ROYAL ACADEMY OF ENGINEERING

Engineering the Future

Engineering an economy that works for all

INDUSTRIAL STRATEGY
Green Paper response

April 2017

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This report has been produced on behalf of Engineering the Future, an alliance of the 38 professional engineering bodies in the UK (see Appendix 2). The report was primarily authored by the following organisations:

- Royal Academy of Engineering
- Institution of Engineering and Technology
- Institution of Mechanical Engineers
- Institution of Chemical Engineers
- Institution of Civil Engineers

With the active support of the following professional engineering organisations:

- BCS – The Chartered Institute for IT
- British Institute of Non-Destructive Testing
- Chartered Institution of Building Services Engineers
- Chartered Institution of Highways & Transportation
- Chartered Institution of Water and Environmental Management
- Energy Institute
- Engineering Council
- EngineeringUK
- Institution of Agricultural Engineers
- Institution of Gas Engineers and Managers
- Institute of Healthcare Engineering & Estate Management
- Institute of Marine Engineering, Science and Technology
- Institute of Measurement and Control
- Institute of Physics
- Institute of Physics & Engineering in Medicine
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Executive summary

Introduction

The government's renewed focus on industrial strategy is a crucial and very welcome step towards engineering an economy that works for all. The success of this endeavour is critical for the future of the UK. It provides an essential opportunity to build a shared vision – across government, industry and civil society – for the UK's new position on the global stage following its departure from the EU, and to create an accompanying policy framework that will ensure that resources are aligned in support of this vision.

This substantial response represents the collective voice of 38 professional engineering organisations supporting 450,000 UK engineers, led by the Royal Academy of Engineering. As this is a direct response to the government's Green Paper, it focuses on the actions for government but it recognises that the strategy must be based on a true partnership between government and industry, with strong interfaces with civil society and academia.

There has been an unprecedented level of engagement by the engineering community during the 12 weeks in which this submission has been prepared, with evidence gathered through a combination of an online survey of nearly 1,300 engineers (see Box 1) and a series of 10 workshops across the home nations and English regions. With engineering-related sectors contributing at least £280 billion in gross value added to the UK economy, some 20% of the total, and underpinning almost 50% of exports by value, engineering will be critical to delivering the outcomes sought by the industrial strategy[1]. The exceptional level of engagement with this consultation demonstrates the UK engineering community's desire and commitment to ensure the industrial strategy succeeds. We stand ready to support the delivery of a modern industrial strategy that works for the whole of the UK.

Key overarching messages

A successful industrial strategy requires the following overarching actions to be taken:

1. **Clearly define an ambitious, bold, global vision**
2. **Provide long-term commitment and stability**
3. **Adopt a systems approach**
4. **Build on what already exists**
5. **Support culture change through communication and engagement**
6. **Embed actions to promote inclusion and societal benefit**
7. **Prepare for a digital future**

Clearly define an ambitious, bold, global vision

An essential component of any strategy is a clearly defined vision of a successful outcome. The industrial strategy must set an ambitious, bold, global vision for the UK as an outward-looking leading trading nation and a top destination for inward investment and international talent, drawing on the UK's existing credentials as a leader in engineering, innovation and manufacturing. Many UK companies have global ambitions and global supply chains and the strategy cannot be considered in isolation from the international context in which it operates; if deployed successfully, it will be the key vehicle through which the UK exploits the opportunities and mitigates the risks associated with exiting the EU.

Provide long-term commitment and stability

An effective industrial strategy must provide a long-term horizon against which industry and other stakeholders can plan and align their activities. Stability and continuity are critical for giving business and others the confidence to make investments over the long term and to accrue the benefits from a wide range of policies, from those related to improving our skills base, to delivering the right infrastructure. Cross-party

[1] Assessing the economic returns of engineering research and postgraduate training in the UK, Technopolis, 2015

support needs to be secured for the key tenets of the strategy, to ensure that these endure beyond the five-year life of a parliament.

Adopt a systems approach

A systems approach will enable risks to be mitigated more effectively and ensure that the different elements of the strategy work together as a coherent whole. A key element of this approach is understanding interdependencies between different parts of the strategy, in order to identify both fragilities and opportunities to aggregate value and reinforce outcomes.

The Economy and Industrial Strategy Cabinet Committee, chaired by the Prime Minister, should take the role of ensuring that the industrial strategy is joined up across government and has high-level participation. The ability of the industrial strategy to achieve longevity and stability depends on the support of, and coordination with, all government departments. A clear strategic framework will also be needed within which central government, devolved governments and regional and local institutions can collaborate and cooperate and so are mutually reinforcing rather than competing.

Build on what already exists

Given the limited resources available, it is crucial that the industrial strategy assimilates and builds on existing successful initiatives, institutions and infrastructures. Our consultation highlighted examples, some national, others regional, of successful schemes and organisations that are already making progress towards the ambitions of the industrial strategy: these should be further championed and supported. Government will maximise returns on previous investments by ensuring the continued operation of successful activities, as well as spreading best practice and learning derived from them.

Support culture change through communication and engagement

An effective policy framework is necessary but not sufficient for a successful industrial strategy: communications and stakeholder engagement are critical too and government needs to place greater emphasis on these than has been the case to date. The development of this strategy provides a powerful opportunity to promote UK industry and academia assertively on the global stage, as well as generating more coherent and aligned messaging across different parts of government and non-governmental UK stakeholders. Efforts to enhance awareness of the support on offer among target groups, especially SMEs, must be redoubled.

There is much to be done to change public perceptions and advance a more positive image of modern engineering and industry – a challenge that needs to be addressed urgently if the UK is to secure the skilled individuals it requires. The consultation demonstrated that engineering employers recognise their leading role in this endeavour. The UK's strengths in the creative industries should be drawn upon in support of this challenge.

Embed actions to promote inclusion and societal benefit

In order to ensure that the strategy delivers its aspiration to develop an economy that works for all, actions to promote equality of opportunity and societal benefit need to be embedded throughout the pillars. This includes using all levers available, including procurement, sector deals, skills support and the communications and marketing activities undertaken in association with the strategy, to promote the inclusion of all groups across society in higher value economic activity. Investment in infrastructure should promote development in underserved communities and be linked to skills support; investments in R&D should accelerate the development of innovations that can address shared environmental and societal challenges. A mark of success for the strategy will be that its benefits are experienced by a wide range of individuals and communities across the UK.

Prepare for a digital future

The UK is strongly placed to develop a leading digitally driven and data-enabled economy and the government's digital strategy will be central to delivering the UK's industrial strategy. Continued investment in the UK's digital infrastructure and enhancing digital skills at all levels will be key enablers of the industrial strategy. The ability of UK engineers to be confident and competent to a high level in digital skills will be pivotal to securing our competitiveness across a range of sectors. Digital skills must now be included in the government's definition of basic skills.

Key actions

Enabling actions
(All Pillars)

- Government must set an ambitious, bold, global vision for the UK as an outward-looking leading trading nation and a top destination for inward investment and global talent, drawing on the UK's strengths in engineering, innovation and manufacturing.

- Close and sustained engagement between government and industry in both the delivery and implementation of the strategy is essential – it must be a true partnership to succeed. Strong interfaces with the whole breadth of the research and innovation base will be vital, as will embedding engagement with civil society.

Innovation
(Pillars 1, 4, 5 and 8)

- Government should set a target of 3% of GDP combined public and private R&D investment, and work with the private sector to formulate a roadmap to achieve the goal. Sector deals should require a shared commitment by businesses in the sector to boost UK investment in R&D and associated manufacturing capability, matched by government co-investment.

- In view of potential changes to state aid restrictions when the UK leaves the EU, government needs to review how levers to stimulate innovation, such as R&D tax credits and procurement policy, can be enhanced. The levy of VAT on shared research facilities with industry should also be addressed in planning for leaving the EU.

- Government needs to demonstrate a greater willingness to accept the risk of failure, or perceptions of it, in its innovation support, including in regard to the Industrial Strategy Challenge Fund and in public procurement. Regulators should explain how risks for innovative technologies are being managed to address public concerns.

- Government should capitalise on the significant potential provided by public procurement to advance economic and social objectives by radically rebooting the Small Business Research Initiative (SBRI), providing greater transparency on procurement spend with SMEs, and ensuring the balanced scorecard approach fully recognises the value of both innovation and diversity and inclusion.

- High-quality opportunities for companies to test and demonstrate their technological innovations in real-world environments should be substantially expanded. A UK-wide register of 'national innovation assets', which can serve as test beds, demonstrators and focal points for skills development, should be compiled and promoted to both UK and international companies.

Skills
(Pillars 1, 2, 4 and 9/10)

- Digital skills should be included in the government's future definition of basic skills and a comprehensive programme of upskilling developed in partnership with industry and training providers to ensure that the UK workforce at all levels, in the public and private sector and in all parts of the UK, has the skills needed to shape and participate in the industries of tomorrow. A global network of chief data officers in cities and regions should be established.

- A much greater, targeted focus is needed on promoting STEM subjects and engineering careers to under-represented groups (including women, people from BAME communities and those from lower socioeconomic backgrounds) to fully unlock the talent potential in the UK. The best teaching in these subjects needs to be available to learners at all ages, and all STEM subjects, including computing and design and technology, should be incentivised in school accountability measures.

- The further education sector needs additional, long-term investment, as well as incentives to promote provision of high-cost subjects such as engineering. Increasing the number of people with higher level technical skills (levels 4 and 5) must be a priority; while Institutes of Technology will help, wider national provision is also needed.

- Universities and colleges should ensure that STEM students and academic staff receive entrepreneurial, business skills

and intellectual property (IP) awareness training to improve their ability to undertake knowledge exchange activities and help companies to generate and absorb innovation. Increased mobility between business and academia is also vital.

- Sensible and proportionate arrangements should be in place to retain and attract non-UK nationals who are essential to the UK's success in engineering, research and innovation.

Infrastructure and energy
(Pillars 3, 7 and 9/10)

- The long-term approach in the National Infrastructure Delivery Plan must be continued after the UK leaves the EU to provide certainty to investors. The current level of infrastructure funding and incentives must be maintained and the UK's status with the European Investment Bank addressed early.

- Regional infrastructure strategies should be developed across the country. Local and combined authorities and sub-national transport bodies should have access to flexible financing options. Strategic bundling of smaller schemes and incentivised partnerships across public and private sectors would support efficient delivery and value for money.

- Regulatory frameworks across all infrastructure sectors should incentivise whole life investment decisions based on outcomes for the end user. Maintenance of assets should be addressed through adoption of a total expenditure method (TOTEX).

- Digital delivery strategies and smart infrastructure solutions should be embedded across all economic and social infrastructure. In addition, government must continue to drive for world-class digital connectivity that is fast, secure and resilient.

- The development of nationally strategic energy and transport projects should be accelerated to increase UK sustainability and productivity.

- Government must take a systems approach to energy that addresses costs to business and the public along with ensuring security and resilience while reducing greenhouse gas emissions. Energy efficiency and resource productivity should be prioritised and addressed through incentives to increase efficiency and stronger enforcement of regulations.

- Government should renew its support for carbon capture and storage as well as ongoing support for small modular reactors, energy storage and options to decarbonise heat. Particular focus needs to be given to real-world, commercial viability at scale and local benefits, alongside active support for community energy schemes.

- To avoid cost overruns, subsidy mechanisms need to have clearly articulated deployment targets and payment reduction structures for when prices of renewable technologies come down.

Growing businesses across the UK
(Pillars 1, 4, 6 and 9/10)

- SMEs need much clearer, simpler signposting to sources of advice and support, with greater exploitation of existing channels and contact points such as banks, HMRC and Companies House. Regional and sectoral dimensions should be taken into account to ensure the most effective marketing channels are used.

- Government should revisit the limits on the amounts that can be invested under the popular Seed Enterprise Investment Scheme, Enterprise Investment Scheme and Venture Capital Trusts, as well as developing additional tax incentives that stimulate longer-term investments. Government, in partnership with others, should promote the investment opportunities and investment successes across the whole of the UK.

- Business owners who have successfully scaled up and who have founded companies that are 'born global' should be promoted as role models, and their stories used as case studies to inspire and educate the next generation of companies with scale-up potential.

Pillar summaries

Pillar 1 - Investing in science, research and innovation

The case for continued investment in our research base as a means of fuelling future prosperity is compelling. However, this needs to be accompanied by a strong focus on our innovation investment and performance if we are to reap the full benefit from the potential in our research base, both public and private. The UK government should set a target of 3% of GDP for combined public and private R&D investment. Working together, government and the private sector should formulate a roadmap to set out how to achieve that goal.

Investment in collaborative R&D between industry and academia delivers real benefits to the UK, driving growth and productivity improvements for firms and high quality research outputs. It is also clear that access to talent has an unequivocal influence on businesses' decisions about investment in R&D. Catalysing connections between businesses of all sizes, academics and investors is critical to improving the successful commercialisation of ideas.

There is a strong appetite among the engineering community for government to focus the Industrial Strategy Challenge Fund, and the wider uplift in R&D funding, on societal challenges that can benefit from research and innovation, alongside economic growth opportunities. The creation of UK Research and Innovation (UKRI) offers the potential to build on successful innovation support initiatives, such as the Catapult Centres and Innovate UK.

Early interactions between regulators and innovators are essential to ensure that regulation does not impede innovation unnecessarily or unintentionally. If technological innovations are to succeed on the market, they must be extensively tested and demonstrated in real-world environments. The UK should prioritise the provision of high-quality opportunities for companies to test and demonstrate their technological innovations. Existing UK infrastructure could be utilised as 'national innovation assets' to provide high-quality testing facilities.

Pillar 2 - Developing skills

A broader view of the education pipeline is required than is currently explicitly covered in the industrial strategy. Primary and secondary education needs to be included to ensure that the right incentives, inspection regimes and funding models for schools are in place to nurture and develop interest, engagement and attainment in key subjects that will support the industrial strategy's skills needs from a young age. Teacher shortages in STEM subjects in schools should be addressed as a matter of urgency and there should be greater investment in subject-specific continuing professional development for teachers, as well as greater adoption of proven technology capable of supporting learning.

Qualifications and curricula need to keep pace with the demands of the industrial strategy's vision of an advanced economy. Digital skills should be included in the government's future definition of basic skills and computing should be part of the core curriculum in schools; design and technology should also be included in the English Baccalaureate accountability measure on schools. A broader post-16 curriculum and qualifications system for those students continuing on the academic pathway towards higher education or employment is also required. T-Level qualifications in engineering and related subjects need to address the knowledge and skills requirements for professional registration at technician level and colleges should receive support to ensure that they are equipped to deliver the new routes.

There is a clear need to improve public understanding and perceptions of engineering. Government, industry and the wider engineering community need to collaborate on a public engagement campaign to promote careers in engineering, especially to young people and their influencers. In addition, there is a major challenge for industry and the professional bodies to drive upskilling and reskilling among the existing engineering workforce. The industrial strategy should give employers the confidence to invest in training and upskilling by bringing policy stability, and sector deals should ensure that this is addressed at the sectoral level.

Pillar 3 - Upgrading infrastructure

High-quality, high performing infrastructure is vital for economic growth and as a catalyst for social and economic inclusion across the country. Government must, as a minimum, maintain the current level of funding and incentives for infrastructure. Innovative financing streams for infrastructure are required. Local and combined authorities and sub-national transport bodies should have access to flexible financing options such a municipal bonds and 'earn back' for infrastructure development. Uncertainty about the UK's future participation with the European Investment Bank (EIB), which has acted as an anchor investor for many large UK infrastructure projects, needs resolving.

Regional infrastructure strategies should be developed across the country; a 'system-of-systems' view of infrastructure planning and delivery is vital for ensuring that the UK's infrastructure is, coordinated, sustainable and resilient. Local populations should have access to training and support to enable them to compete for new opportunities in building local infrastructure.

Maintaining and operating existing infrastructure at highly resilient levels is essential. Reuse or repurposing of existing infrastructure assets will in many cases carry lower financial, social and environmental costs than provision of new. Regulatory frameworks across all infrastructure sectors should incentivise whole-life investment decisions based on outcomes for the end user.

The ambitions for every infrastructure sector are interdependent and contingent on a level of digital connectivity. Digital delivery and smart infrastructure solutions should be embedded across all economic and social infrastructure. Digital strategies should accompany all major infrastructure projects. The UK must build on its considerable existing capabilities in multidisciplinary innovation around data.

Pillar 4 - Supporting businesses to start and grow

Although it is clear that the supply of equity finance is concentrated in London and the South East, this imbalance is being reinforced by insufficient exposure and under-reporting of equity deals beyond London and the South East. Increased visibility of successful equity investments, investors and investable propositions will demonstrate to investors and companies across the UK the opportunities available beyond London and the South East and contribute to building up regional ecosystems.

There is a perception that some UK business owners have relatively modest growth goals and lack the global vision needed to understand how international markets and opportunities can shape business models from the outset. Business owners who have successfully scaled up and who have founded companies that are 'born global' should be promoted as role models, and their stories used as case studies to inspire and educate the next generation of companies with scale-up potential.

There is a need for considerable improvement to the availability and uptake of business and management skills training across the UK. The transition from startup to scale-up requires new skills sets, including those linked to marketing and sales. Without such skills, regardless of how good the product or service is, the business will struggle to grow. Government should explore ways to incentivise companies to take up high quality training opportunities.

One the greatest challenges is to make companies, especially those that have not previously engaged with public support mechanisms, aware of the support that is available to them. With hundreds of publicly funded schemes to support businesses, many of which are targeted at specific industry sectors or locations, there is a clear need for simplification and improvements in signposting for businesses – especially SMEs – regarding the support available.

Pillar 5 - Improving procurement

There are several key features of good procurement practice, including leadership and vision, good specification and planning, an intelligent client and good management of risk. Effective collaboration between the provider and the client's procurement and service delivery teams is vital to ensure that innovation is encouraged, the needs of users of the service are met and broader social and economic outcomes are realised. However, the perception remains that public procurement decisions continue

to prioritise low cost over best value, and risk aversion hinders the introduction of innovative solutions.

Government has a role in articulating the benefits of innovation, and that responsible risk-taking in procurement can deliver better value, to its departments, local authorities and other public sector procurers, as well as to the public and media.

Supporting SMEs to be able to work directly with public sector buyers will help them be more competitive, level the playing field and boost UK productivity. This will require an increase in the number of and spend on direct contracts with SMEs. Providing a fair and transparent way of capturing and managing risk will be important for project success for companies of all sizes.

The Small Business Research Initiative (SBRI) has been greatly underutilised and the review of the scheme is welcome. SBRI would benefit from robust management and auditing, and from clarity over leadership, ownership, funding and governance of the scheme. This would be delivered most effectively by assigning responsibility for the overall coordination and implementation of SBRI to a ministerial champion, as well as promoting its benefits. Government should mandate increased use of SBRI across all appropriate government departments and agencies, and ensure that those involved in the scheme have sufficient skills and knowledge to be intelligent clients.

Pillar 6 - Encouraging trade and inward investment

The development of industrial strategy, combined with the forthcoming departure from the EU, provides a unique opportunity to reinforce the UK's credentials as an outward-looking leading trading nation and a top destination for inward investment and global talent. This can be achieved through ensuring that the industrial strategy presents a clear and ambitious global vision that harnesses the UK's strengths as a leader in engineering, research and innovation, and manufacturing. The Department for International Trade will lead on facilitating and promoting trade and, as such, will need to rapidly grow its capacity and expertise base in order to best support UK industry as regimes change from the known EU processes to new arrangements after the UK leaves the EU. It should also work closely with trade and professional bodies to inform its work and promote its offer to a broader base of businesses – the coalition of engineering organisations that has produced this response offers its support in this regard.

Government must be focused in its support for trade, concentrating on simplifying bureaucracy, developing and promoting its own support initiatives, helping UK business to market their products and services internationally, and upskilling the workforce in areas necessary to trade effectively. This can only be delivered through a strong partnership between industry and government, involving active, sustained and meaningful engagement, so that government intervention is appropriately targeted and utilised to support wealth creation in the UK.

Pillar 7 - Delivering affordable energy and clean growth

Government, through the Emissions Reduction Plan, should deliver a stable medium- to long-term energy strategy that provides the confidence and certainty required for the long-term planning and investment needed to meet the Climate Change Act and Paris Agreement obligations in the most affordable way. The strategy, which needs to take a whole system approach and be tested for public acceptability, should allow government to develop a least-cost solution for decarbonised, integrated and secure energy supply.

Improving energy efficiency and resource productivity needs to be a priority, particularly in buildings and energy networks. The supply of energy needs to be a multi-vector, system wide solution that builds on all available low carbon forms of generation including CCS, nuclear power and heat networks.

Government should enable and support competitive opportunities for innovation in energy by establishing enabling platforms and test facilities that allow whole system testing and the development of products that are fit for market, such as the development and implementation of large-scale energy storage, biomethane plants, district heating and hydrogen trial projects. Government should also maintain existing mechanisms to support the development of community energy, CCS and nuclear power.

Pillar 8 - Cultivating world-leading sectors

Prioritisation is an essential component of any strategy and sector deals provide an opportunity for the public and private sectors to work together to ensure that best value is delivered

from their collective resources. To maximise the opportunity presented by sector deals, government should require a shared commitment by the sector to boost UK investment in R&D and associated manufacturing capability, matched by government co-investment. Sector deals should encompass actions targeted at strengthening access to skilled people and international markets and networks.

The needs and maturity of sectors vary considerably and sector deals must be available to communities focused on enabling technologies and capabilities, such as manufacturing or digital technology, in addition to more traditional sectors. Government needs to support the development of good sector deals by sectors with weaker institutional arrangements, for example by offering a multi-stage approach to the development of the deal and providing access to experts and resources that can help to support sectors through the process. It is important that the UK also looks ahead to the technologies and sectors of the future. Government and industry must work with communities of experts – including in engineering – to ensure that the approach to industrial strategy in general, and sector deals in particular, sufficiently reflects future needs and opportunities.

Sector deals should be subject to regular review, linked to a clear evaluation framework. However, they need to be underpinned by a firm and long-term commitment from government to build investor and business confidence. Sector deals should be used to promote and facilitate investment in pre-competitive collaborative R&D by companies, for example to address shared environmental challenges.

Pillar 9 - Driving growth across the whole country; and Pillar 10 - Creating the right institutions to bring together sectors and places

The industrial strategy needs to ensure that regional and local strategies are coordinated and coherent: the whole needs to be greater than the sum of the parts, which can only be achieved through adopting a systems approach. The landscape for local support is already complex. The focus should be on promoting awareness of what exists, providing a stable framework for support and policy continuity, and seeking to build on what works. There is little appetite for creating a raft of new institutions to support the strategy.

For the industrial strategy to be successful, and for the economy to 'work for all', engagement with civil society needs to be an integral component of the activities undertaken. Government will not be able to deliver the aspirations of the industrial strategy without enhancing technological literacy levels of public servants in both national and local government, alongside efforts to enhance the digital skills of the wider population.

Infrastructure, in all its forms, is essential to the operation of business and research and for reducing inequality across the UK. Government must continue to drive investment in local transport networks, with the NIC playing a crucial role in identifying investment priorities at the regional level. All aspects of society and business are becoming more reliant on data and telecommunications so it is essential that the UK strives for world-class digital connectivity that is fast, secure and resilient.

Government should recognise that the UK's national quality infrastructure, comprising BSI, NMRO, NPL and UKAS, has an important contribution to make to the delivery of the industrial strategy's objectives and needs to be supported and promoted accordingly. 'National innovation assets' should be identified, promoted and supported by government to build a more balanced and effective innovation landscape across the UK.

Box 1:

Consultation survey

In February 2017, the professional engineering organisations conducted a survey of the engineering community on the industrial strategy Green Paper.

The survey received 1,279 responses and the results provide an interesting insight into the views of engineers, although they should not be regarded as constituting a comprehensive picture. The survey included several open questions and some allowed more than one answer; not all respondents answered all questions.

Of the respondents, 90% were primarily UK-based, with 2% being (non-UK) EU-based and 8% based outside the EU, with the heaviest concentration (15%) of these people being based in the USA. Of those respondents who are UK-based, there was a good spread across the regions: South East 19%, North West 15%, South West 14%, London 13%, West Midlands and East of England 6% each, Yorkshire and the Humber and East Midlands at 5% each and the North East 4%. Additionally, 10% of respondents were based in Scotland, 3% in Wales and 1% in Northern Ireland.

The top sectors represented were power and energy at 36%, chemical and process engineering at 21% and manufacturing at 19%. Defence was next at 17%, then electrical and electronics at 14%, aerospace at 13%, building and construction and marine and maritime both at 12% and computing and IT and transport and environmental all at 11% with biomedical and biotechnology, agricultural, materials and mining, automotive and communications also being represented.

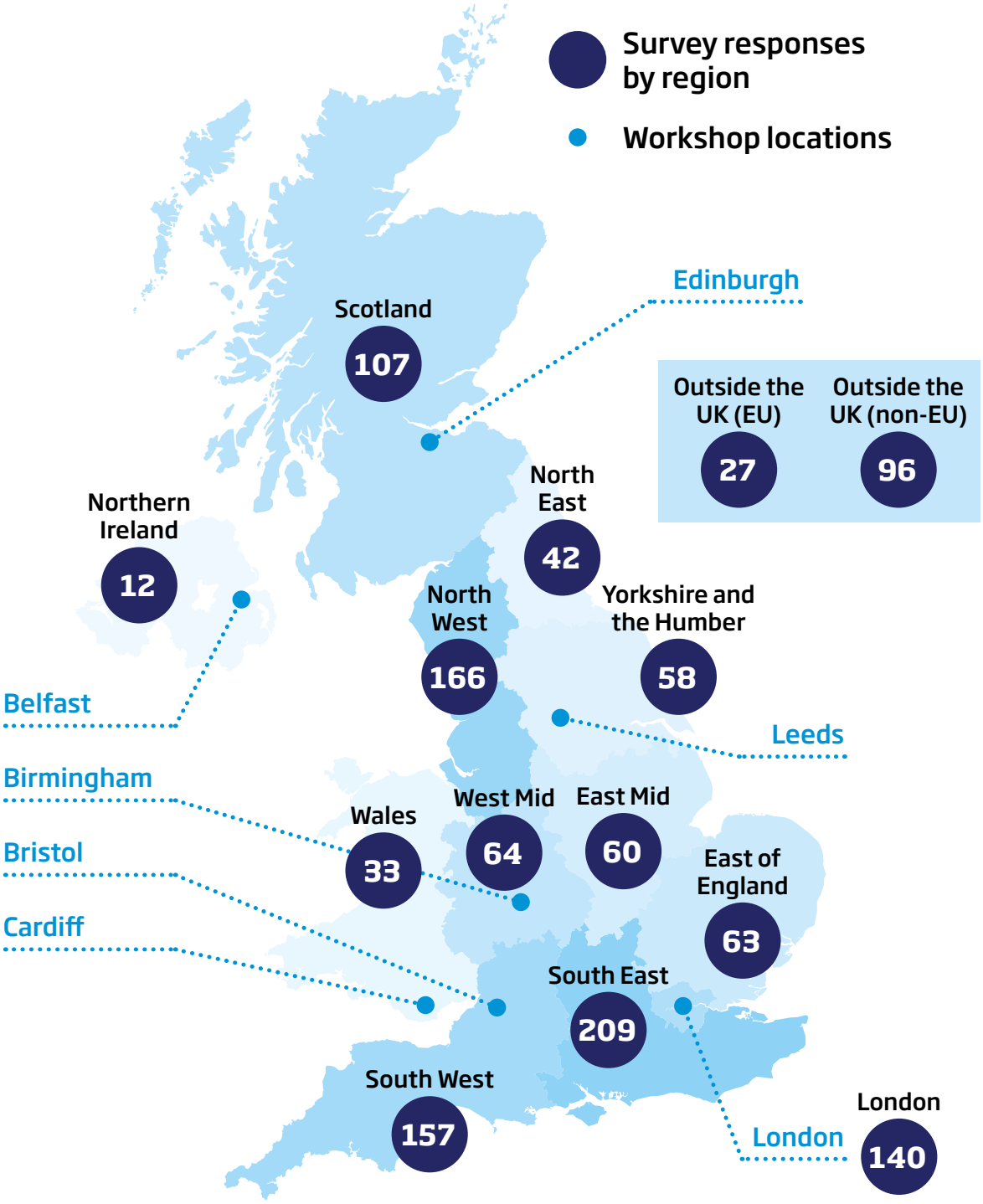
There was a fair spread of organisation size from large businesses (65%) to micro businesses (17%), medium-sized businesses (11%) and small businesses (7%), as well as between private sector businesses (57%), government and public bodies (7%), academia (7%), charities (2%) and research and technology institutes (3%).

Encouragingly, 60% of respondents told us that they considered the industrial strategy to be either 'fairly' or 'very' important to their organisation, which is an indication of the potential for the industrial strategy to make a difference – and perhaps to sound a note of caution as to the high expectations attached to this initiative.

Respondents were on the whole satisfied with the scope of the Green Paper, with only 13% considering that there were 'serious omissions' from the document. For the majority of these responders, the issue was a lack of overall vision, disappointment at the level of 'new' money to be invested, insufficient acknowledgement of the cross-governmental buy-in needed to achieve its aims or a lack of appreciation of the implications of the decision to leave the EU.

When asked about their level of confidence that the industrial strategy will achieve its stated aim of improving living standards and economic growth, the most common response was uncertainty (37%), perhaps not surprising at the Green Paper stage of policy development. Nearly a quarter of respondents (24%) indicated that they were already either somewhat or very confident that the aims of the strategy would be met. These figures indicate that there is work to be done in terms of visible political will, coordinated government actions being taken and positive and assertive messaging to inspire higher levels of industry confidence.

Figure 1: Survey responses and workshops that informed this response to the Green Paper.



Box 2:

Diversity and inclusion – an industrial strategy for all

The industrial strategy has the specific aim of increasing fairness across the UK, and of addressing inequality, particularly regional inequality.

However, if the strategy is to succeed at the highest level, it should explicitly aim to tackle all forms of inequality. The Royal Academy of Engineering is working with the engineering profession and industry to promote diversity and inclusion in engineering. The data and learning from that programme demonstrate why the strategy should promote inclusion, diversity, and fairness across a wide range of dimensions:

- **Gender** – ensuring that opportunity is not focused on one particular gender, and does not disadvantage the others.
- **Age** – the lifelong learning element of the skills pillar is very welcome, and the strategy should provide opportunity for all ages, including returners to the labour market.
- **Ethnicity/race** – the growing diversity of the UK's population in terms of ethnic backgrounds and racial groupings gives UK companies a global advantage.
- **Sexual orientation** – inclusive companies and environments mean that people are able to contribute to their full potential.
- **Disability** – there are untapped resources in the population, in those who have conditions and disabilities that can initially be barriers to success, but which can be surmounted with a small amount of support.
- **Socioeconomic background** – in areas such as education, the differences between regions are small, compared to the advantages enjoyed by higher socioeconomic groupings.
- **Educational route** – capability and attitude are the key to the UK making a success of the industrial strategy, and it is important that the strategy provides opportunities for individuals to benefit from the right route at the right time in their education.

Successful marketing and exports

To be successful in the future, the UK will need to have the widest possible potential markets for our goods and services. Both within the UK, and in terms of global markets, we have to understand the needs and interests of a culturally diverse and economically varied audience. Diversity in the workforce means that companies can develop their 'offer' using the knowledge and experience of their own employees.

We must also recognise the need to respond to investors and shareholders that increasingly expect evidence of diversity and fairness in the companies they choose to support.

Boosting productivity

The industrial strategy can set in place key enablers to support the development of technical skills but, as has been noted in Pillars 2 and 5, these enablers must be applied in a way that embeds equality of opportunity across society. Only through deploying strategy levers to encourage a diverse and inclusive UK workforce as baseline expectation can potential productivity gains[2] be fully realised.

[2] Diversity on Board Barbara Lejczak, Credit Suisse 2015
Maximising women's contribution to future economic growth Women's Business Council 2013
A Report into the Ethnic Diversity of UK Boards Sir John Parker 2016

Box 3:
Systems thinking

Adopting a systems approach will be critical to achieving the best possible outcomes from the industrial strategy.

Systems thinking is common among many professions, but is a particular area of expertise within engineering. Richard Rumult, author of *Good Strategy/Bad Strategy*, was formerly a systems engineer working on the design of spacecraft. He suggests that designing and implementing strategy is like designing a high-performance aircraft, which requires 'fitting various pieces together so that they work as a coherent whole.' He also suggests that, given a set amount of resource, 'the greater the competitive challenge, the greater the need for the clever, tight integration of resources and actions'. Given the scale of the challenge presented in the industrial strategy Green Paper and limited resources, there is a strong case for applying systems thinking.

Industrial strategy comprises a system of policies, resources and actions that are grouped under 10 pillars. Interdependencies exist at a number of levels – between pillars, and between the policies, resources and actions arising from individual pillars. There are also interactions between the industrial strategy and other government strategies at national, regional and local levels. Furthermore, industrial strategy is not isolated from the global political and economic context in which the UK sits. A systems approach would help capture that initial complexity, key relationships and deal with uncertainties, as well as facilitating joined-up thinking. It would also guide the development of an institutional structure, and the roles and responsibilities of institutions and the people who work within them, so that the interdependencies are appropriately managed.

A successful systems approach can be broken up into the following elements:

- **People** – people will be at the core of the industrial strategy. Government will need to gather a wide range of perspectives to build a common purpose. This is particularly important where there are many different motivations, expectations and interests – both from government and other stakeholders. Government should continue to engage with stakeholders after this consultation to ensure that different views are understood and represented in the strategy.
- **System** – the industrial strategy will consist of many sub-systems at multiple levels across all regions of the UK. There will be many types of sub-systems such as institutional systems like companies or government departments, systems of policies or regulations, or virtual networks of people. Understanding their roles and how they interact at the interfaces will be critical. Management of the whole system will require an integrated, high-level perspective but each part of the system must have local autonomy to function efficiently.
- **Design and risk** – each aspect of the industrial strategy will need to be designed through an iterative, creative process that explores the real needs of the relevant stakeholders, and evaluates and selects the best possible solution. This should also identify opportunities and threats before they arise.

At the core of a systems approach to the industrial strategy should be the seemingly simple questions of 'what will success look like?' and 'how will we know if we are making progress?'. The Green Paper is clear that the objective is to improve living standards and economic growth. However, much work remains to be done to refine a clear statement of purpose with effective ongoing performance measurements that will ensure the outcomes are being achieved and that allow learning to be fed into the ongoing management process.

INTRODUCTION

The strategy and its pillars

Industrial strategy Green Paper: areas for focus (Q1)

The Green Paper has set out a broad spread of challenges to which the strategy should respond with an ambitious, global vision. The industrial strategy should seek to build on the UK's sources of advantage and address challenges; therefore, the focus on extending our strengths and closing the gaps is entirely appropriate. A central challenge will be to tackle underperformance across regions and organisations without compromising excellence where it exists already.

Making the UK one of the most competitive places to start or grow a business is a key component of growing the economy and raising productivity (see Pillar 4). For this, the strategy must focus on creating the right environment that attracts inward investment and global talent. Determining the optimum trade arrangements for the UK after it leaves the EU is also a central challenge (see Pillar 6).

Improved productivity can emerge from marginal gains among the majority of established companies as well as those that drive productivity forward with major innovations. The strategy should seek to inspire and enable an increased level of aspiration and performance across all companies, whatever their sector and size.

The pillars and their interdependencies (Q2)

The responses to the survey question 'What are the top three outcomes you would like to see from the industrial strategy?' demonstrate close parallels with the subjects of the 10 pillars. Two other areas were also highlighted: the need for sustainability and a low-carbon economy to be embedded right across the strategy, and a call for the public and government to recognise the value of engineering for its contribution to industry, the economy and society.

The pillars have different roles to play in tackling the challenges outlined in the Green Paper. Increasing the UK's productivity requires improvement in skills, innovation and investment, and infrastructure[3], and these are clearly represented in the initial four pillars along with Pillar 6. Driving growth across the country (Pillar 9) is central to the challenge of distributing growth and productivity regionally, and for this local and regional institutions will certainly need to play a role (Pillar 10). Cultivating world-leading sectors begins to articulate the approach to how best to direct resources and deliver excellence (Pillar 8), while 'improving procurement' and 'delivering affordable energy and clean growth' (Pillars 5 and 7, respectively) are both important enablers.

Numerous interdependencies exist between the different pillars which can be used to positive effect to reinforce outcomes (see Box 3, page 12). Almost every pillar contains new commitments that will help drive growth across the country and it will be critical for implementation to be consistent with local economic plans and initiatives (see Pillar 9/10).

It is clear that the Prime Minister and the government want to create a 'fairer Britain that works for everyone not just the privileged few' and 'where wealth and opportunity are spread across every community in the UK, not just the most prosperous places'. As a consequence, we would have liked to see diversity and inclusion embedded to a greater extent throughout the strategy (see Box 2, page 11).

Central government and local institutions (Q3)

The ability of the industrial strategy to have longevity and stability depends on the support of, and coordination with, all government departments: the industrial strategy cannot operate in isolation. The Economy and Industrial Strategy Cabinet Committee, chaired by the Prime Minister and attended by secretaries of state across government, should take the role of ensuring that the industrial strategy is joined up across government and has high-level participation.

[3] House of Commons Business, Energy and Industrial Strategy Committee (formerly Business, Innovation and Skills Committee) (February 2016), *The Government's Productivity Plan*, Second Report of Session 2015–16

A clear strategic framework must clarify which issues require oversight at a larger geographical level and which can be overseen by regional or local institutions (see Pillar 9/10). A clear articulation of the purpose of the individual institutions is essential. Collaboration and coordination between central government, devolved governments and regional and local institutions will ensure that activities are mutually reinforcing rather than competing. A global context is also important: UK cities and regions are competing globally as well as with other UK regions. Where devolution allows local areas to take control, cities with mayors and institutions and initiatives such as the Northern Powerhouse will need to show confidence, vision and leadership.

The strategy should build on existing institutions that have the potential to support innovation and growth, such as the Catapults and LEPs. There should also be a focus on promoting awareness of what exists and providing a stable framework for support and policy continuity. There are many successful examples of regional centres of excellence in academia and industry from which lessons can be learned. Connectivity between institutions should not have to rely entirely on geographical proximity, and digital connectivity is an important enabler of knowledge transfer and business (see Pillar 9/10).

Lessons from industrial policies in other countries (Q4)

Industrial policies have been widely adopted by the UK's global competitors. Nevertheless, the success of industrial polices will depend on the specific economic, technological and cultural context in which they operate. The industrial policies of other countries may not always translate directly into a UK context.

Countries such as China[4] and South Korea, have ambitious economic plans and industrial strategies that support key growth areas, link industry, science and education to national priorities, and focus on the role of innovation in economic growth. Closer to home, the *Industrie 4.0* initiative in Germany is a good example of how an industrial strategy can work within a western European context. Germany has provided long-term support for industry from local, regional and national government over decades – and also support during downturns. The range of stakeholders engaged in its development is noteworthy: companies, policymakers, regional authorities, economists and sociologists, regulation and standards bodies, and trade unions. It was also very effectively deployed as a means of engaging and exciting the public about the potential of German industry, as a way to attract young people into technical careers, and as an international trade and investment communication tool.

[4] See for example, *The 13th Five-Year Plan: Xi Jinping Reiterates his Vision for China* A major tenet of the plan is innovation, primarily as a driver of economic development and to shift China's economic structure into a higher-quality growth pattern

PILLAR 1

Investing in science, research and innovation

Priorities for investment in research and innovation [Q5]

The case for continued investment in our research base as a means of fuelling future prosperity is compelling. However, this needs to be accompanied by a strong focus on our innovation investment and performance if we are to reap the full benefit from the potential in our research base, both public and private. Innovation is the process by which ideas are converted into value – in the form of new and improved products, services and approaches. It often draws on R&D and may involve commercialisation, but it is not synonymous with either. While technology is a common source of innovation, innovation can also derive from developments in design, business models and mechanisms of service delivery. It is an iterative, non-linear process and there is frequently a complex interplay, including multiple feedback loops, between the actors involved.

> "One of the most significant roles of government in stimulating innovation is in articulating a clear, long-term vision and establishing an accompanying stable and coherent policy framework. This can be as important as the specifics of the policies themselves."
>
> **Dame Judith Hackitt DBE FREng FIChemE, Chair, EEF**

The majority of innovation activity is undertaken in the private sector but government has a pivotal role to play in stimulating innovation. While innovation offers many potential benefits at the level of an individual business, government support is often essential to encourage companies to engage in innovation. This is because innovation is an inherently risky process with an uncertain outcome, the benefits may only materialise over very long timescales and the innovator often accrues only a small proportion of the overall benefit generated. By creating a conducive policy environment, using procurement intelligently and providing targeted direct support, the public sector can be highly effective at encouraging the private sector to invest in innovation. The industrial strategy provides a welcome opportunity to upgrade the role of research, science, engineering and innovation in the UK's economy for the years ahead.

UK R&D investment

As acknowledged in the industrial strategy Green Paper, the UK's combined public and private investment in R&D, at 1.7% of GDP, is significantly lower than the OECD average of 2.4% and the levels of many of the leading innovation nations. The additional £4.7 billion committed by government in the Autumn Statement 2016 therefore provides a significant and very welcome uplift to the UK's R&D investment. Setting a target of 3% of GDP for combined public and private investment in R&D would reinforce the UK's aspiration to be one of the best places in the world for research and innovation. Reaching this target would require both the public and private sectors to substantially increase their R&D investments, which currently account for 0.48% and 0.82% respectively[5].

While a substantial body of evidence has shown that public investment in R&D 'crowds-in' private investment[6], there would still be a need for the private sector to work with government to design a roadmap to achieve public and private investment in R&D of 3% of GDP. It is important to note that to support the aims of industrial strategy, the UK needs to boost investment in innovation and not just basic research, not least since there is evidence suggesting that this is an area in which the UK has historically under-invested[7].

1.1 The UK government should set a target of 3% of GDP combined public and private R&D investment. Working together, government and the private sector should formulate a roadmap to set out how to achieve that goal. An interim objective could be aiming for the OECD averages of 0.66% and 1.47% of GDP for government and industry R&D investment respectively.

Given the low levels of R&D investment by businesses in the UK, our survey asked the engineering community to name the top three actions that the government should take to incentivise private sector companies to invest in R&D. The following groups of actions emerged as high priorities: fiscal incentives, measures to support business-university collaboration and skills development.

Fiscal

Fiscal measures were the most frequently cited theme, identified by just under half of survey respondents. The tax environment is a powerful

5 OECD Main Science and Technology Indicators, 2015 values

6 What is the relationship between public and private investment in science, research and innovation? Economic Insight, BIS, 2015; The Economic Significance of the UK Science Base, Haskel et al, 2014

7 Insights from international benchmarking of the UK science and innovation system, Tera Allas BIS, 2014

lever for government to encourage businesses, both UK and international, to invest in R&D in the UK. The current R&D tax credit scheme has wide support across the engineering community and evidence shows that it is an effective policy for stimulating R&D investment[8]. Areas identified for improvement through the consultation included the following:

- The current R&D tax credit system is deemed overly complicated by some SMEs, which tend to be relatively resource- and time-poor. The benefits of the R&D tax credit system can be outweighed by requiring the employment of accountancy firms that have expertise with R&D tax credits[9].
- As a consequence of the UK leaving the EU, it is expected that there will be changes to the state aid rules, which may create opportunities to extend the use and scope of tax credits.
- R&D tax credits could be used to incentivise increased R&D investment in specific regions, sectors, or approaches to R&D[10]. Such initiatives have been employed by other countries, including France and Japan[11].

1.2 The guidance for R&D tax credits should be improved and simplified. Consideration should also be given to: whether they could become a more powerful incentive in light of potential changes to state aid rules; whether they should offer a preferential tax benefit for collaboration with universities and other public sector organisations; and whether they should be enhanced for businesses doing development in the UK that follows research already cleared for the credit.

A further area for improvement is the levying of VAT on shared facilities between the private and public sector. Current rules mean that publicly-funded research institutes are restricted to 5% commercial activity if they opt not to pay VAT; or they face costly tax bills to co-locate their researchers with industry colleagues. This has serious consequences for research institutions funded by government, universities or charities, such as the Francis Crick Institute and even the Advanced Manufacturing Research Centre (AMRC), part of the High-Value Manufacturing Catapult, which has an explicit remit to support industry[12]. The UK's departure from the EU may have a direct impact on this restriction as European legislation has been identified as the source of the requirement[13].

1.3 The government needs to revisit the issue of VAT on shared facilities in the light of the decision to leave the EU.

Industry-academia interactions

Many respondents identified actions to facilitate interactions between academia and industry as effective ways to incentivise private sector companies to invest in R&D. This type of collaboration further enhances the benefits associated with public support: firms that receive a grant for innovation are more successful in terms of outputs than peers that do not receive such support; but their success is increased if there is an element of cooperation with the public sector, whether via universities, public sector research establishments (PSREs) or government agencies[14].

Business-university interactions provide many benefits to their participants. For academics, these benefits can include the opportunity to

> "Action on diversity and inclusion is a country-wide imperative. Unless we can inspire, recruit and retain the broadest possible talent in engineering, we will never address the productivity, innovation and prosperity challenge we face."
>
> **Allan Cook CBE FREng FIET FRAeS, Chairman, Atkins**

8 Credit where (R&D tax) Credit's Due, Van Reenen, J. & Nguyen, K. 2016
9 Managing intellectual property and technology transfer, Tenth Report of the Session 2016-17, House of Commons Science and Technology Committee, 2016
10 CBI 2016 Autumn Statement Submission, CBI, 2016
11 Creating a collaborative R&D tax credit, The Information Technology & Innovation Foundation, 2011
12 The Dowling Review of Business University Research Collaborations, 2015
13 Leaving the EU: implications and opportunities for science and research, Seventh Report of Session 2016-17, House of Commons Science and Technology Committee, 2016
14 Estimating the effect of UK direct public support for innovation, BIS Analysis Paper, 2014

address challenging research questions with real-world applications, to see their research have tangible impacts and gain access to new skills, data or equipment. Companies can improve business performance through developing new techniques or technologies, de-risk investment in research, and extend the capabilities and expertise available to the firm. Investment in collaborative R&D also delivers real benefits to the UK, driving growth and productivity improvements for firms and high-quality research outputs.

Much work has already been undertaken to understand how to improve the relationships between businesses and the UK's world-leading academic research base, including the *Dowling Review of Business-University Research Collaborations*. Innovate UK in particular was an enthusiastic adopter of the review's recommendations and the creation of UK Research and Innovation (UKRI) provides an opportunity to implement these improvements more broadly[15].

Dowling Review of Business-University Research Collaborations

In July 2015, Professor Dame Ann Dowling OM DBE FREng FRS, President of the Royal Academy of Engineering, published the government commissioned *Dowling Review of Business-University Research Collaborations*[16].

The Review's findings and recommendations clustered into six themes:

- **Complexity** – the UK's research and innovation support is excessively complex. The Review's overarching recommendation was therefore that government should seek to reduce complexity wherever possible and, where simplification is not possible, every effort should be made to ensure that the interface to those seeking support for collaborative R&D is as simple as possible.

- **People** – strong, trusting relationships between people in business and academia form the foundation for successful collaboration. Recommendations centred around practical actions to improve the flow of people between academia and industry, and to raise the esteem of academics working with industry.

- **Brokerage** – connecting up businesses and academics who might find mutual benefit in collaboration is crucial. Effective brokerage requires digital tools to facilitate the identification of potential research partners, complemented by clear signposting and access to support from appropriately informed people.

- **Critical mass** – the Review concluded that there is a gap in the market for a pump-priming scheme that would enable small scale collaborations to grow into group-level partnerships with critical mass and long-term horizons.

- **Terms of engagement** –the handling of intellectual property, contracts and legal negotiations were considered key barriers to collaboration. Recommendations focused on sharing of best practice and encouraging universities to shift the focus away from short-term income generation towards knowledge exchange, partnerships and long-term benefits.

- **Strategy** – research and innovation have a central role to play in supporting industrial strategy and universities should be seen as key partners in its development and delivery. Government has an opportunity to use industrial sectors and key technologies as levers to encourage greater business investment in innovation and R&D and to involve companies of all sizes through the supply chain.

The government response to the Review, which was published in December 2016, fully endorsed the Review's analysis and conclusions[17].

15 Government Response to Dowling Review of Business-University Research Collaborations, 2016
16 The Dowling Review of Business University Research Collaborations, 2015
17 Government Response to Dowling Review of Business-University Research Collaborations, 2016

Our consultation with the engineering community yielded broad support for the recommendations of the Dowling Review and highlighted the opportunity provided by industrial strategy to accelerate progress on implementation. There was particular support for an enhanced focus on stimulating mobility between academic and industrial careers as a means of facilitating knowledge transfer and cultural change. The survey invited comment on two of the key mechanisms used to support this: CASE studentships through which industry and Research Council partners co-sponsor PhD students; and Knowledge Transfer Partnerships, which help support knowledge transfer and seed collaboration. Both schemes were supported by those who had experience of them but in both cases more than half the respondents were unaware of their existence. The issue of low awareness of existing forms of support is returned to later.

1.4 The industrial strategy should be used to accelerate implementation of the Dowling Review recommendations in order to enhance business-university collaboration.

1.5 The industrial partnership PhDs announced in the Spring Budget 2017 should be used to catalyse new business-university partnerships and not be limited to existing Doctoral Training Partnerships.

Skills

Businesses taking part in our consultation were unequivocal about the significance of access to talent in influencing decisions about investment in R&D. They also highlighted the importance of support that would enable them to train and upskill their own employees, which is often essential in order to introduce or adopt an innovative approach. Such innovation adoption can be key to improving productivity.

Concerns were also expressed by the engineering community about its ability to continue to attract highly skilled individuals from overseas. Engineering success is based on people and the UK has a world-class research base and world-renowned engineers across all sectors, drawing on talent from around the globe. Engineering has a particularly mobile workforce; this is true in both industry and academia, and across all skills levels[18]. The pace of technology development combined with the length of time it takes to fully train qualified engineers and engineering technicians means that it is impossible to fill all engineering skills gaps and shortages in the near term by increasing the UK pipeline. While boosting the supply of UK home grown talent to tackle the skills crisis is essential, inward migration of skilled engineers will still be required.

Given that talented individuals from around the world are essential to the UK's success in engineering research and innovation, the government should ensure that its approach to immigration does not impede the ability of UK institutions and organisations to attract these highly skilled individuals.

Industrial Strategy Challenge Fund [Q6]

Challenge areas

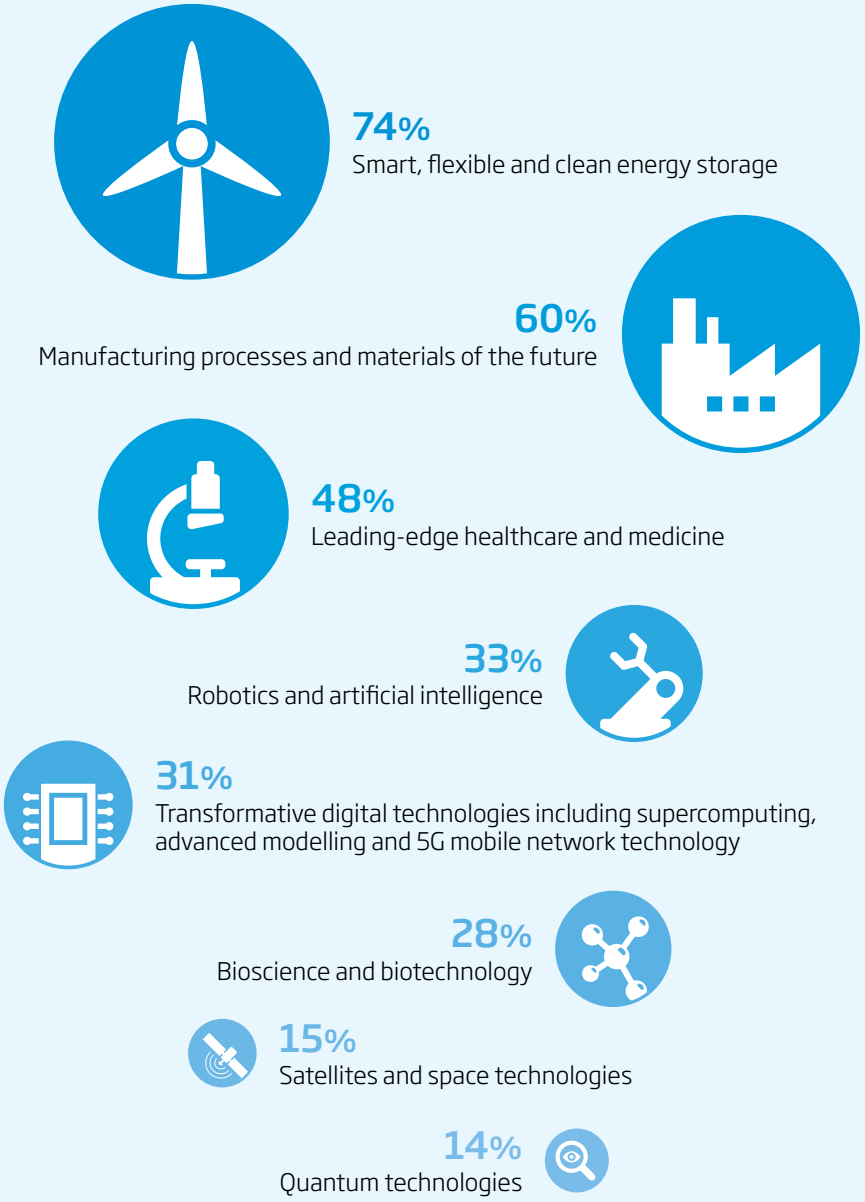
Survey respondents were asked to prioritise the top three challenge fund areas as proposed in the industrial strategy Green Paper. The top three areas cited overall were: smart, flexible and clean energy storage; manufacturing processes and materials of the future; and leading-edge healthcare and medicine (see Figure 2).

Views were also sought on what areas, beyond those listed in the Green Paper, the engineering community would like to see the Industrial Strategy Challenge Fund support[19]. Respondents were clear that the focus on 'energy' needed to go beyond just smart, flexible and clean energy storage to include all aspects of energy, including renewables, infrastructure, distribution, storage and small modular nuclear reactors. There was also strong demand for a focus on challenges related to connected infrastructure and transportation systems, effective recycling and end-to-end waste management, cybersecurity, agriculture and food security.

18 Royal Academy of Engineering submission to House of Commons Home Affairs Committee immigration inquiry, 2017

19 The survey asked two relevant questions, 'Q14b Are there other challenge areas you would like to see included?' and Q16 What should be the funding priorities for government's £4.7 billion R&D investment? (While the Industrial Strategy Challenge Fund will be drawn from the £4.7 billion the government are seeking additional ideas for investment).

Figure 2: Survey question 'The government is creating an Industrial Strategy Challenge Fund to back technologies at all stages, from early research to commercialisation. Which of these challenge areas, identified by government, would you prioritise?'



Respondents were allowed to select up to three options

Public support for research and innovation plays an important role in addressing social and policy challenges, such as responding to demographic change, delivering sustainable, secure and affordable energy supplies and improving the efficiency of the NHS. In these cases, government can signal the importance of the potential future market and incentivise investment by the private sector, as well as directly supporting the development of promising technologies or approaches. This also applies where the public sector itself needs innovation to improve its performance or to support the delivery of public services. The consultation demonstrated a strong appetite among the engineering community for government to focus the Industrial Strategy Challenge Fund, and the wider uplift in R&D funding, on these kinds of societal challenges.

1.6 The challenge areas supported under the Industrial Strategy Challenge Fund should include societal challenges and be framed and promoted in a way that stimulates public engagement and support.

Operation

Direct public support to help bridge the 'valley of death' for innovations associated with risky, emerging, or disruptive technologies can be crucial for both enabling the UK to secure an early foothold in a potentially important future market and preventing UK companies from losing their competitive advantage as other countries take a lead. The public sector has an important role to play in stimulating innovation[20]. However, a cultural tendency towards risk aversion may prevent the UK from fulfilling its innovative potential.

1.7 Government needs to demonstrate a greater willingness to accept the risk of failure, or perceptions of it, in its innovation support, including in regard to the management of the Industrial Strategy Challenge Fund. Regulators also have a role to play and should be encouraged to explain how risks for innovative technologies are being managed to allay public concerns.

Evidence shows that innovation agencies that target higher risk innovations benefit from autonomy and the ability to respond with agility and flexibility[21]. The highly regarded US programmes DARPA, IARPA and the NSF are typically run by well-connected and well-respected academics on secondment for the duration of that funding programme. They truly understand the research questions, and who or what is most likely to solve them, as well as being able to communicate research effectively with political and public audiences alike.

1.8 It is essential that the Industrial Strategy Challenge Fund operates with significant autonomy and is run by staff with relevant expertise.

The engineering community broadly agrees with the Green Paper suggestions for activities that the fund could support:

Joint research projects

1.9 The Industrial Strategy Challenge Fund should facilitate opportunities for industrial competitors to collaborate with one another and work together towards common goals, including for societal benefit. Such pre-competitive collaborations often require public funds to de-risk the venture and it should be noted that EU research and innovation programmes are significant funders of this type of activity.

1.10 To ensure that maximal benefits are reaped, the application process should be quick and simple, followed by a fast release of funds for successful applicants. Involvement of businesses should be based on most relevant expertise rather than factors such as size of business.

Graduate students in companies

1.11 Increased industrial experience for students at all stages of their education should be encouraged by the Industrial Strategy Challenge Fund. However, mobility needs to be bidirectional and opportunities should be increased to allow people in industry to experience academia.

Setting up demonstrators to test near-to-market technologies in real-world environments

The UK should prioritise the provision of high-quality opportunities for companies to test and demonstrate their technological innovations in real world environments, including utilising existing UK infrastructure as 'national innovation assets' (see response to Q9).

Centres to bring together academic experts with entrepreneurs to promote commercialisation

1.12 Priority should be given to using existing physical centres to bring together academic experts with entrepreneurs, for example Catapults. Such centres should assist with legislation, regulation, compliance and standards. The Industrial Strategy Challenge Fund should also facilitate the creation of virtual centres.

20 Investing in Innovation, Royal Academy of Engineering, 2015
21 How Innovation Agencies Work, Nesta, 2016

Support for commercialisation [Q7]

There is a widely held perception that other countries have been more effective at extracting economic value from ideas generated by the UK knowledge base than the UK has been itself[22]. Exploitation of UK-generated knowledge and insights by foreign companies should be welcomed, especially where those companies have UK-based development and manufacturing operations. Nevertheless, it is essential that the UK possesses the ability to capture value from its own investments in research in the academic, private and public sectors, and from ideas generated overseas.

Intellectual property

Intellectual property (IP) protection can be a crucial early step in the commercialisation process. While it is well established that the UK has a world-class IP system[23], it appears that, for many, IP protection is still regarded as a confusing, complex and potentially costly step. The new commitment outlined in the Green Paper to place Intellectual Property Office (IPO) representatives in key UK cities is to be welcomed, as is the announcement that government is reviewing how to maximise incentives created by the IPO to stimulate collaborative innovation and licensing opportunities. However, awareness of the support and resources for IP protection remains low. For example, a favourable tax regime for the exploitation of intellectual property that was cited repeatedly in the survey as a way government could improve the commercialisation of ideas from the research base; yet there were very few mentions of the 'Patent Box' initiative, which provides Corporation Tax relief on profits from patented inventions or certain other innovations.

1.13 Greater promotion of the excellent resources already available from the IPO is needed to help companies and individuals better understand what protecting their intellectual property entails. In addition, the benefits of the Patent Box need to be promoted more effectively, in parallel with ensuring that it is as user-friendly as possible, particularly for SMEs.

The costs associated with protecting and defending intellectual property rights can also act as disincentives for some individuals and smaller companies.

1.14 Government should ensure that perceived or actual IP costs do not act as barriers to the commercialisation process, particularly in areas where public sector support is already involved, for example activities supported by the Industrial Strategy Challenge Fund.

Catalysing connections

A common theme in answers to the call for ideas on how commercialisation could be better supported was the need to increase the breadth and range of connections available across all regions of the UK and to make it easier for those connections to form. To ensure that all ideas reach their commercialisation potential, connections need to be facilitated across a variety of organisations:

- *Business-to-business* connections can offer investment opportunities for startups and spin-outs by large companies, identify opportunities for ideas to be exploited by new sectors, form pre-competitive collaborations and introduce companies to potential customers.
- *Business-to-academia* connections can allow academic researchers to access commercial problems that need solutions and offer companies access to new techniques, technologies and expertise.
- *Business and academia to investor* connections can allow innovators to present their ideas to potential investors and facilitate investors' ability to understand new techniques, technologies and innovative business models.

Shared physical spaces can be invaluable for catalysing connections and creating an environment that fosters knowledge exchange. Physical hubs tend to work best when they provide an attractive and concrete service in addition to shared space[24]. There are already many shared physical spaces that encourage

22 Principles of Economics, Marshall, 1890; Plan I The Case for Innovation-Led Growth, NESTA, 2012
23 Global Intellectual Property Index, 5th report, Taylor Wessing, 2016
24 The Dowling Review of Business University Research Collaborations, 2015

connections, such as the UK's Research and Innovation Organisations[25], including:

- *Public sector research establishments (PSREs),* publicly funded bodies that carry out research in support of government policymaking or regulatory functions. They engage in a range of knowledge transfer activities, which include free dissemination of research outputs, contract research on behalf of industry, and support for spin-off companies, in addition to collaborative research projects[26].
- *Catapults* are now an integral part of the UK's innovation landscape and provide a physical and/or digital infrastructure to support late stage R&D to take innovative ideas from concept to reality.
- *Independent research and technology organisations (IRTOs)* are mainly private non-profit research performers or commercial research enterprises providing R&D services, both to government and business.

Virtual networks and one-off events are also key to catalysing connections – examples include industry open days held by universities and activities supported through the Knowledge Transfer Network (KTN).

1.15 Government should facilitate an increase in the breadth and range of connection opportunities, in response to the requirements of the project, sector or local region, building on and promoting existing effective initiatives.

Regulation

Regulators need to engage early with innovators and experts in relevant technology areas to ensure that regulation does not impede innovation unnecessarily or unintentionally. There are significant advantages to the UK assuming a leadership role in the international negotiations that underpin the development, adoption and implementation of regulation and standards. This can both ensure that they are fit for purpose and maximise the opportunities for success for UK innovators.

1.16 Government needs to give a clear message to regulators that early interactions with innovators and technology expertise are an essential part of their responsibilities and consider how closer working between regulators and innovators can be incentivised or facilitated.

It is also important to raise awareness among R&D and innovation funding bodies and private investors of the value of engaging in the development of regulation to accelerate routes to market and enable the participation of appropriate individuals. In addition, university researchers, who often have relevant expertise, should be provided with the necessary funding or career incentives to participate in international standardisation and regulation activities.

1.17 Existing networks, such as the KTN and the Catapult network, should be utilised to encourage and facilitate participation in the development of regulation and standards. UKRI should be tasked with considering how academic participation in the development of regulation and standards can be encouraged and recognised.

Commercialisation of ideas from academia

The UK has a world-leading academic research base that provides an excellent source of new ideas and discoveries. Through innovation and commercialisation, these discoveries can result in advances in our economic, social and cultural wellbeing and health. In general, universities' TTOs are responsible for protecting and commercialising IP developed at universities by licensing IP rights to existing companies and through establishing spin-out companies[27]. However, there is a perception that a university's objective to maximise returns from the commercialisation of research can take precedence over the objective of maximising exploitation of IP. For universities to 'consider their IP strategies as part of their research strategy rather than earned income strategy', as recommended by the UK's IPO[28], TTOs require long-term financial security. Universities should

25 Research and Innovation Organisation in the UK: Innovation Functions and Policy issues, BIS research paper No.226, 2015

26 7th Survey of Knowledge Transfer Activities in public Sector Research Establishments (PSREs) and Research Councils, WECD, 2014

27 UK University Technology Transfer: behind the headlines, 2015

28 Intellectual asset management for universities, IPO, 2013

consider whether their model of TTO funding and resource level aligns with the role they want their TTO to fulfil. In considering resource levels for TTOs, universities should take into account the significant roles that TTOs have played in generating impact case studies in the Research Excellence Framework (REF), which underpinned the allocation of quality related research (QR) funding.

Greater pooling of skills, sector knowledge and technical expertise may improve universities' support for research commercialisation and result in more efficient use of public funds[29]. There are already examples of universities and TTOs working in collaboration as well as mechanisms for informal sharing of expertise by TTO staff. For example, the SETsquared Partnership is an enterprise collaboration between five research-intensive universities: Bath, Bristol, Exeter, Southampton and Surrey.

Wider adoption of successful approaches across TTOs, including through formal collaborations and networks, could both help the performance of individual institutions and deliver broader public benefits. In addition, TTOs should seek to learn from the approaches taken by successful incubators and accelerators outside the university system.

Improved understanding of how universities approach research commercialisation could have a bearing on where entrepreneurial researchers and businesses choose to work. Such promotion of efficiency and effectiveness could be tied to qualitative indicators used by universities to monitor and incentivise TTO behaviour, such as the time taken to conclude negotiations, secure a licensing deal and satisfaction of key stakeholders[30].

Universities that are confident of the performance of their TTO in supporting arrangements for research commercialisation should publicise statistics that demonstrate their efficiency and effectiveness.

Spin-outs

Spin-outs are one mechanism through which the ideas generated in universities can be commercialised. While the UK clearly has many strengths in research commercialisation, the overall perception in the UK engineering community is that there is still room for improvement in the spinning out process. The announcement in the industrial strategy Green Paper that government will commission research on commercialisation of intellectual property, including the varying sizes of equity stakes taken, is therefore to be welcomed.

Enterprise Hub

The Royal Academy of Engineering's Enterprise Hub, founded in 2013, is a national resource for the UK's most promising engineering entrepreneurs.

The Hub makes awards to exemplars of excellence in engineering innovation who will be the founders and leaders of tomorrow's high-tech companies. Enterprise Fellowships support outstanding entrepreneurial engineers, studying or working at a UK university, to prove the utility of an innovation by spinning out a business based on that innovation. The Hub provides £60,000 for post-doctoral academics wishing to spin-out from a university, or £50,000 for recent graduates wishing to establish a startup without any formal involvement of a university. In addition, the Enterprise Fellow becomes a member of the Enterprise Hub where they receive an intensive bespoke package of training and mentoring, and access to the Hub's network.

Mentoring is provided by leading engineers with first-hand experience of founding, building and leading successful engineering and technology companies. Together, the mentor and mentee develop a plan to address the mentee's specific needs, which includes provision for business training, technical assistance, specialised mentoring and coaching as required. The Hub provides access to activities and opportunities aimed at connecting entrepreneurs with customers, peers, investors and other networks.

To date, the Academy has awarded 58 Enterprise Fellowships to exceptional academic entrepreneurs hosted by 26 different universities.

It is recognised that academics may sometimes be ill-equipped to manage a spin-out company and all that the spinning out process entails. However, the experience of the Academy's Enterprise Fellowship scheme shows that this is not always the case.

29 The Dowling Review of Business-University Research Collaborations, 2015.

30 University Knowledge Exchange framework: Good practice in technology transfer, McMillan group, 2016

A lack of understanding by academic entrepreneurs of the spinning-out process and of the different perspectives of stakeholders contributes to difficulties and can put academic founders at a disadvantage when entering negotiations. Levelling the information asymmetry between the academic entrepreneurs and the university should result in an improvement in the spin-out process for all parties involved.

1.18 Universities should ensure that their IP policies and information about their approach to the spin-out process are easy to find and, ideally, publicly available. Universities may also wish to consider publishing anonymised details of the terms of deals they have agreed.

The allocation of equity during the formation of spin-outs is a complex and contentious issue. The division of equity should incentivise exceptional academic founders to drive the company forward and the amount and quality of support provided by the university should be reflected in the stakes it seeks. One approach is to allow academic founders to decide whether they wish to access commercialisation support from the TTO or from an external provider, with the equity stake adjusted accordingly. If the founder does not wish to secure commercialisation support (such as incubation services) from the TTO, the equity stake taken by the university will simply reflect the support provided by the university that enabled the IP to be generated and protected. This 'two-tier' system enables academic founders with the appropriate skills and motivation to select forms of support and investment best suited to their company. By increasing demand for external entrepreneurial support services, it may increase provision in the market, as well as introducing competition[31].

1.19 Some universities allow academic entrepreneurs to access commercialisation support externally, adjusting their equity stake in the spin-out to reflect this. This decoupling of the support provided by the university that led to the generation of IP, from the wider package of support such as incubation services, can be beneficial and should be available more broadly.

The application of anti-dilution provisions to universities' shareholdings is also viewed by some in the enterprise community as a way to improve the spin-out process in the UK. Anti-dilution provisions, such as the 'golden share' model[32], are intended to ensure that the share is protected from dilution in further rounds of investment, but they are not widely used in the UK and remain unproven in the UK higher education system[33]. The use of anti-dilution provisions may be better suited to particular sectors and could be trialled accordingly.

In recent years, there has been an improvement in the provision of patient capital investment vehicles specifically targeted at the commercialisation of university research, which can help bridge the 'valley of death' between the development of a prototype and a product or service that is an investable proposition[34]. For patient capital investment vehicles to access a steady supply of IP in which they can invest, they may establish partnerships with universities. The nature of these partnerships varies, from exclusive deals whereby the investment vehicle has the exclusive right to commercialise all IP from a university, through to non-exclusive deals whereby a university may show its deal-flow to a specific investment vehicle[35]. Although the increase in patient capital investment vehicles has created a welcome market of investors for universities to choose from, the existence of exclusive deals restricts academic founders from accessing such a market. Establishing an evidence base to demonstrate whether such arrangements deliver best value for academic founders and the UK public purse, which funds much of the research undertaken in universities, would be worthwhile.

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31 Are US university spin-out processes really better than those of UK universities? Lita Nelson and Katherine Ku, 2016

32 Connect People, Build Infrastructure, Growth Clusters, David Cleevely, Sherry Coutu, Hermann Hauser and Andy Richards, 2014

33 Golden Share & Anti-dilution Provisions, Tom Hockaday and Tony Hickson, 2015; University Knowledge Exchange framework: Good practice in technology transfer, McMillan group, 2016

34 The Deal 2015/16; Royal Academy of Engineering Access to Finance submission, 2016; Patient Capital, A new way of funding the commercialization of early-stage UK science, Tony Hickson, 2016

35 Patient Capital, A new way of funding the commercialization of early-stage UK science, Tony Hickson, 2016

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It would be valuable to develop an evidence base on the benefits and feasibility of anti-dilution provisions, including in specific sectors, as well as on the impact of exclusive partnerships between TTOs and patient capital investment vehicles.

Developing research leaders and entrepreneurs [Q8]

International context

UK university engineering and technology departments have higher proportions of international students and staff, including from non-UK EU countries, than the average for all subjects. In 2014/15, 40% of engineering and technology academic staff in the UK were non-UK nationals, compared to 28% across all subjects. Further analysis shows that 18% of engineering and technology academic staff were non-UK EU nationals and 22% were non-EU nationals. The same trend is observed when considering engineering and technology students. In 2014/15, 30% of engineering and technology undergraduate students were non-UK nationals, rising to 68% of engineering and technology postgraduate students[36].

Innovation is critical to the UK's economy and productivity, and like research, it is an international endeavour. The European Startup Monitor, which represents more than 2,300 startups with more than 31,000 employees in all 28 European member states, showed that 25% of UK startups were founded by non-UK EU nationals and 45% of UK start-up employees come from non-UK EU countries – the highest proportion of non-own country EU nationals employed across the 13 countries surveyed (the average was 21%)[37].

1.20 Sensible and proportionate arrangements should be in place to retain and attract non-UK nationals who wish to pursue innovative and entrepreneurial engineering and tech-based activities in the UK.

Moreover, research excellence and innovation flourish when researchers collaborate and work across borders; the UK excels at this[38]. For the UK to continue to support excellence in research and innovation, the industrial strategy will need to ensure that government policies accommodate the unique features of researcher and innovator mobility, as well as access to funding that enables international collaboration[39].

1.21 The UK should seek the closest achievable association with EU research and innovation programmes and ensure that, if needed, new long-term UK funding programmes are available that complement current UK funding streams. These should focus on supporting international mobility and collaboration, including academic and industry partnerships (involving both large and small companies).

Investing in leadership

Fully realising the potential of the most talented doctoral students requires developing both their research leadership and also their leadership skills across a wider range of areas that support or benefit from that research role. Hence, support schemes should encourage a rounded conception of leadership, particularly including engagement with industry and leadership of high-level education programmes, so that the potential of these individuals to pass their knowledge on to the wider skills base should be realised as quickly as possible.

Entrepreneurship and enterprise skills

Ensuring that, at the outset of their careers, undergraduate and postgraduate students in appropriate subjects gain industrial experience and receive basic skills training in topics of relevance to business and entrepreneurial activity should make a long-term contribution to improving the UK's ability to commercialise ideas from the research base. Entrepreneurship education should also enable individuals to develop the transferable skills that will help them to adapt to future work and career changes. Such entrepreneurial and business skills training should also be available for academic staff. In line with the recommendation of the Prime Minister's Council for Science

36 HESA data, accessed 28 September 2016, nationality of undergraduates and postgraduates, 2014/15
37 European Startup Monitor, 2015
38 Joint Academies submission to House of Commons Home Affairs immigration inquiry, 2017
39 Royal Academy of Engineering submission to House of Commons Home Affairs Committee immigration inquiry, 2017

and Technology[40], the Royal Academy of Engineering is working with the national academies to bring together best practice and provide coordinated guidance to universities on entrepreneurship education.

1.22 Universities should ensure that all students in appropriate subjects and academic staff receive wider business skills and IP awareness to improve their ability to undertake knowledge exchange activities across the course of their careers and help companies to generate and absorb innovation.

There is a widespread perception that, despite progress made, success in innovation and entrepreneurship has little impact on recognition and career progression within the academic system. While the inclusion of 'impact' in the Research Excellence Framework (REF) has caused a significant shift away from negative perceptions related to innovation and entrepreneurship, the engineering community believes that there is still more to be done. There is also an opportunity for the Teaching Excellence Framework to encourage entrepreneurship education, particularly if metrics are developed that clearly reflect the career benefits and value of entrepreneurship education for students, stakeholders and the economy.

The use of prizes to reward outstanding R&D, innovation and entrepreneurship was suggested a number of times by respondents to the survey. Prizes not only give recognition to the individuals involved and the activities for which they were awarded the prize, they also serve to raise the public profile of engineering and innovation, which was a theme running throughout all consultation activities. Many forms of recognition for innovation focus on the achievements of individuals, yet most innovation takes place through the activities of teams. Prizes such as the Royal Academy of Engineering MacRobert Award and Queen Elizabeth Prize for Engineering, which are awarded to teams responsible for groundbreaking innovations, provide important opportunities to counterbalance this tendency.

Supporting innovation in local areas [Q9]

Innovation assets

Technological innovations must be extensively tested and demonstrated in real-world environments, if they are to succeed on the market. Such testing also allows for development of key regulations and standards in parallel, which are factors that determine the commercial success of technological innovations. The provision of high-quality testing assets could also act as an attractor for foreign companies to the UK.

1.23 The UK should prioritise the provision of high-quality opportunities for companies to test and demonstrate their technological innovations to allow UK companies to gain competitive advantage and act as an attractor for inward investment.

Provision of high-quality testing facilities does not have to necessitate the creation of new infrastructure; instead, existing UK infrastructure could be utilised as 'national innovation assets'. Examples of such assets could be airfields where drones could be tested, hospitals where innovative approaches to data-driven services could be trialled or factories where novel approaches to automation could be implemented. There are already numerous examples of various types of national assets being exploited to support innovation – from the use of Milton Keynes for testing autonomous vehicles to the trialling of predictive policing approaches in forces in Kent. The *2020 Robotics and Autonomous Systems* strategy makes a compelling case for the benefits of the UK using its innovation assets to test robotics and autonomous systems[41].

This 'innovation assets' approach would extend the geographical reach of innovation activities by taking a more systematic view of opportunities for innovation that takes account of where:

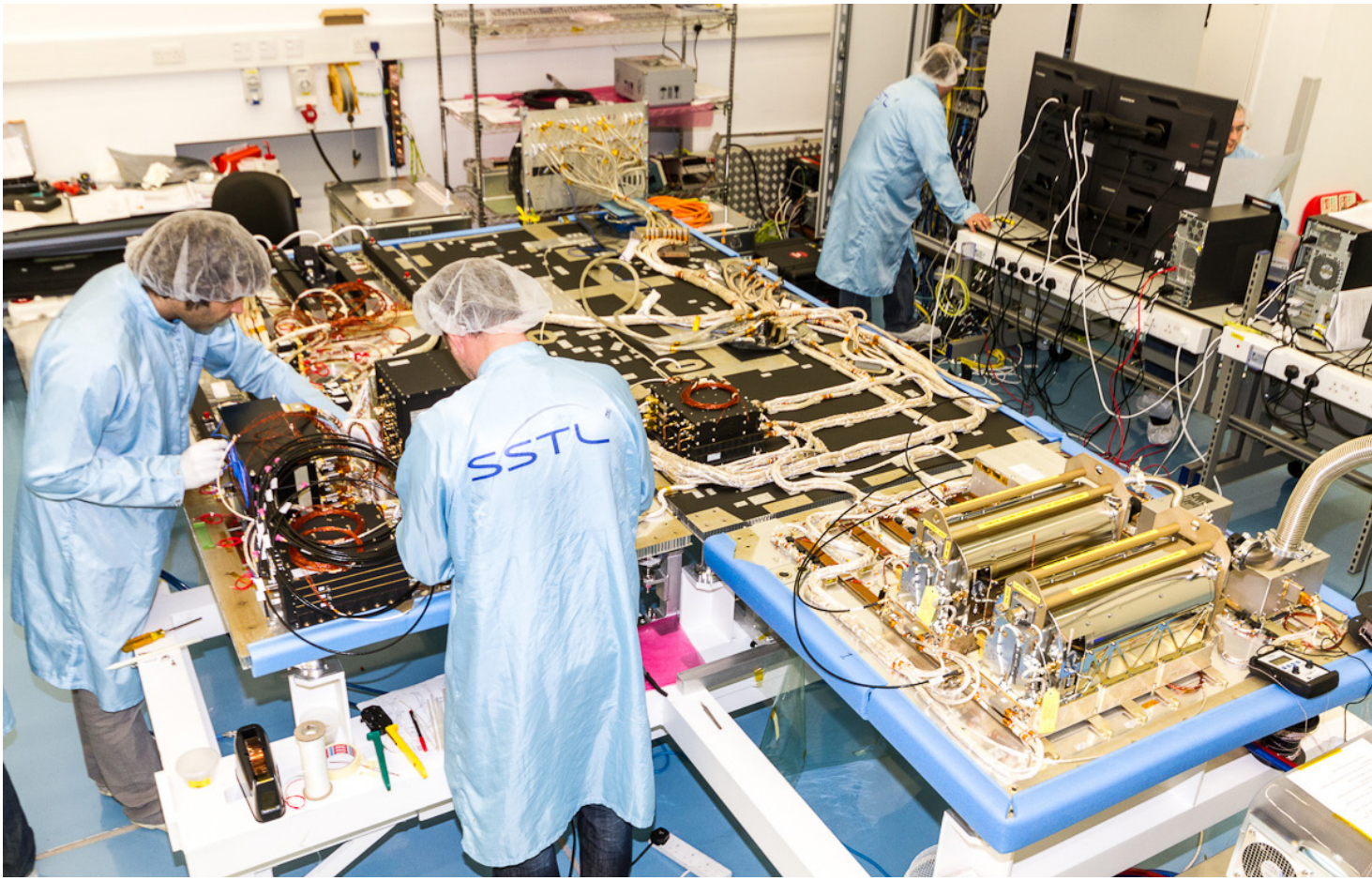
- physical infrastructure already exists – or is being developed
- there may already be relevant skills in the local workforce (for instance, because of the industrial heritage of the area or previous specialist activity)

40 Strengthening entrepreneurship education CST letter, Council for Science and Technology, 2016
41 RAS2020 Robotics and Autonomous Systems, 2014

- there is an appetite to embrace new ideas
- there is an opportunity for a more flexible regulatory or policy environment that can support innovation.

Facilities identified as 'innovation assets' would be expected to receive targeted investment associated with priority technologies or sectors, support from national government to minimise regulatory hurdles, and to become focal points for specialist skills development associated with the relevant area of innovation (which could include legal, public engagement and technical skills at all levels). The national register of 'innovation assets' could also be used as a communication tool to promote the UK as an innovation-driven nation and encourage investment around these assets from both UK and overseas companies.

1.24 A register of 'national innovation assets', with associated policies to support their effective exploitation, should be established to extend the geographical reach of innovation activities beyond current centres of excellence.



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PILLAR 2

Developing skills

Introduction

Our response to this section is presented in three parts in alignment with the Green Paper: basic skills and foundational education, technical education, and future skills needs, upskilling and retraining.

The engineering community welcomes the fact that the Green Paper takes into account large elements of the education pipeline, from basic skills through to post-16 options, technician and professional engineering education, reskilling and upskilling the workforce and lifelong learning.

> "We need an apprentice system that works for SMEs. In my experience, the system is configured to work for corporates; there's a real opportunity now to get this right for smaller businesses."
>
> **Professor Win Rampen FREng FIMechE FRSE, MD, Artemis Intelligent Power**

However, to be a coherent and long-term strategy for the UK, the industrial strategy also needs to reach back further into primary and secondary education, ensuring that the right incentives, inspection regimes and funding models for schools are in place to nurture and develop interest, engagement and attainment from a young age in key subjects that will support the nation's skills needs. It is especially important to reverse the UK's lagging performance in encouraging females and other currently underrepresented groups to view engineering as exciting and relevant to them and mathematics and physics as exciting and valuable subjects in widening their choice of possible careers.

A common message of all our consultation activities across the engineering community was the need for stability and continuity in education and skills. Employers, providers, professional bodies and individuals all want to invest in improving skills, but are keen for reassurance that current reforms will be long-term and (as far as possible) supported by all political parties, with measures in place to prevent further upheaval in the education and skills system in the short and medium term.

The decision to leave the EU also has direct ramifications on the availability of engineering skills. 60% of our survey respondents reported that their organisations were currently 'somewhat', 'very' or 'highly' dependent on recruiting employees from outside the EU. The internationalised nature of the skills base was typically seen as a strength contributing to high performing teams and respondents took pride in belonging to organisations that could be considered truly global.

Many of the additional comments on this questions echoed the sentiment that one respondent expressed as follows:

"The UK doesn't have the monopoly on the best thinkers in the world. A global consulting company needs a mobile international workforce who can apply collective and collaborative thinking in delivering solutions to complex projects/ issues. So the best minds are sought wherever they may be."

This also highlights the need to ensure that the UK's education and training system are closely aligned with the needs of industry. The idea of creating some sort of higher obligation on industry to shape and invest in the creation of the skills it needs can be found in various guises abroad. For example, Germany embeds industry involvement in skills development in a more sophisticated system of sponsorship and ownership in a model widely seen as successful.

Basic skills and foundational education (Q10)

The industrial strategy Green Paper highlights the government's intention to explore increases in the uptake of STEM subjects. Increasing participation and attainment in STEM subjects among young people is a process that needs to start early. To address the challenge of improving basic skills and foundational knowledge in STEM subjects that will underpin the industrial strategy, the government will need to tackle fundamental issues in primary and secondary education. The key areas are:

Improving public perceptions of engineering

Improving public understanding and perceptions of engineering was identified as the action most likely to improve uptake of STEM subjects, with 69% of survey respondents saying that they were very confident and a further 22% saying they were quite confident that it would make an impact. The consultation as a whole demonstrated that engineering employers clearly recognise their leading role in this endeavour, but there was also a strong message that the government needs to work with the engineering community to improve perceptions of engineering and engineering careers among

young people and their influencers. The UK's strengths in the creative industries should be drawn upon in support of this challenge.

A key element of improving public perceptions of engineering will be to reach underrepresented groups and address the significant underrepresentation of particular groups, including women, people from minority ethnic groups, LGBT, people with disabilities and other under-represented groups.

The industrial strategy should provide a platform to address critical skills shortages in engineering, including through government support for a campaign to change public perceptions of engineering; as highlighted in Professor John Perkins' Review of Engineering Skills in his role as Chief Scientific Adviser to BIS[42].

The engineering community is ready to support the government's proposed Year of Engineering campaign. The engineering profession, through the Royal Academy of Engineering, is developing its own five-year public engagement campaign, the Engineering Talent Project[43].

2.1 The government should work closely with the engineering community to promote the Year of Engineering and support longer-term public engagement campaigns.

Digital skills

There is clearly a need to improve English and mathematics attainment among young people to bring the UK into line with other OECD countries and the government's focus on these two aspects of basic skills is, of course, welcome. However, in response to our consultation, the engineering community has clearly articulated that the definition of basic skills needs to be broadened to include digital skills for the UK's advanced 21st century economy.

The ability of the general population to engage with information and communications technologies is fundamental to our success as a nation and to the success of the industrial strategy. A clear message from the engineering community to our consultation is that, for engineering specifically, increasing the digital skills of the workforce is essential. The ability of UK engineers to be confident and competent to a high level in digital skills will be central to our competitiveness in high-value manufacturing and engineering across a range of sectors.

2.2 Digital skills should be included in the government's future definition of basic skills.

Teacher shortages

An essential requirement of ensuring that young people have the basic skills and foundational knowledge in STEM subjects is the adequate supply of specialist teachers in those subjects. There are currently shortages of specialist teachers in all the key disciplines that lead to engineering skills. The 2015 National Audit Office report into teacher shortages highlighted that in English secondary schools, the proportion of lessons taught by non-specialists is considerable: physics (28%), maths (20%) and for computer science almost half of lessons (44%) are taught by teachers without relevant post A-level qualifications. The situation in schools is likely to get worse in the short term as STEM subjects have consistently failed to meet teacher training targets over a number of years. For design and technology (D&T), only 41% of training places were filled against targets in 2015/16. For computing, the equivalent figure is 70%, for physics it is 71% and for mathematics, a more encouraging 93%, but still below the Department for Education's target[44].

Specialist teachers are particularly important in secondary schools, where a teacher's deeper understanding of and confidence in the subject can be instrumental in stimulating interest and engagement among the students. At the same time, it is also important that primary schools provide an appropriate, accurate and inspiring STEM education to children from an early age, through ensuring those coordinating science or

> "Engineers – and employers – benefit from a broad undergraduate curriculum that includes practical experience of working in teams to solve real-life problems."
>
> **Carol Burke CBE FREng MIMechE, MD, Unipart Manufacturing Group**

42 Review of Engineering Skills, Professor John Perkins, 2013
43 Engineering Talent Project www.raeng.org.uk/education/engineering-talent-project
44 Training new teachers. National Audit Office. www.nao.org.uk/report/training-new-teachers/

with responsibility for science are appropriately trained even if themselves not science specialists. Currently, only 5% of primary school teachers have a qualification at A level or above in mathematics or science[45].

Government incentives such as initial teacher education tax-free bursaries for physics, mathematics and computing appear to be having some effect.

2.3 The initial teacher education bursary for D&T should be increased in line with mathematics, physics and computing to help increase teacher recruitment.

One potential solution for addressing teacher shortages could be to attract engineering graduates who do not want to enter industry into teaching. The UK produces some 15,000 UK domiciled engineering graduates each year, approximately 10 times the number of physics graduates. Of these graduates, around 70% enter engineering occupations, potentially leaving sufficient numbers to take up roles in teaching to help fill teacher shortages.

Engineering graduates have the technical knowledge and skills to be able to teach all the shortage subjects (maths, physics, computing, D&T) that lead to engineering. Attracting engineering graduates into teaching may, however, require some structural changes to initial teacher education, with more flexibility around subject combinations (such as maths and physics, or physics and computing) rather than the current model of all sciences (physics, chemistry, biology). The engineering community stands ready to work with government to promote teaching to engineering undergraduates.

While technology cannot replace teachers, the appropriate use of technologies to support teaching and learning may, in some cases, alleviate teaching loads and enhance teaching and learning.

2.4 Government should consider how best to leverage the use of technologies to augment the role of teachers in the classroom to support and enhance learning.

> "It is crucial that schoolteachers gain improved understanding of the world of work so that they can set their teaching in context. Schemes like STEM Insight are making a real difference to their ability to influence skills supply."
>
> **Professor John Perkins CBE FREng FIET FIChemE**

Teacher continual professional development

All teachers need to update their subject knowledge. For teachers of STEM subjects, the pace of change of new knowledge and pedagogies requires more frequent professional development. In addition, the engineering community believes that there is a clear need for teachers in science, computing, D&T and mathematics to provide real-life contexts to the theory that they teach, to make the subjects relevant and inspiring for young people.

There are many teacher CPD programmes available that support STEM teachers, such as *Project Enthuse* delivered by STEM Learning, the Royal Academy of Engineering's *Connecting STEM Teachers* programme, the Institute of Physics *Stimulating Physics Network*, the National Centre for Excellence in the Teaching of Mathematics' *Maths Hubs* and the Computing at School *Master Teacher Network*. The engineering community has particular interest in the programmes that develop a greater knowledge of engineering for STEM teachers. The *STEM Insight* scheme, delivered by STEM Learning, provides work placements in industry for teachers and the *Connecting STEM Teachers* programme delivers training for teachers across STEM subjects in over 700 schools with contextualised engineering resources.

2.5 Government must significantly increase funding for subject-specific teacher CPD for primary and secondary school teachers to ensure that all teachers undertake subject-specific CPD alongside general professional development and training, making annual training compulsory and monitored through OFSTED inspections.

Careers advice and guidance

The engineering profession welcomes the proposal of a new careers strategy and its aim to create a more coherent and effective system for both young people and adults. We look forward to seeing the detail in due course and providing input and support to ensure that it reflects the needs of, and resources available in, the engineering community.

[45] Building expertise – the primary science specialist study. Wellcome Trust, 2013

The current system of increasing employer engagement in schools is a positive step. The engineering community is connecting engineering businesses to schools through the *Tomorrow's Engineers* programme, led by EngineeringUK on behalf of the profession[46]. The *Tomorrow's Engineers* programme is also working closely with the Careers and Enterprise Company. Employer engagement must remain a key element of the new careers strategy and schools should be encouraged to increase the amount of employer engagement activity that they undertake.

However, the new careers strategy will require much more than employer engagement. Our consultation highlighted the need for dedicated, industry-informed careers advisers, either internal or external to schools, but trained to an appropriate level, and with up-to-date knowledge of local labour market needs and engineering and technical careers. Teachers do not have the level of expertise to fulfil this role adequately. Local Enterprise Partnerships (LEPs) must also play a role in shaping careers advice and guidance, providing local labour market information (LMI) and using this knowledge to also shape the post-16 offer for young people through the technical routes.

Careers advice and guidance should also highlight the opportunities afforded by different subjects. Respondents to our consultation felt that there is still a significant misunderstanding among young people and their influencers that STEM subjects narrow future career opportunities rather than broaden options. In addition, careers advice provided in schools must be impartial and students should understand the full range of future learning opportunities available, with equal status given to technical pathways alongside academic routes.

The engineering profession is very supportive of the Gatsby *Good Career Guidance*, and strongly recommends that the proposed careers strategy adopts all these principles. However, unless the quality of careers advice and guidance is measured, it is unlikely that schools will pay attention to this critical aspect of the education system.

2.6 The OFSTED Accountability Framework should include careers education as a limiting judgement so as to ensure substantial improvements in this area.

2.7 The new careers strategy should deliver professional, impartial careers advice linked to local labour market information as well as employer engagement.

Curricula and qualifications

The engineering community welcomes the new national curriculum, in particular the introduction of the computing curriculum that now covers computer science in addition to information technology and digital literacy. The introduction of the new GCSE computer science is essential for the future of the engineering profession. At present, only a small minority of students take this qualification, which is not sufficient to meet the needs of the UK. Schools need sustained long-term support to make sure that this qualification is successful. However, there are serious concerns that the GCSE computer science should not be the only GCSE qualification concerning computing on offer to students, which is currently the case. For UK engineering to thrive, we need to ensure students have access to GCSE qualifications that cover the whole computing curriculum as well as computer science. If not, then the majority of young people will leave compulsory education at age 16 without any formal computing qualification. This could seriously undermine the UK's future industrial strategy. The engineering community would like to see a general computing GCSE introduced as well as increased and sustained support for computer science.

2.8 Existing support for the professional development of computing teachers in schools needs to be sustained and expanded so that as many students as possible are able to take GCSE computer science.

2.9 A new general computing GCSE should be developed alongside the current computer science GCSE and computing designated a core subject in schools.

The engineering community also welcomes the reform of D&T in schools, which places much greater emphasis on knowledge and understanding of the design process, the development of creative problem solving skills in design and the application of science and mathematics to design solutions.

[46] www.tomorrowsengineers.org.uk

The importance of design subjects should be made more explicit in the government's industrial strategy. The UK holds an enviable position of global dominance in design, be it in architecture and the built environment, engineering and product design or advertising, marketing and communications. However, D&T, the subject in schools where young people first encounter design and engineering, and where these knowledge and skills are developed, is in severe decline. Teacher shortages, as highlighted above, increasing costs of provision and a lack of status in school accountability measures means that schools are cutting back on provision.

D&T has the potential to play a significant part in the development of young people with the right skills to help deliver the government's industrial strategy. Robotics, additive manufacturing processes, electronics, systems and control and all manner of high-value design and engineering skills can be taught through D&T. Government should see it as an essential subject to support the industrial strategy and schools' performance here should be measured accordingly.

2.10 D&T should be included in the English Baccalaureate accountability measure on schools.

More broadly on the issue of curricula and qualifications, a clear and strong message from our consultation with the engineering community is that the English education system requires young people to make subject choices at too early an age. This results in future opportunities being cut off before young people are fully informed or aware of the many career options available to them and the impact of the choices that they make at 14 and 16 years old.

While it might be argued that young people are taking a wide range of GCSE and other qualifications at Key Stage 4, including STEM and non-STEM subjects, the very act of choosing the optional subjects is making students start to think about particular career directions at an early age. With many schools now truncating Key Stage 3 to just two years, increasing numbers of students are having to make GCSE choices at age 13, well before they have had any broad understanding of career opportunities and the impact that subject choices can have on closing down particular pathways.

The current post-16 system of A levels for those taking an academic route towards higher education exacerbates this situation. By age 16, the vast majority of young people will cease to study any form of mathematics or science. From a cohort of some 550,000 students in any one year, only around 30,000 students will continue to study mathematics and physics at A level – almost a 95% reduction.

The engineering community would like to see a broader post-16 curriculum that should include a combination of sciences and mathematics alongside humanities and arts subjects.

2.11 The government should introduce a broader post-16 curriculum and qualifications system for those students continuing on the academic pathway towards higher education or employment.

A new technical education system (Q11)

Transition year

The engineering community welcomes the proposal for a transition year as part of the post-16 skills plan. If implemented correctly, it will provide a real opportunity for young people who have not achieved sufficient grades in Key Stage 4 to improve their basic skills in order to go on to college-based technical education or apprenticeships.

However, the engineering community recognised the challenge highlighted in the Green Paper that a significant proportion of those young people who do not attain sufficient grades in basic skills at GCSE struggle to do so in a further education environment. We welcome the proposal to request the expansion of the remit of the Education Endowment Fund to investigate appropriate interventions to support the further education sector.

As stated previously, the engineering community would welcome the inclusion of computing as a basic skill for both the transition year and the technical education qualifications.

Technical education qualifications

The proposals in the Skills Plan to create 15 occupation-focused routes or 'T-levels' are welcome. This will make a significant impact on reducing the complexity and inefficiency in the system. It will make progression to employment much clearer for young people and employers will have a better understanding of the qualifications that young people hold.

It is important that the 'core content' of the curricula in the new T-level qualifications

provides sufficient breadth across a range of engineering disciplines before specialisation towards a narrow set of occupations. The qualifications must also be discipline- or occupation-based, rather than sector-led, as this will enable greater occupational mobility for young people.

The engineering community has already supported the Department for Education on mapping the occupations for engineering and manufacturing, construction and the built environment, and digital.

2.12 The Department for Education and the Institute for Apprenticeships and Technical Education need to work closely with the engineering community to develop the curriculum content for the relevant T-level routes.

A number of key issues will need to be considered as part of the development of qualifications. These include the need to bridge the current system of qualification levels to a new occupational-based system that is understood by young people and employers, and the need to ensure harmonisation of new college-based T-level content with apprenticeship standards. A key element of the development of the qualifications will be to ensure that they lead to technician-level professional registration with engineering, built environment and digital/computing professional bodies.

2.13 T-level qualifications in engineering and manufacturing, construction and built environment, and digital must align with and address the knowledge and skills requirements for professional registration at technician level.

Work experience element

Work experience was highlighted as a crucial element of encouraging young people towards careers in engineering. The three-month work experience element of the new T-levels is therefore very welcome. A key challenge will be to ensure that there are sufficient meaningful work experience places available across England in sufficiently short travel-to-work distances for young people taking the qualifications. LEPs will need to play a key role in ensuring that colleges and employers can match the work experience requirements to places available.

Teaching provision

The key issue raised by the engineering profession during the consultation process in relation to improving the quality and quantity of technical education was the current lack of expert teachers and tutors in further education. The Green Paper recognises this challenge and highlights the task of 'attracting more industry specialists to work in the sector'. The additional annual £500 million to the further education sector announced in the March 2017 Budget will significantly improve developments in this regard. However, given the critical shortages of teachers in the schools system, who tend to receive higher pay than their further education counterparts, this will be a significant challenge. Additionally, colleges have been denuded of investment for many years and will be in critical need of a further substantial injection of funding, particularly in high-cost subjects such as engineering, to ensure that they have the necessary resources, facilities and infrastructure to support the delivery of the new T-level qualifications.

Longer term funding arrangement for periods of three to five years would help stabilise FE provision and stimulate colleges and other providers to work with local agencies such as LEPs to better plan and invest in skills provision to meet local employer needs.

Government needs to be aware of the differential costs associated with different T-levels. Often colleges will subsidise provision of high cost laboratory based subjects from lower cost subjects. In addition subjects such as engineering necessarily take longer to study than others such as retail. This is reflected in the length of apprenticeships and so should equally be reflected in the length and commensurate funding of college-based provision. A more sustainable model of funding that stimulates appropriate growth in STEM T-levels in reflection of local employer demand is therefore favourable.

2.14 The government should incentivise the teaching of high-cost subjects by introducing a differential funding mechanism that would provide colleges with increased student funding for high-cost programmes (such as the new T-levels in engineering and manufacturing and in construction and built environment) and correspondingly lower amounts of funding per student in lower-cost subjects.

The main aspects of improving the quality of teaching in further education that were highlighted in our survey are:

- increasing the pay of technical skills and education lecturers
- supporting the development of lecturers in engineering through CPD
- enabling the further development of dual professionals (such as engineers/tutors) through schemes such as Teach Too[47]
- enabling tutors to come into industry for work placements and experience to refresh their technical and industry knowledge
- encouraging individuals to move back and forth between industry and education, through schemes that keep their knowledge current and articulate the skills they acquire in each to the other.

2.15 Government needs to ensure that colleges are ready to deliver the new routes in terms of the readiness of lecturers and facilities.

Institutes of Technology

The proposed Institutes of Technology (IoTs) garnered a lot of interest from our community. We specifically asked the engineering profession what they thought would be key to their success. The following were common responses and themes offered:

- IoTs need a clear goal that gives them a purpose in the education landscape, and makes their specific focus a distinct addition. This goal should be to support the industrial strategy through the provision of higher level skills and this should not be diluted to support secondary objectives.
- There was little excitement from the engineering profession for the funding for IoTs to be spent on additional infrastructure. Instead, the £170 million should be used to enable current centres of excellence such as the AMRC in Rotherham, TWI in Middlesbrough and the Bristol Composites Centre to develop networks of further education colleges, close gaps in local provision and provide 'improver pathways' to enable those institutes to provide specialist training within a coordinated national programme, to ensure national accessibility.
- IoTs should provide incentive and support for world-class industry specialists to teach in and support provision.
- IoTs must provide the highest quality teaching at the levels they offer, with tutors skilled in delivering technical knowledge and skills in industry relevant contexts. Employers must be central to the co-design and delivery of teaching and learning.
- Industrial experience for both students and tutors must be included and integrated into the IoTs' provision, with close links to local and national employers.
- IoT provision must not try to replicate university provision, but provide genuine additional skills training (at Levels 3–5), and could also offer postgraduate specialist skills provision.
- The value of IoT provision must be monitored through student progression and through analysis of benefits to employers.

2.16 The primary aim of IoTs should be to support growth through the industrial strategy, and this must not be diluted by well-meaning but secondary objectives.

2.17 Employer investment and engagement in IoTs is critical. Teaching provision must be co-designed and delivered to effect maximum impact as well as building on existing successful, national specialist models and their corresponding networks for developing advanced skills.

Simplifying application processes to further education (Q12)

The proposal to make applications for further education and work-based programmes easier is welcome, but using the UCAS system as the template is potentially problematic. UCAS works because universities have agreed to make it the applications portal, and because the undergraduate degree 'offer' is generally quite simple – a full-time, three- or four-year model, in a single location.

[47] Education and Training Foundation Teach Too www.et-foundation.co.uk/supporting/support-for-employers/teach/

The undergraduate fees and loans system underpins this.

Certainly until recently, UCAS was predominantly a clearing house for a single product. Although it now offers more information, it is not a system suited for the variations of further education and apprenticeships.

It is feasible that the current apprenticeship matching service could be improved, and the degree apprenticeship offer made available through UCAS. Outside higher education degree provision, the learning on offer is far more diverse, in terms of location, duration, content, level and cost.

Further education responds to more frequent stimuli such as local demand and employer requests, which changes more than once a year. As a result, aggregation and signposting would be more useful than a single application process through UCAS or equivalent.

A UCAS-style system works for higher education because prospective students are willing and able to relocate to other areas of the UK for the duration of their course and are provided with the funding options to do so. While this may also be an option for 18 year olds seeking to undertake a high-level specialist training course (rather than university), it would not be reasonable to expect 16 year olds to relocate from their homes, support systems and local area to attend a course or have the financial capability to do so.

2.18 Application processes for post-16 education and work experience need to take account of distance-to-learn constraints of young people travelling on public transport.

This also reinforces the need for further education course offerings to be aligned with local labour market information to help ensure there is local business demand for the qualifications offered rather than attempting to ensure full provision of specialist courses around the country.

Skills shortages, upskilling and reskilling (Q13 and 14)

Skills shortages

While there have been macro-studies of engineering skills shortages over recent years, there is limited information about specific sectoral or occupational shortages across the engineering sector. Of our survey respondents, 87% said that they had experienced skills shortages and many said that their companies were struggling to attract and retain people with the skills specific to their discipline or sector.

'Engineering specialist' was the role most often mentioned by respondents as the level at which skills shortages and gaps can currently be found in their sector. This was followed by apprentice and graduate engineer. There is also a growing need for employers to understand how engineering skills and knowledge can be transferred across disciplines and sectors, particularly when trying to recruit for highly specialist roles. It was noted that national supply and demand data might hide nuances in regional skills demand, particularly in rural or remote areas, such as in the nuclear sector.

This leads to a broader point around nationally available data on demand and supply. The UK Commission for Employment and Skills was the body charged with collecting data on future skills demand. Now that it no longer exists, there is uncertainty around how the national picture of skills supply and demand will be collected and this must be addressed within the industrial strategy.

While government considers how to collect future workforce data, it should pay due attention to the granularity of occupational data in order for future analyses to inform provision of technical education to respond appropriately at local and regional level.

2.19 The government should consider the introduction of a five digit standard occupational classification to improve understanding of the national labour market.

A key element of the industrial strategy must be to increase higher technical skills (levels four and five). Technicians at levels two and three must be able to upskill to these higher levels to drive innovations such as industrial digitisation, robotics and advanced manufacturing. Yet this continues to be a weak area of government policy. For example there has been much greater focus on promoting degree apprenticeships than level four and five apprenticeships. While IoTs will go some way towards addressing this issue, more investment is required to ensure a broader range of FE colleges can offer this provision.

The consultation also suggested that employers may be too specific in their requirements, leading to an unnecessary reduction in the pool of potential applicants. Respondents recognised the need to be more flexible in their recruitment, to acknowledge the transferability of engineering skills across sectors and proactive in reaching out to new applicant pools.

Professional registration can help confer mobility to engineers, highlighting knowledge, skills understanding and competencies that individuals have. In addition, professional bodies can provide additional support to companies and individuals wanting to transition between sectors.

2.20 The industrial strategy should give employers the confidence to invest in training and upskilling by bringing policy stability. Sector deals should ensure that this is addressed at the sectoral level in addition to individual employers.

Upskilling and retraining

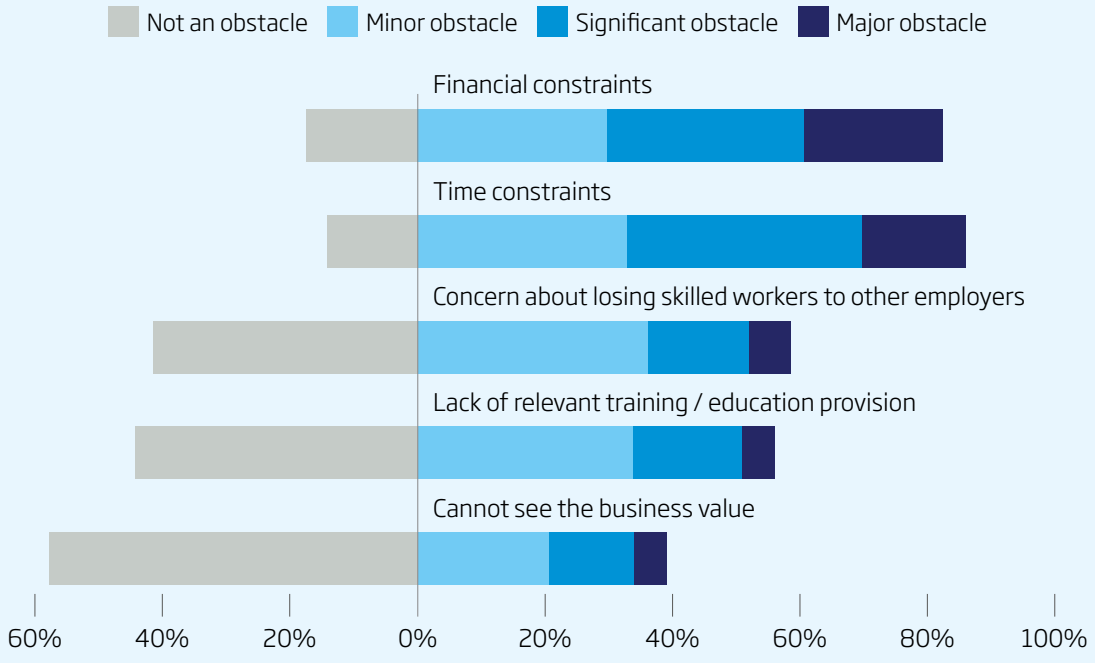
The engineering profession has always been strongly supportive of CPD. The speed of technological change, as well as the growth in global competition, make this an ongoing imperative for UK engineering in order to maintain a leading position internationally.

The profession supports general engineering education, which enables individuals to learn a broad base of technical skills and knowledge, enhanced by specialist provision specific to individual disciplines at later stages.

2.21 Upskilling and professional development of the existing engineering workforce should be through effective existing mechanisms and bodies such as professional registration, which should in turn be encouraged through government procurement policies.

Professional engineering institutions have a key role to play in supporting individuals and companies to keep up-to-date with technological change and global competition. They can inspire, inform, motivate, and help manage careers across engineering disciplines and sectors. This must include reskilling those sections of the workforce carrying out low-added value repetitive tasks that can be carried out by machines as well as ensuring there are more opportunities for non-engineers to enter STEM careers later in life with targeted support such as bursaries,

Figure 3: Survey question 'What are the main obstacles to your organisation training/ educating its workforce?'



scholarships for foundation programmes and/or degree 'conversion' courses.

In the future, it will be increasingly important for engineering to be able to import skills and expertise through conversion courses for those who were previously on a parallel career track. Professional engineering bodies will have an important role to play in considering how to ensure that standards and competencies are met.

As part of our survey of the engineering profession, we asked about the main barriers to their organisation training and educating its workforce (see Figure 3). The majority of obstacles were categorised as financial (lack of money to spend on development versus the cost of training) and time-related (constraints in giving individuals time to train or the lack of flexibility in when training is available) though the risk of investing in training employees only to have them 'poached' by another organisation who would then reap the benefits of the first company's investment was also noted.

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PILLAR 3

Upgrading infrastructure

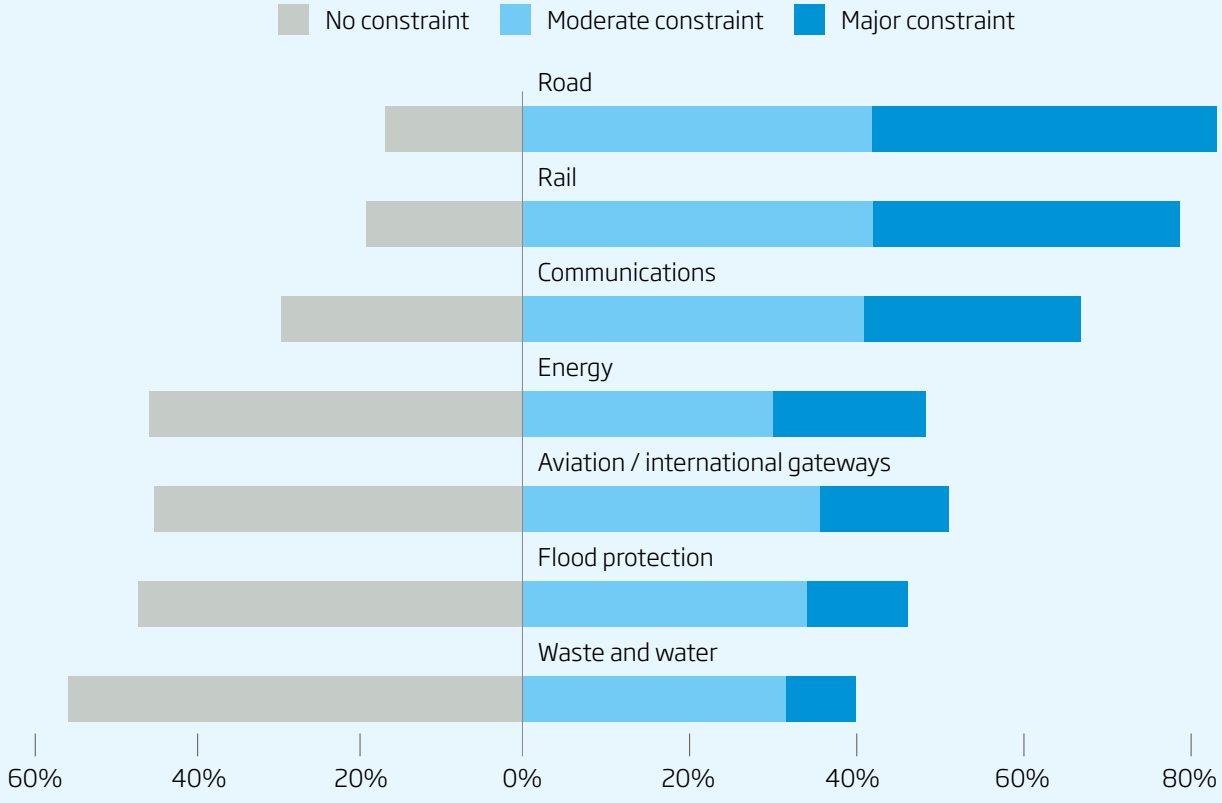
Private investment in infrastructure (Q15)

Between 2010–11 and 2014–15, an average of £49 billion per year from a combination of public and private sources was invested in infrastructure. While undoubtedly commendable, this is likely to fall short of the OECD recommended target of £80 billion per year by 2020–21[48].

The importance of infrastructure, in particular transport, came through clearly in response to the survey question 'To what extent do the following types of infrastructure constrain economic growth in your region?', with 81% of respondents citing 'rail' and 84% citing 'road' as constraints (see Figure 4). In addition, 60% of respondents said they thought that government should be involved in supporting private sector infrastructure investment, while only 15% said they should not and 25% did not know. Similar opinions were expressed at all the regional and home nation workshops, with local transport infrastructure being singled out as a major issue. Energy was also highlighted as an important national infrastructure: issues relating to energy are considered in Pillar 7.

We welcome the 2016 Autumn Statement announcements on infrastructure investment, such as the National Productivity Investment Fund and the Housing Infrastructure Fund[49]. Studies have estimated that, when spent as part

Figure 4: Survey question 'To what extent do the following types of infrastructure constrain economic growth in your region?'



48 *Guardian* (2017) 'Old, overcrowded and underfunded: it is time to overhaul our railways'
49 HM Treasury (2016) 'Autumn Statement 2016: some of the things we've announced'

of a major infrastructure investment, every £1 invested by government sees £3.20 returned through increased GDP, resulting in increased employment of up to 108,000 net jobs a year[50].

3.1 As part of the industrial strategy, government must as a minimum maintain the current level of infrastructure funding and incentives.

In the UK, the majority of development and operation of infrastructure is by the private sector. Private funding accounts for about 50% of the total planned investment between 2016-17 and 2020-21, with 43% coming from the public sector; a mix of public and private money funds the remainder[51]. With this level of investment, the private sector's knowledge and expertise – for example in risk management and contracting – should be used to ensure that projects are delivered on time and budget. A good example of innovation in delivering the UK's infrastructure that will produce better outcomes and reduce waste is provided by the Infrastructure Client Group/ICE Project 13[52].

Funding and revenue models

Private investment in regulated sectors – energy, communications, and to a lesser extent, water – derive the majority of their revenue from user charging. Households and businesses have become accustomed to this method and while there are some issues around affordability, in general, the system is accepted[53]. However, there are other sectors where the principle of 'user pays' has struggled to gain traction. For example, road user charging is rarely applied; the technology exists for its implementation on UK roads (and its subsequent role in demand management) but popular and political acceptance has yet to be gained[54].

Funding for infrastructure at the local and regional level is expected to remain constrained in the near-to-medium term. Therefore, while bearing in mind the need for value for money, new financing streams will be required to deliver growth through infrastructure. Some innovative financing schemes are already being put in place, for example, through issuing of municipal and green bonds, pooling of business rates[55], 'earn back'[56] and non-profit distributing programmes[57].

3.2 All local and combined authorities, and sub-national transport bodies should have access to flexible financing options such as municipal bonds and 'earn back' for infrastructure development.

This will help give a clear, long-term outlook to potential investors and reduce the industry's cyclical fluctuations.

Opportunities exist among local and regional projects to accelerate delivery but this potentially risks coming at the costs of inefficiency and reduction in value for money.

3.3 Strategic bundling of smaller schemes combined with incentivised partnerships across public and private sectors would support both efficient delivery, value for money and potentially attract financing from large institutional investors.

At the national level, the National Infrastructure and Construction Pipeline (NICP) and the National Infrastructure Delivery Plan (NIDP) have provided investors with a forward view of upcoming programmes and projects. This long-term approach is welcome as it reduces exposure to stop-start investment issues.

> "Digital infrastructure is as important to business as physical infrastructure, and the industrial strategy should recognise this."
>
> **Dr Mike Lynch OBE DL FREng FRS MIET, Founder, Invoke Capital Partners**

50 Verco/Cambridge Econometrics (2014) 'Building the Future: The economic and fiscal impacts of making homes energy efficient'
51 House of Commons Library (2017) 'Infrastructure policies and investment'
52 ICE (2016) 'From Transactions to Enterprises'
53 ICE (2016) 'National Needs Assessment - A Vision for UK Infrastructure'
54 ICE (2016) 'National Needs Assessment - A Vision for UK Infrastructure'
55 ICE (2016) State of the Nation: Devolution
56 Centre for Cities (2012) 'City Deal #2 - Manchester earning back tax'
57 Scottish Futures Trust (2017) 'Non-Profit Distributing (NPD)'

3.4 It is vital that the long-term approach in the National Infrastructure Delivery Plan is continued after the UK leaves the EU to provide an element of certainty to investors.

With regard to digital infrastructure, recent policy announcements by government such as the £100 million a year for the Digital Infrastructure Investment Fund[58] in tandem with a renewed commitment to provide world-class digital infrastructure[59], are encouraging. Continued investment in digital infrastructure should spread benefits across the country, increasing productivity and bolstering the economy. This is highlighted by the UK *Broadband Impact Study*[60], which estimated that the availability and take-up of faster broadband speeds will add £17 billion to the UK's annual gross value added (GVA) by 2024. These interventions are projected to return approximately £20 in net economic impact for every £1 of public investment.

> "Improving infrastructure brings many social as well as economic benefits to communities."
>
> **Dervilla Mitchell CBE FREng FICE, Director, Arup**

Among the larger projects, there are several that are at advanced stages of planning but require timely decisions, for example on marine energy and high speed rail.

3.5 The promotion and development of nationally strategic energy and transport projects should be accelerated to increase UK sustainability and productivity.

In turn, such developments would attract the skills, resources and capital required to deliver future projects.

Leaving the EU has the potential – at least in the short term – to reduce levels of investment in infrastructure. One element that will need to be addressed early in negotiations is the UK's status with the European Investment Bank (EIB). The EIB invested €29 billion between 2011 and 2015, acting as an anchor investor mostly in infrastructure projects. Receiving funds from the EIB is not contingent on being an EU member state but being a shareholder in the bank is and shareholders receive the vast majority of investment. In preparation for the possibility of loss of UK shareholding, the government should start consulting with industry now on alternative options for filling this gap in the investment mix. This should include the potential for a UK investment bank to replace EIB funding for future infrastructure projects.

3.6 To ensure continued development of large infrastructure projects, it is essential that the UK's status with the European Investment Bank is addressed early in negotiations for leaving the EU.

Incorporating local needs in national UK infrastructure policy (Q16)

We consider that it would be desirable to devolve many aspects of local infrastructure needs. Infrastructure decisions are already largely devolved in many parts of the UK, and even in England it is devolved to city and region level. Devolution of powers can help rebalance the UK's economy – vital at a time when there is still great disparity between the economic performance of the South East of England and much of the rest of the country. However, local decisions will still need to be aligned to national policy and efforts made to ensure consistency across regions.

In London and more recently in Greater Manchester, programmes of devolution with greater policy focus, investment and decision-making have shown how locating power closer to those it affects can lead to economic growth and prosperity[61]. Of our survey respondents, 38% thought that such initiatives would improve infrastructure provision, double the number of those who thought it would not (19%). A further 43% responded 'don't know', reflecting that it is still early days in the development of these initiatives.

In its *2016 State of the Nation: Devolution* report[62], ICE recommended that regional infrastructure strategies should be developed to identify infrastructure need and the skills requirement for their delivery.

The regional infrastructure strategies' aim should be to determine ongoing infrastructure needs to coincide with aspirations to build

58 HM Treasury (2016) 'Autumn Statement 2016'
59 DCMS (2017) 'Connectivity - building world-class digital infrastructure for the UK'
60 DCMS (2013) 'UK Broadband Impact Study'
61 Centre for Cities (2016) 'The next London mayor can be a global ambassador for all UK cities' and University of Manchester (2015) 'On Devo'
62 ICE (2016) State of the Nation: Devolution

major new economic regions. In each region, key stakeholders should come together in forums to develop regional infrastructure strategies on a cross-sector basis. While they should have regard to the NIC's work, they should not duplicate it, but focus on appropriate regional infrastructure for delivery by bodies including combined authorities, sub-national transport bodies and local councils.

The strategies would highlight key infrastructure challenges, economic, environmental and social benefits, and provide potential investors with a degree of certainty around future planning and development within the region. The Midlands Engine Strategy[63], with its partnership of key stakeholders and its industry board that links it to central government at a ministerial level, provides a potential model[64] (see response to Q 36).

3.7 Regional infrastructure strategies should be developed across the country. The Midlands Engine Strategy provides a good, early example for other to follow.

The National Infrastructure Commission (NIC) is well-placed to develop a 'system-of-systems' view of infrastructure planning and delivery and this is vital for ensuring the UK's infrastructure is sustainable and resilient[65]. The challenge will be to ensure that national and regional decision-making is joined up.

Improving performance against international benchmarks; ensuring the skills and supply chain (Q17)

One of the roles of the Infrastructure and Projects Authority is to consider how to measure the performance of infrastructure. The UK has world-leading infrastructure and engineering capacity but, to improve the UK's performance against international benchmarks, there is a need to enable a whole life approach to infrastructure investment, ensuring that maintenance spending does not fall behind the level necessary.

Maintaining and operating existing infrastructure at highly resilient levels is vital. It is critical to focus on improving the resilience, security and reliability of existing infrastructure, as much as new infrastructure. Reuse or repurposing of existing assets will in many cases carry lower financial, social and environmental costs – including impacts on CO_2 emissions, air quality, noise, destruction and fragmentation of habitats and visual impact – than provision of new.

Non-infrastructure approaches should also be considered. Infrastructure is only one possible solution out of many for achieving the desired outcomes for the UK. It is necessary to ascertain where infrastructure, alongside other interventions, can play its part in achieving the outcomes of the industrial strategy. Understanding the interdependencies between this pillar and other pillars of the industrial strategy is therefore vital.

Achieving growth through the infrastructure agenda set out in the *Fixing the Foundations* productivity plan[66], and more recently in the National Productivity Investment Fund[67], will require improved skills provision: there is little sense in planning new railways or power stations if there is not a trained workforce to build and maintain them.

Energy, water, flood risk management, transport and digital all have capital infrastructure programmes that reach to 2020 and beyond.

3.8 To address shortfalls in maintenance spending, which tends to operate on annualised budgets, we recommend that all sectors should adopt a total expenditure method (TOTEX).

As set out in the ICE's *2017 State of the Nation: Digital Transformation* report, adopting TOTEX will allow industry to begin to make risk-based interventions other than capital replacement, such as extending the life of an asset.

3.9 Regulatory frameworks across all infrastructure sectors should incentivise whole life investment decisions based on outcomes for the end user. It would enable the consideration of 'value' beyond cost, effectively redefining 'value' in the industry.

63 DCLG (2017) 'Midlands Engine Strategy'
64 DCLG (2017) 'Midlands Engine Strategy'
65 Royal Academy of Engineering (February 2017), *Response to the NIC's National Infrastructure Assessment's call for evidence*.
66 HM Treasury (2015) 'Fixing the Foundations'
67 HM Treasury (2016) 'Autumn Statement 2016: some of the things we've announced'

Local skills

Major infrastructure projects have been shown to be effective incubators for both innovation and upskilling the workforce, and the government should consider how this can be further encouraged. For example, Crossrail has implemented a shared innovation scheme, I3P-17[68] with supply-chain partners, which created an incentive to innovate and the potential for shared gains. Successes in publicly funded projects can demonstrate the benefits of innovation investment, educate decision-makers and create a skills and evidence base to support future decisions[69].

3.10 The UK should be training and equipping local populations to compete for new opportunities in building local infrastructure.

Examples of this approach include the Tunnelling and Underground Construction Academy (TUCA)[70], which is a purpose-built facility providing training in the key skills required to work in tunnel excavation and underground construction. TUCA is training the engineers required to deliver Crossrail 2, the Thames Tideway Tunnel and High Speed Two.

In terms of the supply chain, there is an issue with economic infrastructure sectors being typically viewed in isolation. The result has been organisations operating in silos and frequently uncoordinated decision-making. This means that the interdependencies between infrastructure sectors have not been properly accounted for. That is problematic because each infrastructure network makes significant demands upon others – for example requiring energy and digital communications infrastructure. The most catastrophic consequences occur when failure propagates from one infrastructure network to others.

Digital

Digital infrastructure policies will become more important to the UK outside the EU since, to a greater extent than it is now, our capability will be benchmarked against other European countries. The European Commission's Digital Economy and Society Index 2017 ranks the UK as seventh, slipping down one position from 2016[71]. The UK is rated as part of a group of countries that are 'lagging ahead', scoring above the EU average but whose development is now very slow, and as such is lagging in comparison to the progress of the EU as a whole.

Digital transformation offers an opportunity to improve the performance of infrastructure – both existing and new – using digital techniques and technologies including data analytics, digital modelling and design, the internet of things and artificial intelligence alongside advanced digital connectivity[72]. The UK needs high-speed, pervasive, ubiquitous broadband access throughout the country (see also Pillar 9/10) in order to allow the resilient and high-speed transfer of large volumes of data from sensors embedded in infrastructure and other devices.

Sharing of data between different infrastructure sectors will be key in maximising performance and ensuring resilience[73,74]. Data sharing between infrastructure operators and consumers will enable new business models such as 'mobility as a service'. Release of infrastructure data would facilitate research and innovation by third parties. The UK will need to build on its considerable existing capabilities in multidisciplinary innovation around data by addressing barriers that otherwise might reduce the UK's international competitiveness in this field, including the need to ensure that data sharing and the operation of data-driven systems can occur across international, as well as sectoral and organisational boundaries[75].

3.11 Digital delivery and smart infrastructure solutions should be embedded across all economic and social infrastructure. Digital strategies should accompany all major infrastructure projects.

68 RailStaff (2017) 'Crossrail Innovation – The Future?'
69 ICE (2017) 'State of the Nation: Digital Transformation'
70 TUCA
71 European Commission (2017) 'The Digital Economy and Society Index'
72 Royal Academy of Engineering and IET (2015), *Connecting data: driving productivity and innovation*, www.raeng.org.uk/connectingdata
73 ICE (2017) 'State of the Nation: Digital Transformation'
74 Royal Academy of Engineering (February 2017), *Response to the NIC's National Infrastructure Assessment's call for evidence*
75 Ibid

This will not only bring benefits to end-users, but also realise the UK's potential as a world leader in this sector. Digital transformation, which includes digital delivery and smart infrastructure, is a more cost-effective way of adding value to infrastructure than traditional approaches. This is as true of retrofit as it is of new build. Physical enhancements of existing infrastructure generally add 'more of the same', while digital enhancements can transform them[76].

[76] Cambridge Centre for Smart Infrastructure and Construction (2016) 'Smart Infrastructure'

PILLAR 4

Supporting businesses to start and grow

> "New engineering businesses owe it to themselves to find out about the opportunities at national, international but also, importantly, at regional level. A job for the industrial strategy is to signpost better what there is as well as creating new support initiatives."
>
> **Ian Shott CBE FREng FIChemE, MD, Shott Consulting**

Longer-term investment [Q18-19]

Long-term investments, where quick returns are not expected by investors, are of particular importance to the engineering sector. Such funding enables companies to embark on ambitious projects, often to address complex challenges, and helps to address the scale-up challenge (see response to Q22). In addition, a shortage of long-term patient capital has been identified by many experts as a barrier to the ability of UK companies to innovate[77]. Our survey of the engineering community shows that just under half of respondents recorded 'poor' or 'very poor', when asked how well patient capital investment currently supports the growth of UK engineering businesses[78]. The survey also indicated that the performance of patient capital investment was a particular concern for the North East, East Midlands, South West and Scotland, where a greater number of respondents selected 'poor' or 'very poor'.

The recently announced Patient Capital Review is therefore timely. The review will need to give consideration to the different long-term investment requirements of businesses with different characteristics. For example, the needs and returns on investment of an equipment and energy intensive high-value manufacturing company are likely to differ significantly from those of an app-based company.

In general, the investment structure in the UK is perceived to be quite short-term in nature, with many funds structured so that returns on investments are expected in seven to ten years. In addition, there is an expectation that companies will progress through multiple, different funding stages as they grow. At the transition between each stage, there is often an opportunity for investors to see a return on their investment as part of the refinancing process. It could therefore be perceived that there is an incentive for fund managers to support refinancing, potentially to the detriment of the company. Furthermore, the refinancing and transition process can be quite challenging and destabilising for the company and its investors, as a result of changes in board membership, company strategy and other factors.

The creation of the independent Business Growth Fund (BGF) in 2011 has made a significant impact on the UK's investment landscape and demonstrates that the UK has potential investees with sufficient ambition to warrant the provision of long-term patient capital. The government's intention to support the continued expansion of the BGF is to be welcomed.

The British Business Bank (BBB) has made significant investments in a number of growth finance funds and lenders in the UK scale-up sector. Such efforts by the BBB should see a significant uplift, with the government announcing an additional £400 million investment in the BBB to catalyse later stage venture capital investments by the private sector in the Autumn Statement 2016.

4.1 Government should continue and increase its collaborative working with existing financial institutions, as is already done by the BBB, to expand the portfolio of incentives to increase long-term investment by the private sector.

Government incentives can be highly effective mechanisms for influencing investors' behaviours. For example, the Seed Enterprise Investment Scheme (SEIS) introduced in 2012, Entrepreneurs' Relief introduced in 2008, and Enterprise Capital Funds (ECF) have all made significant contributions to improving access to equity investments. However, the majority of tax incentives relating to investment do not incentivise long-term investment. For example, with SEIS and the Enterprise Investment Scheme (EIS) shares only need to have been held for three years to qualify, rising to a five-year minimum for tax incentives relating to Venture Capital Trusts (VCTs); while other tax incentives, such as Entrepreneurs' Relief, return rewards to the investor at the time of business disposal. The engineering community strongly supports the continuation of these schemes, especially as stability and longevity of support is important to

77 Credit and the crisis, Access to finance for innovative small firms since the recession, Lee, Sameen & Martin, Big Innovation Centre, 2013; Investing for Prosperity, Aghion et al., LSE Growth Commission, 2013; and House of Commons Science and Technology Committee, Bridging the valley of death; improving the commercialisation of research, 2013.

78 Excluding the 65% of respondents who answered 'don't know'.

enable investors and businesses to make long-term decisions. Government should, in addition, look to develop additional tax incentives that incentivise long-term investments, for example by focusing rewards on revenue generation. Suggestions have also been raised that the limits on the amount that can be invested, which currently stand at £1 million for EIS and £100,000 for SEIS, should be increased.

4.2 Government should revisit the limits on the amounts that can be invested under the popular Seed Enterprise Investment Scheme (SEIS), Enterprise Investment Scheme (EIS) and Venture Capital Trusts (VCTs), as well as developing additional tax incentives that stimulate longer-term investments.

Large companies, through engagement with, and investment in, small and startup firms can have a significant support role. Such corporate venture capital investments can be of particular importance to relatively high-risk engineering and industrial based startups, which may find it difficult to access finance otherwise. However, it is important to ensure that any resulting requirements imposed on the investee to change accounting practices or changes to eligibility of tax relief do not act as a disproportionate disincentive for participation by SMEs[79].

Equity capital outside London and the South East [Q20]

The provision of equity capital needs to be considered alongside other factors that influence the ability of businesses to start and grow across the UK. Ecosystems, with a critical mass of players who are all connected, are required to increase the number of companies that can be created and grown to scale. Such ecosystems depend on the presence of a range of individuals and organisations, including entrepreneurs, investors, mentors and a skilled workforce, as well as universities, established companies and research and innovation organisations.

The quality of the infrastructure is also likely to have an impact on the success of the ecosystem, especially transport links and digital connectivity. London is a globally competitive ecosystem, ranking third out of 20 global startup ecosystems[80]. While other cities including Edinburgh, Cambridge and Oxford are considered to have good startup ecosystems, there are opportunities for improvement across the UK.

To help catalyse the uptake of equity capital outside London and the South East, the whole startup ecosystem needs to be supported and encouraged. In several regions across the UK, there are already many of the ecosystem components in place, but enhanced interactions between the individuals and organisations present are needed to improve connections and to help the ecosystem act as a whole. A similar theme emerged from the engineering community in response to identifying ways that the commercialisation of ideas could be improved (see *Catalysing Connections* in Pillar 1 for more detail).

4.3 Government should work with the private sector and organisations such as the UK Business Angels' Association (UKBAA) and the British Private Equity and Venture Capital Association (BVCA) to facilitate an increase in the breadth and range of connection opportunities for investors outside London and the South East.

Although it is clear that the supply of equity finance is concentrated in London and the South East, some suggest that this perception is exacerbated by insufficient exposure and underreporting of equity deals beyond the region. Increased visibility of successful equity investments, investors and investable propositions will demonstrate to investors and companies across the UK the opportunities available beyond London and the South East and contribute to building up regional ecosystems. Increased visibility of the opportunities available may also help to encourage the creation of new angel investors.

> "Being a member of the Royal Academy of Engineering's Enterprise Hub has given me access to great people, networks and ideas and brilliant mentors. This level of support should be extended to many more good startup companies around the country."
>
> **Dr Katerina Spranger, CEO, Oxford Heartbeat**

79 Royal Academy of Engineering's submission to the BIS select committee's Access to Finance inquiry, 2016; The Missing Piece, James Clark, BVCA, 2013

80 Start-up ecosystems 2017

4.4 Government, in partnership with organisations such as LEPs, growth hubs, Catapults and universities, should promote the investment opportunities and investment successes across the whole of the UK.

It has been suggested that there is a need to increase businesses' awareness of what equity capital is and how it could contribute to the growth and development of their business. Evidence from the engineering community suggests that there is a need for considerable improvement in the availability and uptake of business and management skills training across the UK. Such training should include discussion of the various financing options available to growing businesses. Business skills are discussed further under Q22.

4.5 In regions where equity uptake is regarded to be especially low, training for entrepreneurs and business leaders should include an emphasis on the opportunities that equity capital investments present.

4.6 To further maximise the impact of EIS and SEIS, government should undertake targeted regional promotion of the schemes to both potential investors and eligible companies.

Public sector investments are able to leverage substantial private sector investment through co-investment requirements. The Angel CoFund is one such example of government leveraging private sector investment to increase equity capital.

4.7 Government should consider creating co-investment funds which target specific regions or sectors to catalyse the uptake of equity capital beyond the South East.

New funding opportunities [Q21]

New funding opportunities cover a wide variety of new financing models that have arisen outside traditional financial institutions. Peer-to-peer lending (debt financing), equity-based crowd-funding and invoice trading are perceived to be the most relevant in relation to the engineering community.

It has been suggested that the increase in alternative finance has also had a wider impact on behaviours, such as encouraging entrepreneurs and companies to present their enterprises in an accessible and compelling way to non-specialist audiences with greater confidence, which is to be welcomed.

Given the dramatic growth seen in the alternative finance sector, it is clear that many investors and investees have confidence in the system. However, despite the introduction of regulation of crowd-funding and peer-to-peer lending, reservations remain that there is not sufficient protection for inexperienced investors, nor sufficient awareness by companies of potential downstream implications.

The perception in the engineering community is that alternative finance models are particularly useful for modest propositions that are quite close to market. However, alternative finance models are unlikely to be suitable for larger-scale engineering activities, which will require longer development timescales and large amounts of capital, such as in manufacturing and the energy sector.

Scale-up challenge [Q22]

The UK has long faced a perceived challenge in scaling up startups, particularly in comparison with the USA. Anecdotal evidence suggests that many UK companies go overseas to access suitable growth and scale-up funding, often resulting in the relocation of their headquarters, with the west coast of the USA one of the most common destinations[81]. However, the lack of data collection on the relocation of companies' headquarters or R&D operations makes it difficult to ascertain the extent to which the UK may be losing successful home grown companies. Startups that grow to scale following acquisition by large corporates or through foreign direct investment yet which retain their operations in the UK, present further nuances to the scale-up challenge.

Scale-up is generally understood to mean rapid growth, whether through job creation or turnover. Typically, the OECD definition of 'an enterprise with average annual growth in employees or in turnover greater than 20% a year over a three-year period, and with 10 or more employees at the beginning of the observation period' is used. However, caution should be exercised when using a strict definition, as there is a risk that the full picture of

> "The nation's productivity can improve by raising performance across multiple companies sector by sector as well as through the big, game-changing innovations. The strategy needs to inspire ambition and aspirational performance across all companies, whatever their size."
>
> **Dr Scott Steedman CBE FREng FICE FInstRE, Director of Standards, BSI**

81 The Scale-Up Report, Sherry Coutu, 2014

growth opportunities in the UK is not captured, such as high-growth companies with fewer than 10 employees. Furthermore, it is important to track and understand the outcomes of those scale-up companies after their three-year period of rapid growth: what, for example, are their longer-term survival rates?

Although there is no one clear reason why the UK struggles to grow its businesses to scale as well as its competitor countries, there is a broad consensus in the engineering community that a number of interlinked factors are involved: scale of ambition, business skills and access to finance.

Scale of ambition and global vision

There is a perception that one of the contributing factors to the UK's scale-up challenge is the fact that UK business owners have relatively modest growth goals for their businesses. Founders may lack sufficient ambition, and be either willing to exit and dispose of their business before scale-up is achieved, or not wish to scale-up in the first place. In addition, some commentators suggest that UK entrepreneurs lack the global vision needed to understand how international markets and opportunities can shape business models from the outset.

4.8 Business owners who have successfully scaled up and who have founded companies that are 'born global' should be promoted as role models, and their stories used as case studies to inspire and educate the next generation of companies with scale-up potential.

The role models and case studies should be recent examples and should be drawn from all different types of businesses across the UK. For the case studies to have maximum impact, they should be honest accounts about the challenges faced and how these were overcome, as well as highlighting the positive outcomes that scaling up has created.

While the use of case studies and role models should help to inspire the next generation of companies with potential for rapid growth, more detailed information is needed to help educate UK businesses about what rapid growth entails and how it can be achieved.

Business skills

The Green Paper's recognition that limited access to skills, particularly leadership and management skills, is a factor reducing the ability of UK companies to achieve ambitious growth goals, aligns with the view of the engineering community. Therefore, one way to help businesses to scale up and achieve greater growth is to ensure that they have easy access to quality expert advice and practically focused business and management skills training opportunities. Evidence shows that expert advice and business skills training can have positive impacts on businesses, including on job creation and increasing turnover[82]. Unfortunately, there is a perception that recent government interventions have prioritised quantity to the potential detriment of quality. There are growing numbers of private and charitable initiatives providing high-quality business support that are starting to bear fruit. Government should learn from these and partner with them where appropriate.

The introduction of the Small Business Charter (SBC) is a good way to signal quality to prospective businesses. The SBC awards chartered status to business schools in the UK that play an effective role in supporting small businesses, local economies and student entrepreneurship, following rigorous assessment.

4.9 Government should explore ways to incentivise companies to take up high-quality training opportunities. Learning, both positive and negative, should be taken on board from such schemes as the Growth Vouchers Programme pilot[83].

Identifying new customers and marketing products and services accordingly are critical success factors for a company seeking to scale up and grow. The transition from startup to scale-up requires new skills sets, including those linked to marketing and sales. Without such skills, regardless of how good the product or service is, the business will struggle to grow.

4.10 Skills training and advice targeted at companies with scale-up potential should include a focus on marketing skills and approaches to sales.

82 Building Small Business Britain, Goldman Sachs, 10,000 Small Businesses, 2016
83 Growth Vouchers programme evaluation: cohort 1, effect at 6 months, BIS 2016

Providing business skills and entrepreneurship training as part of further and higher education also has the potential to reduce the scale-up challenge. Early education in business skills and entrepreneurship may contribute to a shift in cultural mindset to increase the scale of ambition as well as embedding skills for good business practice from business formation. (See Pillar 1 and Pillar 2 for further details).

Non-executive directors, investors, peers and mentors can all be important sources of advice. They can help business owners build valuable networks, including management teams and provide significant business advice, often drawing on substantial first-hand experience. The government's intention to work with relevant stakeholders, including universities, business schools, business bodies, associations and the private sector to build peer-to-peer business networks specifically for fast-growing firms is to be welcomed. However, such networks are likely to bring significant benefits to businesses at all stages of growth and should not just be limited to fast-growing firms. In addition, for businesses to fully understand the valuable role that non-executive directors and investors can play in providing business advice, this topic should be included in business skills training and highlighted in case studies where relevant.

Accessibility and awareness

One of the greatest challenges is to make companies, especially those that have not previously engaged with public support mechanisms, aware of the support that is available to them. With hundreds of publicly funded schemes to support businesses, many of which are targeted at specific industry sectors or locations, there is a clear need for simplification and a relatively simple port of call for businesses, especially SMEs, to find out about the support available to them.

Government-led provision of business support and advice has undergone multiple changes in recent years, including the closure of the British Growth Service (BGS) in 2015. Such restructuring and changes in provision, at least in the short term, make it additionally challenging for businesses, especially SMEs, to keep up-to-date with available options.

Regional organisations have a key role in making their communities aware of what support is available. Scottish Enterprise has been repeatedly cited as an exemplar of what an organisation in a defined region, which has benefited from consistency and longevity, can accomplish. In England, since May 2016, there has been a network of growth hubs, which are local public private sector partnerships, led by LEPs, to join up national and local business support and are intended to act as regional one-stop-shops for growing companies seeking advice and support. Growth hubs are at a relatively early stage of their development, so it is not yet clear how successful they are. However, our survey indicates that the awareness of both growth hubs and LEPs is very low, with 51% and 44% of respondents unaware of growth hubs and LEPs respectively. In comparison, the rate of awareness was considerably higher for local business associations such as Chambers of Commerce, or entrepreneur networks, with only 26% of respondents unaware of their support.

4.11 Efforts are still needed to increase the profile of growth hubs and the support they coordinate and provide.

It is clear that significant and urgent action is needed to help increase awareness among businesses, especially SMEs, of the support available to them. This support includes business skills and training, but also fiscal incentives for which they may be eligible, such as R&D tax credits and the Patent Box (see Pillar 1).

4.12 To ensure that any government's marketing and promotion activities reach their target audience, research should be undertaken into the most effective marketing channels for SMEs, taking into account regional and sectoral dimensions.

In addition, consideration should be given to promoting public support initiatives through channels that SMEs already use. For example, government should work with banks, utilising their very visible presence across the whole of the UK to help promote relevant support to their customers. Other possibilities include providing links or information pop-ups when SMEs are interacting with the HMRC, for example when filing a tax return, or with Companies House, for example when registering a company.

Smart use of government-held data has the potential to allow government to offer bespoke and targeted support to companies. Government's new commitment to explore how data such as that held by HMRC and Companies House can be used to identify scale-up businesses to enable the efficient offer of business growth support (in cooperation with the Behavioural Insights Team and the Scale Up Institute) is to be commended. Such an approach

should use a broad definition of scale-up to ensure maximum impact.

Access to finance

There is a broad consensus across the engineering community that it becomes harder to access finance as companies progress along the investment spectrum, with particular challenges encountered at the growth and later scale-up stages. Frequently, the requirement for relatively short-term returns of many investment funds does not align with the long-term goals of engineering companies wishing to grow. Issues relating to long-term investment decisions have already been discussed (see Q 19).

There is a perception in the engineering community that innovative companies, often based on advanced technologies, face greater challenges when seeking finance because investors with little knowledge of, or experience in, advanced technology and engineering consider them to be riskier investments than they may be in reality. Positive results should arise from increasing the opportunities for businesses to connect with investors to allow innovators to present their ideas and facilitate investors' ability to understand new techniques, technologies and innovative business models (see Pillar 1). The use of case studies about engineering and technology companies that have grown to scale in the UK may also help investors see the opportunities and growth potential of such companies.

Floating a company on a public market, which is typically regarded as an activity that a highly successful company should undertake, is not necessarily the most appropriate or appealing proposition for high-growth technology companies. Given that many such technology companies are funded through equity investments, those investors often wish to retain their stakes, yet flotation on the London Stock Exchange (LSE) requires a minimum free float of 25%. Despite the introduction of the Higher Growth Segment in 2013, which requires only a minimum free float of 10%, and is intended to assist companies with the longer term aspiration of joining the main market, there has not been substantial uptake. Moreover, flotation on the US NASDAQ stock exchange is often considered to be a more favourable option by technology companies, as it is perceived that the valuation is more sophisticated. Given the apparent lack of appetite of high growth technology companies to float on public markets, innovative approaches may be required to help successful large technology companies continue to access capital for their growth.

4.13 Further research should be undertaken to understand why the Higher Growth Segment has not had substantial uptake and to explore how the perceived advantages of the US NASDAQ can be drawn on to enhance UK opportunities.

For many businesses, accessing international markets is an essential part of their growth strategy. However, as has been recognised by government, it is not always an easy or simple process. This topic is addressed in Pillar 6.

Government backed financial guarantee schemes, if designed appropriately, can be used to support long-term investment loans by the private sector, by mitigating the associated risk – the German Kreditanstalt für Wiederaufbau is considered a successful example of this. The Enterprise Finance Guarantee (EFG), launched by the government in 2008, and overseen by the BBB, is intended to facilitate lending to viable businesses that have previously been refused debt financing. Concerns persist that the EFG may encourage lenders to seek liquidation earlier than is always necessary, although the government has refuted this[84].

4.14 Regular and comprehensive reporting on UK equity investment deals would be welcomed to help the government identify any funding gaps.

The challenge for government is then to put in place an overarching vision and a coherent, stable and strategic policy framework to ensure that access to finance is enabled across the spectrum of sectors, stages of development and location within the UK.

84 Government Support for Business, House of Commons Business, Innovation and Skills Committee, Eighth Report of Session 2014–15; Government response to Government Support for Business, 2015

PILLAR 5

Improving procurement

Supporting innovation through public procurement (Q23)

Public procurement has the potential to have a disproportionately transformative effect on UK companies; utilising only a small proportion of the procurement budget to target innovative approaches and SMEs could have a huge impact. While public procurement provides a crucial opportunity to stimulate innovation, the perception remains that public procurement decisions continue to prioritise low cost over best value, and risk aversion hinders the introduction of innovative solutions. Government needs to adopt the established best practice around intelligent procurement that will involve cultural change and a greater willingness to establish and accept an appropriate level of risk.

Government has a role in articulating to the public and the media – as well as to the public sector – that investment in innovation is a means of fuelling our future prosperity and that responsible risk-taking can deliver better value for the UK from procurement[85].

> "Government has a role in articulating the value of innovation in public procurement, and that responsible risk-taking in procurement can deliver better value."
>
> **Dr Peter Bonfield OBE FREng FIET FICE FIMMM HonFIStructE, CEO BRE**

5.1 Government should communicate a clear message to government departments, local authorities and other public sector procurers, as well as to the public and media, on the value of innovation and the importance of supporting innovation through procurement.

5.2 Government should consider how best to change the culture of risk aversion, to encourage government departments and other public bodies to embrace innovative solutions.

In response to the open-ended survey question, 'What are the top three actions that government could take to utilise procurement to more effectively support innovation?', 30% of respondents thought that government should improve the procurement process, for example by simplifying it, ensuring consistent processes within and across government departments, not changing track during the procurement process, or making reporting requirements less onerous. A quarter of respondents considered that government should find ways of encouraging innovation through incentivising or even requiring innovation in procurement bids, or not being prescriptive about technologies in the requirements. Other responses included ensuring better value (13%), supporting UK or local companies (13%), supporting new entrants or SMEs (12%), ensuring government officials involved in procurement have sufficient expertise (12%) and greater risk-taking by government (10%).

Improving SME access to the public sector marketplace

When asked specifically 'What are the top three things the government could do to support SMEs to successfully bid for procurement contracts?', the most frequently cited response was to simplify or streamline the procurement process and reduce bureaucracy (32%), followed by creating a level playing field for SMEs to bid alongside larger companies or even limiting certain bids to SMEs (29%) and providing support for SMEs through advice or training (23%).

SMEs represent 60% of all private sector employment in the UK[86], highlighting the importance of ensuring that they thrive. We welcome the government's target of 33% of procurement spending to reach SMEs by 2020. We support the recommended actions from the National Audit Office (NAO) report on the barriers facing SMEs in accessing the public sector marketplace in helping to achieve this target[87]. Success in achieving the target requires greater transparency of information on government spend both directly with SMEs and through supply chains. At present, as highlighted by the NAO report, there is poor data on the spend

85 Royal Academy of Engineering (May 2016), Submission to the *National Innovation Plan – Call for Ideas*, www.raeng.org.uk/publications/responses/national-innovation-plan-%e2%80%93-call-for-ideas

86 Department for Business, Energy and Industrial Strategy (October 2016), *Business population estimate for the UK and regions: 2016 statistical release*,

87 National Audit Office (March 2016), Government's spending with small and medium-sized enterprises, www.nao.org.uk/wp-content/uploads/2016/03/Governments-spending-with-small-and-medium-sizes-enterprises.pdf

with SMEs as a high proportion is via the system integrators and through the supply chain.

The productivity of smaller suppliers is directly affected by their position in the supply chain, and therefore supporting them to be able to work directly with public sector buyers will help them be more competitive, level the playing field and boost UK productivity. This will require an increase in the number of and spend on direct contracts with SMEs. It will be important to ensure that there is a simple and transparent mechanism by which to ensure that the supply chain places contracts with SMEs – it is not enough that they are named in a tender – and that there is clarity on the mechanism used if targets are not hit. Having SME representatives on the boards or steering groups of major projects could help ensure that their needs are taken into account at all levels and stages of major projects.

There is a need to capture the risk posed by SME suppliers in a transparent way – for all projects, as well as for those that are innovative – and the mitigation measures required. There are risks posed by existing larger suppliers, as well as those provided by smaller companies. Providing a fair and transparent way of capturing and managing risk will be important for project success for companies of all sizes.

5.3 Greater transparency and better data are needed for government procurement spend with SMEs, both directly and through supply chains.

Achieving broader economic and social benefits

We welcome the introduction of a 'balanced scorecard' approach[88] that allows the cost of a procurement project to be balanced against wider social and economic criteria. The balanced scorecard approach should be revisited to ensure that it enables a fair assessment of innovative companies and incentivises submissions that include significant innovations that demonstrate potential economic benefit. It will be important that the approach is simple and transparent in order for it to be workable, and to prevent it from becoming a further burden on the supply chain – in particular, SME suppliers – during bidding.

Procurement levers can have a positive influence on increasing opportunities for diverse and underrepresented groups. It is particularly important for public procurement where government's purchasing power and funding of key projects can influence supplier behaviour throughout the supply chain[89]. For example, HS2's diversity and inclusion requirements – both contractual and pre-contractual – have had a large influence on supplier behaviour and focus on this area[90]. Diversity and inclusion should be included as a priority in the balanced scorecard approach.

An engineering systems approach[91] could help ensure that the UK government's broader objectives for procurement – articulated in the balanced scorecard approach – are realised, by providing a means of identifying how the project interfaces with other policy agendas and brings broader benefits (see Box 3, page 12).

At a project level, a systems approach provides a holistic view of the overall project, so that the interactions and interdependencies of individual elements of the project are identified. These interdependencies might add value, or alternatively introduce vulnerabilities that could cause it to fail. For example, these might be physical interfaces such as regional boundaries in a rail system or supplier interfaces between two ICT systems.

> "Public procurement offers the potential to create levers that encourage greater focus on diversity and inclusion at all levels of the supply chain; embracing greater diversity yields benefits in productivity."
>
> **Dr Nelson Ogunshakin OBE FICE, President & CEO, Association for Consultancy & Engineering**

88 Crown Commercial Service (October 2016), *Procuring growth – balanced scorecard*, www.gov.uk/government/uploads/system/uploads/attachment_data/file/560247/Balanced_Scorecard_paper.pdf

89 Royal Academy of Engineering (February 2017), Diversity and Inclusion Leadership Group, action group on procurement, www.raeng.org.uk/publications/other/winter-2017-newsletter

90 High Speed Two (HS2) Limited (November 2015), *Equality, diversity and inclusion policy*, www.gov.uk/government/publications/hs2-equality-diversity-and-inclusion-policy

91 Royal Academy of Engineering (February 2014), *Public projects and procurement in the UK sharing experience and changing practice*, www.raeng.org.uk/publications/reports/public-projects-and-procurement-in-the-uk-sharing

5.4 Government should ensure the balanced scorecard approach used in procurement fully recognises the value of innovation, as well as diversity and inclusion.

5.5 Government should consider applying a systems engineering approach to ensure that the UK government's broader objectives for procurement are realised.

Private sector procurement practices

Private sector procurement practices, as well as practices in the public sector, need improving. Intermediaries – sometimes known as system integrators – may be used as gatekeepers between a large company or government department and SME suppliers, in order to oversee procurement of complex systems and provide technical expertise. This gatekeeper role should be as light touch and transparent as possible so that it does not create a barrier to effective procurement. There also needs to be good collaboration between technical buyers and the procurement team to enable better decision-making around risk, and better contracts.

Crossrail is a good example of how a large company can promote innovation through its supply chain. Leadership played a key role in setting the right culture for embracing innovation. The company developed an innovation strategy to improve the delivery of the project and create a legacy to improve the performance of the UK construction industry[92].

The procurement process

The procurement process itself can help to address the risks of procuring innovative projects. For example, a two-stage bidding process can allow for a more mature assessment to be made of risk, programme requirements and cost, leading to better understanding by both parties of the scope of the project and the apportionment of risk before committing to the project in full. In addition, contractors can then be remunerated for developing innovative ideas even if they do not go on to win the project contract[93]. Conversely, the procurement process should not itself provide barriers to achieving broader aims. For example, accounting requirements that SMEs are unlikely to be able to achieve should be avoided.

Alternative procurement processes that promote innovation are emerging, such as pre-commercial procurement processes where the public and private sector share the risks and benefits of innovation from the early stages of pre-commercial product development up to the stage where products are ready for commercialisation. One such example is the SILVER project[94], funded by the EU FP7, which explored how pre-commercial procurement processes could be used to find new robotics technologies for assisting elderly people.

Figure 5: Survey question 'How familiar are you with the Small Business Research Initiative (SBRI)?'

92 Crossrail Ltd (February 2013), Crossrail Innovation Strategy, http://learninglegacy.crossrail.co.uk/documents/innovation-strategy/

93 Royal Academy of Engineering (May 2016), Submission to the *National Innovation Plan – Call for Ideas.*

94 SILVER project, Supporting independent living for the elderly through robotics, www.silverpcp.eu/

Government should ensure that it learns from international best practice in procurement processes that would better support innovation.

Alongside supporting innovation, successful procurement practice comprises additional essential elements including strong leadership and vision, robust specification and planning, the involvement of intelligent clients, incentives to encourage the right behaviour and robust processes for managing risk[95].

5.6 In its new guidance for public buyers on how to drive innovation, government should include guidance on improving the procurement process to make it simpler, more consistent and on creating incentives for innovation in procurement. The guidance should also include best practice examples.

SBRI

We welcome the review of the UK SBRI. A first important step would be to raise the profile of SBRI and increase awareness of the scheme among target businesses. This is emphasised by answers to the survey question 'How familiar are you with the Small Business Research Initiative (SBRI)?': 82% of respondents were unaware of the scheme, 16% were aware of it and only 2% had directly participated in it (see Figure 5). The utilisation of SBRI has varied considerably between government departments and agencies, but the overall consensus is that SBRI has been significantly underutilised. Action needs to be taken to increase the use of SBRI across all appropriate government departments and agencies, including local or regional organisations. Government should consider providing incentives – financial or otherwise – to increase participation. SBRI should be promoted through the supply chains of large companies that already have contracts with government departments and agencies[96]. Consideration should be given to whether the name 'Small Business Research Initiative' satisfactorily reflects the nature of the scheme to the target audience of innovative businesses.

Access to the SBRI scheme would be improved if SMEs were given support to produce high quality proposals, and examples of best practice for successful projects were identified and disseminated. The involvement of the appropriate stakeholders at later stages of a successful project – including policymakers and others involved in developing enabling frameworks – would help in achieving successful commercialisation. Opportunities for companies and entrepreneurs to present innovative ideas to government departments and agencies would facilitate a better flow of ideas in both directions, as would more flexibility on the topics that are funded. A scheme that funds follow-on deployment of the technology for successful SBRI projects could be considered. Government should set minimum thresholds of SBRI participation for all FTSE 350 companies that are suppliers to the public sector.

More opportunities for collaboration between larger organisations and smaller, specialist organisations would be beneficial in making use of small organisations' deep knowledge to support the innovation. Furthermore, government should explore whether large companies already involved in public sector procurement could be incentivised to drive innovation in their supply chains as part of SBRI.

SBRI would benefit from robust management and auditing, and from clarity over leadership, ownership, funding and governance of the scheme. This would be delivered most effectively by assigning responsibility for the overall coordination and implementation of SBRI to a ministerial champion, as well as promoting its benefits. Government officials need relevant technical experience; schemes to help facilitate exchange of staff between industry and the civil service would be welcome.

5.7 A radical reboot of SBRI is required. At a minimum, government should mandate increased use of SBRI across all appropriate government departments and agencies, and ensure that those involved in the scheme have the sufficient skills and knowledge to be intelligent clients.

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95 Royal Academy of Engineering (February 2014), *Public projects and procurement in the UK sharing experience and changing practice*, www.raeng.org.uk/publications/reports/public-projects-and-procurement-in-the-uk-sharing

96 Royal Academy of Engineering (February 2017), *Review of the Small Business Research Initiative*, Submission to the Department of Business, Energy and Industrial Strategy.

Public procurement and the UK's exit from the EU

5.8 In the light of the EU referendum result and its implications for Regulations, Directives and other EU law currently applicable in the UK, a review is needed of public procurement and state aid rules as part of the industrial strategy.

Using public procurement to drive the industrial strategy in areas where government is the main client (Q24)

Local government procurement

Local authorities also have a role to play in procuring innovation projects and ensuring that technologies are at the core of local plans, with resulting social and economic benefits. The Mayor of London's *Smart London Plan* provides an example of a vision of how technology and innovation can both help the city as a whole to function better, and are used to better meet the needs of Londoners and businesses[97]. The London Datastore was one of the first platforms to make public data open and accessible, with the aim of catalysing citizen engagement, innovation and the development of new applications. Other examples include innovations in the transport system in London such as the congestion charging system and contactless payment systems.

A very early example of the use of an SBRI-type scheme by a local authority is Durham Smart County[98], an open innovation programme with Durham County Council working in partnership with health organisations, universities, community groups, and private companies. The programme aims to open up longstanding social challenges to new thinking, stimulating the development of innovative products and services to tackle health issues associated with social isolation. The funding is being managed under SBRI guidelines, but Durham County Council is possibly the first local authority to implement such a scheme, using its existing procurement processes to 'buy' innovation. Government must seek to assimilate learning from this experience and encourage wider adoption if successful.

The UK should create more opportunities for demonstrators and pilots to test and de-risk innovations. Such feasibility testing should also be used to build the public's faith in the innovation, for example to explore the use of data in the NHS.

5.9 Local authorities have a role to play in procuring innovation projects and ensuring that technologies are at the core of local plans, with resulting social and economic benefits. Local authorities and local government organisations should share best practice examples where the procurement process has encouraged innovation.

Procurement of innovative products in healthcare

The *Accelerated Access Review*[99] sets out recommendations on speeding up access to innovative medicines, medical technologies, diagnostics and digital products. The recommendations include an enhanced horizon-scanning process for the NHS, an Accelerated Access Pathway for strategically important, transformative products, a better process for assessing emerging technologies, incentives to accelerate the uptake of innovation by the NHS and an Accelerated Access Partnership. If implemented, these recommendations would bring benefits to patients and the NHS, and to the life sciences and medical technologies industries, and are thus welcome.

97 *Smart London Plan*, Using the creative power of new technologies to serve London and improve Londoners' lives

98 Business Durham, Durham Smart County, www.businessdurham.co.uk/innovation-in-county-durham/smart-county

99 Accelerated Access Review (October 2016), Accelerated Access Review – final report, www.gov.uk/government/publications/accelerated-access-review-final-report

PILLAR 6

Encouraging trade and inward investment

> A 21st century industrial strategy – embracing government, business and universities – will be an important plank in the government's plans to promote UK business in global markets. It should also be a key selling point in new trade deals with the rest of the world.
>
> **Sir John Parker GBE FREng FIET FIMAREST FRINA**

Government support for export (Q25)

Opportunities arising from exiting the EU

Of all the pillars in the industrial strategy, the inclusion of trade and inward investment offers the most tangible prospect of capitalising on the opportunities presented by leaving the EU. The UK also has an international leadership role in addressing key global challenges, encapsulated by the UN Sustainable Development Goals, which is reinforced and supported by its strengths in engineering and innovation. This international focus can harness the UK's global reputation for engineering excellence to forge a new global identity for Britain.

Britain's engineers, both individually and as organisations, are already a highly respected, highly mobile community, experienced and skilled at working with colleagues, customers and wider society all over the world. In this vein, the industrial strategy can be seen as a sign of government confidence and a vehicle to help propel the engineering industry forwards into new markets and to be even more ambitious.

However, this scale of ambition must not obscure the very real challenges ahead. With the triggering of Article 50, the UK faces uncertain times in terms of both the road to be navigated and the ultimate destination. Government has been clear in its aim to ensure that negotiations with the EU produce a bespoke agreement (rather than mirroring an existing 'off the shelf' model) and it is still unclear as to whether some sort of transitional deal will be necessary to avoid the disruptive 'cliff edge' that ministers have stated they are seeking to avoid. This inevitably constrains to some extent the ability of industry to plan for the possible outcome of negotiations. Consequently, a certain amount of disruption to business is inevitable, which underlines the critical importance of ensuring that government keeps clear lines of communication open with industry as it works through the legal, economic and diplomatic complexities of establishing a new relationship for the UK with the world.

Primary responsibility for these areas lies with the Department for International Trade (DIT), effectively a new department (albeit one that has inherited some already established operations). DIT will be exercising a function that UK government has not had for over four decades as EU member states sign trade deals as a bloc, negotiated and agreed by Brussels. This will require rapid building of capacity, capability and expertise in trade negotiations (communications, analytical and legal), building effective relationships across Whitehall and in-depth country knowledge. It will also mean learning to effectively navigate the corridors of power of the World Trade Organization in Geneva rather than Brussels.

The UK engineering community stands ready to build on our existing partnership with government to help inform and shape these negotiations so as to ensure the best possible outcome for the UK as a whole.

6.1 The government must use the industrial strategy to set an ambitious bold global vision for the UK as an outward looking leading trading nation and a top destination for inward investment and global talent via the UK's existing credentials as a leader in engineering, innovation and manufacturing.

Industry requirements to support trade

Survey responses and other consultation activities have made it apparent that industry is, on the whole, very enthusiastic about being asked how government can best support it in growing exports, while noting that this is the start of a dialogue around reshaping the UK's capabilities in the export sphere, rather than a one-off activity.

Survey respondents tended to have very clear views on the kind of support that would make a difference to their ability to export, with the three most popular answers being:

- Simplify bureaucracy around importing and exporting.
- Promote the UK both abroad via embassies, trade shows and delegations, and by hosting targeted trading partners in the UK to showcase the UK's potential.
- Provide companies with responsive, tailored market intelligence to help identify opportunities and market gaps and support

business planning, especially given the difficulty of 'moving targets' now that the negotiations for the UK to withdraw from the EU are underway.

Survey responses also emphasised that flexibility from government is essential as different organisations are at very different stages in terms of their readiness to start exporting. Some organisations suggested that they have already identified overseas target markets and the 'nudge' that they would find most useful lies in introductions and awareness raising in that particular country, for example via existing in-country links such as embassies and trade attachés.

It is understood that DIT is in the process of conducting trade audits for an initial tranche of countries. This is to be welcomed although, as with existing government support initiatives (for example increasing awareness and knowledge around UK Export Finance[100]), it is essential that these are communicated effectively. Survey respondents repeatedly pointed out that marketing and communications activities associated with the strategy are as significant as the content of the strategy itself. The strides that have to be made here in a relatively short period of time are demonstrated by the fact that only 9% of survey respondents had heard of the great.gov.uk website, launched in November 2016 with the specific remit of promoting British exports to the world.

This theme of ensuring that government intervention is targeted where industry has identified that it can most add value is mirrored in the concept of 'sector deals' (Pillar 8) where the concept of very specific additionality (as opposed to general cross-cutting themes) is what government would like to be presented with.

Other trends clearly coming through from the survey were the significant minority of survey responses, disproportionately from SME respondents, indicating that what they would be seeking from government would be the provision of some type of financial assistance (such as tax breaks to cover travel for trade purposes and export credit) to cover the risks they would be facing in seeking to diversify their business portfolio in this way. A more creative approach to problem solving here could entail a mentor service matching existing successful exporting firms with those looking to expand in this way.

However, this general call for a more active approach than government has traditionally played in this area has to be contrasted with some survey respondents who indicated that they wanted the government to 'not interfere'.

Other survey respondents noted the crossover with skills and highlighted that a successful transition for them into exporting requires the cultivation of skills perhaps not traditionally as valued in UK industry such as language and cultural awareness as well as the more obvious commercial awareness, legal analysis, trading, marketing and negotiation skills. The stated approach of DIT in assisting SMEs to help with at least part of this in terms of interpretation and navigation of trade agreements is welcome.

In terms of the countries and trading partners that survey respondents would prioritise for trade deals, the results were as follows:

- USA (25%)
- EU (25%)
- China (13%)
- India (9%)
- Australia (5%)
- Canada (4%)

Survey respondents were also enthusiastic about the 'ripple effect' of other benefits flowing from exporting (see Figure 6).

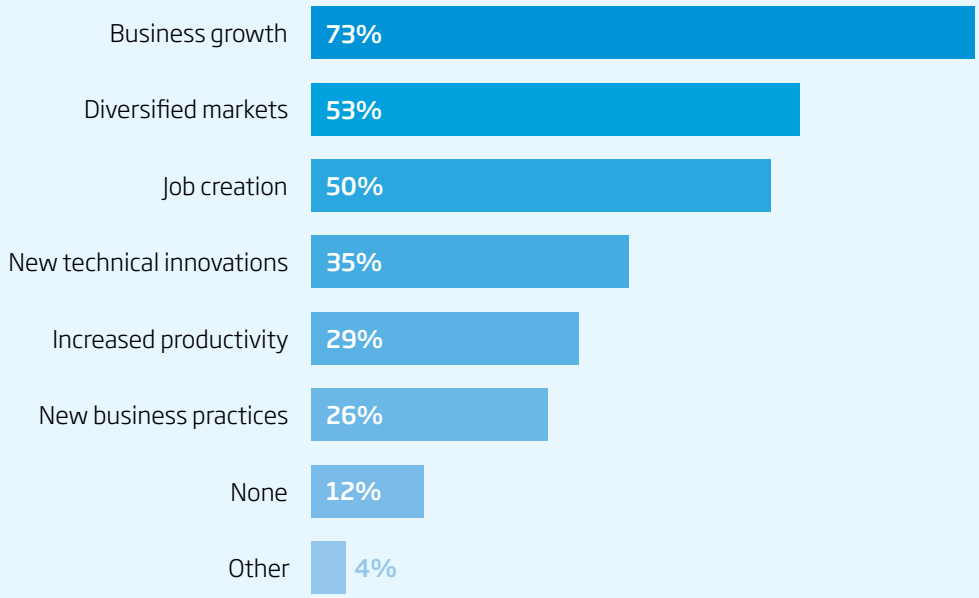
Effectively communicating this multitude of benefits to companies that are considering beginning exporting may provide the encouragement needed for firms to enter the export market.

Finally, it must be remembered that business cannot simply wait until the terms of the UK's split from the EU and our future trade agreements are agreed upon. They have already begun the process of identifying their business links with the EU to assess how these may be affected and minimise disruption to a 'business as usual' approach.

The government must do all it can to support them by providing clarity where it can, either in discrete areas (such as the guarantee of

[100] www.raeng.org.uk/publications/responses/access-to-finance-inquiry

Figure 6: Survey question 'Other than expanding available markets, what advantages, if any, does exporting offer your organisation?'



Respondents were allowed to select up to three options

Horizon 2020 funding until 2020 or signifying whether Intrastat declarations are to remain or be replaced with import/export documents between the UK and EU) or by articulating clear and specific aims for the negotiations in areas of concern.

6.2 Government must be focused in its support for trade, concentrating mainly on simplifying bureaucracy, developing and promoting its own support initiatives, enabling UK business to market their products and services, and upskilling the workforce in areas necessary to trade effectively.

Foreign direct investment (FDI) (Q26)

The issue of foreign direct investment goes hand-in-hand with international trade and securing advantageous trade deals will go a long way towards ensuring the sort of outward-looking, prosperous UK industry that will inspire confidence and attract investment. However, there are additional steps that the government can take in order to support all types of investment, foreign or domestic, including ensuring that the costs of doing business and regulatory frameworks are conducive to attracting a high level of investment.

The UK has a very strong track record in attracting high levels of FDI. The rate of FDI flowing into the UK can be used as a proxy measure for the confidence of global industry in the UK as a stable, productive place for business to thrive long term. However, the current political and economic climate has created uncertainty in general as well as more specific concerns about the UK's future access to the EU market.

The development of the industrial strategy, in itself, is a very positive move in signifying that the UK is open for business. The UK has to compete with other countries for investment and the choice of where to develop and manufacture products and base the provision of services is strategically and commercially very important to investors.

Multiple factors impact on investment decisions. Responses to the survey showed that the skill level of the available workforce was seen by the engineering community as the most important factor, with 56% rating this as 'very important'. Supporting infrastructure, particularly transport, was also highlighted, with over 85% rating this as 'moderately or very important'. Cost of labour and initial capital costs both also rated at around 85%, 'moderately important' or 'very important'. Additional factors including access to markets or supply chains, proximity of research expertise, regulatory regimes and the price of energy all

rated around 70%, 'moderately important' or 'very important'.

6.3 To attract investment, government needs to focus on the factors of most importance to investors, which include, skills, supporting infrastructure and the cost of setting up and running a business.

While the issue of ownership of production capability is complex; there needs to be caution about government intervention in the foreign acquisition of UK companies to avoid creating a culture of protectionism and a loss of commercial edge. It is important that the UK is seen as an attractive place to do business by UK- and overseas-owned companies alike. Of course, certain nationally strategic sectors that have a critical impact on security and social functions may need to be protected, but otherwise the principles of free trade should be followed. The responsibility for the preservation of UK ownership of a company should, generally speaking, lie with company boards, rather than government. Moreover, some highly successful UK-based companies are thriving as a direct result of being bought by investors from abroad.

The successful growth of the UK's industrial ecosystem, through the industrial strategy, will have a much greater impact than intervention by enabling British companies to compete successfully on the global stage.

Ultimately, industrial strategy allows government to make timely, well-signalled, course corrections in markets rather than situations building up to a point at which there is a dramatic shift or U-turn. A good strategy will not make intervention more likely; rather it makes it more predictable – and that builds confidence and supports investment.

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PILLAR 7

Delivering affordable energy and clean growth

> Setting up demonstrators at scale is fundamental to development of new energy technologies, especially where the UK is pushing to secure a market-leadership position.
>
> **Nick Winser CBE FREng FIET, Chair, Energy Systems Catapult**

Keeping down long-term energy costs (Q27)

The cost of energy is of importance to the engineering sector as it has direct impact on the cost of doing business and the UK's international competitiveness. In our survey, 60% of respondents reported that energy costs were a significant issue for their organisation. Electricity was perceived to be the biggest problem, with the cost of gas a close second. Many businesses have taken actions to address this issue: over 72% of respondents said that their organisation had already taken steps to reduce energy costs, with measures including investment in energy-efficient buildings (such as retrofitting existing buildings, smart and/or energy-efficient lighting, improved glazing and insulation), energy audits, installation of onsite generation (mainly solar panels), redesign of chemical processes, and campaigns to raise employee awareness.

This confirms that the government's focus on reducing the cost to consumers is appropriate. At the same time, the importance of reliability of supply should not be overlooked, as serious outages could entail a huge cost to the economy[101]. Furthermore, continued commitment to reducing greenhouse gas emissions, in line with both national and international policy, must be maintained. These three aspects of the so-called energy 'trilemma' are all equally important and interconnected[102].

In order to achieve the goal of secure, stable and affordable energy supply, the government needs to base its policymaking around multi-vector, system-wide solutions that build on end-use energy efficiency measures. They should span low carbon electricity, heat and gas, and other potential energy vectors such as hydrogen. In this, government needs to take a systems view of energy generation, supply and consumption and how these impact on the UK's industrial performance. The system needs to provide stable policies and market arrangements, but still be agile in a fast moving, complex and interdependent global landscape. This needs to be a central theme in the upcoming Emission Reduction Plan.

Energy policy tends to be approached in silos, separately addressing carbon and the environment, security, and cost, resulting in policies potentially pulling against one another. The fact that energy is included in the department responsible for business and industrial strategy is encouraging, but other departments will also have roles to play in terms of infrastructure and the environment, making cross-departmental collaboration vital. Transport is also an essential component of the energy system. This is dealt with in Pillar 3 but its relevance to the energy system should not be overlooked.

7.1 Government, as part of the Emissions Reduction Plan, should take a systems approach to energy policy, addressing the interests of businesses and the wider public, as well as reducing emissions and ensuring secure and resilient networks.

The most important areas to focus on in order to reduce costs, according to survey data, are:

- improving the efficiency of energy use
- reducing the cost of electricity generation
- improving the efficiency of energy networks and their management, by such measures as a smart grid that can balance a wider range of supply sources and demands.

Efficiency gains

In our survey, improving the efficiency of the use of energy was rated as the single most important area for the government to focus on to limit energy costs (see Figure 7). In relation to industry, energy productivity should be a priority; this is the measure of how much energy is required to produce £1 of value in the economy. Boosting energy productivity supports the UK economy by getting more for less. We believe that there is potential for significant improvements in both energy efficiency and resource productivity[103, 104].

101 Counting the cost: the economic and social costs of electricity shortfalls in the UK, Royal Academy of Engineering, 2014
102 A critical time for UK energy policy, Royal Academy of Engineering, 2015
103 Less waste, more growth, The Association for Decentralised Energy
104 The 2016 UK Energy Productivity Audit, The Association for Decentralised Energy

Energy efficiency is often overlooked, but a unit of energy saved is usually much cheaper than all production options. Reducing demand has a double benefit: it benefits the user by reducing their costs and it benefits the system by reducing the amount of generation required. With the right incentives applied at the personal, community, and company level, it could be possible to halve UK energy demand per person by 2050[105]. This would be very challenging but does illustrate the potential gains that are possible in this area.

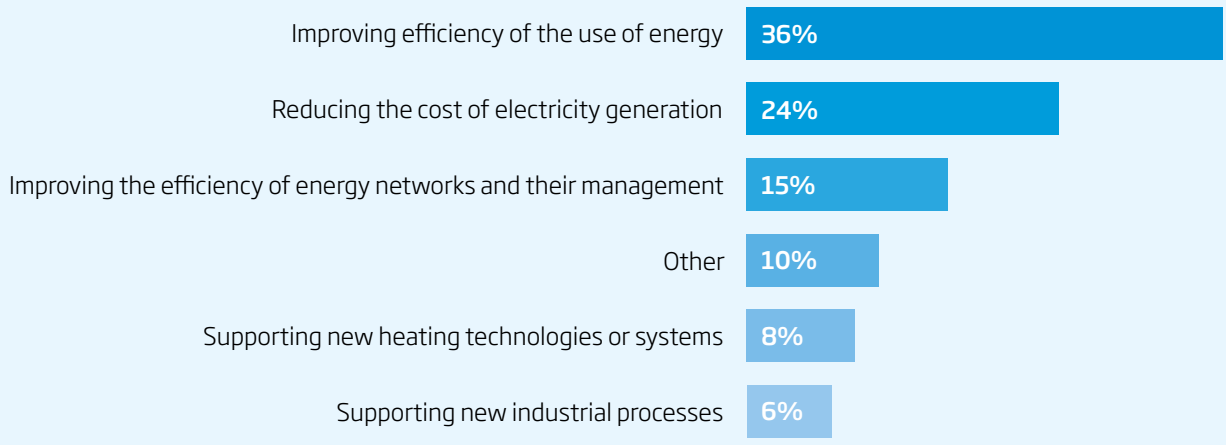
Existing international protocols for the measurement and verification of energy-saving projects are widely used to underpin investments using energy performance contracting models. It is conceivable that the introduction of an Energy Saving Incentive (ESI) scheme that pays out for demonstrated energy saving could result in a significant uptake in energy saving projects. Such projects would directly help the UK meet carbon reduction commitments and ease pressure on security of energy supply.

The Energy Savings Opportunity Scheme (ESOS)[106] has already identified thousands of energy-saving initiatives in buildings, industrial activities, and transportation. Implementing the recommendations in the ESOS reports could save organisations more than £31 billion by 2030, but in the absence of a requirement to act on the recommendations, implementation has been mixed. Incentivising upfront capital investment in energy efficiency improvements, possibly through tax breaks or loans that can be repaid on the back of performance contracts, could help overcome this.

Third-party funding can help overcome barriers, and could be modelled on the energy performance contracting model that has been operating for many decades in the UK and the USA.

Government could play a key role in sharing best practice and highlighting the cost savings arising from resource and energy efficiency projects, enabling industry and consumers to see this as

Figure 7: Survey question 'What is the single most important area that the government should focus on to limit energy costs over the long term?'



105 This has been backed up by a number of peer reviewed detailed studies, including

- *Reducing Energy Demand: What Are the Practical Limits?* - Jonathan M. Cullen, Julian M. Allwood,* and Edward H. Borgstein (Environ. Sci. Technol. 2011, 45, 1711–1718; note Figure 2 and summary on page 7017)
- *Halving global CO_2 by 2050; technologies and costs* - N Shah et al on behalf of Imperial College London Grantham Institute for Climate Change and Energy Futures Lab (www.imperial.ac.uk/grantham/publications/all-publications/halving-global-co2-by-2050-technologies-and-costs.php; See main report and annex, specifically sections on Buildings, Industry and Transport)

106 Energy Savings Opportunity Scheme, Department of Business, Energy and Industrial Strategy, 2014

an investment rather than an additional cost. Approaches that have proved successful in driving culture change in other areas, such as health and safety, could also be adopted.

7.2 Government should address energy efficiency and resource productivity as a priority. We recommend the development of a scheme to identify opportunities, and implement the findings so that energy consumption in an organisation is 'as low as reasonably practicable' (ALARP), insofar as this does not undermine the competitiveness of the business. This should be accompanied by the introduction of an energy saving incentive (ESI).

Building energy efficiency is particularly important. The majority of work in this area has focused on the domestic sector as this represents the bulk of demand. However, the issues and solutions are often equally applicable to the industrial sector. In the domestic and non-domestic building sector, Minimum Energy Efficiency Standards (introduced through the Energy Act 2011) use energy performance certificates initiated in response to the Energy Performance of Buildings Directive. The minimum energy efficiency regulations will mean that, by 1 April 2018, all properties in the private rented sector with energy ratings that fall below a certain level will normally have to be improved to a specified minimum energy efficiency standard before being let to tenants. These standards are proving to be an effective catalyst in both the private rented residential and commercial sectors.

> "Demand-side measures can, effectively, deliver a more efficient, lower carbon, cost-effective system with the same level of service for lower bills – a win-win situation."
>
> **Tom Crotty, Group Director, Ineos**

Incentives and regulation should go hand-in-hand with reporting against energy efficiency benchmarks of performance standards, which many in the professional engineering community would view as a reasonable requirement.

There is significant room to make both private and public housing stock – especially existing stock – more energy efficient. An example of how this might work can be seen in the work of Energiesprong UK, a group of housing providers, construction companies and building performance professionals supported by the National Energy Foundation, which aims to refurbish 111,000 homes to net-zero energy levels[107].

While we have good regulations in place for new build, UK building stock would benefit from greater compliance, more rigorous enforcement of building regulations and for the building control industry to drive higher-quality development and refurbishment. For existing housing stock, the Bonfield report[108] sets out the challenges and suggests possible mechanisms for improving efficiency. Work done previously to investigate the potential for market nudges, such as Stamp Duty rebates for energy efficiency works in a recently-bought home, should be revisited, and the *Each Home Counts* report should be considered as a way to stimulate improved energy efficiency in the domestic sector.

7.3 Heating efficiency savings should be at the core of a drive towards decarbonised heating, resulting from better incentives to make the UK's existing building stock more energy efficient and from tightening and enforcing building regulations on energy efficiency.

Managing demand is equally important and there is significant opportunity to reduce overall carbon and cost by smoothing demand. Smart meters are a starting point to raise consumer awareness, but are only of real value for the energy system when they are used to enable real-time tariffs and as part of the development of the smart grid, and when they are linked to behaviour change initiatives. It is essential that those with smart meters have full access to data about energy use in their home or business, and are able to transfer between energy suppliers with ease.

Time-shifting of demand and storage of energy locally can help to manage demand. Storage mechanisms can be as simple as hot water cylinders and immersion heating, or as complex as battery installations or electric vehicles supplying electricity at times of shortfall. At present, the gas system plays a key role in managing domestic energy demand peaks; in scenarios with reduced use of gas, the role of local storage of heat will become much more important. System integration across the whole energy system will be key to making this work.

Network efficiency and flexibility can also be improved, through the development of energy storage and smart grid infrastructure, as well as

[107] Energiesprong UK

[108] Each Home Counts: An Independent Review of Consumer Advice, Protection, Standards and Enforcement for Energy Efficiency and Renewable Energy, 2016

demand-side response (DSR) technology and implementation.

Electricity generation

Whatever progress is made in terms of improved efficiency and demand reduction, a supply of both electricity and heat will continue to be needed. In order to meet the commitments of the Climate Change Act (2008), this will need to be made up of growing proportions of low carbon generation.

There have been dramatic reductions in the costs of renewables in recent years, driven by global demand and the dynamics of global supply chains. Markets have delivered major cost reductions in offshore wind in recent years and this should continue to be encouraged. Respondents to the survey highlighted tidal power as the most important renewable power source to be supported, noting that tidal power is reliable and does not require back-up, and has huge potential in the UK. Given the relative immaturity of the technology, selective support should be given to projects and technologies that will drive learning and cost reduction.

All forms of renewable energy need to be developed but it is also important that the UK seeks to gain as much commercial advantage as possible in order to boost economic returns. The UK has the most offshore wind installed capacity in Europe but most of the offshore wind developers are based overseas. More needs to be done to increase the UK's market share of this and other renewable energy sectors.

Carbon capture and storage (CCS)

The use of hydrocarbons should be increasingly limited to areas where alternatives are not readily available, such as petrochemicals, aviation, and process industries. Nevertheless, the government must recognise that fossil fuels will continue to play a major role in the country's energy mix well into the second half of this century.

While we acknowledge that carbon capture and utilisation (CCU) also has a role to play, our estimates suggest that chemical utilisation of carbon could only account for around 1% of the carbon that we would be required to remove to meet the Paris 1.5-2 degrees temperature cap target[109]. We therefore chose to refer to just CCS in this section rather than CCUS.

Decarbonising fossil fuel use will be a vital part of meeting our climate change obligations. The UK should continue to phase out the remaining coal-fired power plants as quickly as possible. Carbon capture and storage (CCS) will be essential for meeting the UK carbon budgets after 2023, is likely to play an essential role in decarbonising heat, and must be applied to all fossil fuel power stations running at substantive load factors, and equivalent industrial processes.

The critical role of CCS in the transition to a low carbon energy system – both in large and relatively small-scale plants – was addressed in detail in both the Oxburgh report[110] and the Hackett report[111]. Both of these advocate the need to exploit the cost-saving benefits of implementation of multiple plants at scale and suggest business models whereby, within 10 years, the cost of electricity from fossil fuels plus CCS can be comparable to, or cheaper than, wind and nuclear. Scrapping the CCS demonstration competition has done severe damage to investor confidence in the low carbon programme.

If decarbonisation of heating is to be partly achieved through substitution of natural gas by hydrogen, as is currently being tested, then CCS will be an essential technology to remove the CO_2 produced alongside hydrogen in the shifted steam reformation of gas.

There will be a significant global need for proven and practical CCS technology, as developing countries in particular continue to exploit their indigenous coal reserves. The UK has significant expertise in power and coal research. With the UK withdrawing in the main from coal-fired power, there is only a narrow window for harnessing this expertise before it is lost to retirement and competition.

> "Improving energy efficiency and resource productivity needs to be a priority, particularly in buildings, and a systems-thinking approach is required to deliver this in all sectors."
>
> **Ant Wilson MBE FREng FCIBSE FEI, Director and AECOM Fellow, Sustainability and Advanced Design Building Engineering**

[109] *The role of CO_2 capture and utilization in mitigating climate change*, Niall Mac Dowell, Paul S. Fennell, Nilay Shah and Geoffrey C. Maitland, Nature Climate Change, 2017 DOI: 10.1038/nclimate3231

[110] LOWEST COST DECARBONISATION FOR THE UK: THE CRITICAL ROLE OF CCS, Parliamentary Advisory Group on CCS – Final Report

[111] Commercialisation of CCS – What needs to happen? Leigh Hackett, IChemE, 2016

7.4 Support for CCS needs to be revisited and the technology put back on the agenda. The priority must be the development of a full-scale demonstration plant with the associated transportation and storage network and greater understanding of a viable business model to deliver future plants that are cost competitive.

Nuclear power

The UK nuclear industry has an international reputation for high standards of safety both in terms of operating facilities, decommissioning and new build. It makes a significant contribution to the UK's low carbon electricity, providing some 20% of the country's electricity today and will continue to make a major contribution well into the future through a planned new build programme underway with Hinkley Point C. However, the sector struggles with an ageing workforce and relies on imported reactor designs, which is a lost opportunity for the UK's historically strong engineering and design capacity in this field. In addition, the new build programme is also not progressing as expected, with few global vendors, most of whom are struggling to finance the extremely high capital costs of the latest generation of reactors. There is a serious risk that new generators may not be built in time to even replace the existing capacity of nuclear generation in the UK.

An alternative route could be offered by small modular reactors. The smaller size and modular design could offer much lower capital hurdles and shorter delivery times, and small reactors have operated for years in certain applications such as nuclear submarines. However, commercial civil reactors are yet to be developed and there is much work needed before they reach market, not least in terms of safety regulations. The commercial risks are high but the UK has expertise in this field and the potential rewards both in terms of the energy transition and financial returns are large.

7.5 There is an opportunity for the UK supply chain to play a part in the development of small modular nuclear reactors; however, this will be likely to need some form of catalytic activity from government and a clearer focus from the industry on commercially viable solutions, notably those that minimise licensing and regulatory requirements outside the factory environment. The UK could use its history of reactor development and international reputation for safety and quality to develop and promulgate UK participation in technology for a worldwide market.

Decarbonised heating

Heating buildings and hot water accounts for 40% of UK energy consumption and 20% of greenhouse gas emissions but progress on decarbonising these has stalled[112]. Electrification of heat using heat pumps would facilitate the decarbonisation of heat, but fully removing heat from the energy mix and replacing it with electrical energy would be very expensive and disruptive[113]. Promising alternative approaches include repurposing the existing gas grid to deliver low-carbon fuels, developing district heating and combined heat and power (CHP), and recovering and reusing waste heat. The Energy Systems Catapult's Smart Systems and Heat programme is working with local authorities to create the capability to deliver local area energy plans specific to their communities.

National Grid's Energy Strategy and Policy Group found that introducing renewable gas could save £500 million a year in 2030 (for 37 TWh per annum of renewable gas) rising to £3.9 billion a year in 2050 compared with continued use of natural gas (for 100 TWh per annum of renewable gas)[114]. To accommodate the changes in feedstocks and use patterns, the existing gas distribution network will need to become smarter, more flexible and responsive, to ensure that network capacity does not become a barrier. All these technologies are expected to require significant upfront investment but will yield benefits in the long term.

112 www.theccc.org.uk/publication/next-steps-for-uk-heat-policy/

113 KPMG: 2050 Energy Scenarios - The UK Gas Networks role in a 2050 whole energy system www.energynetworks.org/gas/futures/the-uk-gas-networks-role-in-a-2050-whole-energy-system.html

114 www.ofgem.gov.uk/sites/default/files/docs/national_grid_gas_distribution_-_commercial_biosng_demonstration_plant.pdf (Appendix 2)

The option of using hydrogen (100% or blended) is currently being explored. However, safety concerns must be addressed before the technology can be rolled out beyond restricted and carefully regulated public schemes. CCS is likely to be a critical element in the production of clean hydrogen produced from natural gas.

The November 2015 Spending Review provided £300 million to fund heat networks over the next five years, which is expected to create up to 200 large heat networks in England and Wales, heating commercial offices, public sector buildings such as hospitals and schools, as well as flats and houses by 2025. Heat networks not only allow heat recovery but also yield benefits in terms of grid balancing, demand management, energy storage and flexibility.

Ground- and air-source heat pumps have been installed in the UK since 2004, but high upfront costs, low cost savings, and the age and size of the UK housing stock have all contributed to the slow uptake of the technology in the UK (it currently accounts for around 1% of heating systems in the country). There is an interesting opportunity to use heat pumps as a low-carbon source of energy for district heating schemes. While the integration of heat pumps into heat networks is a new phenomenon in the UK, such schemes have been running successfully elsewhere in Europe for over 10 years[115].

7.6 Multiple options for the decarbonisation of the supply of heat need to be investigated. These should include renewable gas (biomethane), district heating networks, hydrogen and heat pumps. Each needs to be assessed for their commercial viability at scale, local benefits and consumer acceptability.

Moving beyond subsidy in the energy markets (Q28)

One of the main purposes of subsidies in the energy sector is to encourage the development of immature technologies that have the potential to deliver at scale new products or services that will further the aims of national policy. This is necessary as traditional technologies such as coal or gas generation have had many decades to drive costs down and occupy a significant market share. The 'valley of death' is also particularly brutal in the energy sector due to narrow margins, high levels of regulation and risk aversion. However, in some instances, innovations in energy technologies have advanced faster than expected, leading to significant cost reductions and excessively generous subsidy mechanisms. Solar PV is one such example. It is therefore important that subsidy mechanisms are designed to take account of this possibility.

Some renewables are nearing the price of gas generation in the UK, including wind and solar PV. However, other forms of low-carbon energy remain significantly more expensive than using hydrocarbons. Previous initiatives aimed at making renewables competitive were created in a time of high oil prices. With the oil price at current levels, and no international carbon pricing mechanism yet in place, it is likely that some subsidy will be required to achieve a competitive market supplying cheap low-carbon energy to industry. Government funding would be well-used to ensure effective integration of these renewables into a flexible UK electricity grid by reducing the time and cost of connection. At the same time, efficiency measures should reduce the amount of new generation required.

7.7 It is recommended that subsidy regimes have clearly articulated deployment targets and payment reduction structures for when prices of renewable technologies come down. This could help avoid subsidy cost overruns as well as industry shocks as subsidies are reduced or removed.

Most future UK energy scenarios also see a continuing role for unabated gas generation. The declining output of the UK continental shelf in the North Sea has meant that the UK now imports the majority of its gas, which has had a detrimental effect on the UK's balance of trade. One possible alternative to reverse this trend is the development of shale gas in the UK. Shale gas can offer a secure and local source of energy and with appropriate technology and oversight can be exploited safely. However, public acceptance presents a non-trivial barrier, and any significant production may be years away. Government needs to adopt a more proactive approach to informing the public with balanced and proven evidence of the benefits and risks of exploiting shale gas, and how these can be safely managed[116], as well as for other future energy issues such as CCS, hydrogen and biofuels,

115 Heat Pumps in District Heating, Department of Energy and Climate Change, 2016
116 A Guide to Shale Gas, Energy Institute, 2015

which play a key role in a long-term UK energy strategy. The Royal Academy of Engineering and the Royal Society set out the regulatory and other concerns that need to be addressed to give confidence to shale gas exploration and production[117]. Furthermore, while national emissions could be reduced by replacing the remaining coal-fired generation with gas in the short term, due consideration needs to be given to how this would fit into the government's long-term commitment to reducing greenhouse gas emissions by 80% by 2050.

In Germany, the cost of electricity is borne disproportionately by commerce, government and domestic consumers, while heavy industrial users pay only the marginal costs of electricity generation. Industry would no doubt welcome a similar approach being taken in the UK. However, this is not compatible with the government's current focus on improving energy affordability for all users.

Distributed and community energy offer opportunities for higher efficiencies and cost advantages through higher end-use efficiencies, potential reuse of waste products in a circular economy and avoidance of transmission losses. Community schemes benefit from greater local transparency and potentially local involvement and acceptance of low carbon generation, which could improve public acceptance of higher prices. District heating schemes should be used to make more efficient use of waste heat from industrial processes, and will require regulation to ensure consumer protection.

7.8 Government should maintain existing mechanisms to support and accelerate the development of community energy and heating.

In the longer term, we would like to see a future where there is an internationally level playing field, enabled by standardised carbon pricing or tax, however this seems some way off despite the Paris Agreement in 2015. Currently, different sustainability standards adopted by individual countries distort the market and push high-carbon and high-emission industries to countries with less advanced environmental policies. Accounting for the global cost of CO_2 emissions would resolve the current market failure and

© Total

[117] Shale gas extraction in the UK, Royal Academy of Engineering, 2012

benefit the UK's economy by incentivising sustainable products and services rather than offshored emissions. Money raised from a carbon tax could be reinvested to support a faster transition to a low-carbon economy.

7.9 To achieve an internationally level playing field, the UK should maintain a leadership role in global climate negotiations and mitigation efforts.

Our survey showed strong support for reforming the regulatory framework in the energy system, with 52% of respondents in favour and only 2% against. However, respondents stressed that changes need to be introduced gradually and with plenty of notice.

Developing opportunities from innovation in energy and our industrial strengths (Q29)

The UK should aim to maintain energy research funding as a proportion of GDP at near the G8 level. Government should base funding decisions on comprehensive evidence such as life cycle assessments detailing total energy costs and environmental impact as well as ancillary effects, such as the need for back-up power for intermittent sources. Government should prioritise funding of long-term solutions and whole-system approaches. At the same time, research should explore how better to enable new business models that allow market-based innovation to flourish, and to make the UK a first choice for innovators in this area.

Cities, and cities-within-cities such as university campuses or hospitals, could be used as a test bed for fully joined-up energy systems comprising community heating and electricity, which would allow for the testing of new technologies as well as systems integration and consumer acceptability. Frequently, there is considerable community interest but insufficient infrastructure: a limited amount of government funding could unlock significant potential and catalyse development and investment in the regions. Regional innovation and development will be vital, but this will need to fit clearly into a national energy framework to ensure that least cost energy solutions are delivered.

To encourage the introduction of new technology to improve productivity and fuel consumption, a promising approach is fostering partnerships between energy-intensive industries and entrepreneurial SMEs in fields such as bioenergy, hydrogen and CO_2 utilisation.

Australia, through the Commonwealth Scientific and Industrial Research Organisation, is establishing innovation hubs in the buildings energy efficiency arena, from which the UK may be able to learn, both about the overall process and in detail at the technology level.

We expect that UKRI will decide on research funding for energy and look forward to seeing its thinking and focus.

7.10 The engineering community would welcome a funding arrangement that actively fosters links between academia and industry to encourage a focus on real-world energy issues and commercialisation, potentially utilising local institutions as test beds for innovations. Such innovation could be encouraged through tax relief for research and development.

The UK needs to address the challenge of supporting the transition of promising innovations into commercialisation. Lack of investment and funding for scale-up projects, along with legal, regulatory and human resource barriers, all risk causing promising UK research to be commercialised elsewhere.

Catapults have an important role to play with helping innovations bridge the gap from R&D to commercialisation, particularly in SMEs. The Energy Systems Catapult in particular is focused on whole-system issues in electricity and heat, including the establishment of enabling platforms for innovators to bring forward new technologies and business models. Many of the most promising new technologies and business models lie close to the end user, and are driven by the same technology ecosystems that have produced the internet and smartphone revolutions.

PILLAR 8

Cultivating world-leading sectors

> "Emerging and disruptive technologies, such as robotics and artificial intelligence, will continue to increase their impact across traditional vertical sectors. Sector deals that recognise the productivity potential of these new horizontal sectors will pull new technologies from the research base to a wide variety of industrial applications."
>
> **Professor David Lane CBE FREng FRSE FIET, Director, Ocean Systems Laboratory, Heriot-Watt University, Chairman, Consequential Robotics**

Sector deals (Q31 and 32)

Identifying sectors

The development of the industrial strategy provides a welcome and much-needed signal to business (both domestic and overseas) that government is committed to providing a stable policy framework for key sectors and technologies. Prioritisation is an essential component of any strategy and sector deals provide an opportunity for the public and private sectors to work together to ensure that best value is delivered from their collective resources. The aerospace and automotive industries provide excellent examples of what can be achieved through effective sector leadership councils with strong political and industry buy-in, creating business confidence and a clear vision for the sector (see Box 4, page 76). However, the needs and maturity of sectors vary considerably. The government's 'open door' offer for sector deals is therefore welcome.

The UK has sectors with heterogeneous characteristics:

- Strong established sectors such as energy, aerospace and automotive that the UK wants to grow.
- New or emerging sectors that are not in the position to act collectively and need to be supported.
- Critical enabling sectors, such as construction and digital, that create large numbers of jobs and deliver infrastructure that underpins productivity, but may or may not have strong interfaces with government.

Sectors also vary widely in terms of the lifecycle for introducing new products and processes, capital intensity and the barriers they face, as well as their institutional structures. Therefore, a sectoral approach will need to be flexible and tailored to each sector's specific issues.

Most workshop participants were of the view that communities clustered around platform technologies or underpinning capabilities should be considered eligible for sector deals, in addition to more traditional sectors (such as the four suggested in the Green Paper). For example, manufacturing is a capability that spans sectors and industries: advances in manufacturing can result in significant improvements in productivity across a wide range of other sectors, and will also be critical to the development of emerging industries such as synthetic biology and the newer frontiers of quantum technologies.

There is a perception that industry silos will decrease over time as more enabling technologies and capabilities that underpin numerous sectors emerge. An example of the importance of such capabilities is provided by the review of industrial digitalisation announced in the Green Paper, which will consider how UK industry – and advanced manufacturing in particular – can benefit from the accelerated adoption of digital technology. The impact of digital technologies across all industry is so pervasive and far-reaching that the UK cannot afford not to develop its leadership credentials in this area.

8.1 Sector deals must be available to communities focused on enabling technologies and capabilities, such as digital technology, in addition to more traditional sectors. These type of sector deals should directly address opportunities to maximise the benefits of the technology or capability across all relevant sectors.

Government must recognise that smaller or emerging sectors, especially those with large numbers of startups and without corporate champions, may find it harder to emulate the success of well-established sectors. Notwithstanding, there are examples of previously fragmented sectors that are coming together with resulting benefits. For example, robotics was a fragmented community of university groups and SMEs but has now made real progress in building an innovation pipeline of spin-out companies that are connecting to large companies through strengthened supply chains.

Respondents to our survey selected from a list provided which criteria they would prioritise when identifying which sector deals to support (see Figure 8).

Priority actions

In our survey, we asked the engineering community for the top three actions that government could take to help their sector achieve its economic potential. The key themes

identified are listed below, in order of the frequency with which they were cited.

Skills and immigration

- Address the skills shortage
- Support for technical, higher and further education
- Address concerns around student immigration restrictions
- Ensure access to skilled personnel from overseas
- Increase support for apprenticeships

International support

- Strengthen international networks and partnerships
- Tariff-free access to EU markets
- Access to international markets
- Support international exports of engineering services
- Establish and build international trade deals (with China, US and Australia)
- Increased support for SMEs to export

Investment in R&D

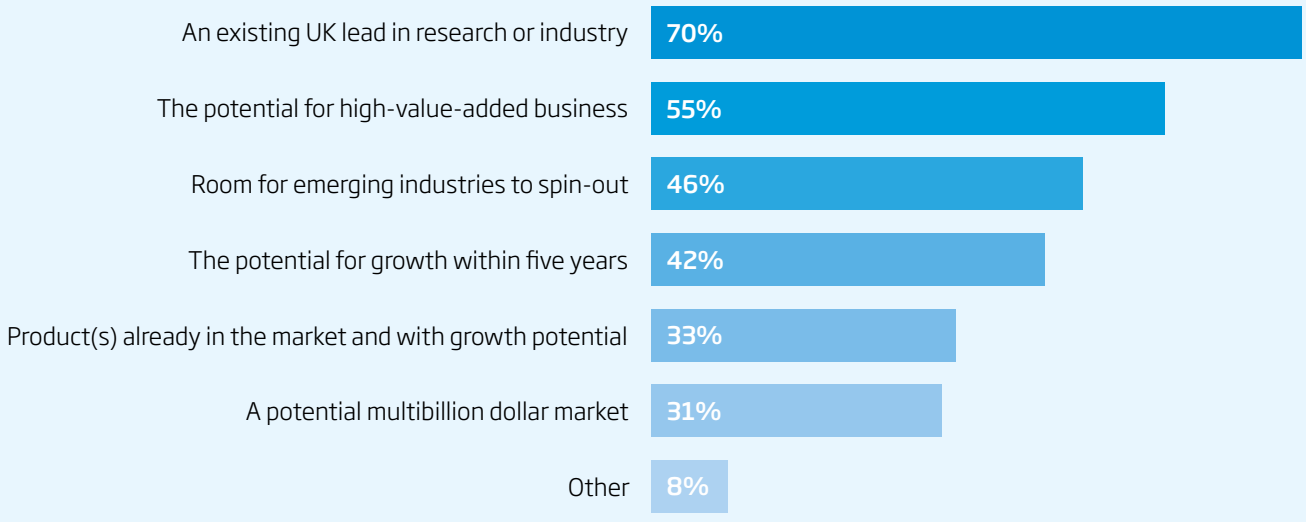
- Tax relief and incentives
- Simplification of R&D tax credits for micro businesses
- Increase in public investment in R&D

The next most popular actions concerned improvements to infrastructure, more effective public sector procurement, including a greater emphasis on 'buying British', a favourable approach to regulation and standards, and a stable policy environment.

8.2 Sector deals should encompass actions targeted at strengthening access to skilled people, international markets and networks and investment in R&D.

More generally, the survey demonstrated strong support for sector deals being set within clear and transparent frameworks that would facilitate the assessment of progress. Metrics are important to enable both government and industry to evaluate progress and understand which approaches are most successful. The deals should also be subject to regular review with appropriate review points linked to decisions over whether to extend the partnership. While sector deals should be established for a specific duration (in the first instance), it was also recognised that they will not deliver best value and impact unless there is a genuine long-term commitment behind them to give investors and businesses confidence. It can be highly damaging when changes in ministers or governments result in sector support being dismantled in an ad hoc manner.

Figure 8: Survey question 'Which of the following criteria should the government take into account when identifying which sector deals to support?'



Respondents were allowed to select up to three options

8.3 Sector deals should be subject to regular review, linked to a clear evaluation framework. However, they need to be underpinned by a firm and long-term commitment from government to build investor and business confidence.

Productivity

A key aim of the sector deals should be to address the UK's lagging productivity levels. Respondents to our survey identified four priority actions that organisations could take to improve their productivity. They are listed below in order of the frequency with which they were cited.

Recruitment, training and retention of staff

- Increase availability/investment in staff training and development
- Greater access to skilled personnel/ easier recruitment of foreign staff
- Improve job security to retain staff
- Increase investment in staff overall
- Improve talent pool and leadership

Automation

- Increase application of artificial intelligence and robotics
- Automation of mundane tasks, such as production lines

Administrative burdens

- Reduce administration and paperwork burden on employees
- Improve internal and external communication systems
- HR resources
- Reduced administrative costs e.g. tax compliance
- Improved business models
- Reduce the amount of 'red tape in organisational processes'

Data and infrastructure

- Better IT systems
- Better telecoms infrastructure
- Better use of data analytics

8.4 Sector deals provide a crucial opportunity to drive improvements in productivity through, for example, upskilling of staff and expansion of talent pools; automation and increased application of AI and robotics; reducing the administrative burden; and implementation of modern IT and data infrastructure and techniques.

Leverage

As outlined in Pillar 1, the UK suffers from low levels of business investment in R&D. The creation of sector deals provides a valuable opportunity to stimulate business investment in R&D. In view of the significance of research and innovation activities, a sector-wide commitment to an increase in R&D – or associated investments in innovation and manufacturing capability in the UK – would be an appropriate criterion to be used in selecting sectors to be awarded deals (recognising that the maturity of different sectors will influence the nature of the commitment they can offer). The impact of this approach would be amplified if government also committed to provide an increase in R&D investment of relevance to the sector, in proportion to the increase in private investment secured. Innovate UK would be the natural lead for both monitoring the R&D expenditure levels across the sector and managing the matched funding stream provided by government.

8.5 Sector deals should offer the possibility of an uplift in public investment in R&D, conditional on a commensurate increase in investment in associated activities by business.

Pre-competitive collaboration

Pre-competitive research provides opportunities for industrial competitors to collaborate with each other to address challenges that have significance across a sector. Collaborative work of this nature can be valuable for tackling shared issues, such as environmental challenges, and can raise standards across a sector by offering insights into new techniques or potential efficiencies. Sector deals present a mechanism by which pre-competitive research can be facilitated and incentivised. The development of roadmaps or strategies across a sector may highlight common technological or societal challenges across a sector to be pursued on a pre-competitive basis. The types of activities facilitated by pre-competitive research, such as creating large-scale demonstrators, are also

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often considered too risky for one company to embark on alone. It should be noted that this kind of support, which brings together multiple industry partners to engage in pre-competitive research, has to date received significant support from EU funding streams, which are currently greater in scale than most equivalent UK-driven activities.

8.6 Sector deals should be used to promote and facilitate investment in pre-competitive collaborative R&D by companies, for example to address shared environmental challenges.

Partnerships and business leadership

The engineering profession agrees with the government's intention that business should lead the sector deals and that businesses should collaborate with other stakeholders and local leaders to produce a clear proposal for boosting the productivity of their sectors. As outlined in Pillar 1, encouraging businesses to undertake research in collaboration with universities can be a particularly productive means of industrial support. However, the Dowling Review (see page 17) found that academics had very low awareness and understanding of the previous industrial strategy, and the review concluded that this was a missed opportunity, especially since there was strong demand from academics for an improved understanding of UK national strategy in relation to innovation. Already, it appears that the development of this industrial strategy is involving significant engagement with the higher education sector and recognises the significant resource provided by the UK's world-class research base. The UK's Research and Innovation Organisations should also be key stakeholders[118].

8.7 When developing the industrial strategy and other long-term sectoral strategies, government and business should consult universities and Research and Innovation Organisations as key partners. Innovation should be a core component of policies aimed at promoting productivity and competitiveness, with full consideration given to its role in different sectors.

Supply chains

The industrial strategy should identify those elements of supply chains where the UK is strong and intends to be competitive and also any significant gaps that need to be closed in the UK supply chain for key sectors, bearing in mind that supply chains are often global and the UK cannot retain every single part of the supply chain.

Sector deals can provide a valuable means of engaging SMEs in R&D and skills development, with original equipment manufacturers (OEMs) acting as traction engines to pull through improvements in their supply chains. For example, in mature sectors such as aerospace, dominant OEMs actively encourage innovative supply networks to form and help drive upskilling in the supply chain, in the knowledge that a quality supply network is a competitive advantage for their business. They can also help catalyse SME investment in R&D.

However, it is also important to note that companies in supply chains often do not see themselves as aligned with a specific sector. A manufacturer of a company specialising in precision engineering, for example, may sell their products into oil and gas companies as well as automotive companies. As a result, the focus on sectors does not resonate well with some SMEs and government needs to ensure that its support can help small businesses grow and expand through supply chains to competitors. The development of clusters around universities, research institutes and science parks is one way of doing this (see Pillar 9/10).

Cross-sectoral opportunities

Many innovations will occur at the interface between sectors, and therefore opportunities for cross-fertilisation of ideas between sectors must be maximised. Cross-sector collaboration will enable a multitude of benefits, including the ability for sectors to learn from each other, introduce innovations into established industries and develop cross-sectoral capabilities in businesses, and in particular in supply chains. A key challenge will be breaking down existing silos between established industry sectors.

One example where cross-sectoral working plays a key role is the space sector, where the majority of future growth is expected from space data, services, and space-enabled applications, rather

[118] Research and Innovation Organisations in the UK: Innovation Functions and Policy issues, BIS research paper No.226, 2015

than from space infrastructure such as satellites. This has required the space industry to seek out other vertical sectors, such as agriculture and infrastructure, in order to identify innovative opportunities for the use of such services as space data or global navigation satellite system (GNSS).

The development of such applications requires collaboration between a range of disciplines including space engineers, data scientists and software engineers. There is clear demand for cross-sectoral collaboration from the engineering community. Encouraging and facilitating collaboration across sectors emerged as one of the main themes in answer to the survey question 'What are the top three cross-sector support initiatives that would increase productivity and prosperity?'. The following activities would help enable collaboration:

8.8 Government should facilitate a rolling programme of workshops for bringing together relevant players across the various sector groups and other key players (such as UKRI) to examine opportunities for innovation that cut across different sectors and to learn from approaches being adopted by other sectors.

8.9 Regular meetings should be convened between leadership councils or similar institutions representing sectors in order to help identify opportunities for cross-sector working, and to identify where coordination will provide leverage in cross-cutting issues such as skills.

International context

It is essential to make a strong link between export opportunities and sector deals – our consultation has demonstrated strong demand for support for international engagement by UK engineering companies. Participants suggested that the industrial strategy as a whole needs to be more clearly positioned in a global context. For example, in relation to sector deals, there needs to be more investigation into emerging sectors globally and what innovation they can bring into the UK. This matters because innovation adoption is one of the most important ways a company can increase its productivity[119].

8.10 Government should ensure that the industrial strategy is clearly positioned in its global context, including by taking into account opportunities to adopt innovation developed elsewhere and focusing on how sector deals can support exports.

Emerging technologies and business models [Q33]

Four key themes emerged from our consultation as challenges faced by emerging technology sectors that government support could help to address:

Investment

- lack of funding and patient finance (particularly for startups)
- shortage of risk capital on the scale needed
- access to R&D tax credits/ the need to simplify tax regimes

Risk

- public perceptions and low acceptance of new technologies
- general low risk tolerance and culture in UK
- risk to existing business lines and models

Regulation

- currently no established regulatory or safety management framework
- compliance with EU legislation
- inconsistent regulatory approaches

Market access and international competition

- lack of markets (further uncertainties post-Brexit)
- 'speed to market' – competitors frequently outpace UK
- limited UK market for high tech products
- foreign competition at cheaper prices
- market awareness

Several participants in our consultation also highlighted the importance of skills (see Pillar 2), policy stability and stronger government support for innovative businesses, including through both enhanced access to finance and smarter procurement practices (see Pillars 4 and 5). There was also a high level of demand across the consultation for a greater emphasis

[119] Investing in Innovation, Royal Academy of Engineering, 2015

on demonstrators and test beds, which are addressed in the section on 'national innovation assets' (see response to Q9).

In responses to the survey, regulation was repeatedly raised as a barrier for emerging technologies and new business models. It is critical that regulators engage early with innovators and experts in relevant technology areas to ensure that regulation does not impede innovation unnecessarily or unintentionally, as outlined in Pillar 1. The government's Challenger Business Programme aims to address the challenges posed by regulation that stops innovative businesses from thriving. For example, the programme led to exemptions for the space and satellite sector from Insurance Premium Tax, which, prior to the exemption, was disproportionately affected by the tax. The Challenger Business Programme also has an important role looking ahead to the technologies and new sectors of the future, and helping to identify disparate startups that, if brought together, would have a significant critical mass. The Challenger Business Programme is an important mechanism through which the industrial strategy and sector deals can be delivered. Increased visibility of the programme would be welcomed.

8.11 Government needs to support the development of good sector deals by sectors with weaker institutional arrangements, for example by offering a multi-stage approach to the development of the deal and providing access to experts and resources that can help to support sectors through the process.

Sector deals are highly likely to reflect current sectoral structures but it is important that the UK looks ahead to the technologies and sectors of the future.

8.12 Government must work with communities of experts – including in engineering – to ensure that its approach to industrial strategy in general, and sector deals in particular, sufficiently reflect future needs and opportunities.

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Box 4:

Sector deals: Aerospace Growth Partnership

The UK has a vibrant and successful aerospace sector, the largest in Europe and the second largest in the world after the US, exporting over 90% of its production, which was worth £27 billion in 2015.

Despite being a world leader in the production of aircraft, high-value, complex components and the provision of maintenance, repair and overhaul (MRO) capability in a highly competitive international market, UK aerospace cannot be taken for granted as new global market entrants threated to challenge the UK's pre-eminence.

It is in the interests of the aerospace industry and the government to maintain this current success well into the future and to work together to exploit opportunities for growth, especially as $55 trillion worth of greener, quieter and more economic aircraft will be needed over the next two decades.

To support the long-term health of the sector, the Aerospace Growth Partnership (AGP), a strategic partnership between the government and industry, was established in 2010.

The AGP has not only led to a change in the relationship between government and the aerospace industry, but also encourages companies within the sector to work together more closely to address challenges that affect the whole sector.

The Secretary of State for Business, Energy and the Industrial Strategy has hailed the AGP "as an exemplar of successful engagement between industry and government".

So, what has made the aerospace sector deal so successful?

- **Long-term vision:** it takes 10 to 15 years to develop a completely new aircraft, so planning and investment decisions need to be taken for the long term. The government and industry share a long-term ambition the sector – beyond parliamentary cycles.
- **Coordination:** government involvement has helped industry work better with itself, encouraging collaboration between competitor companies in order to achieve a common view of the challenges and areas on which government and industry can cooperate.
- **Co-investment:** government and industry together are investing more in R&D than at any time since the 1970s, supported by the creation of the Aerospace Technology Institute, to better align early research and development, avoid industry duplication and capitalise on the certainty of the investment horizon. Government listened to why the sector needed more investment in R&D and showed unprecedented commitment to the sector for the long term – £1.95 billion from 2013-26 – matched 100% by the industry for a combined total of £3.9 billion.
- **Supply chain competitiveness:** The AGP, with government funding, has put in place a wide range of support programmes to help companies improve their competitiveness, including the investment in and creation of 500 new aerospace engineering master's level bursaries. Of those bursary recipients who are employed, 90% work in aerospace.

PILLARS 9 and 10

Driving growth across the whole country
Creating the right institutions to bring together sectors and places

Principles to support regional growth (Q34)

The Green Paper sets out four main principles in its framework to build on local strengths and enable growth: infrastructure, skills, local science and innovation, and institutional frameworks. These are, largely, the right areas to focus on with each being highlighted as important across all the regional and home nations workshops.

Transport infrastructure

Infrastructure, in all its forms, was cited in our consultation as essential to the operation of business and research. Transport, in particular, was identified as being a barrier to growth in many regions. Attendees at several workshops cited the fact that it was often more convenient to work with partners in London than locally, as the transport links to the capital were much better than between local areas. This even extended to international links for trade and collaboration. For example, at our workshop in Northern Ireland, it was noted that Belfast had recently lost its only direct flight to the USA despite the potential for strong business links between NI and America.

Infrastructure was, as expected, seen differently in different places. Of people based in Wales who responded to our survey, 62% saw railways as a major constraint on growth compared to just 20% in Northern Ireland or 30% in London. Roads were most negatively viewed in the East of England, and communications, surprisingly, in London. Feedback from the London workshop, however, shed light on this as people reported often working at home in the evening when they could get faster connectivity.

The impact of poor local transport infrastructure is felt at many levels. It can affect staff directly, simply in terms of commuting – making companies less productive or making it difficult to attract and keep staff. It can also affect the ability of companies to collaborate with local partners or make the most of local assets. Sectors earmarked to grow in support of nationally significant capabilities, such as the nuclear sector, can be limited if the supporting infrastructure does not keep pace. Poor links to national or international transport networks will also impact on companies' abilities to connect to a wider customer base and expand markets.

Investment in local transport infrastructure is therefore vital to support local business. The local road network (97% of the total network) is most important given its dominant role in local transport networks. But consideration should also be given to improving public transport for local and inter-urban connections and modes of transport (such as buses and light rail) that make more efficient use of existing transport infrastructure. Integration across multiple modes of transport is also critical. The National Infrastructure Commission (NIC) will clearly have a central role to play in the development of the future transport system but government must continue to invest in local transport alongside national schemes.

9.1 Government must continue to drive investment in local transport networks, particularly the local road network and public transport. The NIC has a crucial role in identifying investment priorities at the regional level.

> "There is no 'one-size-fits-all' model for local needs for support and encouraging leadership. Governance structures to enable growth need to recognise this."
>
> **Professor Norman Apsley OBE FREng FInstP, CEO, Northern Ireland Science Park**

Shipping and aviation are also essential components of transport infrastructure, particularly in terms of their link to international trade. Ports must be able to compete fairly for business, independent of location. They must be fit to cope with the rise in international environmental legislation and be competitive in Europe. Short sea shipping should be encouraged to increase port usage evenly around the UK. Short sea shipping decreases the reliance on road freight which burdens the road infrastructure and in turn will reduce carbon emissions (where per tonne-km shipping is the most efficient method of transportation of mass goods).

There should also be consideration of how UK ports can support other industrial growth sectors in the UK – such as offshore renewables, cruise tourism (7% growth in 2016) and emerging 'blue growth' sectors such as autonomous shipping, aquaculture, blue biotech and also to assist with export capability.

In aviation, the current Airports National Policy Statement is only concerned with delivering the third runway at Heathrow. This is a missed opportunity to deliver on the government's priority for distributed growth across the country. The government should be providing a stronger, clearer vision for airport growth across the country in support of all the other industrial and economic

objectives. The forthcoming Aviation Strategy will for the first-time deal with issues such as aviation skills, many of which will be engineering-based, alongside themes such as growth and investment, technology and innovation, and market access and trade. This strategy must be seamlessly dovetailed with the wider industrial strategy to avoid unintended consequences, particularly in terms of UK commitments to reductions in greenhouse gas emissions.

9.2 Government must support both shipping and aviation sectors as part of the industrial strategy as vital components of international trade and opportunities to drive growth across the UK.

Digital connectivity

The digital network is just as important as physical networks, if not more so. All aspects of society and business are becoming more and more reliant on data and telecommunications. The UK needs high-speed, pervasive, ubiquitous broadband access throughout the country. A mix of technologies will be the best way to deliver this in the short to medium term, with increasing direct fibre access in the long term. UK government needs to specify not just minimum download speeds but other system properties such as upload speed, latency and packet loss. Better, and more effective, access to existing infrastructure for the purpose of connection is also sought, especially in remote locations where fast connections can be most difficult to supply.

In addition, access to appropriate spectrum is also going to be increasingly important. The ability to leverage local resources and self-help arrangements will be important for cost-effective rural provision.

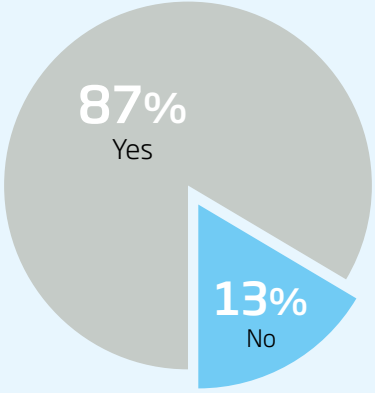
The need for resilience and reliability is also critical. An increasingly significant proportion of other infrastructure now depends on effective telecommunications and any loss of service through either deliberate or accidental breach could have potentially catastrophic social or economic consequences. Digital strategy will be central to delivering the UK's digital infrastructure and provides a clear example of how the industrial strategy will have many interdependencies across government departments and policies.

9.3 Government must continue to drive for world-class digital connectivity that is fast, secure and resilient.

> "Data stores and data champions in cities could help business and the public sector make full use of big data with revolutionary results."
>
> **Stephen Pattison FBCS, Vice President Public Affairs, ARM Holdings**

Figure 9: Survey question 'Are there skills shortages in your sector?'

'Shortage' refers to an *insufficiency of people* with the required skills.



Raising skills levels across regions (Q35)

In our survey, skills shortages were reported by 87% of those who commented. In many cases, there was no regional variation in their views (see Figure 9).

Some differences did emerge:

- The West Midlands, the South West and Wales all had over 60% favouring more employer engagement in schools as a recommended action. This percentage was just 44% in the East Midlands.
- Three-quarters of respondents in many regions also felt very confident that improving public perceptions of engineering would make a difference. This proportion was lower in the East Midlands, where there was a greater emphasis on recruiting and supporting more specialist STEM school teachers.

There was little regional variation in the 54% who reported that their employer operated an apprenticeship scheme, although just over twice as many did so in the North East as did in Yorkshire and Humber. An encouraging 82% of respondents said that their organisation operated a system for educating and training its workforce.

The workshops that were run in the English regions and the home nations included specific opportunities to comment on raising engineering skills levels. While the comments and priorities were remarkably similar across the UK, there were some specific elements reported:

- In Scotland, the pilot Scottish Apprenticeship Scheme was viewed favourably, and it was suggested that other parts of the UK could learn from its experience.
- Wales is currently moving to a more skills-based education system, which might offer insight useful across the UK.

However, as emphasised in Pillar 2, there is a substantial and urgent task to raise skills levels across the whole of the UK in order to ensure that our workforce remains globally competitive and able to embrace the opportunities enabled by new technology.

Local investments in connectivity and innovation (Q35)

The concept of 'national innovation assets' was described in Pillar 1 (see response to Q9). A register of national innovation assets, combined with appropriate policies, investment and marketing, could make a significant contribution to creating a more balanced and effective innovation landscape across the UK.

In addition to this, it is important to recognise that organisations such as universities, research and innovation organisations (including PSREs and Catapults) and major companies can act as 'anchor institutions' for an area. These anchor institutions can create jobs and economic activity, drive the development of infrastructure and act as catalysts for the formation of clusters of small businesses and facilities.

Certain places have particular strengths that should be built on. Scotland, for example, has the European Marine Energy Centre in Orkney and the Saltire Prize, which have done much to promote the clean energy sector in Scotland. Northern Ireland has the Institute of Electronics, Communications and Information Technology and the Centre for Secure Information Technologies, which have drawn on local expertise to create national centres of excellence for early-stage commercialisation of disruptive technologies. In Wales, Cardiff University and industry have established the Compound Semiconductor Centre that provides facilities to help develop new technologies and materials from research.

9.4 'National innovation assets' should be identified, promoted and supported by government to build a more balanced and effective innovation landscape across the UK. Anchor institutions can also help to seed clusters of local economic activity.

Exploitation of innovation assets and anchor institutions would be greatly facilitated by a clearer mapping of local industrial and innovation ecosystems. Workshop participants expressed the view that they were often not aware of activities in their area that are relevant to their own work. SMEs in particular can find themselves operating in isolation and, as a result, miss out on opportunities to collaborate with other organisations in their area. This can include research being carried out at local universities or research facilities or other businesses working in a similar field. Making such links could provide multiple benefits. Researchers could be exposed to potential needs within industry for their

research and businesses could find research collaborators to help develop new products or services. Businesses could also see opportunities to collaborate for new markets, and learn about business or marketing practices that could help boost productivity.

Science and Innovation Audits go some way towards addressing this need, but there is more to do, particularly to understand industrial activities and map skills. The production of the audits has also emphasised the value of exercises in bringing people together, which is quite distinct from the formal outputs they may yield. Our consultation further highlighted a belief that mechanisms for enabling people within a region to meet and collaborate was a high priority need that was not yet being met.

9.5 Government should build on the Science and Innovation Audits to develop more comprehensive mapping of local industrial capabilities and innovation ecosystems. This needs to be accompanied by an ongoing process of stakeholder engagement; the full value of the mapping will not be realised without this.

European funding

European funding has played a significant role in enabling regional investments in support of research, innovation and associated activities. The stated purpose of the European Structural and Investment Funds (ESIF) is to invest in job creation and a sustainable and healthy European economy and environment. The European Regional Development Fund (ERDF) is part of ESIF and aims to strengthen economic and social cohesion in the EU by correcting imbalances between its regions. ERDF investments focus on key priority areas, including 'innovation and research' and 'competitiveness for SMEs'. Over the period 2014 to 2020, the planned EU spend for the UK of ERDF for 'research and innovation' is €1.4 billion, rising to €1.9 billion for 'competitiveness of SMEs'[120]. As such, funding from ERDF plays a key role in supporting businesses to start and grow across the UK, particularly with regard to regional provision of business and management skills training. As the UK proceeds with the negotiations to leave the EU, it will be essential that measures are put in place to ensure continuity and that UK funding streams are introduced to support this type of regional development in the future.

9.6 It is essential that the industrial strategy puts in place plans to ensure that the regional development needed to underpin inclusive economic growth can be supported when the UK has left the EU.

Local institutions (Q36-38)

In our survey, existing local institutions received a mixed response in terms of respondents' awareness and views of their effectiveness. Over 40% of respondents said that they were unaware of how effective LEPs, growth hubs, university enterprise zones and Catapults are at supporting growth. Other institutions were seen as ineffective at supporting growth, particularly local authorities (48% of respondents). A moderate number of respondents considered innovation districts and science parks to be effective (36% of respondents), while universities fared best, with 51% of respondents stating that they were effective at supporting growth. The importance of raising awareness of current support, particularly among SMEs, is highlighted in Pillars 1 and 4.

For those from the home nations, an encouraging 73% of respondents in Wales saw their local administration as very or moderately effective; 67% for those in Northern Ireland but only 37% in Scotland. There was a widespread view that the landscape of organisations involved in supporting local growth was too complex and in need of review. It was additionally noted that longevity of support and continuity of policy often yield better results, with Scottish Enterprise, Scottish Development International and Highlands and Islands Enterprise cited as positive examples.

It is essential that local institutions have the capacity and capability to deliver the support they are expected to provide at sufficient quality. For example, government has given LEPs a remit in England to support innovation within local areas but, while there are examples of excellent practice, their performance to date has been patchy and there is a need to set a clear national direction and provide stronger support to enable them to fulfil this role.121 By sharing good practice on innovation support amongst the LEPs, collaboration between LEPs, establishing

[120] Data from European Structural and Investment Funds Data, https://cohesiondata.ec.europa.eu/countries/UK accessed 12 April 2017

[121] The Dowling Review of Business-University Research Collaborations, 2015

rich networks with stakeholders and ensuring their work is coordinated, the potential to capitalise on regional strengths will be optimised.

9.7 The landscape for local support is already complex. The focus should be on promoting awareness of what exists, providing a stable framework for support and policy continuity, and seeking to build on what works.

> "Rather than creating new layers of organisation across the country, government should be identifying what works and build on that."
>
> **Ian Ritchie CBE FREng FRSE FBCS, Chairman Iomart plc**

A systems approach needs to be adopted not only to local decisions but also to coordination across the UK. Previous interventions, notably the RDAs, resulted in competition between regions to become the lead in one sector. It is clearly neither desirable nor feasible for every region in the UK to be a global leader in, say, nanotechnology or artificial intelligence. National coordination is essential to ensure that local strategies and priorities add up to a coherent whole. This coordination also needs to operate at a number of levels, including devolved administrations, LEPs, local authorities and mayoral cities. Even locally, it is crucial that opportunities to stimulate related industry employment or indeed to avoid collateral damage (such as occurred with the aluminium smelter in Anglesey when it lost its local electricity supply) are not missed.

9.8 The industrial strategy needs to ensure that regional and local strategies are coordinated and coherent: the whole needs to be greater than the sum of the parts, which can only be achieved through adopting a systems approach.

9.9 It is also essential that the industrial strategy recognises that not all regions can be identical in terms of their productivity. Different sectors have different characteristics and the metrics of success need to be more sophisticated than a single average value GDP per capita that will be distorted by local industries and demographics.

Public sector skills

The role of technology in enabling and shaping our economy and society is already profound and is expected to grow substantially in the years ahead. If public services are to keep pace with development in the private sector and the expectations of the public, as well as maximising gains in efficiency and effectiveness, it will be essential to raise the technological literacy levels among public servants. While a broad range of technical and technological skills are required across the spectrum of departmental, agency and local government roles, one of the most important and widely required skills sets will be that related to data management, analysis and visualisation. It is important to note that even where deep technical skills are not required, policy makers and those who support them will need to develop the skills and knowledge to act as intelligent customers and consumers of data. Moreover, it will not be possible to affect the scale of change needed without senior level champions – both civil servants and ministers – for digital transformation of public services.

9.10 Government will not be able to deliver the aspirations of the industrial strategy without enhancing technological literacy levels of public servants in both national and local government. Urgent action needs to be taken to embed training in digital and data skills across the public sector. This must include efforts to raise the technical skill levels of the senior civil service and local government leaders.

If such change can be enabled, there are enormous possibilities for broad-based benefits to be delivered across public services in all parts of the UK. This is often most easily achieved when new approaches are developed or piloted within specific regions. The UK is not alone in seeking to effect digital transformation of public services and a number of cities and regions globally, such as Chicago, Copenhagen and Singapore, have achieved significant results already, and lessons can be learned from their approaches.

9.11 Government should promote the creation of chief data officers in all major UK cities or regions and convene a network that enables the sharing of best practice both between these cities and regions and with global cities that have achieved success in delivering data-driven improvements to public services.

Our consultation also highlighted a view that greater mobility between the public sector and both industry and academia could be valuable for improving policy making in areas such as industrial strategy, as well as enabling people from industry and academia to broaden their understanding of government. An expanded

programme of secondments may become essential in order to meet the additional demands being placed on civil servants after the UK leaves the EU, not only in terms of navigating trade agreements and regulatory issues but also in order to deliver at national level functions that have previously been delegated to the EU.

9.12 An expanded programme of secondments involving the exchange of personnel between the civil service and both business and academia should be established, with a particular focus on building the technical capabilities of the public sector and improving the understanding of policy and government in the private sector and academia.

Engagement with civil society

Following the outcome of the EU referendum, there has been much debate about the extent to which actors in the public and private sectors and academia have been successful in engaging with civil society. It is very welcome to see that the Midlands Engine Strategy launched in March has emphasised the importance of 'enhancing quality of life' as well as the core issues of connectivity, skills, R&D and local leadership.

9.13 For the industrial strategy to be successful, and for the economy to 'work for all', engagement with civil society needs to be an integral component of the activities undertaken.

Actors engaged in research and innovation should also be encouraged and incentivised to consider how they could strengthen their engagement with the public at large and local populations in particular.

9.14 UKRI should be tasked with considering how procedures for assessing grant applications and research excellence can be utilised to drive more and better public engagement by individual researchers, universities and businesses.

National quality infrastructure

The announcement in the industrial strategy Green Paper that the government will be developing a UK Measurement Strategy is very welcome. This needs to be positioned in its broader context as part of the UK's quality infrastructure. This quality infrastructure comprises BSI (British Standards Institution), NMRO (National Measurement and Regulation Office), NPL (National Physical Laboratory) and UKAS (United Kingdom Accreditation Service). Together, these institutions oversee standardisation, testing and measurement, certification, and accreditation across a broad range of sectors and all regions of the UK. As such, they constitute an important component of the institutional framework required to support the delivery of the industrial strategy. These institutions also deliver international services, underpin exports and help reinforce the UK's reputation for excellence in on the global stage.

9.15 Government should recognise that the UK's national quality infrastructure, comprising BSI, NMRO, NPL and UKAS, has an important contribution to make to the delivery of the Industrial Strategy's objectives and needs to be supported and promoted accordingly.

Professional engineering institutions

Professional engineering institutions (PEIs) have great potential in terms of the capability and capacity to offer engagement opportunities of value in communicating and implementing the industrial strategy. There are approximately 450,000 members of PEIs across the UK. The regional and local branches of the PEIs form an active network stimulating connections between industry, academia and broader society as well as identifying and facilitating the sharing of best practice engineering and industrial standards. With members committed to mandatory personal professional development, they make an important contribution to driving local economic growth. Many PEIs also have international branches, members and links, and enjoy an excellent reputation throughout the industrialised world; doing a great deal to promote UK industry, high standards of professionalism and 'the race to the top' around the globe.

9.16 Professional engineering institutions and other professional bodies have a critical interface with engineers across all disciplines. Governments should capitalise on the offer from the profession to engage closely with the industrial strategy.

Appendices

Appendix 1 - Methodology

Approach

This project has deployed various approaches to gather evidence and opinion from the engineering profession on the proposals in the industrial strategy Green Paper, and to underpin advice to government on the future development of the UK's industrial strategy.

The Engineering the Future alliance, through the professional engineering bodies that constitutes its membership, has access to 450,000 engineers across industry, academia and the public sector. The primary aim of our collaboration was to seek evidence on which to base advice that would enable government to ensure the industrial strategy is able to achieve its aims of improving living standards and economic growth by increasing productivity and driving growth across the whole country.

In the initial stages, the Royal Academy of Engineering and professional engineering organisations directly contacted their Fellows and members to identify the key issues, opportunities and areas of concern. From this, the project team split into sub-groups to work on the pillars as well as considering the interdependencies between the pillars and overarching points.

Members of the project team also undertook extensive desk research, interviews and less formal conversations to provide information across all 10 pillars in the industrial strategy Green Paper.

Survey

An online survey was distributed to members of the engineering profession via the professional bodies of the Engineering the Future alliance.

The survey was conducted over a two-week period ending on 13 March 2017. It included questions on the industrial strategy Green Paper proposals as a whole, and on aspects of the individual pillars. The survey received 1,297 responses from engineers employed in industry, academia, public bodies, research and technology institutes, charities and other organisations, representing a broad range of sectors and located across England, Wales, Scotland and Northern Ireland (see Figure 1).

The results provide an interesting snapshot of views among those in engineering sectors but should not be considered a comprehensive picture. A number of questions elicited free text and some allowed more than one answer; not all respondents answered all questions.

Workshops

Workshops were held in the capital cities of each of the three home nations –Scotland, Wales and Northern Ireland – and in four regions of England – London, West Midlands, South West and Yorks and Humberside. Four topic-based workshops were also held in London on 'Investing in science, research and innovation', 'Cultivating world-leading sectors' and 'Developing skills'. All workshops were held during March 2017, and were attended by a total of over 150 invitees.

- Scotland – Edinburgh (Chair: Professor Gordon Masterton OBE FREng FRSE)
- Wales – Cardiff (Chair: Professor Hywel Thomas CBE FREng FRS FLSW)
- Northern Ireland – Belfast (Chair: Professor Norman Apsley OBE FREng FInstP)

Regions:

- London/South East/East of England – London (Chair: Lawrie Quinn)
- East Midlands/West Midlands – Birmingham (Chair: David Wright FIET)
- South West – Bristol (Chair: Dr Mike Purshouse FREng FIET)
- North East/North West/Yorks and Humberside – Leeds (Chair: Richard Threlfall)

Topic-based workshops:

- London – Investing in science, research and innovation (Chair: David Eyton FREng)
- London – Innovators Network workshop (Chair: Elspeth Finch)
- London – Cultivating world-leading sectors (Chair: Professor Steve Evans MIET)
- London – Developing skills (Chair: Professor John Perkins CBE FREng and Carol Burke CBE FREng)

Appendix 2 - Acknowledgements

The Academy and Engineering the Future would like to thank all individuals who attended workshops, responded to the survey, met members of the project team and otherwise submitted their views to the report team.

Engineering the Future

The following institutions make up the Engineering the Future alliance:

- BCS – The Chartered Institute for IT
- British Institute of Non-Destructive Testing
- Chartered Institution of Building Services Engineers
- Chartered Institution of Highways & Transportation
- Chartered Institute of Plumbing and Heating Engineering
- Chartered Institution of Water and Environmental Management
- Energy Institute
- Engineering Council
- EngineeringUK
- Institution of Agricultural Engineers
- Institution of Civil Engineers
- Institution of Chemical Engineers
- Institute of Cast Metals Engineers
- The Institution of Diesel and Gas Turbine Engineers
- Institution of Engineering Designers
- Institution of Engineering and Technology
- Institution of Fire Engineers
- Institution of Gas Engineers and Managers
- Institute of Highway Engineers
- Institute of Healthcare Engineering & Estate Management
- Institution of Lighting Professionals
- Institute of Marine Engineering, Science and Technology
- Institution of Mechanical Engineers
- Institute of Measurement and Control
- Institution of Royal Engineers
- Institute of Acoustics
- Institute of Materials, Minerals and Mining
- Institute of Physics
- Institute of Physics & Engineering in Medicine
- Institution of Railway Signal Engineers
- Institution of Structural Engineers
- Institute of Water
- Nuclear Institute
- Royal Academy of Engineering
- Royal Aeronautical Society
- Royal Institution of Naval Architects
- Society of Operations Engineers
- Society of Environmental Engineers
- The Welding Institute

List of recommendations

Pillar 1 - Investing in science, research and innovation

Investment in research and innovation

1.1 The UK government should set a target of 3% of GDP combined public and private R&D investment. Working together, government and the private sector should formulate a roadmap to set out how to achieve that goal. An interim objective could be aiming for the OECD averages of 0.66% and 1.47% of GDP for government and industry R&D investment respectively.

1.2 The guidance for R&D tax credits should be improved and simplified. Consideration should also be given to: whether they could become a more powerful incentive in light of potential changes to state aid rules; whether they should offer a preferential tax benefit for collaboration with universities and other public sector organisations; and whether they should be enhanced for businesses doing development in the UK that follows research already cleared for the credit.

1.3 The government needs to revisit the issue of VAT on shared facilities in light of the decision to leave the EU.

1.4 The industrial strategy should be used to accelerate implementation of the Dowling Review recommendations in order to enhance business-university collaboration.

1.5 The industrial partnership PhDs announced in Spring Budget 2017 should be used to catalyse new business-university partnerships and not be limited to existing Doctoral Training Partnerships.

Industrial Strategy Challenge Fund

1.6 The Challenge areas supported under the Industrial Strategy Challenge Fund should include societal challenges and be framed and promoted in a way that stimulates public engagement and support.

1.7 Government needs to demonstrate a greater willingness to accept the risk of failure, or perceptions of it, in its innovation support, including in regard to the management of the Industrial Strategy Challenge Fund. Regulators also have a role to play and should be encouraged to explain how risks for innovative technologies are being managed to allay public concerns.

1.8 It is essential that the Industrial Strategy Challenge Fund operates with significant autonomy and is run by staff with relevant expertise.

1.9 The Industrial Strategy Challenge Fund should facilitate opportunities for industrial competitors to collaborate with one another and work together towards common goals, including for societal benefit.

1.10 To ensure that maximal benefits are reaped, the application process should be quick and simple, followed by a fast release of funds for successful applicants. Involvement of businesses should be based on most relevant expertise rather than factors such as size of business.

1.11 Increased industrial experience for students at all stages of their education should be encouraged by the Challenge Fund. However, mobility needs to be bidirectional and opportunities should be increased to allow people in industry to experience academia.

1.12 Priority should be given to using existing physical centres to bring together academic experts with entrepreneurs, for example Catapults. Such centres should assist with legislation, regulation, compliance and standards. The Challenge Fund should also facilitate the creation of virtual centres.

Commercialisation

1.13 Greater promotion of the excellent resources already available from the Intellectual Property Office (IPO) is needed to help companies and individuals better understand what protecting their intellectual property entails. In addition, the benefits of the Patent Box need to be promoted more effectively, in parallel with ensuring that it is as user-friendly as possible, particularly for SMEs.

1.14 Government should ensure that perceived or actual intellectual property (IP) costs do not act as barriers to the commercialisation process, particularly in areas where public sector support is already involved, for example activities supported by the Industrial Strategy Challenge Fund.

1.15 Government should facilitate an increase in the breadth and range of connection opportunities, in response to the requirements of the project, sector or local region, building on and promoting existing effective initiatives.

1.16 Government needs to give a clear message to regulators that early interactions with innovators and technology expertise are an essential part of their responsibilities and consider how closer working between regulators and innovators can be incentivised or facilitated.

1.17 Existing networks, such as the Knowledge Transfer Network and the Catapult network, should be utilised to encourage and facilitate participation in the development of regulation and standards. UKRI should be tasked with considering how academic participation in the development of regulation and standards can be encouraged and recognised.

1.18 Universities should ensure that their IP policies and information about their approach to the spin out process are easy to find and, ideally, publicly available. Universities may also wish to consider publishing anonymised details of the terms of deals they have agreed.

1.19 Some universities allow academic entrepreneurs to access commercialisation support externally, adjusting their equity stake in the spin-out to reflect this. This decoupling of the support provided by the university that led to the generation of IP, from the wider package of support such as incubation services, can be beneficial and should be available more broadly.

Developing research leaders and entrepreneurs

1.20 Sensible and proportionate arrangements should be in place to retain and attract non-UK nationals who wish to pursue innovative and entrepreneurial engineering and tech-based activities in the UK.

1.21 The UK should seek the closest achievable association with EU research and innovation programmes and ensure that, if needed, new long-term UK funding programmes are available that complement current UK funding streams. These should focus on supporting international mobility and collaboration, including academic and industry partnerships (involving both large and small companies).

1.22 Universities should ensure that all students in appropriate subjects and academic staff receive wider business skills and IP awareness to improve their ability to undertake knowledge exchange activities across the course of their careers and help companies to generate and absorb innovation.

Supporting innovation in local areas

1.23 The UK should prioritise the provision of high-quality opportunities for companies to test and demonstrate their technological innovations to allow UK companies to gain competitive advantage and act as an attractor for inward investment.

1.24 A register of 'national innovation assets', with associated policies to support their effective exploitation should be established to extend the geographical reach of innovation activities beyond current centres of excellence.

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Pillar 2 - Developing skills

2.1 The government should work closely with the engineering community to promote the Year of Engineering and support longer-term public engagement campaigns.

2.2 Digital skills should be included in the government's future definition of basic skills.

2.3 The initial teacher education bursary for D&T should be increased in line with mathematics, physics and computing to help boost teacher recruitment.

2.4 Government should consider how best to leverage the use of technologies to augment the role of teachers in the classroom to support and enhance learning.

2.5 Government should significantly increase funding for subject-specific teacher CPD for primary and secondary school teachers to ensure that all teachers undertake subject-specific CPD alongside general professional development and training, making annual training compulsory and monitored through OFSTED inspections.

2.6 The OFSTED Accountability Framework should include careers education as a limiting judgement so as to ensure substantial improvements in this area.

2.7 The new careers strategy should deliver professional, impartial careers advice linked to local labour market information as well as employer engagement.

2.8 Existing support for the professional development of computing teachers in schools needs to be sustained and expanded so that as many students as possible are able to take GCSE computer science.

2.9 A new general computing GCSE should be developed alongside the current computer science GCSE and computing designated a core subject in schools.

2.10 D&T should be included in the English Baccalaureate accountability measure on schools.

2.11 The government should introduce a broader post-16 curriculum and qualifications system for those students continuing on the academic pathway towards higher education or employment

2.12 The Department for Education and the Institute for Apprenticeships and Technical Education need to work closely with the engineering community to develop the curriculum content for the relevant T-level routes.

2.13 T-Level qualifications in engineering and manufacturing, construction and built environment and digital must align with and address the knowledge and skills requirements for professional registration at technician level.

2.14 The government should incentivise the teaching of high-cost subjects by introducing a differential funding mechanism that would provide colleges with increased student funding for high-cost programmes (such as the new T-Levels in engineering and manufacturing and in construction and built environment) and correspondingly lower amounts of funding per student in lower cost subjects.

2.15 Government needs to ensure that colleges are ready to deliver the new routes in terms of the readiness of lecturers and facilities.

2.16 The primary aim of Institutes of Technology (IoT) should be to support growth through the industrial strategy, and this must not be diluted by well-meaning but secondary objectives.

2.17 Employer investment and engagement in IoTs is critical. Teaching provision must be co-designed and delivered to effect maximum impact as well as building on existing successful, national specialist models and their corresponding networks for developing advanced skills.

2.18 Application processes for post-16 education and work experience need to take account of distance-to-learn constraints of young people travelling on public transport.

2.19 The government should consider the introduction of a five digit standard occupational classification to improve understanding of the national labour market.

2.20 The industrial strategy should give employers the confidence to invest in

training and upskilling by bringing policy stability. Sector deals should ensure that this is addressed at the sectoral level in addition to by individual employers.

2.21 Upskilling and professional development of the existing engineering workforce should be through effective existing mechanisms and bodies such as professional registration, which should in turn be encouraged through government procurement policies.

Pillar 3 - Infrastructure

Investment in infrastructure

3.1 As part of the industrial strategy, government must as a minimum maintain the current level of infrastructure funding and incentives.

3.2 All local and combined authorities, and sub-national transport bodies should have access to flexible financing options such as municipal bonds and 'earn back' for infrastructure development.

3.3 Strategic bundling of smaller schemes combined with incentivised partnerships across public and private sectors would support both efficient delivery, value for money and potentially attract financing from large institutional investors.

3.4 It is vital that the long-term approach in the National Infrastructure Delivery Plan is continued after the UK leaves the EU to provide an element of certainty to investors.

3.5 The promotion and development of nationally strategic energy and transport projects should be accelerated to increase UK sustainability and productivity.

3.6 To ensure continued development of large infrastructure projects, it is essential that the UK's status with the European Investment Bank is addressed early in negotiations for leaving the EU.

3.7 Regional infrastructure strategies should be developed across the country. The Midlands Engine Strategy provides a good, early example for other to follow.

3.8 To address shortfalls in maintenance spending, which tends to operate on annualised budgets, we recommend that all sectors should adopt a total expenditure method (TOTEX).

3.9 Regulatory frameworks across all infrastructure sectors should incentivise whole life investment decisions based on outcomes for the end user. It would enable the consideration of 'value' beyond cost, effectively redefining 'value' in the industry.

3.10 The UK should be training and equipping local populations to compete for new opportunities in building local infrastructure.

3.11 Digital delivery and smart infrastructure solutions should be embedded across all economic and social infrastructure. Digital strategies should accompany all major infrastructure projects.

Pillar 4 - Supporting businesses to start and grow

Investment

4.1 Government should continue and increase its collaborative working with existing financial institutions, as is already done by the British Business Bank, to expand the portfolio of incentives to increase long-term investment by the private sector.

4.2 Government should revisit the limits on the amounts that can be invested under the popular Seed Enterprise Investment Scheme (SEIS), Enterprise Investment Scheme (EIS) and Venture Capital Trusts (VCTs), as well as developing additional tax incentives that stimulate longer-term investments.

Equity investment outside London and the South East

4.3 Government should work with the private sector and organisations such as the UK Business Angels' Association (UKBAA) and the British Private Equity and Venture Capital Association (BVCA) to facilitate an increase in the breadth and range of connection opportunities for investors outside London and the South East.

4.4 Government, in partnership with organisations such as LEPs, growth hubs, Catapults and universities, should promote the investment opportunities and

investment successes across the whole of the UK.

4.5 In regions where equity uptake is regarded to be especially low, training for entrepreneurs and business leaders should include an emphasis on the opportunities that equity capital investments present.

4.6 To further maximise the impact of EIS and SEIS, government should undertake targeted regional promotion of the schemes to both potential investors and eligible companies.

4.7 Government should consider creating co-investment funds which target specific regions or sectors to catalyse the uptake of equity capital beyond the South East.

Scale-up challenge

4.8 Business owners who have successfully scaled up and who have founded companies that are 'born global' should be promoted as role models, and their stories used as case studies to inspire and educate the next generation of companies with scale-up potential.

4.9 Government should explore ways to incentivise companies to take up high quality training opportunities. Learning, both positive and negative, should be taken on board from such schemes as the Growth Vouchers Programme pilot.

4.10 Skills training and advice targeted at companies with scale-up potential should include a focus on marketing skills and approaches to sales.

4.11 Efforts are still needed to increase the profile of growth hubs and the support they coordinate and provide.

4.12 To ensure that government's marketing and promotion activities reach their target audience, research should be undertaken into the most effective marketing channels for SMEs, taking into account regional and sectoral dimensions.

4.13 Further research should be undertaken to understand why the Higher Growth Segment of the London Stock Exchange has not had substantial uptake and to explore how the perceived advantages of the US NASDAQ can be drawn on to enhance UK opportunities.

4.14 Regular and comprehensive reporting on UK equity investment deals would be welcomed to help the government identify any funding gaps.

Pillar 5 - Procurement

5.1 Government should communicate a clear message to government departments, local authorities and other public sector procurers, as well as to the public and media, on the value of innovation and the importance of supporting innovation through procurement.

5.2 Government should consider how best to change the culture of risk aversion, to encourage government departments and other public bodies to embrace innovative solutions.

5.3 Greater transparency and better data are needed for government procurement spend with SMEs, both directly and through supply chains.

5.4 Government should ensure the balanced scorecard approach used in procurement fully recognises the value of innovation, as well as diversity and inclusion.

5.5 Government should consider applying a systems engineering approach to ensure that the UK government's broader objectives for procurement are realised.

5.6 In its new guidance for public buyers on how to drive innovation, government should include guidance on improving the procurement process to make it simpler, more consistent and on creating incentives for innovation in procurement. The guidance should also include best practice examples.

5.7 A radical reboot of SBRI is required. At a minimum, government should mandate increased use of SBRI across all appropriate government departments and agencies, and ensure that those involved in the scheme have the sufficient skills and knowledge to be intelligent clients.

5.8 In the light of the EU referendum result and its implications for Regulations, Directives and other EU law currently applicable in the UK, a review is needed of public procurement and state aid rules as part of the industrial strategy.

5.9 Local authorities have a role to play in procuring innovation projects and ensuring that technologies are at the core of local plans, with resulting social and economic benefits. Local authorities and local government organisations should share best practice examples where the procurement process has encouraged innovation.

Pillar 6 - Encouraging trade and inward investment

6.1 The government must use the industrial strategy to set an ambitious bold global vision for the UK as an outward looking leading trading nation and a top destination for inward investment and global talent via the UK's existing credentials as a leader in engineering, innovation and manufacturing.

6.2 Government must be focused in its support for trade, concentrating on simplifying bureaucracy, developing and promoting support initiatives, enabling UK businesses to market their products and services, and upskilling the workforce in areas necessary to trade effectively.

6.3 To attract investment, government needs to focus on the factors of most importance to investors, which include, skills, supporting infrastructure and the cost of setting up and running a business.

Pillar 7 - Delivering affordable energy and clean growth

7.1 Government, as part of the Emissions Reduction Plan, should take a systems approach to energy policy, addressing the interests of businesses and the wider public, as well as reducing emissions and ensuring secure and resilient networks.

7.2 Government should address energy efficiency and resource productivity as a priority. We recommend the development of a scheme to identify opportunities, and implement the findings so that energy consumption in an organisation is 'as low as reasonably practicable' (ALARP), insofar as this does not undermine the competitiveness of the business. This should be accompanied by the introduction of an Energy Saving Incentive (ESI).

7.3 Heating efficiency savings should be at the core of a drive towards decarbonised heating, resulting from better incentives to make the UK's existing building stock more energy efficient and from tightening and enforcing building regulations on energy efficiency.

7.4 Support for CCS needs to be revisited and the technology put back on the agenda. The priority must be the development of a full-scale demonstration plant with the associated transportation and storage network and greater understanding of a viable business model to deliver future plants that are cost competitive.

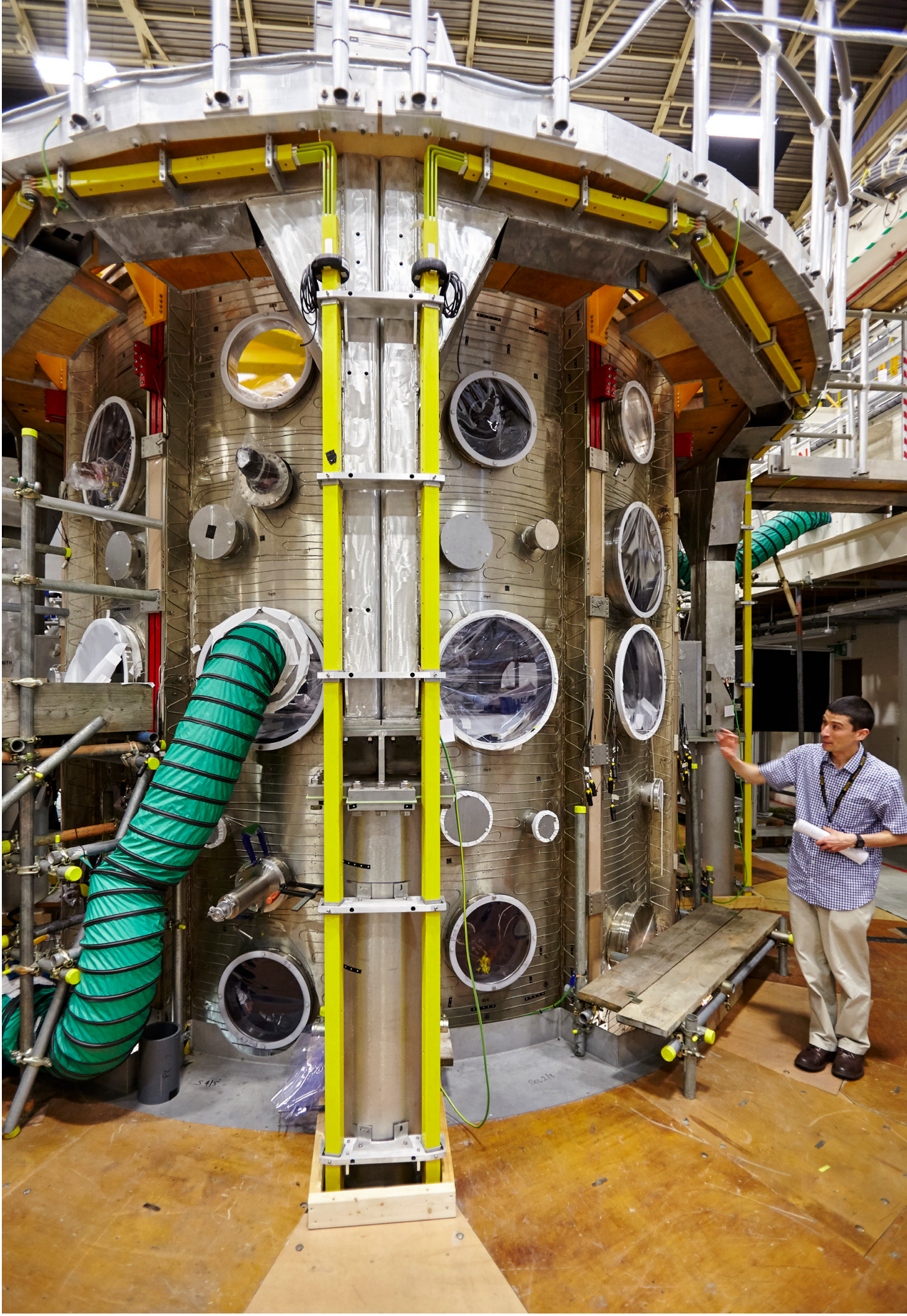
7.5 There is an opportunity for the UK supply chain to play some part in the development of small modular nuclear reactors; however, this will be likely to need some form of catalytic activity from government and a clearer focus from the industry on commercially viable solutions, notably those that minimise licensing and regulatory requirements outside the factory environment. The UK could use its history of reactor development and international reputation for safety and quality to develop and promulgate UK participation in technology for a worldwide market.

7.6 Multiple options for the decarbonisation of the supply of heat need to be investigated. These should include renewable gas (biomethane), district heating networks, hydrogen and heat pumps. Each needs to be assessed for its commercial viability at scale, local benefits and consumer acceptability.

7.7 It is recommended that subsidy regimes have clearly-articulated deployment targets and payment reduction structures for when prices of renewable technologies come down. This could help avoid subsidy cost overruns as well as industry shocks as subsidies are reduced or removed.

7.8 Government should maintain existing mechanisms to support and accelerate the development of community energy and heating.

7.9 To achieve an internationally-level playing field, the UK should maintain a leadership role in global climate negotiations and mitigation efforts.



© Doug King FREng, experimental fusion reactor at Culham Centre for Fusion Energy

7.10 The engineering community would welcome a funding arrangement that actively fosters links between academia and industry to encourage a focus on real-world energy issues and commercialisation, potentially utilising local institutions as test-beds for innovations. Such innovation could be encouraged through tax relief for research and development.

Pillar 8 - Cultivating world-leading sectors

8.1 Sector deals must be available to communities focused on enabling technologies and capabilities, such as digital technology, in addition to more traditional sectors. These type of sector deals should directly address opportunities to maximise the benefits of the technology or capability across all relevant sectors.

8.2 Sector deals should encompass actions targeted at strengthening access to skilled people, international markets and networks and investment in R&D.

8.3 Sector deals should be subject to regular review, linked to a clear evaluation framework. However, they need to be underpinned by a firm and long-term commitment from government to build investor and business confidence.

8.4 Sector deals should facilitate improvements in productivity through, for example, upskilling of staff and expansion of talent pools; automation and increased application of AI and robotics; reducing the administrative burden; and implementation of modern IT and data infrastructure and techniques.

8.5 Sector deals should offer the possibility of an uplift in public investment in R&D for sectors, conditional on a commensurate increase in investment in associated activities by business.

8.6 Sector deals should be used to promote and facilitate investment in pre-competitive collaborative R&D by companies, for example to address shared environmental challenges.

8.7 When developing the industrial strategy and other long-term sectoral strategies, government and business should consult universities and Research and Innovation Organisations as key partners. Innovation should be a core component of policies aimed at promoting productivity and competitiveness, with full consideration given to its role in different sectors.

8.8 Government should facilitate a rolling programme of workshops for bringing together relevant players across the various sector groups and other key players (such as UKRI) to examine opportunities for innovation that cut across different sectors and to learn from approaches being adopted by other sectors.

8.9 Regular meetings should be convened between leadership councils or similar institutions representing sectors in order to help identify opportunities for cross-sector working, and to identify where coordination will provide leverage in cross-cutting issues such as skills.

8.10 Government should ensure that the industrial strategy is clearly positioned in its global context, including by taking into account opportunities to adopt innovation developed elsewhere and focusing on how sector deals can support exports.

8.11 Government needs to support the development of good sector deals by sectors with weaker institutional arrangements, for example by offering a multi-stage approach to the development of the deal and providing access to experts and resources that can help to support sectors through the process.

8.12 Government must work with communities of experts – including in engineering – to ensure that its approach to industrial strategy in general, and sector deals in particular, sufficiently reflect future needs and opportunities.

Pillar 9 - Driving growth across the whole country and Pillar 10 - Creating the right institutions to bring together sectors and places

9.1 Government must continue to drive investment in local transport networks, particularly the local road network and public transport. The NIC has a crucial role in identifying investment priorities at the regional level.

9.2 Government must support both shipping and aviation sectors as part of the industrial strategy as vital components of international trade and opportunities to drive growth across the UK.

9.3 Government must continue to drive for world-class digital connectivity that is fast, secure and resilient.

9.4 'National innovation assets' should be identified, promoted and supported by government to build a more balanced and effective innovation landscape across the UK. Anchor institutions can also help to seed clusters of local economic activity.

9.5 Government should build on the Science & Innovation Audits to develop more comprehensive mapping of local industrial capabilities and innovation ecosystems. This needs to be accompanied by an ongoing process of stakeholder engagement; the full value of the mapping will not be realised without this.

9.6 It is essential that the industrial strategy puts in place plans to ensure that the regional development needed to underpin inclusive economic growth can be supported when the UK has left the EU.

9.7 The landscape for local support is already complex. The focus should be on promoting awareness of what exists, providing a stable framework for support and policy continuity, and seeking to build on what works.

9.8 The industrial strategy needs to ensure that regional and local strategies are coordinated and coherent: the whole needs to be greater than the sum of the parts, which can only be achieved through adopting a systems approach.

9.9 It is also essential that the industrial strategy recognises that not all regions can be identical in terms of their productivity. Different sectors have different characteristics and the metrics of success need to be more sophisticated than a single average value GDP per capita that will be distorted by local industries and demographics.

9.10 Government will not be able to deliver the aspirations of the industrial strategy without enhancing technological literacy levels of public servants in both national and local government. Urgent action needs to be taken to embed training in digital and data skills across the public sector. This must include efforts to raise the technical skill levels of the senior civil service and local government leaders.

9.11 Government should promote the creation of chief data officers in all major UK cities or regions and convene a network that enables the sharing of best practice both between these cities and regions and with global cities that have achieved success in delivering data-driven improvements to public services.

9.12 An expanded programme of secondments involving the exchange of personnel between the civil service and both business and academia should be established, with a particular focus on building the technical capabilities of the public sector and improving the understanding of policy and government in the private sector and academia.

9.13 For the industrial strategy to be successful, and for the economy to 'work for all', engagement with civil society needs to be an integral component of the activities undertaken.

9.14 UKRI should be tasked with considering how procedures for assessing grant applications and research excellence can be utilised to drive more and better public engagement by individual researchers, universities and businesses.

9.15 Government should recognise that the UK's national quality infrastructure, comprising BSI, NMRO, NPL and UKAS, has an important contribution to make to the delivery of the industrial strategy's objectives and needs to be supported and promoted accordingly.

9.16 Professional engineering institutions and other professional bodies have a critical interface with engineers across all disciplines. Governments should capitalise on the offer from the profession to engage closely with the industrial strategy.

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ENGINEERING

Royal Academy of Engineering

As the UK's national academy for engineering, we bring together the most successful and talented engineers for a shared purpose: to advance and promote excellence in engineering.

We have four strategic challenges:

Make the UK the leading nation for engineering innovation

Supporting the development of successful engineering innovation and businesses in the UK in order to create wealth, employment and benefit for the nation.

Position engineering at the heart of society

Improving public awareness and recognition of the crucial role of engineers everywhere.

Address the engineering skills crisis

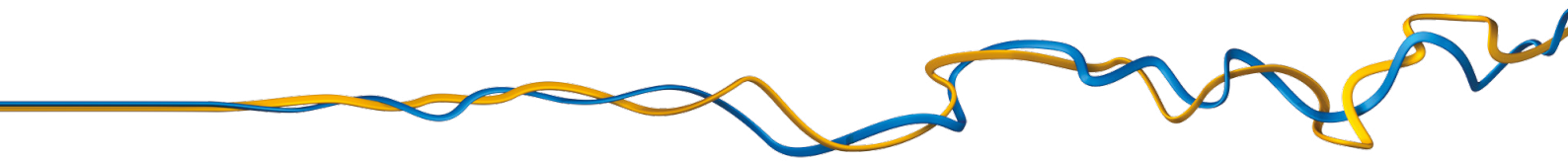
Meeting the UK's needs by inspiring a generation of young people from all backgrounds and equipping them with the high quality skills they need for a rewarding career in engineering.

Lead the profession

Harnessing the expertise, energy and capacity of the profession to provide strategic direction for engineering and collaborate on solutions to engineering grand challenges.

Engineering the Future

Engineering the Future (EtF) is an alliance of professional engineering institutions and national organisations that between them represent 450,000 professional engineers. Through EtF, the engineering profession speaks with one voice on engineering issues of national and international importance. We provide independent – and expert – engineering advice to government. We promote understanding of the critical contribution that engineering makes to national policy and to addressing the grand challenges.



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