Grantham Research Institute on Climate Change and the Environment

Centre for Climate Change Economics and Policy

Consultation response: 'Building our Industrial Strategy'

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This policy paper is intended to inform decision-makers in the public, private and third sectors. It has been reviewed by at least two internal referees before publication. The views expressed in this paper represent those of the authors and do not necessarily represent those of the host institutions or funders.

1. Does this document identify the right areas of focus: extending our strengths; closing the gaps; and making the UK one of the most competitive places to start or grow a business?

The Green Paper states that the Industrial Strategy aims to provide a comprehensive plan for fostering competitive advantage and long-term growth in the UK. With the Government committed to the implementation of the Paris Agreement, compliance with the Climate Change Act and carbon budgets, and the rapid growth of clean technologies, the future of a forward-looking and globally competitive economy for the UK must be low-carbon and climate-resilient, as outlined by Carvalho and Fankhauser (2017).

The recognition of the importance of low-carbon and climate-resilient growth and innovation is already implicit throughout the Industrial Strategy – in particular, in the form of renewable energy, battery technologies, smart grids, flood defences, and low-emission vehicles – but the Industrial Strategy should also be explicitly coordinated with the Clean Growth Plan, due to be published later this year. A more explicitly acknowledgement of the central importance to the Industrial Strategy of low-carbon growth and innovation would offer the opportunity for better alignment between Government Departments. For example, combining R&D in smart grid and battery technologies with support for renewable energy could achieve multiple objectives: by increasing the efficacy of electricity production and storage, it would also have benefits in terms of energy security, innovation, lower costs and lower emissions, as well as exploiting 'home market effects' to increase competitiveness in the global marketplace.

References for Question 1

Carvalho, M. and Fankhauser, S., 2017. *UK export opportunities in the low-carbon economy.* London: ESRC Centre for Climate Change Economics and Policy and Grantham Research Institute on Climate Change and the Environment. Available from: http://www.lse.ac.uk/GranthamInstitute/wp-content/uploads/2017/04/Carvalho-and-Fankhauser-2017.pdf

2. Are the ten pillars suggested the right ones to tackle low productivity and unbalanced growth? If not, which areas are missing?

As outlined in the policy briefs attached to this submission – 'UK export opportunities in the low-carbon economy' and 'Financing low-carbon growth and innovation in the UK Industrial Strategy' – developing a comparative advantage and encouraging investment in low-carbon goods and services would offer strategic advantages for the UK. To realise these advantages, the Government should identify areas of horizontal alignment across pillars, particularly in low-carbon growth and innovation. Clean growth already cuts across several pillars of the Industrial Strategy, particularly: investing in low-carbon technology (Pillars 1, 7, 8); developing areas of comparative advantage in low-carbon goods and services (LCGS) (Pillars 1, 2, 6, 7, 8); creating long-term and climate-resilient infrastructure (Pillars 2, 6, and 7). Horizontal alignment across pillars would make the individual policies more effective by positioning them as part of a cohesive overall strategy.

References for Question 2

Carvalho, M. and Fankhauser, S., 2017. *UK export opportunities in the low-carbon economy.* London: ESRC Centre for Climate Change Economics and Policy and Grantham Research Institute on Climate Change and the Environment. Available from: http://www.lse.ac.uk/GranthamInstitute/wp-content/uploads/2017/04/Carvalho-and-Fankhauser-2017.pdf

Matikainen, S., 2017. *Financing low-carbon growth and innovation in the UK Industrial Strategy*, London: ESRC Centre for Climate Change Economics and Policy and Grantham Research Institute on Climate Change and the Environment. Available from: http://www.lse.ac.uk/GranthamInstitute/wp-content/uploads/2017/04/Matikainen-2017.pdf

4. Are there important lessons we can learn from the industrial policies of other countries which are not reflected in these ten pillars?

In terms of government support for R&D and innovation, the United States can be seen as both a positive and cautionary example. As noted by Mazzucato (2011), long-term government investment in research has resulted in a number of innovative technological developments – including the Global Positioning System (GPS), the internet, and touchscreen technology – that underpin successful American companies. The United States Government invested in riskier technologies at an earlier stage than the private sector was willing to, because it was better able to bear the risk of long-term projects with uncertain returns. This highlights the importance of not just facilitating private sector R&D spending, but also the government investing directly itself.

Rodrik (2014) acknowledges the important role the government plays in taking on riskier and longer-term projects than those the private sector is willing to accept. However, Rodrik also points out the case of other US ventures – such as the failure of the solar technology company Solyndra – to show the danger that comes from government being politically obliged to continue its funding after it should have stopped. To address this, Rodrik suggests that government needs to work closely with the private sector while still retaining enough independence and public accountability to make decisions that are in the public interest, for example by increasing transparency around the decision-making process or appointing a high-level political champion who can be held accountable for the project outcomes.

As for infrastructure, the academic literature on industrial policy can offer some guidelines for how to reduce costs and deliver better value for money in public–private partnerships. Drawing on analysis of major infrastructure projects across 14 countries, Flyvbjerg (2009) notes that project developers often underestimate costs and overestimate benefits in the business cases for their projects, in order to obtain funding. In response, Flyvbjerg suggests that projected spending forecasts should be benchmarked against comparable projects and be subjected to independent review, and project developers should be held accountable for overspend. Helm and Mayer (2016) suggest that taking a balance sheet approach – i.e. focusing on the total value of infrastructure assets and the long-term liabilities associated with them, rather than current accounts or yearly outflows – would allow a more holistic approach that emphasises long-term thinking: for example, taking into account declining future revenues in North Sea oil and gas when deciding whether or not to encourage additional infrastructure investment.

References for Question 4

Flyvbjerg, B. 2009: 'Survival of the unfittest: Why the worst infrastructure gets built – and what we can do about it,' *Oxford Review of Economic Policy*, 25 (3), pp. 344-367.

Helm, D., and C. Mayer, 2016: 'Infrastructure: Why it is under provided and badly managed,' *Oxford Review of Economic Policy*, 32 (3), pp. 343-359.

Mazzucato, M., 2011: *The entrepreneurial state*, London: Demos.

Rodrik, D., 2014: 'Green industrial policy,' *Oxford Review of Economic Policy*, 30 (3), pp. 469–491.

5. What should be the priority areas for science, research and innovation investment?

The Department for Business, Energy and Industrial Strategy should make low-carbon research, innovation and skills a cross-cutting theme for the Industrial Strategy, in order to cultivate world-leading sectors that encourage trade and investment.

As shown by Dechezleprêtre et al. (2016), low-carbon innovation has extremely high growth benefits, comparable to those derived from information technology. This justifies Government support for clean technology, which should be provided throughout the innovation process, from research to development, demonstration and deployment.

The low-carbon growth potential extends well beyond current market assessments to include not just clean energy but also transport, industry, agriculture, forestry, consumer products and services. It affects the product mix, production processes and consumption patterns of virtually the entire economy.

The low-carbon transition has been likened to the technological paradigm shifts associated with the Industrial Revolution or information technology (Perez 2009), in that it is a comprehensive change to the entire system. Accordingly, effective planning for the low-carbon transition will require taking an overall system-wide perspective. By identifying the best way to incorporate low-carbon technologies into existing infrastructures and networks, this will enable the creation of a circular economy that is more resource-efficient and reuses existing materials. For further elaboration of examples of specific low-carbon goods and services needed for various sectors, see Table 1 in Carvalho and Fankhauser (2017).

Dechezleprêtre and Sato (2013) identify electric motors, electricity distribution, domestic appliances, low-emission vehicles and batteries as sectors in which the UK is effective in low-carbon innovation. For these technologies, innovation investment should focus on scaling up production in order to reduce costs.

However, Dechezleprêtre and Sato (2013) also demonstrate that 13 of the UK's 15 largest industrial sectors – including aircraft and spacecraft, motor vehicles and steam generators – are less effective in low-carbon innovation than their global competitors. This is a concern. While patents are not a perfect indicator of low-carbon innovation (as they ignore, for example, the roles of learning-by-doing and technology adoption), the analysis suggests that large parts of UK industry are at risk of losing market share to cleaner competitors in Germany, Japan and elsewhere. Boosting low-carbon innovation for these sectors will thus be necessary for the UK to retain competitive advantage in a global economy that is increasingly pursuing a low-carbon path to implement the Paris Agreement. The Industry Challenge Fund can help these sectors in decarbonising through its focus on 'Manufacturing processes and materials of the future'.

References for Question 5

Carvalho, M. and Fankhauser, S., 2017. *UK exports for a low-carbon economy.* London: ESRC Centre for Climate Change Economics and Policy and Grantham Research Institute on Climate Change and the Environment. Available at: http://www.lse.ac.uk/GranthamInstitute/wp-content/uploads/2017/04/Carvalho-and-Fankhauser-2017.pdf.

Dechezleprêtre, A., Martin, R. and Bassi, S., 2016. *Climate change policy, innovation and growth.* London: ESRC Centre for Climate Change Economics and Policy and Grantham Research Institute on Climate Change and the Environment. Available at: http://www.lse.ac.uk/GranthamInstitute/wp-content/uploads/2016/01/Dechezlepretre-et-al-policy-brief-Jan-2016.pdf.

Dechezleprêtre, A. and Sato, M., 2013. *The position of the UK in the emerging green economy*. London: ESRC Centre for Climate Change Economics and Policy and Grantham Research Institute on Climate Change and the Environment. Available at: http://www.lse.ac.uk/GranthamInstitute/wp-content/uploads/2013/07/Position-of-UK-in-the-emerging-green-economy-1.pdf.

Perez, C., 2009. 'Technological revolutions and techno-economic paradigms.' *Cambridge Journal of Economics,* 34(1), pp.185–202.

6. Which challenge areas should the Industrial Strategy Challenge Fund focus on to drive maximum economic impact?

The Industrial Strategy Challenge Fund has identified 'Smart, flexible and clean energy technologies' as one of the eight major areas in which it will use public money to work with the UK private sector to commercialise technologies. The Fund should also be integrated with support for the 'Eight Great Technologies' (such as robotics and artificial intelligence, and transformative digital technologies) to enable a smart, flexible and clean energy system.

To integrate smart grids into the energy system, several issues need to be addressed. The Fund could leverage expertise in other sectors to achieve this, in particular telecommunications (for the management of transmitting large amount of data in real time over networks) and software (in developing dynamic response systems that are resilient to cyber attack) (Rowlands-Rees et al., 2016; International Energy Agency, 2011).

Dechezleprêtre and Sato (2013) conclude that the UK is lagging behind other countries in terms of innovation levels for energy storage (particularly accumulators, primary cells and batteries). Therefore, the proposed new institution to support the acceleration of battery technology will be essential for making the UK's electric vehicle, smart energy systems, and consumer electronics industries globally competitive.

The Fund should also earmark support for behavioural insights research, to help understand how different incentives can overcome the energy efficiency gap caused by consumers under-investing, along with understanding incentives to modify energy consumption behaviours (as discussed in Gillingham and Palmery, 2014).

References for Question 6

Dechezleprêtre, A. and Sato, M., 2013. *The position of the UK in the emerging green economy.* London: ESRC Centre for Climate Change Economics and Policy and Grantham Research Institute on Climate Change and the Environment. Available at: http://www.lse.ac.uk/GranthamInstitute/wp-content/uploads/2013/07/Position-of-UK-in-the-emerging-green-economy-1.pdf

Gillingham, K. and Palmery, K., 2014. 'Bridging the energy efficiency gap: Policy insights from economic theory and empirical evidence.' *Review of Environmental Economics and Policy*, 8(1), pp.18–38.

IInternational Energy Agency, 2011. *Technology Roadmap - Smart Grids*, Paris: IEA. Available at: https://www.iea.org/publications/freepublications/publication/smartgrids_roadmap.pdf

Rowlands-Rees, T. et al., 2016. *Energy Efficiency Trends* Vol. 17, London: EEVS, Bloomberg New Energy Finance. Available at: http://www.eevs.co.uk/media/trendsq316.pdf

13. What skills shortages do we have or expect to have, in particular sectors or local areas, and how can we link the skills needs of industry to skills provision by educational institutions in local areas?

All regions of the UK will need to decarbonise in order to meet the carbon reduction targets set out in the Climate Change Act and the carbon budgets. The 2016 Progress Report by the Committee on Climate Change points out that, while the UK has reduced emissions in the power sector, other sectors such as transport, buildings and industry will need to undertake significantly greater efforts in order for the UK to meet its target of reducing annual emissions of greenhouse gases by at least 80 per cent by 2050 compared with 1990.

Table 1 in Carvalho and Fankhauser (2017) sets out the types of low-carbon goods and services that will be needed to decarbonise different sectors of the economy. It also indicates that a wide range of skills will be needed for this transition across sectors, requiring both vocational and academic training for existing and new low-carbon sectors.

Enabling decarbonisation across sectors means not only having the necessary low-carbon technologies available, but having the skills to install, operate and maintain these technologies in the different sectors. Therefore, the development of the kinds of skills that will be needed for the low-carbon transition will need to occur in conjunction with the early deployment of technologies. Hence, UK Research and Innovation should also work closely with technical institutes to develop the educational and vocational curricula needed to advance low-carbon technologies into different regions of the UK.

References for question 13

Carvalho, M. and Fankhauser, S., 2017. *UK exports for a low-carbon economy.* London: ESRC Centre for Climate Change Economics and Policy and Grantham Research Institute on Climate Change and the Environment. Available at: http://www.lse.ac.uk/GranthamInstitute/wp-content/uploads/2017/04/Carvalho-and-Fankhauser-2017.pdf

Committee on Climate Change, 2016. *Meeting Carbon Budgets - 2016 Progress Report to Parliament,* London: CCC. Available at: https://www.theccc.org.uk/wp-content/uploads/2016/06/2016-CCC-Progress-Report.pdf

15. Are there further actions we could take to support private investment in infrastructure?

The attached policy brief (Matikainen, 2017) outlines the importance of clear and forward-looking policy and targeted Government support in order to reduce uncertainty and encourage long-term investment in sustainable infrastructure.

In order to feel confident about making long-term commitments, investors seek forward-looking policy that is coherent, consistent and credible. Previous policy reversals in the UK – for instance, on carbon capture and storage and zero-carbon homes – has undermined investor confidence and dampened investment in renewable energy. To rebuild investor confidence, the Industrial Strategy needs to be supported by a credible framework of climate policy fundamentals, particularly in relation to energy efficiency, transport beyond 2020, carbon capture and storage, and mature low-carbon energy generation (e.g. onshore wind). Clarification of the replacement for the Levy Control Framework will give renewable energy investors and project developers better insight into key factors, such as wholesale energy price) that underpin their decisions to commit to new projects.

The public sector has also crowded in private sector investment by providing co-funding, credit enhancement and expertise in the development of new infrastructure projects, through the support of the European Investment Bank (EIB) and the Green Investment Bank (GIB). However, the future roles of the EIB and GIB in supporting renewable energy investment are uncertain, because they depend on the outcomes of Brexit negotiations and privatisation, respectively. The Government should develop a contingency plan in case the EIB and GIB are unable to play the same roles in crowding in private sector investment, and scaling up investment to the level necessary for the low-carbon transition.

References for Question 15

Matikainen, S., 2017. *Financing low-carbon growth and innovation in the UK Industrial Strategy,* London: ESRC Centre for Climate Change Economics and Policy and Grantham Research Institute on Climate Change and the Environment. Available from: http://www.lse.ac.uk/GranthamInstitute/wp-content/uploads/2017/04/Matikainen-2017.pdf

16. How can local infrastructure needs be incorporated within national UK infrastructure policy most effectively?

Urban infrastructure is becoming increasingly important, as cities are drivers of economic and productivity growth, and the investments made now in fixed infrastructure could be in place for decades to come. The management and operation of much of this vital urban infrastructure will fall to local authorities, and so it is important that local government coordinates and works together with national government to deliver cost-effective investment.

The financing for such activities is often too big for city halls, which will need partnerships with central government and the private sector. Policy clarity and stability, together with a level of public sector support – for example through risk guarantees or the creation of a procurement pipeline – can crowd-in substantial private finance.

Investment in urban infrastructure needs to be seen as part of the broader Industrial Strategy, with local, regional and central government coordinating to achieve common policy aims, rather than acting as competing claims on the public purse.

The uncertainty regarding the direction of future technological growth – for example, how the use of autonomous vehicles could affect demand for fixed mass transit – calls for flexibility in the design of long-term infrastructure.

18. What are the most important causes of lower rates of fixed capital investment in the UK compared to other countries, and how can they be addressed?

Drawing on a roundtable sponsored by the Economic and Social Research Council and with participants from the private sector, the attached policy brief (Matikainen, 2017) notes the dampening effect that climate policy reversals in the UK have had on infrastructure investment. Ernst and Young has showed the UK steadily dropping in attractiveness for renewable energy investors compared with other countries, and analysis of the National Infrastructure and Construction Pipeline suggests a significant dearth of renewable energy investment after 2020–21. Forward-looking policy guidance, in particular about the future of the Levy Control Framework, post-2020 transport policy, carbon capture and storage, and mature low-carbon energy generation could help restore investor certainty.

References for Question 18

Matikainen, S., 2017. *Financing low-carbon growth and innovation in the UK Industrial Strategy,* London: ESRC Centre for Climate Change Economics and Policy and Grantham Research Institute on Climate Change and the Environment. Available from: http://www.lse.ac.uk/GranthamInstitute/wp-content/uploads/2017/04/Matikainen-2017.pdf

19. What are the most important factors which constrain quoted companies and fund managers from making longer term investment decisions, and how can we best address these factors?

The attached policy brief (Matikainen, 2017) highlights several market failures associated with long-term investment in emerging clean technology and sustainable infrastructure. Some are related to the uncertainties associated with the underlying investments, where previous policy reversals and future ambiguity have left investors and project developers uncertain about making long-term commitments. A well-designed policy framework can help address this by clearly telegraphing forward-looking policy guidance about carbon budgets, low-emissions transport, and renewable energy, in particular.

Other market failures are related to the financial sector itself, where investors may be discouraged by higher risk (real or perceived) associated with low-carbon investment, a lack of adequate expertise to assess low-carbon projects, insufficient information, or a maturity mismatch between their investment horizon and the time horizon for the project. Government intervention and coordination in infrastructure and other key sectors crowds in private sector investment by de-risking projects: through taking a cornerstone investment stake, credit enhancement, or providing expertise. The Government should consider how the roles played by European Union funding, the European Investment Bank and Green Investment Bank may change in the future, and how to safeguard, supplement, or – depending on the outcomes of privatisation and Brexit negotiations – possibly replace their financial support for key projects.

For more proven technologies like onshore wind and solar, and smaller-scale projects such as loans to increase energy efficiency, financial markets can help scale up corporate financing and bank lending. There are barriers to incorporating climate considerations into capital markets, such as a lack of information (either about the risks associated with high-carbon assets or appropriate labelling of low-carbon assets), cognitive biases (for example, herd behaviour and optimism bias that could downplay investment risks), and a tendency towards short-term thinking. Standardisation and labelling of green financial products can provide additional information and transparency for investors in order to stimulate demand, and a greater degree of financial disclosure could help encourage longer-term thinking about climate risks and opportunities.

References for Question 19

Matikainen, S., 2017. *Financing low-carbon growth and innovation in the UK Industrial Strategy,* London: ESRC Centre for Climate Change Economics and Policy and Grantham Research Institute on Climate Change and the Environment. Available

from: http://www.lse.ac.uk/GranthamInstitute/wp-content/uploads/2017/04/Matikainen-2017.pdf

22. What are the barriers faced by those businesses that have the potential to scale-up and achieve greater growth, and how can we address these barriers? Where are the outstanding examples of business networks for fast growing firms which we could learn from or spread?

A key barrier faced by businesses that have the potential to scale up technologies is a lack of early-stage financing: the so-called 'valley of death' results from a lack of early-stage financing from venture capital/private equity, industry or Government to take promising technologies from laboratory to demonstration stage to larger-scale production (see Grubb, 2014).

A further, and related, key challenge for investors into scaling up has been uncertainty around expectations about the future market size for low-carbon technologies. This is driven by policy support in the form of subsidies or carbon pricing, and it is essential for the Government to have clear, consistent, and long-term policies to create the market signals that drive private sector investments. The response to question 19 explains how Government policy can crowd in private investment for the low-carbon sector.

Carvalho (2015) points out that a key failure in scaling up technologies has been the lack of partnerships between innovative research institutions (universities or dedicated research entities) and industrial partners. It is essential to help foster these partnerships by providing key incentive programmes for both research institutions and industry to work together more closely in scaling up technologies. These partnerships would be necessary to identify complementarity between potential new product innovations with existing technologies that industries use to enable the scaling up of production.

Dechezleprêtre et al. (2016) provide a case study on how Germany has created and maintained highly competitive technology industries through the creation of the largest network of applied research institutes in Europe. Known as the Fraunhofer-Gesellschaft (or the Fraunhofer Society), this network comprises 67 different institutes that cluster advanced scientific and engineering expertise in different technological fields. A significant percentage of the funding for each institute is provided by industry, creating incentives for collaborative learning that leverages the advanced research capabilities of the institutes with the engineering capabilities and facilities of the industrial firms. The Fraunhofer Institute for Solar Energy Systems is especially important in supporting high-level photovoltaic innovation for the solar industry – particularly in helping domestic semiconductor companies develop and sell factory equipment (often referred to as capital equipment or fabrication lines) that are then installed in crystalline photovoltaic factories - particularly to companies in China that manufacture downstream solar photovoltaic products. According to the latest National Renewable Energy Laboratory results for 'Best-in class cell efficiencies' for solar photovoltaics, this Institute also holds the world record for the most efficient crystalline silicon solar cells (in laboratory settings).

Other studies have also explored the importance of alumni student networks – including international student networks – in reinforcing the relationships between research institutes and industry (see, for example, Carvalho, 2015, and de la Tour et al., 2011, for further case studies on research institute–industry partnerships in the global solar photovoltaic industry).

References for Question 22

Carvalho, M.D., 2015. *How does the presence – or absence – of domestic industries affect the commercialisation of technologies?* London School of Economics and Political Science. Available at: http://etheses.lse.ac.uk/3083/

Dechezleprêtre, A., Martin, R. and Bassi, S., 2016. *Climate change policy, innovation and growth*, London: ESRC Centre for Climate Change Economics and Policy and Grantham Research Institute on Climate Change and the Environment. Available at: http://www.lse.ac.uk/GranthamInstitute/wp-content/uploads/2016/01/Dechezlepretre-et-al-policy-brief-Jan-2016.pdf

Grubb, M., 2014. *Planetary Economics: the technology and innovation pillar* First. M. Grubb, ed., London and New York City: Routledge, Taylor & Francis.

de la Tour, A., Glachant, M. and Ménière, Y., 2011. 'Innovation and international technology transfer: The case of the Chinese photovoltaic industry.' *Energy Policy*, 39(2), pp.761–770. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0301421510008013

National Renewable Energy Laboratory (NREL), 2017. *NREL Best Research-Cell Efficiencies 2017.* Available at: https://www.nrel.gov/pv/assets/images/efficiency-chart.png

25. What can the Government do to improve our support for firms wanting to start exporting? What can the Government do to improve support for firms in increasing their exports?

The Department for International Trade (DIT) should make low-carbon goods and, in particular, services a cornerstone of the UK's post-Brexit international trade strategy. By 2030, global exports for low-carbon goods and services could be worth £1.0–1.8 trillion a year, seven to 12 times more than today, according to estimates by Ricardo AEA (2017). Gaining even a small market share of low-carbon trade would create substantial export opportunities for the UK.

The DIT should secure a strong plurilateral Environmental Goods Agreement (EGA) to support free trade in low-carbon goods. Since 2014, the European Union, China, United States, and many other member countries of the Organisation for Economic Cooperation and Development have been negotiating a plurilateral EGA, which would cut duties on products used in a variety of environmentally-related functions including solar photovoltaics, solar thermal, wind power and energy saving. The UK should push for a strong EGA while it is still a member of the European Union and seek to join the Agreement after Brexit. For more in-depth analysis, see Carvalho and Fankhauser (2017).

The DIT should also secure bilateral deals for key sectors not covered by the EGA, including products, such as low-emission vehicles, that could be of growing importance to the UK economy. For example, the Nissan Leaf car plant in Sunderland has the capacity to manufacture 50,000 electric vehicles a year (Edelstein, 2016). Based on individual country targets, the global market is set to grow by 16 times its current size to 12.9 million electric vehicles by 2020 (International Energy Agency, 2016). Securing a share of just four per cent of this market would be equivalent to hosting 10 Leaf production lines in the UK, approximately matching the current output of Jaguar Land Rover in the UK.

Furthermore, the UK should ensure reduction in trade barriers for low-carbon services, including potential non-tariff barriers relating to bundled packages offering the sales of low-carbon goods with complementary services, such as bespoke design solutions, maintenance contracts and regular product upgrades.

The Foreign and Commonwealth Office, Department for International Development and Department for Business, Energy and Industrial Strategy are implementing the UK's commitment to help developing countries with their low-carbon transitions. Cross-Whitehall initiatives including the Prosperity Fund, which seeks to improve the business environment for low-carbon goods and services in developing countries, are part of a commitment by the UK and other industrialised countries, reiterated in the Paris Agreement, to provide international climate finance. Without jeopardising the primary objective, cooperation across Government Departments would help link UK firms with international markets, help them to understand international low-carbon needs and to advance the low-carbon transition of these markets.

References for question 25

AEA Ricardo, 2017. UK business opportunities of moving to a low carbon economy, London: AEA Ricardo. Available at: https://www.theccc.org.uk/publication/uk-energy-prices-and-bills-2017-report-supporting-research/.

Carvalho, M. and Fankhauser, S., 2017. *UK exports for a low-carbon economy.* London: ESRC Centre for Climate Change Economics and Policy and Grantham Research Institute on Climate Change and the Environment. Available at: http://www.lse.ac.uk/GranthamInstitute/wp-content/uploads/2017/04/Carvalho-and-Fankhauser-2017.pdf.

Edelstein, S., 2016. '50,000th Nissan Leaf electric car built in UK plant.' *Green Car Reports*. Available at: http://www.greencarreports.com/news/1104010_50000th-nissan-leaf-electric-car-built-in-u-k-plant [Accessed May 30, 2017].

International Energy Agency, 2016. *Global EV Outlook 2016 Electric Vehicles Initiative*, Paris: IEA. Available at: https://www.iea.org/publications/freepublications/publication/Global_EV_Outlook_2016.pdf.

27. What are the most important steps the Government should take to limit energy costs over the long-term?

It is important to note that energy costs are widely distributed throughout the economy and between households and businesses. For instance, the power sector only accounted for 17.8 per cent of the final consumption of energy in the UK in 2015, according to the most recent figures published by the Department for Business, Energy and Industrial Strategy (2016a), even though the costs associated with electricity generation are often central to discussions about energy costs. Many of the biggest challenges for UK energy policy, particularly in addressing the 'trilemma' of affordability, security and sustainability, currently lie outside the power sector, and relate, for instance, to transport and domestic and business heating. The Government should be concerned about both the overall level and the distribution of these costs across the whole economy.

The goals of the Climate Change Act mean the UK's entire energy system must be extensively decarbonised by 2050. This will require a significant investment in new infrastructure and systems, but the benefits in terms of avoided impacts from climate change, air pollution, congestion and other factors are likely to be even greater. These investments will also be a source of economic growth and new jobs. It is important that Government takes account of the full benefits of these investments over the short, medium and long term. It would be a mistake, for instance, to enact short-term cost-cutting measures that mean forfeiting substantial long-term benefits in terms of improved health and well-being.

Opponents of climate change action often exaggerate the costs of decarbonising the UK's economy, and downplay the benefits. But it is indisputable that between 1990 and 2016 the UK reduced its annual emissions of greenhouse gases by about 42 per cent while increasing its gross domestic product by about 67 per cent. Hence, the UK has successfully made large reductions in its annual emissions of greenhouse gases while continuing its economic growth. Much of the emissions reductions have been achieved by a fall in the consumption of coal for electricity generation.

The overall costs of decarbonisation of the UK's energy system in the future can be minimised by the Government through clear and consistent policies. Investors and the private sector frequently point out that policy risk adds significantly to the cost of capital and acts as a disincentive to investment. While the Government cannot eliminate all risks, and policy changes are sometimes required in light of new developments, there have been too many recent examples of policy reversals that have undermined confidence. Fortunately, the UK has strong framework legislation in the form of the Climate Change Act which helps to mitigate policy risk to some extent. The Government has an opportunity with its forthcoming Clean Growth Plan to provide a clear signal about the pace of decarbonisation of energy over the period up to and including the Fifth Carbon Budget (2028-32).

In terms of the distribution of the costs of energy decarbonisation, it is important to differentiate between business and household consumers, and between costs arising from carbon pricing and those from the support for low-carbon energy.

On carbon pricing, both UK households and businesses are charged relatively low rates on gas and electricity through the combination of auctioning and trading of allowances within the European Union Emissions Trading System and the Carbon Price Support Rate, currently amounting in total to about £23 per tonne of carbon dioxide (£23/tCO_2). The UK does not operate any other explicit carbon pricing mechanisms, although it is possible to consider other taxes and levies, such as fuel duty for vehicles, as if they were implicit carbon prices. For instance, an analysis by researchers at the Institute for Fiscal Studies and ESRC Centre for Climate Change Economics and Policy (Advani et al., 2013) showed that the implicit carbon price levied across the economy, and applied to both businesses and households, is uneven, and is the result of complicated and overlapping policies and regulations. This means, for instance, that the implicit carbon price on electricity is effectively higher than that on natural gas at present.

The UK's low rate of carbon pricing is equivalent to an implicit subsidy for fossil fuels. A study for the International Monetary Fund (2015) concluded that weak carbon pricing in the UK was equivalent to an annual subsidy of US$13.74 billion for fossil fuels in 2015, based on a very conservative estimate of the social cost of carbon. In addition, the study found that weak regulation of the local air pollution created by the consumption of fossil fuels was equivalent to a further annual subsidy in the UK of US$23.35 billion in 2015. This combined implicit subsidy of about £30 billion for fossil fuels is much greater than the direct annual subsidy for low-carbon energy in the UK.

In its assessment of power sector scenarios that would be consistent with the UK's Fifth Carbon Budget, the Committee on Climate Change (2015) highlighted the results of the Government's modelling of the carbon price that would be consistent with the international goal, ahead of the United Nations climate change summit in Paris in 2015, of avoiding a rise in global mean surface temperature of more than 2°C above its pre-industrial level. In the central case, the model estimated a carbon price of £78/tCO_2 in 2030 rising to £220/tCO_2 in 2050. But the Committee noted independent forecasts that the carbon price in the European Union Emissions Trading System will be about £24/tCO_2 in 2030. It pointed out that if the Carbon Price Support Rate remains capped at £18/tCO_2, the Carbon Price Floor in 2030 would only be £42/tCO_2, well below the target projection originally set by the Government.

Hence, there is a compelling case for the UK to remove completely the implicit subsidy for fossil fuels by applying a stronger carbon price uniformly across the economy. The revenues that are raised could be used, in part, to provide fixed-term assistance to energy-intensive companies that are trade-exposed, and to fund measures to help poorer households.

In addition, business and household consumers also provide direct financial support to low-carbon electricity generation through charges levied on their bills. The Committee on Climate Change (2017) concluded that in 2016, of a typical annual dual fuel bill of about £1164, about £57 (4.9 per cent) was accounted for by support for low-carbon energy, a further £40 (3.4 per cent) was due to carbon pricing, and £70 (6.0 per cent) was for energy efficiency. Hence, low-carbon policies, including both carbon pricing and support for low-carbon electricity, currently account for only a small fraction of annual household dual fuel bills.

Recent figures published by the Department for Business, Energy and Industrial Strategy (2017) show that, for July to December 2016, UK domestic electricity prices, including tax, for medium consumers were the sixth lowest in the EU 15 (fourth highest when taxes are excluded), whilst domestic gas prices, including tax, for medium consumers were the third lowest in the EU 15 (seventh lowest when taxes are excluded). The figures also show that, in February 2017, the UK price for petrol at the pump was the seventh lowest in the EU 15, whilst the UK price for diesel was the second highest in the EU 15.

The Committee on Climate Change (2017) expects that low-carbon policies will account for a gradually larger proportion of domestic dual fuel bills over the next 15 years as a consequence of the decarbonisation of the UK's electricity generation system. The Committee projects that a typical annual dual fuel bill will increase to £1501 in 2030, with £169 (11.3 per cent) due to support for low-carbon electricity and £39 (2.6 per cent) due to carbon pricing. However, the Committee noted the potential for households to significantly reduce their annual bills through improved energy efficiency.

Numerous studies have shown that poorer households spend a higher proportion of their incomes on energy (e.g. Ofgem, 2017). As such, the current policy of supporting low-carbon electricity generation through a levy on consumer bills is a regressive measure compared with, for instance, support through revenues from income tax.

While targeted subsidies for poor households may help in the short term, the longer term solution is to help these households to lower their bills through more efficient use of energy (e.g. Hills, 2012). The Energy Company Obligation scheme is designed to promote this objective, and its weakening has slowed down efforts to help poorer consumers to make their homes more energy efficient. The termination of the 'Green Deal' has also damaged efforts to incentivise households more generally to make their homes more energy efficient.

For industrial consumers, fewer data are available for the costs of carbon pricing and support for low-carbon electricity generation, so analysis is more difficult. Figures published by the Department for Business Energy and Industrial Strategy (2016b) show that, on the basis of a purchasing power standard, the UK has the third lowest industrial prices for natural gas among the 28 Member States of the European Union, and the 11th lowest industrial electricity prices.

Other figures published by the Department for Business, Energy and Industrial Strategy have compared prices in nominal terms. For instance, its most recent figures (2017) show that, for July to December 2016, UK industrial electricity prices, including tax, for medium consumers were the third highest in the EU 15 (fourth highest when taxes are excluded), whilst industrial gas prices, including tax, for medium consumers were the second lowest in the EU 15 (fifth lowest when taxes are excluded). These data appear to show that the UK's industrial electricity prices are due primarily to the wholesale price and network costs, rather than regulatory costs. However, such a comparison does not allow a proper analysis of the impact of electricity prices on the competitiveness of UK industry. A more meaningful analysis would compare the size of energy bills as a share of total production costs for UK industrial electricity consumers with their counterparts abroad.

Another study by Sato et al. (2015) found that the UK was not exceptional when comparing international industrial energy prices (including electricity, coal, gas and oil prices) over the period between 1995 and 2011, and taking into account both inflation (by using prices in real rather than nominal terms) and comparative price levels (using both purchasing power parity and market exchange rate conversions). Hence, there is no compelling evidence that the UK is an outlier when comparing industrial energy costs internationally.

Nevertheless, energy costs do matter to a small group of energy-intensive sectors such as the production of basic materials (e.g. basic chemicals, iron and steel, clinker and cement, pulp and paper, aluminium, refinery products). Many of the businesses in these sub-sectors are able to pass on energy price rises to their consumers to different degrees (CE Delft and Oeko-Institut, 2015). Furthermore, there is strong evidence that higher energy prices are directly associated with greater energy efficiency. Research has also shown that low-carbon policies, including the European Union Emissions Trading System, stimulate technological progress and innovation output in regulated companies (Dechezleprêtre et al., 2016). A robust energy/carbon price signal is thus a necessary part of a portfolio of policies to formulate coherent strategies needed to deliver decarbonisation of energy-intensive sectors. Depending on which sectors and, for example, their ability to pass on costs and the length of the investment cycle, other policies will be necessary to achieve the transformation, such as support for the development of breakthrough technologies and deployment of new technologies, procurement policies, building standards and regulations, and consumer-side policies to create new markets for low-carbon alternatives.

Thus far, there is no real evidence that energy prices have directly caused the loss of industrial capacity in the UK. The effects of energy prices on international trade have been found to be extremely small and focused on heavy industry (Sato and Dechezleprêtre, 2015). Many industries are exempt from environmental or climate taxation/regulation costs, including both direct and indirect costs. Decarbonisation of UK electricity generation (or even reducing the consumption of coal through the Carbon Price Support Rate) is likely to help to reduce industrial electricity costs.

Ofgem (2016a) pointed out that although wholesale prices have dropped slightly in the past two years, they are still substantially higher than before 2004 when the UK became a net importer of natural gas. Its report on 'Wholesale Energy Markets in 2016' states: "Over the past decade, both gas and power wholesale prices generally rose as GB moved away from self-sufficiency in gas supplies and now must compete in a global marketplace. Over this period, gas-fired generation has been setting the power price, and as such wholesale electricity prices have followed the wholesale price of gas."

Some have suggested that a supply of natural gas from shale and other unconventional sources in the UK could lead to a significant reduction in the price of heating and electricity. This does not seem likely. As a detailed assessment by Bassi et al. (2013) pointed out, the UK obtains much of its natural gas on the European market and so even if reserves of shale gas in the UK turn out to be at the upper end of current estimates, they will not be sufficient to make much difference to prices.

Even with shale gas, the UK will remain a net importer of natural gas for the foreseeable future.

Projections by the Committee on Climate Change (2015) show that, under most scenarios, the UK will still be consuming about the same volumes of natural gas for electricity generation in 2030 as it does today. However, beyond 2030, the amount of natural gas that can be consumed while meeting the long-term goal of reducing annual emissions of greenhouse gases by at least 80 per cent by 2050 compared with 1990 will depend on the availability of carbon capture and storage technology, as the Committee on Climate Change has pointed out.

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28. How can we move towards a position in which energy is supplied by competitive markets without the requirement for on-going subsidy?

A central part of the Government's contribution to the UK's industrial strategy should be a set of policies that effectively address the numerous market failures that prevent energy markets operating efficiently. In particular, it is well understood that climate change is the result of a number of market failures that prevent low-carbon energy technologies from competing against fossil fuels on a level playing field (e.g. Romani et al., 2011).

These policies must begin by correcting what Stern (2006) described as the biggest market failure the world has seen, which means the prices of goods and services that involve emissions of greenhouse gases do not reflect the costs they impose on others through climate change impacts. Hence the pricing of greenhouse gas emissions, through regulation, taxes or trading, is a necessary, but not sufficient requirement for efficient energy markets.

There are other key market failures which must be dealt with at the same time to avoid shackling low-carbon energy. A second crucial market failure results from the public nature of ideas – those who innovate and demonstrate provide learning for others. Policy should help create the conditions for fostering and sharing knowledge about new energy technologies. A third market failure occurs because capital markets are limited in their ability to manage the risks associated with investment in new energy technologies, particularly because of the scale and long-term nature of much of the investment. A fourth set of market failures are associated with network externalities, and can be overcome by enabling access to networks, such as new and better grids or public transport. A fifth set of market failures are associated with information, which can be overcome by creating awareness of the different carbon contents of energy sources, and the options available for emission reductions. All of these are fundamental to markets playing their role efficiently and effectively: a carbon price is crucial but on its own is not enough.

It has been common practice to attempt to overcome these other market failures through direct subsidies for low-carbon energy. In principle, these subsidies, although less targeted than policies that specifically tackle the market failures, can provide the boost that allows new energy technologies to develop to the point where they can compete unsubsidised with fossil fuels. For instance, the system of subsidies for solar photovoltaics has allowed significant cost reductions to the point where, in many parts of the world, they can produce unsubsidised electricity that is cheaper than that generated by fossil fuels. In the UK, onshore wind farms in some locations may now be able to produce electricity that is cheaper than fossil fuels that are subject to a very modest carbon price.

Hence, such subsidies have proven to be successful to the point where they can be phased out. Although rent-seeking behaviour may be, in principle, just as prevalent among low-carbon electricity generators as their high-carbon competitors, investments can still realise a healthy return even when subsidies are time-bound. However, if the phase-out of subsidies is sudden and unpredictable, it adds to policy risk, deterring investors and increasing the cost of capital. While the rate at which a new energy technology may be able to overcome market failures to become cost-competitive with mature fossil fuels may not be precisely predictable, the criteria for deciding the pace of phasing out subsidies should be transparent and clear to minimise policy risk for investors. Unfortunately, recent UK Governments have a track record for sudden or unpredictable changes in support for electricity generation by onshore wind, solar photovoltaics and carbon capture and storage.

The UK caps the total annual amount of support that electricity consumers provide for renewable power though the Levy Control Framework. The Framework was introduced by the Coalition Government in 2011-12 to guide the total amount of support for the Renewables Obligation, Feed-in Tariffs and Warm Homes Discount that was passed onto consumers through their bills each year until 2015-16. In

November 2012, a second phase of the Framework was announced for the period from 2012-13 until 2020-21, with total support rising from £2.35 billion to £7.6 billion (in 2011-12 prices). The Framework includes in its second phase support for the Renewables Obligation, Feed-in Tariffs and Contracts for Difference. One of the explicit objectives for the second phase of the Framework is "to support investor confidence in the market for renewables".

In July 2015, the Office of Budget Responsibility estimated that expenditure covered by the Framework would likely be £9.1 billion in 2020-21 (in 2011-12 prices). This higher spending by £1.5 billion was attributed by the Government to "accelerated developments in technological efficiency, higher than expected uptake of demand-led schemes and changes in wholesale prices". This was confirmed by Kelly (2016) in his assessment carried out in 2015 of the projected overspend, which were attributed largely to the following factors:

- a fundamental fall in the price of wholesale electricity following the drop in the global price of fossil fuels which began in summer 2014;
- a surge in demand for both the Renewables Obligation and Feed-in Tariffs; and
- technological advances leading to a step change in the load factors for both existing and new offshore wind turbines enabling those generators to be eligible to collect more financial support, a technical gain that has worked to the advantage of the producers, without that advantage being passed through to consumers.

The Government subsequently introduced some measures to reduce the expected overspend under the Framework by 2020-21 (Department for Business, Energy and Industrial Strategy, 2016):

- removing grandfathering for biomass co-firing and conversion projects under the Renewables Obligation;
- closing the Renewables Obligation to onshore wind and small-scale solar before the end the scheme in March 2017; and
- capping the amount of renewables capacity supported by Feed-in Tariffs.

As a result, the projected expenditure in 2020-21 under the Levy Control Framework was reduced to £8.4 billion (in 2011-12 prices). An analysis by the National Audit Office (Comptroller and Auditor General, 2016) concluded that the reduction in the overspend amounted to a cut from £20 to £17 in the extra amount that would be added to the average annual fuel bill for a consumer.

While the Government has now addressed the potential overspend covered by the Framework, it has not extended it beyond 2020-21, creating uncertainty for investors in low-carbon electricity. Her Majesty's Treasury (2017) announced in the Spring Budget 2017 that "the existing Levy Control Framework has helped to control the costs of low carbon subsidies in recent years, and will be replaced by a new set of controls", which "will be set out later in the year". However, the Government has yet to disclose what it is seeking to achieve with the replacement of the Framework.

Importantly, the Spring Budget 2017 also announced that "starting in 2021-22, the government will target a total carbon price and set the specific tax rate at a later date, giving businesses greater clarity on the total price they will pay", while promising that "further details on carbon prices for the 2020s will be set out at Autumn Budget 2017".

It is essential that these two reviews are not carried out in isolation from each other. The level of subsidy required to support new low-carbon energy technologies depends largely on the extent to which fossil fuels are confronted with their real costs. There is a risk that direct subsidies for renewables currently need to compensate for relatively weak carbon prices in the UK.

The carbon prices applied to gas and electricity through the combination of auctioning and trading allowances within the European Union Emissions Trading System and the Carbon Price Support Rate, currently amount in total to about £23 per tonne of carbon dioxide (£23/tCO_2). This low rate of carbon pricing constitutes an implicit subsidy for fossil fuels. A study for the International Monetary Fund (2015) concluded that weak carbon pricing in the UK was equivalent to an annual subsidy of US$13.74 billion for fossil fuels in 2015, based on a very conservative estimate of the social cost of carbon. In addition, the study found that weak regulation of the local air pollution created by the consumption of fossil fuels was equivalent to a further annual subsidy of US$23.35 billion in 2015. This combined implicit subsidy of about £30 billion for fossil fuels is much greater than the direct annual subsidy for low-carbon energy in the UK through the Levy Control Framework and other measures.

In its assessment of power sector scenarios that would be consistent with the UK's Fifth Carbon Budget, the Committee on Climate Change (2015) highlighted the results of the Government's modelling of the carbon price that would be consistent with the international goal, ahead of the United Nations climate change summit in Paris in 2015, of avoiding a rise in global mean surface temperature of more than 2°C above its pre-industrial level. In the central case, the model estimated a carbon price of £78/tCO_2 in 2030 rising to £220/tCO_2 in 2050. But the Committee noted independent forecasts that the carbon price in the European Union Emissions Trading Scheme will be about £24/tCO_2 in 2030. It pointed out that if the Carbon Price Support Rate remains capped at £18/tCO_2, the Carbon Price Floor in 2030 would only be £42/tCO_2, well below the target projection originally set by the Government.

Hence, there is a compelling case for the UK to remove completely the implicit subsidy for fossil fuels by applying a stronger carbon price uniformly across the economy. This would decrease, but not eliminate, the level of subsidies required to directly support low-carbon electricity generation.

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29. How can the Government, business and researchers work together to develop the competitive opportunities from innovation in energy and our existing industrial strengths?

It is essential to foster partnerships between innovative research institutions (universities or dedicated research entities) and UK industrial partners to identify how to scale up production technologies. Existing industrial strengths need to match with complementary production technologies that can be used to scale up new product innovations. These production technologies do not necessarily have to be in the same 'sector' as the product innovation – for example, organic photovoltaic technologies can use printing equipment for new cells, while the production equipment for crystalline photovoltaic cells would be less appropriate (see Chapter 5 in Carvalho, 2015). The key is to identify the complementarity between new product innovations and the equipment used to manufacture technologies.

Additionally, research institutions can work with UK industry on high-level process innovations that can bring down the costs of manufacturing new technologies. This would require high-level engineering, including automation, and increased resource (both material and energy) efficiencies that reduce waste.

If there are no appropriate industrial partners in the UK to help scale up potential low-carbon innovations developed in UK research institutions, two avenues can be explored to help commercialise these technologies. The first is for Department for Business, Energy and Industrial Strategy to help UK research institutions to enable commercialisation of these technologies, either via investing in early demonstration projects, or creating strategic niche markets to help these products learn to operate in market conditions, or by helping UK research institutions with potential commercial spin-offs of these products (potentially as part of the UK Research Partnership Investment Fund). Alternatively, the Department for International Trade can help attract overseas industrial firms to invest and work with UK low-carbon innovations in order to scale up production. Given the need to accelerate the commercialisation of low-carbon solutions, the latter option may be more viable, and would benefit the UK economy by attracting inward investment.

Lastly, the relevant research institutes can provide an understanding of the evolution of the technological landscapes, roadmaps and markets, to help advise the Government about the development and diffusion of technologies. However, in order for such research institutes to have an understanding of the dynamics between the technological and market landscape, they must work closely with researchers, businesses and the Government.

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33. How can the Government and industry collaborate to enable growth in new sectors of the future that emerge around new technologies and new business models? Are there particular sectors where this could be appropriate?

The low-carbon economy combines hardware with services and new business models. Some of the required changes will be small, for example the way in which banks extend mortgages to low-carbon homes. Others will be transformative, either technologically or in terms of business models, or both. Examples include new regulatory arrangements in the electricity market to accommodate intermittent renewable supply, a new infrastructure for charging electric vehicles, smart appliances and power grids, and monitoring systems for gas networks or land use (see Table 1 in Carvalho and Fankhauser, 2017).

There are significant low-carbon opportunities in high-value services but they need to be better understood and assessed. Four-fifths of UK GDP comes from services, catering to both domestic and global markets. The UK's natural advantage thus lies in services for a low-carbon economy, including financing for low-carbon projects, climate risk assessments, legal and consulting expertise on low-carbon regulations, and software applications that enable the efficient use of resources.

The Department for Business, Energy and Industrial Strategy needs to carry out more analysis about low-carbon services and assess the opportunities for leveraging the UK's existing advantage in high-value services for export. The knowledge base is incomplete, and basic statistics are lacking, such as data on the size of the sector. More analysis will be required to understand how to maximise UK exports of services associated with the low-carbon transition.

The Government should work with key information services, industry associations and research institutions in order to understand the opportunities and challenges associated with low-carbon goods and services and their role within the wider economy. It can also work with international research networks to draw important lessons about how these industries are emerging in other countries.

Potential industry associations: New Energy Services division under Energy UK; Renewable Energy Association; RenewableUK; Carbon Markets Industry Association; UK Green Building Council; ClimateWise (for insurance)
Potential academic research networks: British Institute for Energy Economics, UK Energy Research Community
International research networks/organisations: IRENA

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