears many risks and dependencies. It is vital to recognise and manage these risks and dependencies during the process of scaling up hydrogen's role in the energy system to deliver rapid emissions reduction and maximise the whole-system benefits that are achievable.

33. The NEPC report[32] outlines in detail the most critical issues related to the scaling up and integration of blue and green hydrogen into the wider energy system. These are:

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[28] Future Power System Architecture report – FPSA 1, Energy Systems Catapult, 2016

[29] These include the Offshore transmission network review, Review of Electricity Market Arrangements, the recent Ofgem open letter on future systems and network regulation and ongoing work on the Future System Operator.

[30] British energy security strategy, HM Government, 2022

[31] The role of hydrogen in a net zero energy system, National Engineering Policy Centre, 2022

[32] The role of hydrogen in a net zero energy system, National Engineering Policy Centre, 2022

- Blue hydrogen[33]:
    - Dependence on carbon capture and storage technology
    - Dependence on fossil fuel supply
    - Fugitive emissions from fossil fuel extraction and blue hydrogen production and transportation processes.
- Green hydrogen[34]:
    - Dependence on renewable electricity generation and supply
    - Competition for renewable energy between direct electrification and green hydrogen production
    - Electrolyser build rates and supply of the critical scarce materials required.
- Wider hydrogen value chain:
    - Blue and green hydrogen competition
    - The 'chicken-and-egg' situation in the simultaneous scaling up of production and end use and the complexity of the hydrogen value chain
    - Skills gap
    - Safety and public trust
    - Global production and use of hydrogen
    - Cost and emissions uncertainties of hydrogen imports.

34. Risks inherent within all these areas must be managed if hydrogen production and end uses are to be low carbon and therefore contribute to achieving net zero. A technology-neutral and outcome-oriented approach is essential to ensure low-carbon hydrogen value chains develop in practice. The government has rightly recognised this need by developing a low-carbon hydrogen standard that focuses on the greenhouse gas intensity per heating value of hydrogen. The further measures needed to scale up the role of hydrogen in a net zero energy system while managing the associated risks and dependencies are outlined in Question 4.

Limited resources of minerals and precious metals

35. Greater focus on the role of materials in the net zero transition must be prioritised if the UK is to achieve net zero. Different materials including minerals and precious metals will play a key role in the net zero transition however an understanding of their role, and associated sustainability challenges are a significantly underserved aspect of the net zero transition, with a lack clear lines of governance, a lack of data, lack of an understanding of the relationship between materials and greenhouse gas emissions and a lack of awareness of the systemic social, ethical and safety challenges that exist throughout extraction, supply chains and end-of-life processes for materials.

36. There is an urgent need for a coordinated strategy that sets out the role of different materials in the net zero transition. This is vital as action here has significant potential for reducing global greenhouse gas emissions through reducing embedded carbon, the emissions associated with extraction, processing and manufacturing, the carbon intensity of different supply chain infrastructures, and their resulting impacts on infrastructure choices, consumption patterns and

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[33] Blue hydrogen is produced from autothermal reforming, steam methane reforming, or coal gasification from fossil fuels (e.g. natural gas and coal), where the CO_2 produced during the production process is mostly abated using carbon capture and storage.

[34] Green hydrogen is produced through electrolysis of water using renewable electricity. This requires water as a feedstock and produces oxygen as a by-product.

the social, ethical and safety issues. A coordinated strategy would prioritise scarce materials that will be key to a successful net zero transition. Solutions and interventions can have significant co-benefits for supply chain resilience and in mitigating health and social impacts.

Infrastructure and the built environment

37. Decarbonising the built environment must also be viewed as a top priority to not only achieve net zero but also to promote growth. Meeting net zero will require new or retrofitted infrastructure, programmes of buildings retrofit and new and revitalised industrial supply chains, including supply of low carbon construction materials. This is an opportunity for investment and economic growth, to progress the levelling-up agenda, an opportunity to create the pull to modernise (and decarbonise) the construction sector and should also be treated as an opportunity to embed climate resilience alongside decarbonisation and economic renewal. This can ensure that the UK is as resilient as possible to a warming climate.

38. Within construction, government has a central role to play in mandating the sector's action as well as driving innovation and decarbonisation via public procurement. Both together can ensure decarbonisation takes place at speed and scale. Government has previously provided welcome support for change, for example investment in research and innovation, learning from other sectors, adopting emerging technologies and providing guidance on the sourcing and contracting of public projects and programmes as is described in the Construction Playbook[35], Construction 2025[36] and the Construction Sector Deal[37]. The NEPC has identified the actions that are now needed from government to stimulate transformation not only in the construction sector but also in the wider built environment, these are set out in Question 4 in terms of the actions needed now, next (within the next 4 years) and in the future (beyond 2025).[38]

Skills and Education

39. Unlike almost any other profession, engineers' influence extends across all the industries mentioned in the Green Jobs Taskforce Report[39] – industries that must now transform to meet the net zero target. Engineers can therefore contribute significantly to decarbonisation and the creation of a sustainable economy.

40. Achieving net zero in the medium-term and maintaining sustainable development in the long-term requires current and future engineers to think differently and be equipped to make decisions about the design, manufacture, and end of life of products, services, technologies and infrastructure. Engineers must be equipped with the knowledge, skills and behaviours that the challenge of a low carbon, sustainable future demands.

41. But just as the demand for engineering skills is increasing within the key sectors of the future clean economy, the supply of engineering skills in the UK is failing to keep up with demand. Recent research (conducted pre-Covid) suggested an annual 35,000-50,000 shortage of engineers and technicians from level 3/advanced level technicians' roles upwards.[40] Added to this, the 2021 government Green Jobs Taskforce Report suggested an additional circa 500,000 new engineering and manufacturing jobs would be needed to support the green economy by

[35] The Construction Playbook, HM Government, 2022
[36] Construction 2025, HM Government, 2013
[37] Industrial Strategy: Construction Sector Deal, Department for Business, Energy and Industrial Strategy, 2019
[38] Decarbonising Construction: building a new net zero industry, National Engineering Policy Centre, 2021
[39] Green Jobs Taskforce Report, Independent Report commissioned by Department for Business, Energy and Industrial Strategy and Department for Education, 2021
[40] Trends in the engineering workforce Between 2010 and 2021, Engineering UK, 2022

2050, with around 300,000 expected by the end of this decade.[41] This additional demand is on top of business-as-usual activity.

42. For some industries, this also coincides with expected disruptions[42]. For example, the engineering construction sector expects to lose 20,000 employees per year over the next 6 years due to an ageing workforce. Other sectors face steep re-skilling and recruitment forecasts due in large part to the UK decarbonisation target, for example:

    - The energy sector will need to fill 400,000 roles by 2050, 260,000 of which will be new roles (equating to 65% and 10,000 each year)
    - In the buildings sector, retrofitting will require the training of 45,000 technicians each year at its peak in 5 to 10 years' time (30,000 each year in fabric improvement and 15,000 each year in heat pump installation).

43. The science, engineering and technology communities across the UK have, for several decades, been trying to increase the number of young people progressing towards science and engineering careers and there is an increasingly urgent need to encourage more individuals, both young people going through formative education and those already in work (career changers), to follow progression paths to engineering.

44. EngineeringUK, the body that engages young people to consider engineering careers on behalf of the engineering profession, is a central organisation in coordinating the efforts of many bodies to promote engineering careers. The Neon Futures platform provides a one-stop-shop for teachers to find a range of careers resources and engaging STEM experiences for their pupils. EngineeringUK also leads on the Tomorrows Engineers Code, encouraging employers to engage with science, technology, engineering and mathematics (STEM) activities in schools. The Royal Academy of Engineering runs the This is Engineering campaign that promotes engineering careers directly to young people through the social media channels that they consume. Many other organisations such as Smallpeice Trust, F1 in Schools, Primary Engineer and countless others all work at encouraging young people into engineering. All of this effort is key in improving the overall knowledge of engineering, what careers it offers and the pay that can be expected. This has been key in attracting more, and a more diverse group of young people into careers in engineering. Research by EngineeringUK clearly shows that young people who know more about what engineers do are more likely to consider a career in engineering.[43]

45. While crucial, the impact of all this effort has however resulted in mixed success. Recent data for post-16 STEM subjects which are feeders into engineering show that:

    - At A level, mathematics is now the most popular subject with around 90,000 entries per year and a reasonably good gender split with around 60-65% boys and 35-40% girls.
    - Physics A level, has however remained relatively static over the past ten years, only recently breaking through 40,000 entries before falling again. Its gender split is also much lower – around 20% of the cohort are girls, representing an absolute number of around 7-8,000.
    - Computer science is a relatively new introduction to A levels following a re-design of the subject (from IT) in 2015. The latest A level cohort was around 15,000, with 10% girls taking the subject.

[41] Green Jobs Taskforce Report, Independent Report commissioned by Department for Business, Energy and Industrial Strategy and Department for Education, 2021
[42] Net zero workforce: An analysis of existing research, Engineering UK, 2022
[43] Engineering Brand Monitor 2019, EngineeringUK, 2020

46. Other pathways to engineering include vocational/technical qualifications and apprenticeships. The Department for Education has introduced T' levels, new technical qualifications being introduced in post-16 education in England. This September has seen the first cohort of engineering and manufacturing students and, while it is too soon to see whether it is successful, significant challenges have been identified such as the lack of awareness among young people, their influencers and employers and the need for 45-day work placements, which are expected to prove hard to achieve due to lack of employer engagement.[44] Meanwhile, there are around 57,000 apprentices starting each year but with a significant shortage starting at level 4, where demand is already high and increasing[45].

47. Engineering students currently represent around 5% of the total number of UK university students and of these, around 18% are women. For higher education, around 26,000 UK domiciled students start engineering degrees each year. While, in absolute terms, the number of engineering students has increased, the overall proportion of the total higher education population has not changed in any significant way in over twenty years. As just one example, given the importance of increased electrification across a wide range of sectors, the persistent decline over the past ten years in the number of students choosing electronics and electrical engineering should be a pressing concern.

48. From civil engineering to electronics, sustainability criteria like energy performance, embodied carbon and design for deconstruction are becoming increasingly commonplace. These considerations bring about the need for new skill sets that are critical in the formation and ongoing professional development of engineers and technicians - from interdisciplinary systems thinking, regenerative design and parametric design to carbon costing and efficiency calculations, and end of life engineering decisions. The engineering community recognise the need for a greater focus on sustainability in the education of engineers and technicians and the importance that this education includes teaching the holistic approaches to decarbonisation which will be key to decarbonisation. The Royal Academy of Engineering's *sustainability in engineering higher education* project is seeking to place climate change and sustainability as the core context for the teaching of all engineering undergraduates. Some engineering institutions have already significantly increased expectations of the teaching of sustainability in universities, for example, the Joint Board of Moderators making explicit reference to climate change in its guidance for civil engineering and built environment degrees.

49. Upskilling and reskilling the current engineering workforce continue to be crucial. New ways of learning and training must be developed locally and supported by individuals, employers, education and training providers to provide workers the advanced abilities and understanding they need to take up high-level, high-wage jobs. The UK Government's focus on modular, flexible, lifelong learning designed to address the skills needed to drive higher levels of productivity is welcome but needs to be further embedded in local skills improvement plans.

50. A persistent and entrenched challenge for engineering is Diversity and Inclusion. The profession has a chronic underrepresentation of women, currently at just 16% of the workforce.[46] Ethnic minorities represent around 10% of engineers and technicians, again under-represented against the working population. But diversity is being recognised, not just in terms of the moral case of engineers reflecting the society they serve, but also in terms of the improved business and engineering innovation outcomes. There is also increasing recognition of the need for inclusivity

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[44] Unlocking Talent: Ensuring T' Levels deliver the workforce of the Future, Engineering UK and Make UK, 2022
[45] Intermediate apprenticeship (Level 2): 23,000; Advanced apprenticeship (Level 3): 32,000 and Higher apprenticeship (Level 4+): 2,000, Department for Education, 2022
[46] New analysis shows increase of women working in engineering, Engineering UK, 2022

when designing engineering solutions - considering all stakeholders throughout the life cycle. This has particularly come to light with the Royal Academy of Engineering's Engineering X programme focusing on open burning of electronic waste in West Africa.

51. Measures to address the issue of supply and availability of engineering skills are outlined in Question 4.

Question 3: What opportunities are there for new/amended measures to stimulate or facilitate the transition to net zero in a way that is pro-growth and/or pro-business?

52. Immediate investment in low-regrets measures to reduce carbon emissions can support economic growth, through creating new jobs, markets and UK-based supply chains while having the added benefit of setting the UK on the path to net zero. Conversely, measures that support the return to a high-carbon economy or policies that lock-in the use of high-emitting sources can make the necessary decarbonisation the UK must undertake more expensive, or even impossible, to reach.

53. The NEPC has set out a decision framework[47] that can aid government in identifying low regrets measures to prioritise and has illustrated this with examples, these are further outlined in detail as part of our response to Question 5. The NEPC has also recently produced an in-depth analysis of the significant opportunities available from hydrogen in a net zero energy system as well as the barriers and uncertainties that need to be addressed and the risks that need to be managed in deployment and scale up[48]. Salient details are summarised as part of our responses to Question 2 and Question 4.

54. Overall, to build upon the UK's strengths and capabilities in clean technologies and demonstrate global leadership that will be vital for ensuring international competitiveness and strengthens the position of UK manufacturers in global supply chains, government needs to:

   - Stimulate immediate, low-regrets actions that help set the UK on a confident path to achieve the 2050 net-zero target
   - Step up the level of investment in clean growth to a scale that is comparable with other ambitious nations and build upon the UK's strengths and capabilities in clean technologies.
   - Ensure policymaking encourages and leverages a shift in investor behaviour towards low-climate risk investments.

55. As noted in Questions 2, while the UK's system of legislative governance, built around the CCC, is world leading, there is no formal system of governance for translating high-level targets to national and local levels. A governance model which provides a credible and comprehensive plan accounting for all emitting sectors, providing a combination of progressive targets and incentives for decarbonisation is urgently needed on a sector-by-sector basis is urgently needed.

56. Some sector specific details are provided below, however as noted in Question 1, overall, the UK's Environmental Goods and Services Sector (EGSS)[49] (which last year was worth £200 billion and employed 1.2 million people[50]) should be seen as renowned for its high-quality expertise.

[47] Rapid 'low regrets' decision making for net zero policy, National Engineering Policy Centre, 2021
[48] The role of hydrogen in a net zero energy system, National Engineering Policy Centre, 2022
[49] UK environmental goods and services sector (EGSS):2019, Office for national statistics, 2022
[50] UK low carbon environmental goods and services sector, KMatrix, 2021

The sector's contributors are drawn from various standard industry classifications and, as a result, it has sometimes struggled to be seen and heard as a coherent whole by government. However, the growth opportunities in the UK and overseas are clear and much could be achieved with deeper promotion of the EGSS and recognition of its high-quality expertise and contribution to growth. Some specific opportunities were listed in Question 1.

57. Some contributors to this response highlighted that they saw the Commission on Environmental Markets and Economic Performance (CEMEP) that reported in November 2007 as a successful vehicle for galvanising the EGSS sector around growth opportunities. There could be merit in a new Commission that sets out and quantifies the opportunities for green economic growth for the UK sector, globally.

Energy

58. As described above in Question 2 and revisited in Question 6, for both decarbonisation and energy security, expanding renewable generation capacity and speeding up its development must be recognised as a top priority. Market arrangements need to be designed to increase the pace and breadth of investment in renewable generation. To enable further renewables penetration, aspects such as increasing system flexibility, providing efficient locational signals for network upgrades, maintaining system operability and managing price volatility must also be addressed. In this regard, we welcome recent consultations and reviews by relevant bodies and the objectives they set out.[51] These activities will need to be backed up by urgent action to implement the necessary steps to achieve the vital goal of a fully decarbonised electricity grid by 2035. Also as set out in more depth in Question 2, the significant levels of innovation (in technology and in the frameworks employed across regulation, delivery, and operation) and the commonality of the challenges for power systems worldwide mean there are significant commercial opportunities for countries that tackle these innovations early.

59. The UK could do much more to ensure that the growth opportunities from expanded renewables generation are captured in the UK. For example, about 15 years ago, Advantage West Midlands had a project called "Windsupply" that worked with local engineering businesses to find opportunities for them to join the supply chain for wind turbines and connect them with wind turbine manufacturers. This kind of locally based, pro-business, pro-growth, measure could contribute well to levelling up.

Infrastructure and the Built Environment

60. Meeting net zero will require new or retrofitted infrastructure, systematic programmes of buildings retrofit at significant scale and new and revitalised industrial supply chains. This is an opportunity for investment and economic growth, to progress the levelling-up agenda, to create the pull to modernise (and decarbonise) the construction sector and should also be treated as an opportunity to embed climate resilience alongside decarbonisation and economic renewal. This can ensure that the UK is as resilient as possible to a warming climate.

61. Government must adopt a joined up, systems approach to decarbonising infrastructure and the built environment and modernising the construction industry. As described in a cross-sector Vision for the Built Environment, the current construction system is resource-hungry and wasteful. As a striking example, after water concrete is the most widely used material on earth

[51] These include the Offshore transmission network review, Review of Electricity Market Arrangements, the recent Ofgem open letter on future systems and network regulation and ongoing work on the Future System Operator.

but is responsible for around 5-7% of global carbon emissions. Overall, the built environment must become more sustainable, secure and resilient yet responsibility for infrastructure and the built environment falls within the remit of many different government departments which prevents it from being treated coherently. A set of aspirations and policies that are consistent, coherent and clearly sequenced are needed. This would lower costs, create greater value for money and create other co-benefits.

62. In the case of construction, the NEPC has identified a comprehensive set of measures for government and industry across the whole life cycle of built assets from changes in procurement and the specification of outcomes through to design, construction and reuse.[52] These are set out according to what is required now, next (before 2025) and future (beyond 2025). These are set out in full in Question 4.

63. By encouraging retrofit and reuse in the built environment, the government can realise both societal and economic co-benefits through the creation of jobs and supply chains around maintenance and retrofit activities. Government, as a procurer, can incentivise this move towards circularity by changing how it evaluates projects, products and companies so that reuse is prioritised.

64. The built environment can be further decarbonised while achieving growth through changes to business models and supply chains. Current business models are not suitable for achieving the net zero transformation, with some contractors in the built environment typically working on very low profit margins. This often leads to a conservative approach to innovation, including innovation for decarbonisation. There is an opportunity to promote future business models that not only stimulate the decarbonisation of the sector but also necessitate sustainable profit margins that protect jobs in the long term. A rethink about productivity performance and how risk is shared across the supply chain is needed to counter the risk-averse nature of the industry, which can hold back innovation.

65. Digitalisation can also play a key part in improving productivity and performance. For example, new business models might be supported by digital technologies, drawing on learning from sectors that do this well such as the manufacturing industry. In particular, the construction sector needs to be challenged to implement and use the UK Building Information Management (BIM) Framework for information management and data exchange to realise significant productivity gains and improved whole life performance and management of the built environment.

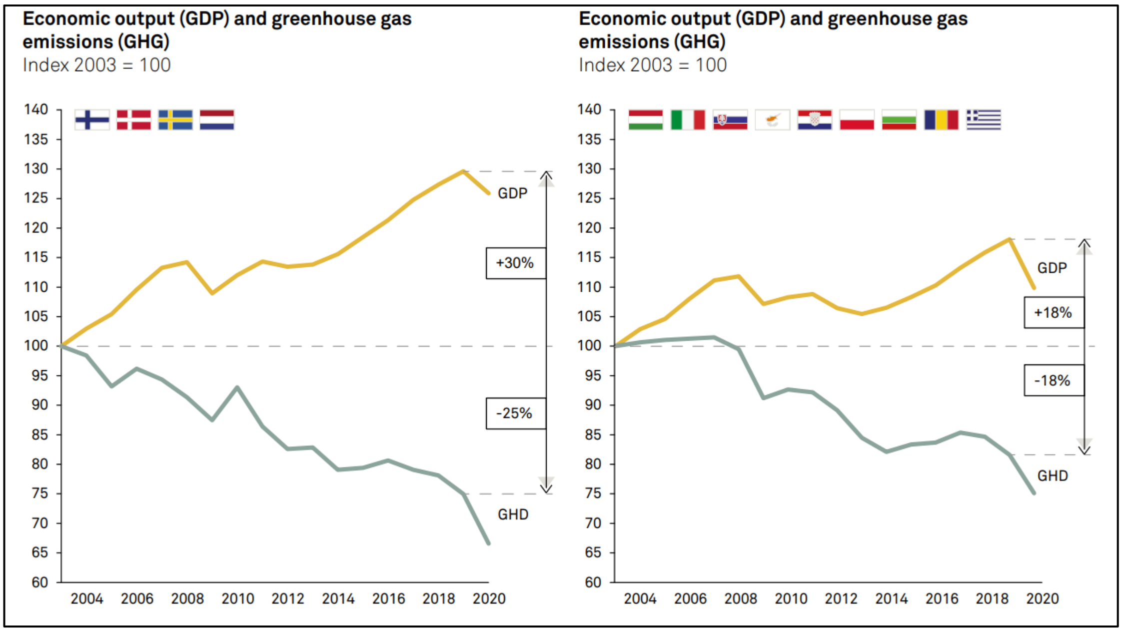
Digitalisation

66. Government driven digitalisation is an essential enabler in ensuring businesses, consumers and other actors decarbonise, ensuring resilience and can also boost productivity. Data-driven 'cyber-physical systems' are now possible because of advances in computing power and digital communications that have led to huge reductions in the unit-cost of collecting, transmitting, processing, and storing data. It is vital that we take advantage of these cost-effective technologies to enable decarbonisation across different economic sectors.

67. The implement consulting group found that decarbonisation has happened fastest in the most digitalised economies. Europe's most advanced digital economies reduced their GHG by 25% between 2003 and 2019 and, at the same time, grew their economies by 30% in the same

[52] Decarbonising Construction: building a new net zero industry, National Engineering Policy Centre, 2021

period. Europe's least digital economies also reduced their GHG in that period, but only by 18% while growing their economies by 18%[53].



Economic output (GDP) and greenhouse gas emissions (GHG) between 2003 and 2019 for the most digitalised economies (left) and the least (right)

68. As described by the International Energy Agency[54], immediate government action to enable digitalisation can help in achieving decarbonisation by:

- Monitoring progress on reaching carbon targets
- Enabling organisations and individuals to reduce emissions
- Reducing carbon emissions in infrastructure
- Reducing waste and enabling circularity
- Enabling the transition to smart local energy systems
- Facilitate decentralisation and decarbonisation of the energy system and allow incorporation of smaller-scale energy assets.

69. As described in an NEPC report on the post-Covid 19 foundations for net zero recovery[55], government can act now to support this digitisation by:

- Supporting the development and adoption of digital technologies as enablers of decarbonisation and a contributor to productivity across all sectors, while addressing interdependent social and technical factors that affect their adoption
- Strengthening the UK's digital infrastructure through support for broadband and 5G to improve equitable access to the internet, ensuring resilience and enabling a data-driven economy
- Put in place policies that will ensure that digitally enabled systems are adopted but are also resilient and secure.

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[53] Digital Decarbonisation: How the digital sector is supporting climate action, Implement Consulting Group, 2022
[54] Digitalisation and Energy, International Energy Agency, 2017
[55] Beyond Covid-19: laying the foundations for a net zero recovery, National Engineering Policy Centre, 2020

70. For the UK to realise the full benefits of digitalisation it is important for government to recognise that increasing digitalisation to economic sectors is a socio-technical change, and the social aspects of the change are at least as important as the technical. Therefore, digitalisation must be guided by our values. It must be fair, inclusive, democratic, ethical, just and compassionate.

71. Digitalisation is already having a major transformative and enabling effects across sectors including transport, the built environment and in industry including increasing efficiency, productivity and energy savings[56]. Technologies such as digital twinning, digital prototyping, digital asset management and predictive maintenance have all enabled these transformations and have made them more economically efficient. However, the digital workforce in the UK has a mismatch between supply and demand and remains unrepresentative of the population[57]. Smaller businesses are particularly challenged and find it difficult not only to embrace industrial digital technologies but are well behind peers in Europe and beyond in the adoption of other productivity-based technologies such as CRM and Enterprise Resource Planning (ERP). To address the challenges of net zero, energy efficient homes and the evolution of the automotive industry, many more jobs with significant digital components will be needed to address the core functions but also to manage and exploit data and to protect and secure data and information through the system. The ecosystem will evolve to include many actors who traditionally have not collaborated. The convergence of Information Technology (IT), Operational Technology (OT) and Biotechnology brings huge new challenges but enormous opportunities which are underpinned by a confident and skilled workforce.

72. Building on the details already presented in Question 2, further details on the opportunities and necessity of digitalisation in the energy sector are presented here to further substantiate the need to advance this agenda. As described by the Energy Data Taskforce[58], decarbonisation and decentralisation are already transforming the energy sector, offering new opportunities to deliver a more productive, efficient and cost reflective energy system. This is involving a fundamental shift from centralised command and control-based structures to more interactive behaviours, networked actions, collaborative solutions and layering of interventions. The management of this new system, by multiple actors at different levels, will require the exchange and interoperability of data.

73. With Government support, the digitalisation of the energy system has the potential to:

- Enable future system management through:
    - Improving and optimising of the energy system
    - Facilitating the efficient integration of renewable energy by delivering flexible electricity systems that provide demand-side solutions and energy storage[59]
    - Optimising across energy vectors which will enable the sector to better understand the impact of vector shifting solutions

[56] Digitalisation and Energy, International Energy Agency, 2017

[57] Many employers already face significant digital skills gaps, particularly relating to advanced digital skills. One in four (23%) employers say that their current workforce lacks the basic digital skills that they need, rising to over one in three (37%) in relation to advanced digital skills. Such skills gaps can have a significant impact on businesses; three in four (76%) businesses say that a lack of digital skills would affect the profitability of their business. Digital poverty is particularly prevalent among those from lower socio-economic groups, where one in five (21%) households with children have no access to an appropriate device, and over one in twenty (6%) have no access to the internet. See Disconnected – exploring the digital skills gap, WorldSkills, 2022

[58] A strategy for a Modern Digitalised Energy System, Energy Data Taskforce, 2022

[59] Digitalisation of the energy system, European Commission, 2022

    - Unlock the flexibility in the market by opening to a wider range of assets, business models and competition from small and larger potential actors thereby increasing the range of flexibility sources and drive down costs.
- Ensure system stability and facilitate risk assessment by:
    - Enabling clarity across the multiple actors in the system as more visible assets, multiple actors can collaborate, coordinate and secure system stability
    - Securing the system from potential risks as with increased data transparency and openness risks can be much better understood and mitigated.
- Reduce full system costs:
    - Optimising procurement and cost reduction: A greater visibility of infrastructure and assets and their operation both individually and in system context combined with an evidence-based forecast for future demand will provide significant opportunities. It will be possible to more precisely deploy smart technologies and focus the acquisition of new assets.

74. From a consumer's perspective, the Energy Data Taskforce emphasises that the digital transformation of the energy system will almost certainly cost less and offer better products if we embrace data driven technologies that enable superior price discovery, drive efficiency and create productivity gains.

75. Failure to respond to the challenge of successfully harnessing the potential of data, or delay in doing so, carries significant costs and has substantial implications for the energy system which cannot be afforded in the current crisis. Without action, we can expect:

- A slower and more expensive transformation of the energy system
- Increased risk to system stability (i.e. poor visibility of assets, their operation and how they interact with each other at local and national levels), a factor that will become an increasingly important as system operation becomes distributed across multiple entities
- Reduced innovation since low visibility and accessibility of data reduces the ability for innovators, especially SMEs, to break into the sector to create new products and technologies which can improve consumer experience, drive efficiencies and deliver carbon reductions.

76. While the above focusses on the example of the energy sector, there are equally transformative opportunities available from digitalisation across other sectors, such as digital twinning, digital prototyping and digital asset management and predictive maintenance in infrastructure and the built environment.

Question 4: What more could government do to support businesses, consumers and other actors to decarbonise?

The need for consistent and sequenced policies and incentives

77. As outlined in Question 3, government can act now with immediate investment in low-regrets measures to reduce carbon emissions and support economic growth, through creating new jobs, markets and UK-based supply chains while having the added benefit of setting the UK on the path to net zero. Short-term actions such as these can help the government to support business, consumers and actors in the short term. However, low regrets decisions alone will not achieve

net zero. Policymakers will also have to make bigger, higher stakes decisions if the UK is to achieve net zero and for these to be effective, it is urgent that government develop consistent and clearly sequenced policies and priorities, this clarity will in itself support businesses, consumers and other actors on what needs to be done and when. To help with this, the NEPC has frequently employed a ‘now, next, future’ framework. This is first summarised at a high level below and then demonstrated at a more granular level for actions in key areas of policy.

NOW	NEXT	FUTURE
Do...	Plan...	Invest...
Explain what must be done, when and why	Articulate and evaluate future options available to put the UK on the path to net zero	Options and approaches to be developed
Deploy known technologies that can decarbonise economic sectors	Technology needs to be developed Trials to demonstrate / validate approaches and get buy in from businesses and consumers	Any further innovation required to achieve net zero
Review current business models to identify barriers and enablers to decarbonisation	Develop new business models that enable the net zero transition in a way that is pro-growth	
Review the current skills base to identify skills gaps	Retraining / development of new skills needed to achieve net zero	Broad range of new skills operational
Identify no and low regrets decisions (see Qs 3 and 6) that can put the UK on the pathway to net zero		Ideas to be evaluated and developed
Incentivise the private sector to act by setting out stronger policy and regulatory requirements	Joint public / private initiatives	Government led investment taking long term view

Sequenced and consistent policies to decarbonise infrastructure and the built environment

78. The transition to net zero will require a large amount of new infrastructure, this is an opportunity for investment and economic growth and also an opportunity to create the pull to modernise (and decarbonise) the construction sector. To achieve this, the construction sector requires sequenced and consistent policies, support and incentives. The NEPC have set out a sequenced and consistent approach, covering four key mission areas, which can provide clarity for who has to take action and when.[60] The details of this sequencing are presented in **Appendix 1**.

79. As with government policies in general, a cross-mission area for the built environment is to also adopt a joined up, systems approach. Government must adopt different approaches to decision making that enable consistent and coherent policies across different government departments, local government and devolved administrations. The built environment sectors themselves must employ more holistic design approaches for the built environment. This can be achieved through

[60] Decarbonising Construction: building a new net zero industry, National Engineering Policy Centre, 2021

choice of design practices and driving more efficiency within designs as well as requiring more, materials reuse within design and construction.

Sequenced and consistent policies to realise the role of hydrogen in the net zero energy system

80. As detailed in Question 2, a strategy that maximises the production of low-carbon hydrogen while also managing the associate risks and dependencies is required. This will require a region-specific approach to developing local hydrogen economies. Low carbon hydrogen production and end use should focus on industrial clusters where current production and use of grey hydrogen[61] is located. When low-carbon production capacity (and the enabling infrastructure this requires) has been sufficiently scaled up in these clusters, and with available transmission infrastructure connecting these clusters to other areas, hydrogen deployment can be expanded from these industrial clusters for more widespread use in the energy system for buildings, transport and flexible power generation. This means that the degree and phasing of hydrogen deployment will vary significantly across different regions and be subject to regional variations such as the cost and efficiencies of low-carbon hydrogen production, storage and transportation infrastructures, the availability of low-carbon hydrogen over time, and the development of other decarbonisation options for different end uses.

81. By displaying leadership to match their ambition for the role of hydrogen in the future energy system (as set out in Question 2), government can bring confidence to invest in hydrogen. To capture the opportunities presented by low-carbon hydrogen and make the best use of its potential to contribute to achieving net zero, policies must:

    1. achieve a rapid scaling up of low-carbon hydrogen infrastructure – with particular attention to those end uses for which hydrogen deployment offers the greatest value to decarbonisation of the whole energy system
    2. manage the risks and dependencies when scaling up hydrogen value chains.

82. These two overarching requirements need to be achieved in the next few years if low-carbon hydrogen is to be successfully scaled up as part of a net zero energy system. The NEPC recommendations for how these two overarching needs can be addressed, including measures needed now and those needed within the next five years are set out in **Appendix 2**.

Skills and Education

83. To address the issues of supply and availability of engineering skills set out in Question 2, government needs to:

    - Implement the recommendations from the Green Jobs Taskforce, which we support
    - Invest in a long-term STEM education and skills strategy that among other things provides a guarantee that all pupils receive high quality, up-to-date STEM careers advice and guidance, supported by additional funding of £40 million annually to support careers activities in schools and ensures that there is a truly joined-up approach to STEM education and skills leaving young people inspired to move into an engineering/ technology career.[62]

[61] This is hydrogen produced from autothermal reforming, steam methane reforming, or coal gasification from fossil fuels (e.g. natural gas and coal). The UK currently produces around 27 TWh of hydrogen each year, 96% of which is grey hydrogen and is used predominantly as industrial feedstocks in the petrochemical and fertiliser sector.
[62] Engineering UK submission to Net Zero Review, 2022

- Support and invest in stakeholders active within Local Skills Improvement Plans, specifically to develop new opportunities for micro-learning to support upskilling and reskilling of the local workforce in growth sectors supporting net zero e.g. UK government ambitions to build a high-tech, high-value, high-skill battery industry in the UK[63].
- To support UK Government's focus on modular, flexible, lifelong learning, government should support innovations in skills development such as 'micro credentials', new, ''bite-sized' learning opportunities that can be studied flexibly and are designed to be accessible and inclusive. Micro credentials at level 4 and above are meant to allow workers to reach and stay at the cutting edge of their chosen industries: to refresh, upskill, reskill, and retrain in light of technological advances.[64] Ultimately, micro credentials are intended as a way of bridging the needs of employers and employees, especially at the local but also the national level.

Take a systems approach to decarbonisation

84. As described in Question 1, the target of net zero territorial emissions by 2050 requires an unprecedented breadth, scale, complexity and pace of change. It has implications for businesses and consumers that will impact financing, regulation, institutions, behaviour change, social norms, world views, culture, and politics.

85. To support businesses, consumers and other actors, the government needs to take a consistent, systems approach.[65] A change towards a systems mindset is required, where policy areas that are currently approached separately or in isolation need to be recognised as interconnected systems.

86. By deploying cross-sectoral systems approaches to policymaking, the government can ensure that policy interventions for different sectors and stakeholders work most effectively together to achieve net-zero and deliver co-benefits, reduce the risk of unintended consequences and help account for social, cultural, economic and behavioural factors that can act as both barriers to and levers for change[66]. As with decarbonisation, resilience is also a system-wide issue. Cross-sectoral systems approaches are vital in ensuring resilience of organisations, consumers infrastructure, supply chains or policy.

87. As outlined in an NEPC report on the post-covid foundations for a net zero recovery[67], actions that government can take now to take a systems approach and support businesses, consumers and other stakeholders are:

    1. Reinforce mechanisms that facilitate genuine cross-sectoral working, to enable all stakeholders to act together at scale and in a coordinated way.
    2. Strengthen central, devolved, and local government capability and capacity to provide systems leadership and operationalise cross-sectoral systems approaches.
    3. In the near term, apply systems approaches to inform decision-making on multiple, urgent low regrets options across different sectors, setting the UK on the right path to net-zero.

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[63] Record funding uplift for UK battery research and development: The UK's world-leading manufacturing industries will be boosted thanks to £211 million in new government funding for battery research and innovation, Department for Business, Energy and Industrial Strategy and UK Research and Innovation, 2022
[64] The Role of Micro Credentials in Modular Learning, Lifelong Education Commission, 2022
[65] Net Zero: A systems perspective on the climate challenge, National Engineering Policy Centre, 2020
[66] Beyond Covid-19: laying the foundations for a net zero recovery, National Engineering Policy Centre, 2020
[67] Beyond Covid-19: laying the foundations for a net zero recovery, National Engineering Policy Centre, 2020

Question 5: Where and in what areas of policy focus could net zero be achieved in a more economically efficient manner?

88. As described in Question 3, immediate investment in low-regrets measures to reduce carbon emissions can support economic growth, through creating new jobs, markets and UK-based supply chains while having the added benefit of setting the UK on the path to net zero while minimising costs.[68] Wisely chosen low regrets decisions can:

    - Play a significant role in reducing UK carbon emissions
    - Avoid technological lock-in to high carbon technologies and instead unlock low-carbon pathways and providing flexibility for further low carbon interventions in the future
    - Be capable of progressive upscaling so that costs will reduce in the future
    - Make the best use of a limited resources
    - Provide co-benefits or synergies with other policy objectives.

89. Low-regrets decisions that the Government can implement now, in some instances at reduced costs, include:

- Scaling up deployment of proven technologies as fast as possible
    - Upgrading the electricity grid to deal with greater electrification and renewables
    - Scaling up energy storage capabilities
    - Upgrading electric charging infrastructure
- Demonstration of low carbon technologies so they are ready to be deployed in the future, such as investment in research, demonstration and testing of low carbon technologies such as hydrogen and CCS
- Improving efficiencies in resource and energy use across domestic, commercial, transport and industrial applications
    - Driving decarbonisation using new building standards[69]
    - Retrofitting existing buildings
    - Mandating hydrogen ready appliances
- Demand reduction
    - Rolling out smart meters
    - Public engagement, including improving the information available on the steps and measures that can be taken to reduce their personal emissions and reduce demand.

90. The NEPC's report on low regrets measures provides further substantiates some of these key examples, summarised below.[70]

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[68] Rapid 'low regrets' decision making for net zero policy, National Engineering Policy Centre, 2021

[69] There are significant opportunities to raise standards, for example on energy efficiency in new build. While there have been reservations this would increase construction cost and claims this would increase house prices, in practice house prices depend on what people are willing or able to pay. The latter is driven by the number of homes available in each area, incomes, interest rates and perceptions of future movements in house prices. The price of houses in the UK has varied far more than building costs. Higher standards of energy efficiency are likely to have little impact on house prices whereas studies do show that the most efficient homes sell for a scarcity premium above the capitalised value of their energy savings compared to less efficient homes (The value of energy efficiency in residential buildings, Geske, 2022). Increasing the supply of such homes would reduce their scarcity premium and lead to much needed energy efficiency within the housing stock.

[70] Rapid 'low regrets' decision making for net zero policy, National Engineering Policy Centre, 2021

Building retrofit

91. The net zero transition will require reduction in the consumption of energy and water within our buildings and the switching to zero-carbon heating systems, or ones which will become zero-carbon as more low-carbon electricity generation comes onto the electricity grid (see Question 2). Retrofitting buildings will play a major part in reducing carbon emissions from the built environment. Retrofit here covers interventions on a building's fabric, building services, and equipment with the aim to reduce demand and meet the remaining demand via a low carbon technology, or facilitate the incorporation of low-carbon technology in the future.

92. Decarbonising heat within buildings is a major step in all scenarios for reaching the net zero target. Given that the vast majority of buildings that will be in use in 2050 have already been built and do not have the carbon performance necessary to achieve net zero, retrofit must play a major role in reducing carbon emissions. The Climate Change Committee's 6th Carbon Budget highlights retrofitting and upgrading all buildings in the next 10–15 years as a priority. Their budget assumes a 12% reduction in heat demand from improvements in energy efficiency, which they consider conservative. Retrofit is required under any decarbonisation scenario and is an enabler for the electrification of the energy, building and transport systems. Retrofit also offers clear co-benefits at the building and system level:

- Benefits to residents:
    - Reducing energy costs: this would help mitigate increases in energy prices due to decarbonisation.[71]
    - Improved comfort and health, particularly for households in fuel poverty.
    - Tackled as part of wider works, it can contribute to enhancing the value and lifetime of properties.
- Reducing air polluting emissions from energy use:
    - Reducing fossil fuel consumption will reduce air polluting emissions, as well as carbon emissions. This is less significant in an all-electric scenario, but for hydrogen, by using well optimised burner designs, combustion emits less nitrous oxides (NOx) than burning natural gas[72].
- Job retention and creation:
    - It is estimated that, spread across the UK, around 500,000 new professionals and trades will be required[73].
- Systems-level benefits:
    - Without reductions in demand, the transition to low-carbon heat by 2050 (whether via electrification, through hydrogen, or a mix) is unlikely given the infrastructure and investment it would require and the financial impact on consumers. As with all sources of demand reduction, at the system level, building retrofit reduces the generation, storage and distribution infrastructure required and improves system resilience.

93. Retrofit is also scalable. Tackling all buildings will necessarily happen gradually, which provides opportunities for developing new supply chains, learning lessons and continuously improving delivery and outcomes, including cost effectiveness. 'Hard to treat' properties could be tackled in later phases, benefiting from these improvements. Innovative solutions[74] tackle a group of homes (e.g. a terraced row) at once. They use standardised approaches and are not applicable

[71] The Sixth Carbon Budget: The UK's path to net zero, Climate Change Committee, 2020
[72] Hy4Heat Final Progress Report, BEIS and Hy4Heat, 2022
[73] Will Covid-19 fiscal recovery packages accelerate or retard progress on climate change, Hepburn *et al*, 2020
[74] For example Energiesprong UK

everywhere (e.g. conservation areas), but they offer significant benefits in costs, speed, and minimised disruption. Alongside more bespoke individual building solutions, these approaches are best deployed as part of a national strategy which has clear area-based strategies sitting beneath it.

Battery Electric Vehicle (BEV) charging infrastructure

94. The transport sector currently accounts for a third of all carbon dioxide emissions, the large majority of which are from road transport.[75] Electric vehicles are a viable medium-term solution for some road traffic applications and developing a BEV charging network will offer clear co-benefits such as, by reducing the number of petrol/diesel vehicles on the road, improved air quality and health impacts from air pollution associated with road vehicles.

95. Developing a BEV charging network can also be progressively upscaled to reduce costs for the future. Increasing the scale of the UK's BEV charging network should increase consumer confidence in BEVs, increasing uptake and ownership. As a result, there would be an increased demand for charging and therefore potential economies of scale. Procuring charging infrastructure at scale should also drive delivery capacity and drive down future costs (though it is important to acknowledge that costs from maintenance of the charging network will continue into the future).

96. While the increased electrification of transport will result in an uplift in the demand for low-carbon electricity, overtime and coupled with flexible tariffs and an effective smart grid, BEVs should represent a large and flexible domestic load. For many users, it is possible to charge at almost any times in the day or night, either at home, at work, or in a car park, this would allow the Electrical System Operator (ESO) to schedule the charging load in real time providing the ESO with the ability to reduce the peaks and 'filling in the troughs' of demands on the grid, thereby increasing the load factor on low carbon generation and improving the economic performance of the system. This ability to control and limit the peaks in demand is a key factor in allowing BEV charging alongside other uses of electricity, such as the electrification of heating, while avoiding severe peaks in demand at key times that would reduce the utilisation factor of the grid and increases prices.

97. Linked within the wider system of BEV charging and use are the BEVs themselves, including the manufacturing of the batteries used in the vehicles. Ongoing assessment of the demands from increased BEV manufacture will be needed since, depending on the chemistry of the batteries, the supply chains for some materials face potential obstacles including high costs and environmental concerns associated with the extraction and processing of materials[76]. Studies have suggested that both the future supply of cobalt[77] and lithium, key components for some battery compositions, will not be able to meet demand due to limitations in materials availability, mining, security of supply chains and manufacturing. To help tackle this supply issue, the Royal Society of Chemistry is advocating the approach of 'reduce, reuse, recycle'[78]. Flexibility is available from different battery options, but it is important to maintain ongoing analysis of potential limitations, costs and environmental impacts in the supply chains for materials.

Deployment of critical technologies

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[75] 2019 UK greenhouse gas emissions, Department for Business, Energy and Industrial Strategy, 2019
[76] Rare Earth Metals, Parliamentary Office of Science and Technology, 2011
[77] Cobalt Demand: Past, Present, and Future, Massachusetts Institute of Technology, 2018
[78] Elements in danger, Royal Society of Chemistry, 2021

98. Urgent deployment of critical technologies such as hydrogen and CCS were also outlined in the NEPC paper on low regrets options but the case for this has been dealt with in Question 2 and the measures needed to realising the role of hydrogen in decarbonisation in a way that manages the associated risks, including those associated with the wider infrastructure systems that will be needed to produce of low-carbon hydrogen, are dealt with in Question 4.

Planning and supply chain constraints

99. All customers and businesses need a supplier base and there is both a need and opportunity to address significant constraints in supply chains in key areas. For example, when rolling out the requisite infrastructure and technologies for low carbon energy, companies will work with clients to make a decision on the technological solution. This may be the installation of renewables, battery technologies, or green hydrogen production and switching technologies. Sites will be identified and planning permission and permits applied for. The speed of this process is dependent on the scale of the project but currently can take anything from 1-3 years. Anything from 1-3 years can be added to this if a Crown Estates license is required and a project would be unlikely to seek planning permission without a confirmed license. It is very unlikely that any project will procure equipment until planning is given.

100. To provide one example of current supply chain constraints, electrolysers for the production of green hydrogen are currently all bespoke and often hand-made. They require integration and containerisation or to be housed in another way. Most orders currently have at least a 1 year lead time but could be longer and this will get worse as demand scales up. These lead time increases the capital expenditure (CapEx) of projects and ultimately the cost of the output energy. Though there is at least one producer of Polymer Electrolyte Membrane (PEM) Electrolysers in the UK, there are no UK-based producers of alkaline electrolysers of the kind that have been used in industry for decades. These are all produced overseas adding another layer of delay around shipping and potential risks to supply chains. Developing domestic supply chains could play a key role in the supply chain challenges described here and has the added economic opportunity of positioning the UK as an exporter.

101. Examples of other key technologies with long lead times include solar panels and electrical control systems, compressors and batteries. Many of these are becoming increasingly expensive as demand is growing but the raw materials are increasingly costly. If we compare this current situation to a future in which the CBI estimate that the UK could potentially capture £8bn in additional revenues from hydrogen electrolyser production, the current barriers and the growth benefits available from addressing them are clear.[79]

Digitalisation

102. As described in Question 3, digitalisation can again play a significant role in introducing efficiencies (economic and environmental) across many sectors.

Transport

103. Currently the overwhelming emphasis for transport decarbonisation is placed on technological solutions. For example, in terms of passenger transport, a large emphasis is placed on electric vehicles. Electric vehicles can and play a role, and this is why developing BEV charging infrastructure is a low regrets measure to prioritise now. However, if from tomorrow all new cars purchased were electric vehicles, it would take 15 years before every car on the road was

[79] Race to net zero: driving the UK's sustainable future, CBI, 2022

electric, due to the time it takes to renew the vehicle fleet. Electric car purchases are currently no more than 10% of the total globally. We cannot afford to rely solely on such incremental shifts.

104. A useful framework for approaching transport decarbonisation from a whole-system perspective is the hierarchy of:

1. Avoid
2. Shift
3. Improve

105. As has been reference for other sectors in this response, the priority in this hierarchy is to help ***avoid*** the need for transport altogether (demand reduction). For passenger transport, requires smart infrastructure and planning which places people's needs such as work, shops, leisure, within easy reach. When we cannot avoid transport altogether, we need to ***shift*** from high-emission journeys to low-emission journeys such as to active transport (e.g. walking and cycling), to public transport and low-emission vehicles. Where we cannot avoid or shift the high-carbon journey we need to ***improve*** the efficiencies of both vehicles and the infrastructure on which they run.

106. Key infrastructure interventions present the opportunity to promote modal shifts and introduce much needed efficiencies and co-benefits within our transport system. An example of this which is outside of passenger transport, is in our freight and logistic operations where a shift from road to rail would provide not just significant efficiencies for the UK road system but also significant environmental, social and economic benefits from reduced congestion.

107. Modal shift is a fundamental part of the Freight and Logistics decarbonisation strategy. Based on analysis underway of findings prepared for and by the Rail Freight Group and by the Chartered Institute of Logistics and Transport (CILT), CILT estimate that over a third (approx. 38%) of all HGV tonne kms are likely to be suitable for modal shift to rail provided the following set of strategic rail electrification works and the use of intermodal equipment (containers, swap bodies) in freight operations:

- 50 miles of 'infill schemes' (connecting existing freight hubs to the current electrified network) would lead to approx. 20% of freight tonne kms to be electrically hauled
- A further 370 miles of electrification of rail lines on so-called 'Volume Routes' would allow for approx. 60% of freight tonne kms to be electrically hauled
- A further 380 miles of electrification on the Core Freight Network would allow for approach 95% of freight tonne kms to be electrically hauled.

108. While quantifying carbon savings from this is difficult, HGV fuel consumption is driven by tonne kms so an approx.38% modal shift from diesel road haulage to electric rail haulage can be expected to save around a third of all HGV carbon emissions. This would be once, as covered above (Question 2), a decarbonised electricity grid has been achieved and generating capacity for traction energy on electrified rail lines is therefore carbon free.

109. Freight that would be enabled to shift from road to electrified rail would include almost all very long road hauls over 300km, a significant proportion in the 200-300km range and some heavy bulk commodities in the 100-200km range (mostly construction materials). The analysis assumes that battery electric HGVs (or other forms of low carbon HGV, for example, biomethane or hydrogen fuel cell electric (FCEV) HGVs) with a range of 200km, which are now becoming

available, will be used for shorter distance local and regional hauls. With improving battery and charging technology - and assuming that fast charging will become available at key locations such as distribution centres and major stores - it is likely that effective electric HGV range will increase toward 300km. Hence the view that rail will cater for some but not all hauls in the 200-300km range.

110. It follows that the combination of rail for regular, long-distance routes and various low-carbon HGVs (battery electric, biomethane or FCEV) for short and medium range distribution allows UK land freight to achieve close to full decarbonisation. As battery HGV range seems unlikely to extend much above 300km in the foreseeable future and, while technically feasible, Motorway Electrification faces operational, funding and safety challenges, there is arguably no viable alternative for decarbonising long-distance haulage. Therefore, while various low-carbon HGVs are likely to cater for short and medium distance movements, an electrified rail freight network is likely to be essential for the decarbonisation of long-distance freight haulage in the UK.

Question 6: How should we balance our priorities to maintaining energy security with our commitments to delivering net zero by 2050?

111. The consequences of the Russian invasion of Ukraine have exposed the vulnerability in UK energy security and has made the task of achieving net zero more complex. However, the energy crisis brings with it the opportunity to pivot away from fossil fuels towards cheaper renewables and a low carbon energy system as well as to support vulnerable people with measures such as buildings retrofit for demand reduction, such as home insulation and energy efficient appliances, and renewable generation. We agree with the assessment from the National Infrastructure Commission and the Committee on Climate Change[80] that the government should redouble our efforts on shifting from fossil fuels to renewables along with reducing energy demand and retrofitting buildings. This can address both the UK's short term energy crisis and embed long-term progress on decarbonisation.

112. Energy security and reducing the UK's exposure to volatile fossil fuel prices requires strong policies that reduce energy waste across the economy and boost domestic production of cheap and secure low carbon energy. The following actions can support this:

1. Develop credible policies for energy efficiency in buildings
2. Provide and promote a comprehensive energy advice service
3. Deliver a working market-based mechanism for low-carbon heat
4. Make full use of new auctions for onshore wind and solar
5. Deliver updated National Policy Statements for energy and act at pace to resolve barriers to deployment of strategic energy infrastructure.

113. Electricity market reform will also be key in balancing energy security with achieving net zero. We welcome the Review of Electricity Market Arrangement (REMA) consultation[81] and the objectives it sets out. The consultation rightly recognised the three key objectives for the electricity market reform – decarbonisation, security of supply and cost-effectiveness:

[80] National Infrastructure Commission and Climate Change Committee letter to Prime Minister 6th September 2022, National Infrastructure Committee and Climate Change Committee, 2022
[81] Review of Electricity Market Arrangement, Department for Business, Energy and Industrial Strategy, 2022

- Decarbonisation – The market arrangements need to acknowledge the scale of the challenge, and to facilitate the deployment of renewables at pace to meet the 2035 fully decarbonised power system target and put the UK on track to net zero by 2050.
- Security of supply – The market arrangements need to ensure adequate capacity and operability. The sufficient dispatchable generation and the operability services of a high renewable electricity system must be incentivised to enable a safe and secure operation of a fully decarbonised power system, this includes adequate storage for both energy security and flexibility.
- Cost-effectiveness – The market arrangements need to account for the cost structure of renewables being high capital cost and low to minimal operational cost. Wider system costs for systems services such as energy storage and grid stability must also be valued appropriately to deliver the fully decarbonised power system in the most cost-effective manner.

114. The Review of Electricity Market Arrangements[82] also rightly identified the future challenges for electricity market arrangements to deliver a fully decarbonised power system. Expanding renewable generation capacity and speeding up its development must be recognised as a top priority. The market arrangements need to be designed to increase the pace and breadth of investment in renewable generation. To accommodate a power system increasingly dominated by renewable generation, aspects such as increasing system flexibility, providing efficient locational signals for network upgrades, maintaining system operability and managing price volatility must also be addressed to enable further renewables penetration and accelerate progress toward a low carbon electricity system in an affordable way.

115. As described in the Electricity Engineering Independent Standards Review[83], energy security can also be balanced with delivering net zero by digitalising the energy system as described previously in Q3 and expanded here. The energy system can no longer be separated from the large number and diverse range of smart “edge devices” that connect to it such as electric vehicles, heat pumps, smart appliances and energy storage systems. Managed well this provides increase reliability, resilience and security in the energy system as well as significant scope to reduce costs, accelerate deployment of low carbon technologies, and give greater value to customers.

116. The cost saving opportunities from a flexible and resilient whole electricity system are significant, particularly so for a net-zero economy. Recent modelling by the Carbon Trust and Imperial College London, suggests that a fully flexible energy system could lead to net savings of £9.6bn-£16.7bn per annum in 2050.[84] The same Imperial study recommends that to capturing this opportunity associated with greater system security and avoiding the accompanying risks requires greater interoperability between the devices and the platforms which manage the electricity system and networks. Increased interoperability will enable co-benefits including:

- Mutually beneficial interaction between sources of flexibility and the system, hence enabling a whole-system approach to delivering decarbonisation, affordability and security
- Active interaction between subsystems, allowing increased supply efficiency under normal operating conditions and increased security of supply through sharing of responsibilities and resources under contingent and extreme conditions

[82] Review of Electricity Market Arrangement, Department for Business, Energy and Industrial Strategy, 2022
[83] Electrical engineering standards: independent review, Department for Business, Energy and Industrial Strategy, 2019
[84] Flexibility in Great Britain, The Carbon Trust, 2021

- Multi-vector coordination to allow the electricity system to access flexibility and other resources provided by other energy vectors
- Greater interaction and coordination between national, regional and local systems, enabling both greater citizen engagement in the energy system and improved resilience when the system is under stress
- Faster response to changes in technologies, markets and customer behaviours
- Easier access for innovators to provide new services to the energy system, with resultant benefits to energy costs, security of supply and decarbonisation
- More finely tuned management of the relationship between the system and its customers.

Question 7: What export opportunities does the transition to net zero present for the UK economy or UK businesses?

117. As detailed in Question 1, the UK's Environmental Goods and Services Sector (EGSS)[85] should be seen as renowned for its high-quality expertise. The sector's contributors are drawn from various standard industry classifications and, as a result, it has sometimes struggled to be seen and heard as a coherent whole by government. However, the growth opportunities in the UK and overseas are clear and much could be achieved with deeper promotion of the EGSS and recognition of its high quality expertise and contribution to growth. Government has the opportunity to further support and promote of the UK's EGSS as part of 'Global Britain'.

118. Some contributors to this response highlighted that they saw the Commission on Environmental Markets and Economic Performance (CEMEP) that reported in November 2007 as a successful vehicle for galvanising the EGSS sector around growth opportunities. There could be merit in a new Commission that sets out and quantifies the opportunities for green economic growth for the UK sector, globally. Opportunities include:

- ongoing growth in environmental goods and services
- specific engineering opportunities in offshore technologies, renewables energy and energy system innovation, civil and environmental engineering, electric automotive and in bankability appraisals[86] for global investment
- UK higher education provision, innovation and export, especially in postgraduate specialisms where the UK has a prime position
- policy and regulatory leadership, including green finance, policy development and regulatory design
- corporate sustainability, circular economy, resource efficiency advocacy and services support
- climate adaptation.

119. Some other specific opportunities identified in the course of developing this response are as follows:

[85] UK environmental goods and services sector (EGSS):2019, Office for national statistics, 2022
[86] Required for private sector financing during investment appraisal, bankability means that a project provides clear incentives for lenders to consider financing it i.e. that equity and loan commitments are adequate to service the capital and operational requirements of the project. Assessments of a project's bankability draw heavily on future income and expenditure estimates and so requires evidence-based prediction of future costs and benefits.

- Energy:
    - As outlined in Question 2, the electricity system requires urgent innovation across electricity generation, the electricity network, whole system flexibility and in enabling decentralisation and digitalisation. The innovations required are across both technology and the frameworks employed across regulation, delivery and operation. The challenges of systems change and operation to which these innovations are a response are common to power systems globally which means there are significant commercial opportunities for countries that tackle these innovations early.
    - There could be a specific opportunity from the coordinated approach to infrastructure between offshore renewables projects argued for in Question 2. Not only would a coordinated design reduce the overall cost of connecting winds farms to the GB power system, but it could also create export opportunities by directly connecting that network to the continental grid, at a significantly lower cost than if cross-border interconnectors were developed separately.[87]
- There is an opportunity to support rapid growth of a major UK manufacturing industry in low-carbon products and materials. EU countries such as Sweden, Denmark and Holland are already leading on this and their experience is demonstrating that low-carbon products, including low-carbon steel, can sell well in advance of their actual manufacturing dates. Changes to public procurement that place a greater value on carbon (including embodied carbon) could be used to stimulate a more reliable local market and set a path for a valuable export industry as other governments shift to this procurement model. There are already UK start-ups that are trying to access these markets and such measures can support their growth and scale-up.
- New infrastructure needed to decarbonise can be a stimulus to modernise and decarbonise the construction sector, as well as to further grow the services (design and engineering consultancy) around infrastructure and the built environment – both of which are an export opportunity.

Question 29: How can we ensure that we seize the benefits from future innovation and technologies?

Research and Development

120. To achieve net zero there is a need to accelerate the innovation and commercialisation (testing, development, demonstration and scale up) of net zero solutions and innovation. In part because climate mitigation is a concern globally, there are potentially significant market opportunities for first movers. Decarbonisation and the growth opportunities that flow from it will depend significantly on the health of the UK's research and development (R&D) ecosystem.

121. The high quality of UK academic research and the ability to collaborate with universities are key factors in attracting R&D investment to the UK. However, more business-university interactions should be facilitated, as well as translation, diffusion and talent mobility between academia and industry. Recommendations from the Dowling Review of business-university research collaborations[88] should be implemented and successful recent and existing schemes should be restarted or expanded, including the Catalysts, CASE studentships and the KTPs.

[87] Offshore wind in the north seas from ambition to delivery, Skillings and Strbac, 2021
[88] The Dowling Review of Business-University Research Collaboration, Department for Education and Department for Business, Energy and Industrial Strategy, 2015

Additionally, a UKRI-wide approach to support for R&D and innovation for decarbonisation would be welcome to maximise the impact of spending.

122. When technology push turns into market pull especially for hard-to-decarbonise industries such as steel, ammonia and shipping, the size of investment goes up by an order of magnitude and companies still need support to scale up. Given that decarbonisation and growth are both in the public interest, there is a clear role for government to help manage risk and accelerate innovations. Late-stage R&D, like all R&D and innovation carries risk. The risk is multifaceted, arising from the scale of the technical challenge, cost, timings, certainty of market opportunity, competitive environment and opportunities or barriers to commercialisation. There is a compelling case for the public sector to support businesses to manage the risks associated with late-stage R&D and incentivise business investment – the socio-economic benefits from the new products, processes, services, and technologies are shared, so the risk must be too.

123. While support for the science base is necessary it is not sufficient - engineering and technology that exploits UK research will make be the determinant of whether the UK is a global leader in research and realises the substantial socio-economic and environmental benefits of exploiting R&D. But many businesses choose global locations for high value late-stage R&D activities, from multinationals with multiple R&D sites to mobile innovative SMEs with growth ambitions and existing UK support for late-stage R&D is not meeting businesses' needs and is considered poor compared to competitor countries[89]. Late-stage R&D is a key part of the innovation process, taking a proof of concept or prototype through to commercial application, and is the majority of R&D that businesses do. The National Engineering Policy Centre has set out recommendations to encourage business R&D investment, bringing returns, environmental and socio-economic benefits to people in all parts of the UK, beyond the individual business contributing to growth in the local area, with tradeable solutions, new markets and jobs, increased productivity. Government should:

- Target support for late-stage R&D, including through co-designed industry-led programmes building on the success of examples such as the Aerospace Technology Institute.
- Strengthen and scale existing initiatives and infrastructures that support late-stage R&D, including with the uplift in Innovate UK's budget and by promoting and supporting strategic innovation infrastructures such as the NPL and Catapult Centres.
- Signal to the world the UK is the place for businesses to undertake late-stage R&D and unleash net zero innovation with clear signposting of the UK offer.

124. For low carbon solutions and technologies in particular, there is a need for more physical and digital infrastructures to support late-stage R&D by accelerating and de-risking the testing, certification, development and deployment of new products, processes, services and technologies safely and effectively.

125. Public procurement is also an under-leveraged tool and has the potential to be a key lever for driving innovation, for example in the infrastructure and construction sectors. As an example, government can take inspiration from examples of international best practice on utilising public sector procurement as a tool to drive innovation and decarbonisation such as in the construction sector in Denmark, where, once a contractor is awarded tender for an infrastructure project they are obliged to show where embodied carbon savings are being made in the design. This is a key tool in driving decarbonisation.[90] With real commitment from government, it has the

[89] Increasing R&D investment: business perspectives, National Engineering Policy Centre (2018).
[90] Decarbonising construction: building a new net zero industry, National Engineering Policy Centre, 2021

potential to transform companies' investment in R&D in the UK, stimulate innovation, business growth and adoption across supply chains[91, 92]. Government, as an intelligent customer, can provide the pull-through to stimulate greater market uptake and deliver best value to the public purse. Leadership and action are critical to change culture across government, embed openness to procure innovation and act as early adopter. Increased use of pre-procurement processes, including collaboration between contractors and innovators for co-creation of solutions would help manage the risk of procuring innovation, with a good, shared understanding of the needs of the customers, the problems to solve and the solutions innovation to deliver best value outcomes.

126. Outcomes-based procurement processes should be deployed to drive low carbon innovation in public-sector infrastructure and building projects[93]. Procurement is a vitally important lever in delivering the net zero transformation at pace and at scale, especially in the infrastructure and construction sectors which represent a significant proportion of the UK economy and where government is a major customer. However, despite reductions in emissions since 1990, the built environment still contributes around 40% of the UK's carbon emissions. Whole-life analysis is important to account for the capital and operational carbon, as well as the impacts of demolition or regeneration.

127. Strategic advantage through science and technology is a vehicle to progress net zero innovation. The government's Integrated Review set out the ambition to realise UK strategic advantage through science and technology. The consideration of the research, innovation and skills ecosystem in the round, such as in the Integrated Review, is welcome and to be further encouraged as it is essential to achieve and sustain the ambition to realise UK strategic advantage through science and technology. However, it is noteworthy that competitor countries are embarking on extremely significant and ambitious interventions, including significant subsidies for clean tech scale up and deployment. These include the Inflation Reduction Act in the United States and the European Commission's REPowerEU programme[94] and, in a world of first mover advantage and highly mobile investment and skills, with these initiatives unavailable to UK companies directly, they introduce an uneven playing field and research-intensive employers are already reporting losing talent and investment to these countries due to these largescale programmes.

128. Finally, engineering companies also find strategic engagement across UK government organisations frustrating and fragmented, and this makes the UK less attractive to invest in R&D. It is crucial that government's strategy builds on a deep understanding of the structures, processes and institutions that already work and have enabled success as well as those that created barriers. Lessons and good practice should be drawn from previous initiatives such as the Industrial Strategy, Industrial Strategy Challenge Fund and Global Grand Challenges.

Skills and Education

129. While the measures on R&D outlined above will be crucial, as outlined above (Question 2), there is a significant and growing challenge in the supply and availability of engineering skills for the implementation of the innovations, technologies, and programmes of retrofit and infrastructure upgrade that are needed to achieve net zero and realise the significant economic

[91] Public projects and procurement in the UK, Royal Academy of Engineering, 2014
[92] Consultation response: transforming public procurement, Royal Academy of Engineering, 2021
[93] Consultation response: transforming public procurement, Royal Academy of Engineering, 2021
[94] REPowerEU: affordable, secure and sustainable energy for Europe, European Commission, 2022

opportunities this presents. To take just one example, as described in Question 2, just as there is a need for rapid electrification across a wide range of sectors, there is an ongoing decline in the number of students choosing electronics and electrical engineering which has persisted over the past ten years.

130. Without the availability of the skills needed, the widespread development, scale up and implementation of the innovations and opportunities outlined throughout this response will not be possible. This will render the opportunities for growth and for decarbonisation on the timescale needed to avoid the significant harms of climate change unavailable across the economy. Some steps government need to take to address the availability of skills were outlined above (Question 4).

Appendix 1: Sequenced and consistent policies to decarbonise infrastructure and the built environment

Mission Area: Design and specification **Outcome:** Setting progressive targets - a government/industry partnership improving skills for net zero	
Now	**Next (within the next four years)**
Design and performance standards should be updated to include new approaches to risk that will improve the material efficiency and carbon performance of buildings and infrastructure, including the reuse of materials and components. This can be achieved through updated standards that set out more efficient design practices to enable greater material efficiency and reuse and greater consideration for the life expectancy of materials. This may require cutting down the last few percent of performance confidence. To drive change in practices in material reuse across all projects, designers should be required to consider the reuse of materials, including the reuse of building foundations, and when constructing from new materials, evidence must be presented to show that constructing from reused materials is not possible. The construction sector must begin to employ more holistic design approaches for the built environment. This can be achieved through choice of design practices and driving more efficiency within designs as well as requiring more materials reuse within design and construction. Engineering education must change to include continuous professional development and upskilling in net zero technologies and the tools and frameworks that enable the assessment of carbon performance. The engineering profession must prioritise a pipeline of transferrable STEM skills from primary education through to higher education, reviewing future skills needed to complement a net-zero roadmap for the sector.	Practical and user-friendly tools to enable consistent assessment of carbon performance of built environment systems, and not just individual components, need to be developed and embedded within design and procurement. This can be achieved through the increased use of data and digital technologies to assess carbon performance and opportunities for decarbonisation. Government, supported by industry, must introduce a certification process for all materials used in the construction process. In tandem, government must carry out regular inspection to enforce the use of low-carbon materials and supply chains.

Mission Area: Changes to procurement **Outcome:** Embedding quantitative whole-life carbon assessment into public procurement		
Now	**Next (within the next four years)**	**In the future (beyond 2025)**
For the construction process and material extraction, increasingly stringent carbon reduction targets should be introduced over time. These targets should include embedded carbon in imported construction materials and be in line with the ambition of UK emission reduction targets of 68% by 2030 and 78% by 2035 compared to 1990 levels. For operational carbon of the built environment, which partly results from decisions made at the earliest stages of the construction process, more stringent targets are required as new infrastructure will continue to be in operation beyond 2050. This can be achieved by working in close partnership with the construction sector and applying targets immediately to the infrastructure that is currently being procured, as part of the National Infrastructure and Construction Procurement Pipeline as well as to publicly procured buildings. Private clients will look to government for guidance and follow suit.	Industry needs to embed low-carbon design and implementation rapidly and at scale over the next five years so that infrastructure products are performing adequately by 2030. This can be achieved through committed leadership to drive change, both within organisations and across the supply chain. Government and industry need to take a different approach to productivity performance and risk to foster innovation and collaboration across the supply chain, if the industry is to create the innovative solutions needed to meet carbon targets. Digitalisation across the sector will be a key enabler.	Government must urgently change appro aches to procurement, at central, devolved and local levels to reflect broader definitions of whole-life value, including whole-life carbon performance, and not just short-term cost. Government can achieve this by using its purchasing power and the requirements that are set out in public contracts to drive better carbon performance.

Mission Area: Construction and reuse **Outcome:** Increasing design efficiency, materials reuse and retrofit of buildings	
Now	**Next (within the next four years)**
Industry must begin to demonstrate best practice by considering materials reuse as standard and it must be made a requirement to provide a justification for when materials are not reused. The sector should also measure and articulate the benefits of reuse and address the risks associated with reuse using tools developed with the support of engineers, scientists and economists. Action must also be taken by the sector to use only non-fossil fuel powered plant and equipment to eliminate carbon emissions from sites and reduce materials wastage during construction.	Government should ensure that building planning and consent stages take better account of both the carbon performance and the potential co-benefits, such as improved health and job creation, that can be achieved through retrofit options as opposed to building new. This requires a systems approach to decision-making.

Action must be taken by the sector to use only non-fossil fuel powered plant and equipment to eliminate carbon emissions from sites and reduce materials wastage during construction.	

Mission Area: Product outcomes **Outcome:** Improving whole-life carbon performance	
Now	**Next (within the next four years)**
In government, the built environment falls within the remit of many different departments, and this can prevent the built environment being treated coherently as a whole system. A joined-up response across government departments would lead to a set of aspirations and policies that are consistent and coherent, lower costs and greater value for money, and which have potential to deliver other co-benefits. Net zero and sustainability principles and practices must be a mandatory inclusion in engineering education, continuous professional development and upskilling.	The construction sector must demonstrate how approaches to decarbonisation fit within new models of economic growth that minimise resource use, reverse ecological damage and contribute to the net zero target. This will be aided by using the updated tools and guidance set out in HMT Green Book. Government and the industry can learn from and propagate examples of best practice. This includes other countries, such as Denmark and the Netherlands, and other sectors, such as the UK's energy sector, which are setting targets and developing new processes to drive better carbon performance. For the construction process, material extraction and imported materials, increasingly stringent carbon reduction targets should be introduced which, over time remain in line with overall UK emission reduction targets of 68% reduction by 2030 and 78% by 2035 compared to 1990 levels. More stringent targets for the operational carbon of the built environment are required to achieve net zero.

Appendix 2: Sequenced and consistent policies to realise the role of hydrogen in the net zero energy system

To achieve a rapid scaling up of the low-carbon hydrogen infrastructure - with particular attention to those end uses for which hydrogen deployment offers the greatest value to decarbonisation of the whole energy system for following measures are needed:	
Now	**Next (within the next 5 years)**
Invest in rapid and early pilot projects to provide sufficient evidence to determine the hydrogen end uses that can achieve the highest carbon savings and cost efficiencies from a whole-system perspective. These can address all outstanding uncertainties, including any concerns over safety, drive down costs to enable the transition, and, thus, support industry adoption.	Develop and implement an ambitious but pragmatic roadmap for how low-carbon hydrogen production is to be scaled up to meet demand, with details about the contributions of each type of hydrogen production, including taking a whole system approach to the scaling up of key requisite technologies (i.e., CCS, renewable electricity generation, and electrolysers).

Finalise the hydrogen business model in 2022 as committed in the UK's hydrogen strategy.134 This should also identify areas that require outcome-based market interventions, such as subsidies and auctions to reduce costs, frontload investment, stimulate innovation, development, and deployment, and minimise the risks of investment.	Ensure low-carbon hydrogen is available for the end uses in which hydrogen deployment has the potential to become the best or only low-/ zero-carbon option available. This will maximise hydrogen's value to decarbonisation of the whole energy system and close the emissions gap to put the UK on track with its Fifth and Sixth Carbon Budgets and the 2050 net zero target

In order to manage the risks and dependencies when scaling up hydrogen value chains, government must also provide clarity to support stakeholders by taking the following sequenced steps now and in the next 5 years:	
Now	**Next (within the next 5 years)**
Wider hydrogen value chain	
Implement stringent, outcome-oriented low carbon hydrogen standards that include emissions throughout the whole production and supply process to ensure a low level of CO_2 per unit of hydrogen. These standards must incentivise engineering solutions for leakages in hydrogen infrastructure to minimise the atmospheric greenhouse effects of hydrogen and apply to any imports to avoid the risk of offshoring emissions.	Address the primary skills gaps relating to the key technologies of CCS, renewable electricity generation, and hydrogen to enable widescale deployment. Further research should be undertaken to understand the skills gaps in detail, to develop a green skills strategy to sufficiently upskill the workforce for these emerging sectors, and to ensure a just transition for the UK's offshore energy workforce.
Build up all relevant regulators' capability to uphold robust enforcement and monitoring of crucial regulations, such as the low-carbon hydrogen standard, and to cope with the rapid scaling up of hydrogen value chains. Regulators should identify and develop regulatory and commercial frameworks accordingly as the hydrogen infrastructure and economy develops.	Consider a mandatory minimum whole-life carbon standard to minimise operational and embodied carbon at the construction stage for new hydrogen plants.
Investigate and ensure the safety of hydrogen through further safety assessments. Outcomes of the safety assessments shall be used to establish safety standards to safeguard health and safety as hydrogen production, transportation, storage, and end use scale up in society. At the same time, the government should ensure meaningful public engagement and stakeholder engagement as the hydrogen value chain develops.	Foster the development of globally assured standards and certification mechanisms to create the conditions for an international market in low carbon hydrogen.
Mandate hydrogen ready appliances.	
Blue hydrogen	
Ensure sufficient domestic CCS capacity to meet the CO_2 capture requirements for blue hydrogen production and other sectors by enabling the necessary infrastructure deployment and putting in place a robust monitoring regime to verify the emissions removals.	

Address the risks associated with the fossil fuel supply chain, including driving fugitive emissions reductions by improving measurement and reporting of emissions data (including process emissions and reservoir leakages) and by imposing the environmental costs of pollution (e.g. carbon tax). This will enable efficient regulatory interventions and incentivise investment in methane emissions reduction.	
Green hydrogen	
Safeguard the electricity transition while in parallel creating the conditions for future largescale green hydrogen production. The enabling policy interventions must ensure and catalyse additional deployment of renewable electricity to meet the demand for green hydrogen production.	Invest in research and innovation to reduce or ultimately remove the need for critical scarce materials within electrolysers.
Manage the supply risks associated with critical scarce materials for electrolysers and other technologies, such as batteries, including design standards for resource efficiency to improve the lifetime and recyclability of electrolysers and/or the recovery and reuse of materials.	Commission further investigations on the implications of electrolysis at scale on water supply and waste management systems. Determine the impacts on water purification, supply, and wastewater production. These findings must be applied in determining the location of green hydrogen production.