Crawley Borough Council

Crawley 2035

Ref No:

Office use only

Crawley Submission draft Local Plan Representation

Please return your completed representation form to Crawley Borough Council by 5pm on 2 March 2020.

Representations can be made via this form and emailed to forward.planning@crawley.gov.uk or sent via post to: Local Plan Consultation, Strategic Planning, Crawley Borough Council, Town Hall, The Boulevard, Crawley, RH10 1UZ. Alternatively, representations can be made online using the eform which allows attachments of documents.

This form has two parts:

PART A – Personal details

By law, representations cannot be made anonymously. All representations will be published alongside your name, company name (if applicable), and your client's name/company (if applicable). The Council will use the information you submit to assist with formulating planning policy.

Further information about Data Protection Rights in line with the provisions of the General Data Protection Regulations and Data Protection Act 2018, for example, how to contact the Data Protection Officer, how long information is held or how we process your personal information can be found at www.crawley.gov.uk/privacy. Specific reference to the Local Plan and planning policy related public consultation can be found on: www.crawley.gov.uk/pw/web/PUB351893

PART B – Your representation

Please fill in a separate sheet for each representation you wish to make. You may submit multiple "PART B" sections with a single "PART A" completed.

PART A – Personal details

Please ensure that you complete all fields in 1. If a planning agent is appointed, please enter the Title, Name and Organisation in 1, and complete the full contact details of the agent in 2.

	1. Personal details	2. Agent's details
Title:	[redacted]	
First name:	[redacted]	
Surname:	[redacted]	
Organisation:		
Address line 1:	[redacted]	

Address line 2:	[redacted]	
Town/city:	[redacted]	
Postcode:	[redacted]	
Telephone:	[redacted]	
Email:	[redacted]	

PART B – Your representation

3. Please tick the document that you would like to make a representation on:

- [x] Crawley submission Local Plan
- [ ] Crawley submission Local Plan Map
- [ ] Crawley submission Sustainability Appraisal
- [ ] Habitats Regulation Assessment Screening Report

4. Which part of the Local Plan does this representation relate to?

Paragraph:		Policy:	Omission of digital communication infrastructure policy	Other:	

5. Do you consider the Local Plan to be: *(Please tick)*

5.1. Legally compliant?	Yes	[x]	No	[ ]
5.2. Sound?	Yes	[ ]	No	[x]
5.3. Compliant with the duty to co-operate?	Yes	[x]	No	[ ]

6. Please give details explaining your response to 5.1, 5.2, or 5.3 below. Please be as clear as possible.

Digital communication infrastructure is playing an ever increasing role in the populations everyday lives. However it is now becoming a fundamental requirement in the provision of business services as well as providing key social economic benefits by supporting health, education and social services. Resilient digital communications is also fundamental to the management of all the other key infrastructure elements, electricity, gas, water (including flood management), emergency services and road management as well as providing the underlying structure for mobile digital service such as 5G and Fibre to the Premises (FTTP). While all these services are provided by others, it is a serious omission for the local government not to have policies in place to enable and support the planning of Crawley's digital communication infrastructure to help develop the supply of digital communications to its residence and businesses in the 21 century as it does with the other infrastructure elements already mentioned. I would argue that for the future development of the area, a holistic approach to digital communications infrastructure is as important and the other policies already covered in

this document.

If required, please continue your response on an additional piece of paper and securely attach it to this response

7. **Please set out what modification(s) you consider necessary to resolve the issues you have identified above. You need to state why this modification will make the Local Plan legally compliant or sound. It would be helpful if you are able to suggest how the wording of any policy or text should be revised. Please be as clear as possible.** *Any non-compliance with the duty to co-operate is incapable of modification at examination.*

The inclusion of a digital communication infrastructure policy in the local plan. This will involve quite a bit of additional work as it has not been included at all before.

If required, please continue your response on an additional piece of paper and securely attach it to this response

Your representation should cover succinctly all the information, evidence and supporting information necessary to support/justify the representation and the suggested modification, as there will not normally be a subsequent opportunity to make further representations. ***After this stage, further submissions will only be at the request of the Inspector, based on the matters and issues s/he identifies for examination.***

8. **If your representation is seeking a modification, do you consider it necessary to participate in the public examination hearings?** *(Please tick)*

No, I do not wish to participate in the examination hearings ■ Yes, I wish to participate in the examination hearings ☐

9. **If you wish to participate in the public examination hearings, please outline why you consider this to be necessary:**

As this has not been included in the future plan before, this could involve collecting evidence from additional expertise's that may not currently exist within the current team.

The Inspector will determine the most appropriate procedure to adopt to hear those who have indicated that they wish to participate at the public examination.

If you would like to make a representation on another policy or part of the Local Plan then please complete a separate PART B section of the form or securely attach an additional piece of paper. Copies of the representation form can also be downloaded from the council's website at: www.crawley.gov.uk/crawley2035

Signature [redacted]

Date 20/01/2020

Ofcom
making communications work
for everyone

CONNECTED NATIONS **2016**

Published: 16 December 2016

FULL DOCUMENT

About this document

The United Kingdom depends on various infrastructures, and one of the most important is the nation's communications.

Fast, reliable communications enable businesses to generate prosperity and employment, and our countries to compete. They empower every citizen to take a full part in society and benefit from life's opportunities. Communications also save lives, bind families and friends together, and keep us entertained.

Part of Ofcom's role is to make sure that, as far as possible, we can make the calls we want to, where we need to and that we can use the internet at acceptable speeds.

This annual report tracks the communications providers' progress in growing the availability of good communications, and how the UK is working towards a robust and visionary next generation of services.

Contents

Section 1

Dashboard

The data for 2016 was collected during June. Data for 2015, where available, is provided for comparison[1], and all figures for data usage combine both download and upload volumes.

Fixed broadband	2016	2015
Broadband, all speeds		
Coverage, premises	≈100%	≈100%
Take-up, premises	78%	78%
Average download sync speed	37Mbit/s	29Mbit/s
Average upload sync speed	4Mbit/s	4Mbit/s
Total fixed data usage	2,750PB	N/A
Average monthly data usage, per residential connection	132GB	97GB
Broadband (download speed of 10Mbit/s and higher)		
Coverage, premises	95%	92%
Take-up, premises	54%	50%
Average download sync speed	51Mbit/s	N/A
Average upload sync speed	5Mbit/s	N/A
Total fixed data usage	2,230PB	N/A
Average monthly data usage, per residential connection	153GB	N/A
Superfast broadband (download speed of 30Mbit/s and higher)		
Coverage, premises	89%	83%
Take-up, premises	31%	27%
Average download sync speed	74Mbit/s	65Mbit/s
Average upload sync speed	8Mbit/s	8Mbit/s
Total fixed data usage	1,434PB	N/A
Average monthly data usage, per residential connection	169GB	112GB
Ultrafast broadband (download speed of 300Mbit/s and higher)		
Coverage, premises	2%	2%
Take-up, premises	0.09%	0.003%
Broadband (download speed up to 10Mbit/s)		
Coverage, premises	5%	8%
Take-up, premises	24%	26%
Average download sync speed	6Mbit/s	N/A
Average upload sync speed	1Mbit/s	N/A
Total fixed data usage	521PB	N/A
Average monthly data usage, per residential connection	81GB	N/A

[1] This year our fixed networks analysis is based on a more detailed data set than was available in previous years. Therefore, it is not possible to provide year-on-year comparisons for all metrics.

Mobile[2]	2016	2015
4G services		
Premises (indoor) covered by all operators	72%	29%
Premises (indoor) not covered by any operator	4%	16%
Geographic area covered by all operators	40%	8%
Geographic area not covered by any operator	28%	52%
Coverage of A and B roads by all operators	38%	9%
A and B roads not covered by any operator	20%	47%
Voice services (2G, 3G and 4G)		
Premises (indoor) covered by all operators	89%	85%
Premises (indoor) not covered by any operator	1%	2%
Geographic area covered by all operators	66%	58%
Geographic area not covered by any operator	10%	13%
Coverage of A and B roads by all operators	61%	52%
A and B roads not covered by any operator	6%	10%
Data services (3G and 4G)		
Premises (indoor) covered by all operators	80%	77%
Premises (indoor) not covered by any operator	2%	3%
Geographic area covered by all operators	52%	38%
Geographic area not covered by any operator	16%	21%
Coverage of A and B roads by all operators	45%	37%
A and B roads not covered by any operator	11%	15%
Mobile (data use)		
Total number of active mobile connections	83.6m	83.7m
Total mobile data usage	105.5PB	72.9PB
Average monthly data usage, per SIM	1.3GB	0.87GB

[2] Coverage thresholds are: 2G indoor (-71dBm), 2G outdoor (-81dBm), 3G indoor (-90dBm), 3G outdoor (-100dBm), 4G indoor (-105dBm) and 4G outdoor (-115dBm).

Section 2

Executive Summary

2.1 Over the course of 2016, the UK took another step forward in the coverage of its fixed and mobile communications. More people are, or can be, connected to the communications they need, and they are consuming more data as fixed and mobile services become increasingly woven into the fabric of their daily lives and work.

2.2 But it would be wrong to infer that the picture is universally a rosy one. For a significant number of consumers, and in many parts of the country, fixed broadband speeds are slow and mobile coverage is poor or indeed non-existent. Ofcom is therefore continuing to work with industry, the UK Government and the devolved administrations to explore ways to improve the availability and performance of these vital communications services.

2.3 A key part of this work is this annual Connected Nations Report; a 'state of the union' update on the coverage and performance of fixed broadband and mobile services that the UK's consumers and small businesses are receiving. We also cover important developments in broadcasting and internet services and track security incidents that affect communications networks and services.

2.4 Below we present the highlights of this year's findings, and expand on them further in the remainder of the report.

Fixed broadband services

2.5 Three levels of fixed broadband service are offered in the UK, typically defined in terms of the download speed they offer. Standard broadband services have download speeds of between 10 and 30Mbit/s, whilst superfast broadband[3] services have download speeds greater than 30Mbit/s. The performance of both standard and superfast broadband services is limited by the use of copper-based technologies in the access network. We are now starting to see the emergence of new ultrafast broadband services, which make greater use of fibre connections, and which we currently define as delivering download speeds of at least 300Mbit/s[4].

2.6 The headline findings on the state of the UK's fixed broadband in 2016 are as follows:

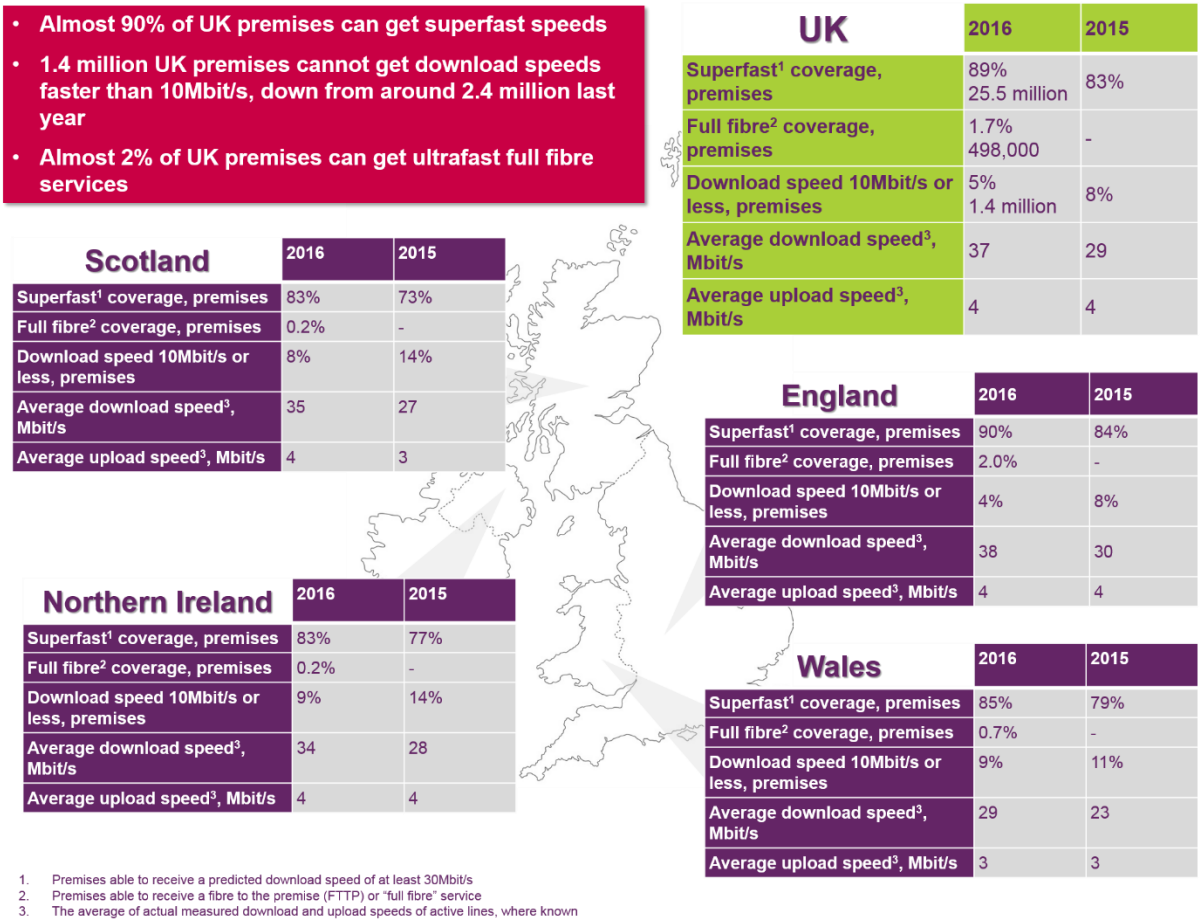
2.7 **The availability of superfast broadband has improved, but a significant number of homes and businesses are still at risk of digital exclusion.** In 2015 around 8% of UK premises (2.4 million) were unable to receive broadband speeds faster than 10Mbit/s. Although this figure has since fallen to 5% of UK premises, this still means 1.4 million premises are being poorly served and may fall within a broadband universal service obligation.

2.8 We recognise that upload, as well as download, speeds can affect the consumer experience, and increase the number of UK premises that are poorly served. If we also require a standard broadband service to deliver an upload speed of at least

[3] The UK Government defines superfast as having download speeds of 24Mbit/s or more.
[4] There is not a consensus on the definition of ultrafast services currently, with views ranging from 100Mbit/s to 1Gbit/s.

1Mbit/s, then the number of UK premises that are poorly served increases to 2.6 million.

Figure 1: The state of fixed broadband in the UK



Source: Ofcom analysis of operator data

2.9 **Superfast coverage has improved, though SMEs still see poorer availability than residential consumers.** 89% of UK homes and small and medium-sized businesses (25.5 million) are now able to receive superfast download speeds of 30Mbit/s or higher. This is up from 83% (24 million), last year. There is also an improving picture in rural areas, where more consumers are now better connected: superfast coverage is reaching 59% of homes and businesses (2.3 million), up from 44% in 2015. However, although superfast coverage has improved in Scotland, Wales and Northern Ireland, they still lag behind the UK as a whole.

2.10 SMEs still experience poorer superfast broadband coverage compared to consumers as a whole. This is because many are located in areas that are less well served. Only 80% of SMEs (1.9 million) have access to superfast services in the UK, compared to 89% of all premises; this leaves almost 480,000 SMEs without access to superfast broadband. Almost 192,000 SMEs cannot currently access speeds above 10Mbit/s.

2.11 The Government defines superfast as having a download speed of greater than 24Mbit/s, and plans to provide this to 95% of premises by the end of 2017. They have made progress, and our findings support their view that, by June 2016, 90% of UK premises were covered by these speeds or faster. This is up from 85% last year.

2.12 **Ultrafast Fibre to the Premises (FTTP) services**. Approximately 1.7% of UK premises (498,000) have access to "full fibre" FTTP services, which offer download speeds of between 250Mbit/s and 1Gbit/s. Around 450,000 of these premises are in England. A number of providers, of varying scale and reach, are committed to deploying full fibre services and we would expect to see coverage increase over the coming 12 months.

2.13 **Increased take-up of superfast services is driving greater consumption.** Around 31% of UK premises (9 million) now subscribe to superfast broadband services. Although this is up from 27% in 2015, it remains relatively low, given that superfast is an option for 89% of UK premises. The percentage of premises not taking up a fixed broadband service at all is 22%.

2.14 The average speed of superfast services has increased by 14% over the last year, to 74Mbit/s. This, coupled with increased take-up of superfast services, means that the average download speed across all active broadband services is now 37Mbit/s, a 28% increase compared to 2015.

2.15 As speeds and take-up of superfast broadband increased, households across the UK consumed an average of 132GB of data per month in 2016, up from 97GB in 2015. As in previous years, there is evidence that households with higher speed connections are consuming significantly more data, especially those with superfast speeds.

Mobile services

2.16 Presenting a clear picture of mobile coverage across the UK is a challenge. Firstly, three different generations of technology are used in the UK's mobile networks, each with different characteristics and qualities. Secondly, consumers access mobile networks in many different ways and, as a result, there is an expectation that mobile phones will work both indoors and outdoors, in towns and in cities and while travelling on the roads and railways.

2.17 The headline findings on the state of the UK's mobile networks in 2016 are as follows:

2.18 **Indoor coverage has increased:** Effective indoor coverage[5] of voice services from all operators is around 89% of UK premises (26 million), up from 85% last year. The coverage of data services has also improved, rising from 77% of UK premises in 2015 to 80% (23 million) this year. We expect commercially-available technologies that build on the increasing availability of fixed broadband, such as Wi-Fi calling, to lead to further improvements in indoor coverage.

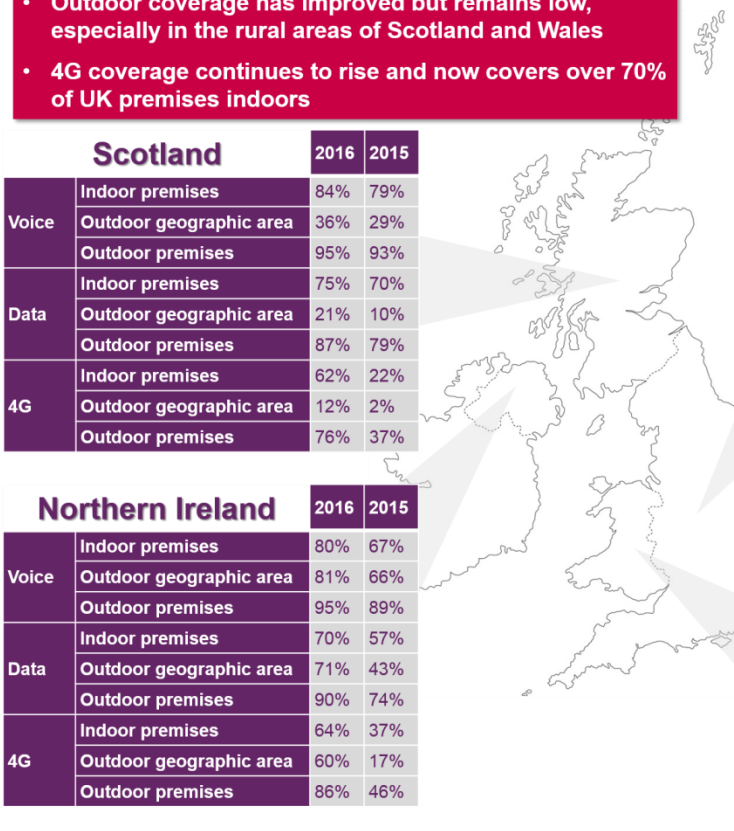
2.19 **There is still some way to go with geographic coverage:** Outdoor coverage of both voice and data services has increased. Consumers can now make and receive phone calls on all operators' networks in 66% of UK landmass, up from 58% last year; and the coverage of data services from all operators has increased from 38% to 52% this year. There is, however, an enduring concern that geographic coverage is still relatively low and that future commercial rollouts are unlikely to fully address the

[5] In this report we use definitions of coverage based on signal strength thresholds that we believe accurately reflect the typical consumer experience, e.g. there is a greater than 95% chance of being able to make a phone call using a modern smartphone. These definitions will be different from those used elsewhere, e.g. in current licence obligations.

situation. There is, therefore, a risk that consumers in rural parts of the UK and its constituent nations, and those travelling by car and train, will continue to experience difficulties in using their mobile phones.

Figure 2: The state of mobile services in the UK

- Consumers can use their phones for voice calls inside almost 90% of UK premises and data services inside around 80% of UK premises
- Outdoor coverage has improved but remains low, especially in the rural areas of Scotland and Wales
- 4G coverage continues to rise and now covers over 70% of UK premises indoors



Scotland		2016	2015
Voice	Indoor premises	84%	79%
	Outdoor geographic area	36%	29%
	Outdoor premises	95%	93%
Data	Indoor premises	75%	70%
	Outdoor geographic area	21%	10%
	Outdoor premises	87%	79%
4G	Indoor premises	62%	22%
	Outdoor geographic area	12%	2%
	Outdoor premises	76%	37%

Northern Ireland		2016	2015
Voice	Indoor premises	80%	67%
	Outdoor geographic area	81%	66%
	Outdoor premises	95%	89%
Data	Indoor premises	70%	57%
	Outdoor geographic area	71%	43%
	Outdoor premises	90%	74%
4G	Indoor premises	64%	37%
	Outdoor geographic area	60%	17%
	Outdoor premises	86%	46%

UK		2016	2015
Voice	Indoor premises	89%	85%
	Outdoor geographic area	66%	58%
	Outdoor premises	97%	96%
Data	Indoor premises	80%	77%
	Outdoor geographic area	52%	38%
	Outdoor premises	93%	88%
4G	Indoor premises	72%	28%
	Outdoor geographic area	40%	8%
	Outdoor premises	86%	46%

England		2016	2015
Voice	Indoor premises	91%	87%
	Outdoor geographic area	84%	77%
	Outdoor premises	98%	97%
Data	Indoor premises	82%	81%
	Outdoor geographic area	72%	57%
	Outdoor premises	95%	91%
4G	Indoor premises	76%	31%
	Outdoor geographic area	60%	11%
	Outdoor premises	90%	50%

Wales		2016	2015
Voice	Indoor premises	73%	65%
	Outdoor geographic area	52%	46%
	Outdoor premises	90%	88%
Data	Indoor premises	57%	47%
	Outdoor geographic area	27%	17%
	Outdoor premises	76%	67%
4G	Indoor premises	34%	10%
	Outdoor geographic area	13%	2%
	Outdoor premises	53%	20%

Coverage is for all operators, i.e. the percentage of premises or geographic area where there is likely to be a signal from all operators. Coverage levels for individual operators may be higher.

Source: Ofcom analysis of operator data

2.20 **Rapid strides in 4G coverage:** All four operators are in the middle of a major 4G rollout programme and the coverage of these higher-speed data services has increased significantly, with geographic coverage from all operators now reaching 40% of UK landmass, up from just 8% in 2015. The launch of 4G voice call services by EE and Three has started to have a beneficial effect on their voice network coverage, in particular by improving coverage indoors.

2.21 **…although 4G is mainly urban:** Most of the first phase of 4G deployments have been focused on urban areas. As a result, geographic 4G coverage in the UK's rural areas is only 37% of landmass, compared to 89% in towns and cities. Coverage inside premises, where many consumers use their phones, remains relatively low, even in urban areas; 72% of UK premises (21 million) receive a 4G signal from all operators indoors.

2.22 **4G is driving data usage:** With growing coverage and greater take-up, 4G is driving greater volumes of data downloads and uploads. The average volume of data consumed per subscriber is now 1.3GB per month, up from 0.9GB in 2015. A total of

106PB was sent over all mobile networks in June 2016, a 44% increase on the year before. Even so, this represents just 4% of the volume of data sent over fixed broadband networks.

2.23 We are committed to providing consumers with information on mobile coverage, via mobile apps and online tools, that is accessible, accurate and comparable. This equips consumers to make informed decisions on which operator best meets their needs. Equally, it gives operators an increased incentive to compete on coverage. Including coverage obligations in operators' licences is also an important lever, to make sure consumers receive an improved mobile experience.

2.24 However, the coverage improvements provided by these existing measures and commercial deployments are unlikely to fully address consumer needs. Without additional steps, the consumer experience in many rural areas, on roads and on the railways is likely to fall short of consumer expectations. We note, however, that achieving near universal coverage throughout the geographical area of the UK and across the road and rail networks, will require significant new investments in mobile infrastructure.

Resilience

2.25 As consumers and businesses become ever-more dependent on communications services, Ofcom's duty to focus on network resilience becomes increasingly important. Although there has been no significant increase in network failures, in either number or impact, underlying changes in network technology have implications for consumers that need an appropriate regulatory and policy response.

2.26 In this year's report we have identified two resilience-related issues that could have a significant impact on consumers – the long-term provision of fixed voice services and the resilience of mobile communications.

2.27 An important technology change in the next few years will be so-called "PSTN switch off"[6]. This refers to the decommissioning of the legacy telephone network and migrating voice services to a service delivered over broadband and, as such, could have a significant impact on consumers. Our key principles are to ensure minimum disruption for consumers and businesses, that providers must communicate the migration process clearly to their customers and that no voice service users are worse off after the technology change, either financially or functionally. We will manage the risks through an active programme of engagement with CPs and other stakeholder groups.

2.28 Meanwhile, mobile is increasingly coming to the fore in meeting overall consumer and business communications needs. However, its infrastructure is more prone to failing during widespread power outages than typical fixed voice services. This is a concern, as mobile has become the primary life-line during emergencies, and it would need a significant investment to reduce its dependence on mains electricity. There will be a need for more focussed activity in this area involving Ofcom, Government and industry as part of the programme of securing and making key elements of critical national infrastructure more resilient.

[6] The Public Switched Telephone Network.

Preparing this report

2.29 The information in this report is derived from a significant volume of raw data which is provided to us by a range of fixed and mobile network operators. The data is highly detailed and contains, among other things:

2.29.1 Predictions of the broadband speeds capable of being delivered to every home or small business in the country;

2.29.2 Actual measured download and upload speeds of every broadband line in the country;

2.29.3 Predicted signal strengths of the voice and data networks for every mobile operator and for each $100m^2$ grid of the UK's landmass; and

2.29.4 The amount of data downloaded and uploaded on all of the UK's fixed and mobile networks.

2.30 We also undertake technical studies, such as our continuing work to measure fixed and mobile broadband quality of experience, and collect information from operators on matters concerning security and resilience of networks and services.

Section 3

Background to the report

3.1 Under the Communications Act 2003 ('the Act') Ofcom is required to submit a report to the Secretary of State every three years, describing the state of the electronic communications networks and services in the UK[7]. We published the first report in 2011 and the second report in 2014.

3.2 However, we recognised after publishing the first report that some aspects of the communications infrastructure were developing rapidly and/or were of particular interest to Government and industry stakeholders, and therefore committed to providing updates on an annual basis. These updates have mainly focused on the areas of greatest change, such as coverage and capacity of fixed and mobile networks. This year's Connected Nations Report updates the report[8] published in December 2015.

Approach and context

3.3 For fixed broadband services this report considers services provided to residential consumers and to small and medium-sized enterprises (SMEs). We use data gathered from the largest operators in each sector, as well as information already held by Ofcom. Where possible we have re-used data already provided to Ofcom, in order to minimise the burden on stakeholders. We have also gathered data from a number of other smaller network and service providers for various aspects of this report, including some providers of fibre to the premises (FTTP) networks.

3.4 We present a detailed description of our data sources and methodologies in Annex 1.

Improving the information available to consumers and other stakeholders

3.5 Alongside this report we are launching two tools to help consumers and other stakeholders find out more about fixed and mobile services in the UK:

3.5.1 **A new app for mobile phones and tablet PCs**, which enables consumers to find out about the fixed broadband and mobile services that are available at their address. In addition, the app will allow consumers to test the speed of their fixed and mobile connections and identify the issues most likely to be affecting their performance. A web-based tool will also be available for use on desktop and laptop computers.

3.5.2 **An online visualisation tool**, which presents some of the key highlights from this year's report in an intuitive and graphical way. The tool allows the user to drill down into the detail of some of the data, for example to find out more about mobile coverage in a specific area.

3.6 As in previous years, we will be making data available to download via our website. We recognise the value in making this data available to third parties for their own

[7] http://www.legislation.gov.uk/ukpga/2010/24/section/1
[8] http://stakeholders.ofcom.org.uk/market-data-research/market-data/infrastructure/connected-nations-2015/

analysis and we continue to work as part of our broader open data initiative to explore ways in which to further improve this.

The International Communications Market Report

3.7 Ofcom's International Communications Market Report (ICMR) 2016[9], published alongside this report, provides comparative international data on the communications sector. Its purpose is to benchmark the UK against 17 comparator countries in terms of the availability, take-up and use of communications services. A range of different data sources are used to inform the analysis presented in the ICMR, including consumer research commissioned by Ofcom, data already held by Ofcom and data sourced from either desk research or third party providers.

3.8 There are a number of metrics in the ICMR that are similar to those in this report (most notably those present in the *Telecoms and networks* chapter of the ICMR). However, data used in the ICMR differs from those used in this report on a number of counts, such as time period (data presented in the ICMR is generally end of 2015 unless otherwise stated, compared to June 2016 for the data in this report) and definitions behind metrics.

3.9 For example, 4G population coverage in the ICMR is defined as being from at least one operator, whereas this report typically expresses coverage from all operators. In instances where metrics differ between the ICMR and this report, the difference is explained. Further explanation behind differences is detailed in the document *Measuring the networks: the methodologies behind Ofcom's research reports*.[10]

Outline of this report

3.10 The remainder of the report is structured as follows:

- Section 4: Fixed broadband networks and services
- Section 5: Mobile voice and data services
- Section 6: Internet Access Services
- Section 7: Security and resilience
- Section 8: The continuing evolution of television
- Annex 1: Methodology
- Annex 2: Glossary

3.11 We welcome comments from consumers and stakeholders on the report. Please contact us at connectednationsreport@ofcom.org.uk.

[9] https://www.ofcom.org.uk/research-and-data/cmr/cmr16/international
[10] https://www.ofcom.org.uk/research-and-data/infrastructure-research/connected-nations-2016

Section 4

Fixed broadband networks and services

4.1 The quality and reach of fixed broadband infrastructure in the UK has advanced considerably over the last few years, both in terms of technology and services offered. Superfast broadband is now available to almost 90% of homes and small businesses across the UK and continuing investment by industry and Government will ensure further increases in coverage over the next few years.

4.2 This section explores the coverage and performance of fixed broadband services in the UK and highlights how consumers are using their broadband connections to send and receive more data than ever before. We note, however, that many consumers still cannot access adequate broadband speeds and highlight ongoing Government and industry initiatives aimed at improving the quality of broadband services for all.

4.3 The most important messages are:

4.3.1 **Superfast broadband coverage in the UK has improved significantly over the last few years.** The coverage of superfast broadband has extended to over 25 million (or 89% of) UK premises, up from 83% in 2015. This creates the potential for better speeds and improved quality of service for both residential and SME consumers.

4.3.2 **There are still gaps in broadband coverage.** Progress has been made in reducing the number of premises that cannot get acceptable speeds. However, around 1.4 million, or 5% of, homes and small businesses in the UK are still unable to receive download speeds greater than 10Mbit/s. This represents the lowest number of premises that would fall within the UK Government's proposed broadband Universal Service Obligation (USO), depending in its specification;

4.3.3 **The growth in the number of premises taking up superfast broadband appears to be slowing.** Over 9 million, or 31% of, UK premises now subscribe to superfast services, up from 27% in 2015 and 21% in 2014. While this latest year-on-year increase is a reasonable improvement, these figures suggest that growth in superfast take-up might be reaching a plateau. Given the relatively high levels of superfast coverage, it is unclear why more consumers are not actively taking up faster services.

4.3.4 **Faster speeds mean that more data is being consumed.** The average download speed of all broadband products in the UK is now 37Mbit/s, up from 29Mbit/s in 2015. Average monthly data volumes per household have increased by 36% over the past year, from 97GB to 132GB. The total volume of data transferred over fixed broadband networks in June 2016 was 2,750PB[11].

[11] A petabyte, or PB, is equivalent to one million gigabytes.

What is superfast broadband and how is it delivered to homes and small businesses?

We define superfast broadband as supporting download speeds of at least 30Mbit/s. In order to deliver these speeds, service providers typically need to install fibre optic cabling, which supports higher speeds than the copper cables used in traditional networks.

The current generation of superfast broadband is typically delivered by replacing the copper cable between the local exchange and the street cabinet with optical fibre. The cable between the street cabinet and the consumer's home or business is still made of copper. The replacement of copper with fibre in the connection enables higher speeds for the consumer. It is also possible to use fibre optic from the exchange all the way to the consumer's premises. This offers speeds that are even higher than superfast, which we call ultrafast broadband.

Note that the UK Government uses a slightly different definition of superfast. They define superfast as supporting download speeds of at least 24Mbit/s.

Some common terms used to describe broadband services include:

Fibre to the cabinet (FTTC): This describes a superfast broadband connection that uses optical fibre from the exchange to the street cabinet and a copper cable to connect the cabinet to the home or office, as described above. Providers such as BT, Sky and TalkTalk offer FTTC services.

Cable: This is a similar concept to FTTC, but the connection between the cabinet and the home or office is made of a particular type of copper cable that can support very high speeds. Virgin Media offers this kind of service, delivering superfast broadband and television services over its cable network.

Fibre to the premises (FTTP): This describes a service that uses fibre from the exchange directly to the consumer's home or office. FTTP, or "full fibre" networks can deliver very high speeds and is offered to different extents by BT, KCOM in and around Kingston Upon Hull, and several smaller providers such as B4RN in rural Lancashire, Hyperoptic and Gigaclear.

Wireless: This describes a service that uses a wireless connection between the consumer's home or office and the provider's network. This kind of service is often based on similar technologies to those used in mobile networks, and can deliver superfast speeds. These services are offered by providers such as Relish and Quickline.

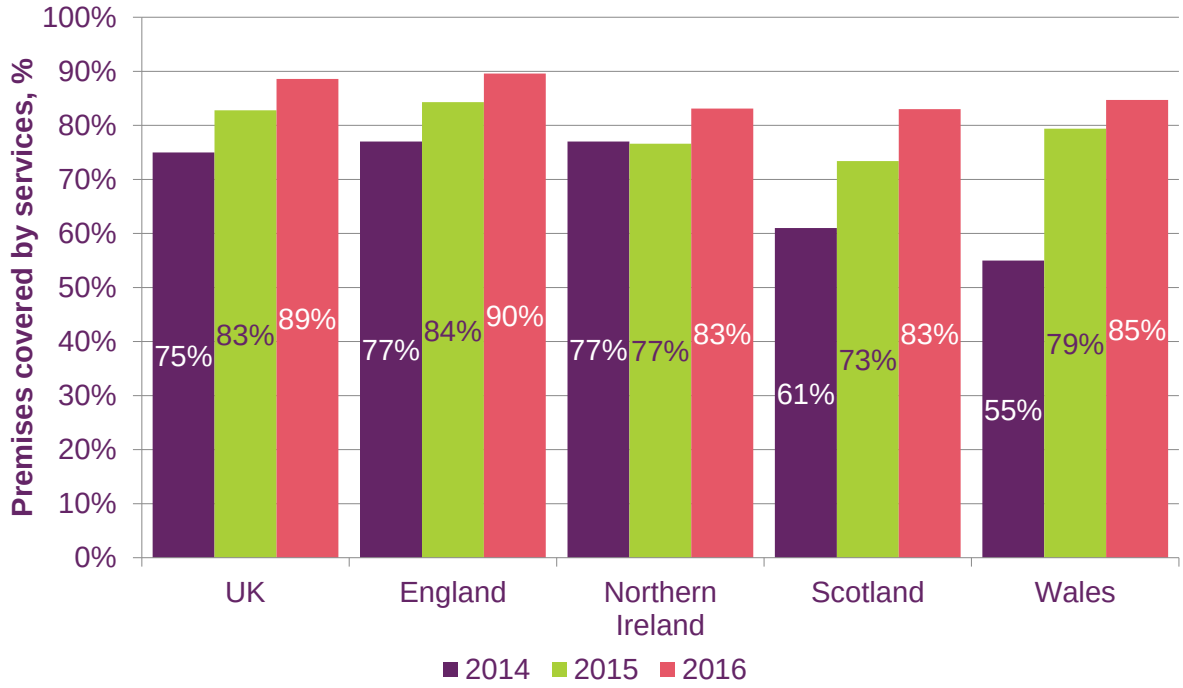
Coverage of superfast broadband has increased to almost 90% of UK premises

4.4 Around 25.5 million, or 89%, of premises across the UK can now access networks offering at least 30Mbit/s. The average download speed[12] of these superfast connections is now 74Mbit/s, a 14% increase on last year's speeds. The average

[12] This is the average of actual measured speeds of active superfast or ultrafast lines, where known. The sync speed of a connection is the maximum speed achievable between a consumer's premises and their internet service provider's (ISP's) network.

upload speed for superfast services in the UK is unchanged from last year, at 8Mbit/s.

Figure 3: The number of properties that can access broadband services with superfast speeds or higher continues to increase



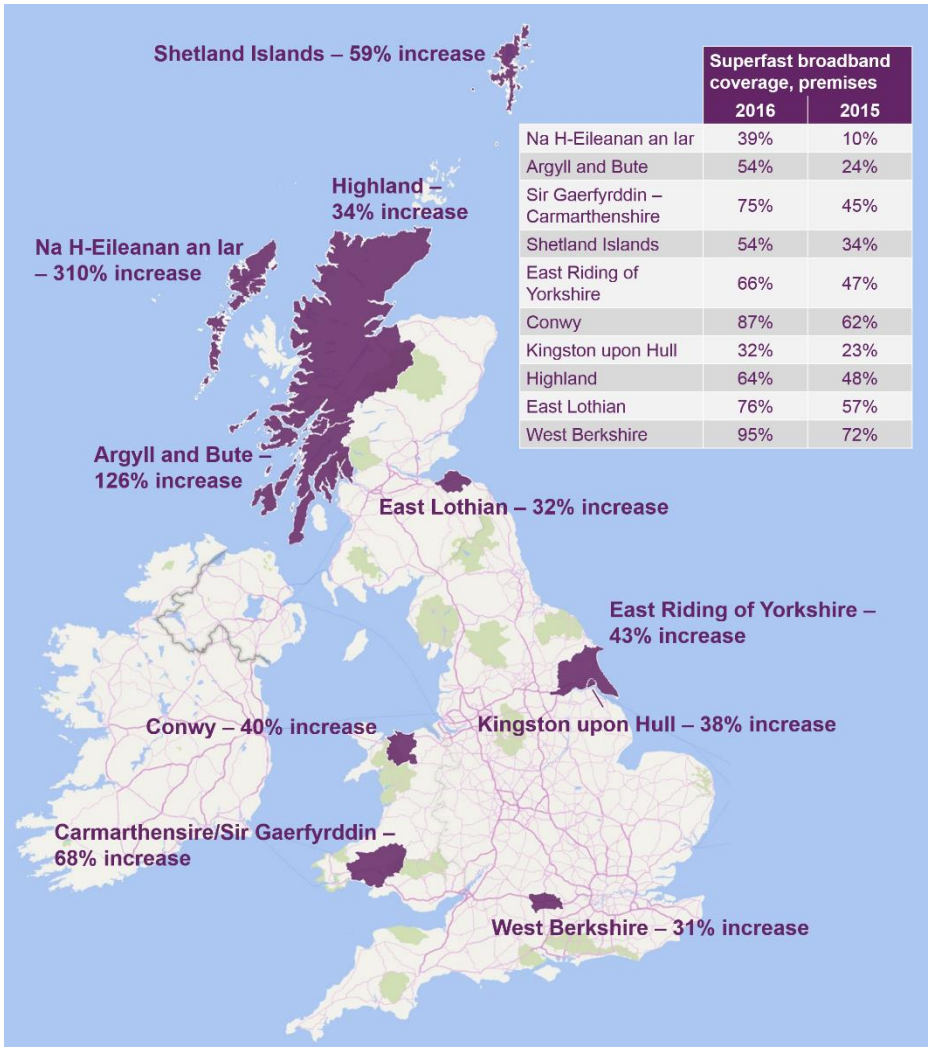
Source: Ofcom analysis of operator data

4.5 As Figure 3 shows, coverage of services offering superfast speeds of 30Mbit/s or higher has increased across all of the UK's nations. The greatest increase was in Scotland, with a year-on-year rise of almost 14%, compared to an average of around 7% for the other nations. However, superfast coverage in Scotland and Northern Ireland still remains lower than in other nations.

4.6 Targeted investment by industry and Government has led to some areas of the UK experiencing significant increases in superfast broadband coverage over the past year, as shown in Figure 4. In many cases, these areas previously had very low levels of coverage and, even with recent increases, the availability of superfast broadband remains low compared with the UK as a whole. Nonetheless, these improvements will be welcomed by consumers in these areas, many of whom will be experiencing significant improvements in the quality and speed of their broadband services.

4.7 Although the coverage of broadband services remains better in urban areas, there has been significant increase in the availability of superfast in rural areas. As Figure 5 shows, around 60% of UK rural premises can now access speeds of over 30Mbit/s, up from 44% in 2015.

Figure 4: Areas of the UK have seen a significant increase in the availability of superfast broadband



	Superfast broadband coverage, premises	
	2016	2015
Na H-Eileanan an Iar	39%	10%
Argyll and Bute	54%	24%
Sir Gaerfyrddin – Carmarthenshire	75%	45%
Shetland Islands	54%	34%
East Riding of Yorkshire	66%	47%
Conwy	87%	62%
Kingston upon Hull	32%	23%
Highland	64%	48%
East Lothian	76%	57%
West Berkshire	95%	72%

Source: Ofcom analysis of operator data

Figure 5: Superfast broadband coverage in rural areas has increased by around 35%

	Availability of superfast broadband in rural areas, premises		
	2016	2015	Approximate year-on-year increase
UK	59%	44%	35%
England	62%	45%	38%
Northern Ireland	52%	40%	29%
Scotland	46%	31%	46%
Wales	57%	54%	5%

Source: Ofcom analysis of operator data

The coverage of ultrafast services is largely unchanged

4.8 Alongside the continuing roll-out of superfast services, a new range of broadband services are now increasingly available that offer download speeds of several hundred Mbit/s or higher. These services are enabled via upgrades to the capacity of existing networks or by new technologies such as FTTP (see the box above).

4.9 As we noted last year, there is not a consensus on a definition for these ultrafast services, with views on the minimum download speed ranging from 100Mbit/s to 1Gbit/s. Figure 6 shows the coverage of broadband services for this range of speeds[13].

Figure 6: Coverage of faster broadband services with download speeds of 100Mbit/s or higher

	Coverage of premises, %		
	Download speed of at least 100Mbit/s	Download speed of at least 300Mbit/s	Download speed of at least 1Gbit/s
UK	46%	1.7%	0.8%
England	49%	1.9%	1.0%
Northern Ireland	27%	0.2%	0%
Scotland	36%	0.2%	0.2%
Wales	22%	0.7%	0.2%

Source: Ofcom analysis of operator data

4.10 The coverage of these services is broadly unchanged from 2015. Around 13 million, or 46% of, UK premises have access to broadband services with download speeds of 100Mbit/s or more; and download speeds of 300Mbit/s and above are available to around 2% of UK premises (480,000).

4.11 Since supplying us with their network coverage data in June, Virgin Media has started to offer services with download speeds of 300Mbit/s. The availability of these services is not reflected in this year's data but we would expect to see a significant increase in the number of premises that can receive download speeds of 300Mbit/s or more in subsequent reports. We would also expect to see these figures increase as a result of Virgin Media's ongoing Project Lightning activity, which is seeking to extend their network coverage to around 17 million premises by 2020.

4.12 As with last year, for this report we have defined ultrafast services as those delivering a download speed of 300Mbit/s or more. We will continue to monitor the coverage of these faster services and may, if appropriate, refine our definition as the market evolves.

[13] Last year we reported that the coverage of services with download speeds of at least 300Mbit/s in Scotland and Wales was 2% and 5% respectively. This year we are reporting lower levels of coverage; however, this is likely a result of this year's more accurate data set, which is based on address-level granularity, rather than any real reduction in coverage.

Almost half a million homes and small businesses have access to "full fibre" broadband

4.13 In addition to the ongoing deployment of fibre to the cabinet (FTTC) services to support superfast speeds, some operators are also in the process of rolling out fibre to the premises (FTTP) or "full fibre" networks. These are networks where the entire connection, from the operator's core network to the customer's premise, is based on fibre optic links.

4.14 One important benefit of full fibre networks is that they are able to support very high speeds, ranging from several hundred Mbit/s to 1Gbit/s or more. In addition, full fibre networks can be more reliable and experience fewer faults than services based fully or partially on the traditional telephone networks, as they are less susceptible to damage from water ingress. The increased capacity of full fibre networks also can mean that the speeds actually experienced by consumers will be more stable and less likely to degrade at peak times.

4.15 Coverage of full fibre services is low, reflecting what is currently an immature market. Around 1.7% of homes and small businesses (500,000) have access to full fibre services across the UK and, as Figure 7 shows, most (over 90%) of these premises are in England.

Figure 7: Percentage of premises that receive full fibre services

	Premises covered, number (%)
UK	500,000 (1.7%)
England	480,000 (2.0%)
Northern Ireland	1,600 (0.2%)
Scotland	6,000 (0.2%)
Wales	11,000 (0.7%)

Source: Ofcom analysis of operator data

4.16 A range of providers, both large and small, are beginning to offer full fibre services:

4.16.1 Openreach is a national provider of full fibre services, with the largest coverage footprint in the UK. In addition to its commercial roll-out, Openreach has been deploying full fibre services to some parts of the country as part of its agreement with the UK Government to improve broadband speeds as part of the BDUK Superfast Broadband Programme[14];

4.16.2 Virgin Media is also starting to offer full fibre services across the country. The company intends to add around four million premises to its coverage

[14] The UK Government's Broadband Delivery UK (BDUK) Superfast Broadband Programme is seeking to deliver download speeds of 24Mbit/s or more to 95% of the UK by the end of 2017.

footprint by 2020 as part of its Project Lightning expansion plans, around half of which will be full fibre connections[15];

4.16.3 Kingston Communications (KCOM), who are responsible for operating the network in and around the city of Kingston upon Hull; and

4.16.4 A number of smaller providers, such as Gigaclear, Hyperoptic and B4RN that often target areas that would otherwise remain unserved by other, larger operators.

4.17 While levels of superfast coverage are relatively high, the UK has a low level of full fibre coverage compared to other countries, as we describe in our International Communications Market Report[16]. For example, Germany, France and Portugal have full fibre coverage levels of 7%, 16% and 75% respectively. Further afield, 95% of premises in Singapore, and 97% in Japan, have access to full fibre broadband.

4.18 The next two sections look in more detail at deployments of full fibre networks in Kingston upon Hull and by smaller providers throughout the country.

Kingston upon Hull has a relatively high availability of full fibre services

4.19 The English city of Kingston upon Hull is the only city in the UK that is not served by BT. Telecommunications services are instead provided by Kingston Communications, or KCOM, which is the incumbent operator in the city and the neighbouring areas in East Yorkshire.

4.20 KCOM has followed a different approach to upgrading its broadband network, compared to BT in other parts of the country. KCOM is pursuing a strategy of upgrading its network to offer mainly full fibre services, rather than the fibre to the cabinet (FTTC) services that underpin most of BT's superfast services[17].

4.21 KCOM's focus on the deployment of full fibre networks means that around 30% of homes and small businesses in the Hull area can now benefit from download speeds of at least 250Mbit/s, more predictable performance at peak times and a more reliable service. The network is also more future-proofed than fully or partially copper-based networks, meaning that the speeds delivered to consumers can continue to grow.

4.22 KCOM have more recently announced[18] that they are accelerating their FTTP plans with the aim of passing 150,000 properties by the end of 2017. This would represent a significant increase in FTTP availability in the area where they are the incumbent.

4.23 However, the shorter tem price of this revolutionary approach, as opposed to the evolutionary approach of upgrading to FTTC services, is that it runs the risk of creating a two-tier online community. Where these full fibre services are not available, the relative lack of FTTC deployment in Hull means that consumers in the city rely on slower, all copper-based services. As a result, based on the June 2016

[15] Virgin Media Q3 2016 results, http://www.virginmedia.com/corporate/media-centre/press-releases/virgin-media-q3-2016-results.html
[16] https://www.ofcom.org.uk/research-and-data/cmr/cmr16/international
[17] KCOM has deployed some FTTC and will continue to do so but FTTP will provide the main NGA connectivity solution.
[18] http://www.kcomplc.com/business-insight/news-and-media/kcom-announces-major-milestone-in-ultrafast-broadband-rollout/

data used in this report, around 28% of premises in the Hull area are unable to get more than 10Mbit/s.

Smaller providers are playing an important role in delivering high speed broadband services throughout the country

4.24 As we reported in previous years, a number of smaller providers are continuing to invest in the infrastructure required to deliver high speed broadband services. These providers sometimes target areas with little or no superfast coverage and, without their deployments, consumers in these areas would continue to experience poor broadband performance.

4.25 Recognising the important role that these smaller providers play in improving the coverage of broadband services, we collected data from a sample of five providers operating throughout the UK. The combined coverage of these providers is around 570,000 premises, or 2% of all premises in the UK. As a result of this coverage, around 185,000 premises that previously were unable to get superfast speeds or higher are now connected.

Figure 8: Number of premises that are served by superfast services, or faster, from smaller providers

	Number of premises served
England	563,000
Scotland	4,540
Wales	2,430

Source: Ofcom analysis of operator data

4.26 As Figure 8 shows, the majority of the premises served by smaller providers are in England. The majority of these premises are in London, where coverage is provided by a mix of full fibre and fixed wireless services. Outside of larger cities there are also targeted deployments of full fibre services in rural areas, such as the counties of Lancashire, Cumbria and North Yorkshire. In these cases, smaller providers are playing a vital role in delivering superfast, or even ultrafast, services to consumers who had previously lacked acceptable broadband.

4.27 In Scotland and Wales, coverage is focused in the cities of Glasgow and Cardiff respectively. We do not currently hold data on the coverage of smaller providers in Northern Ireland. We aim to include coverage from a greater number of smaller providers in next year's report.

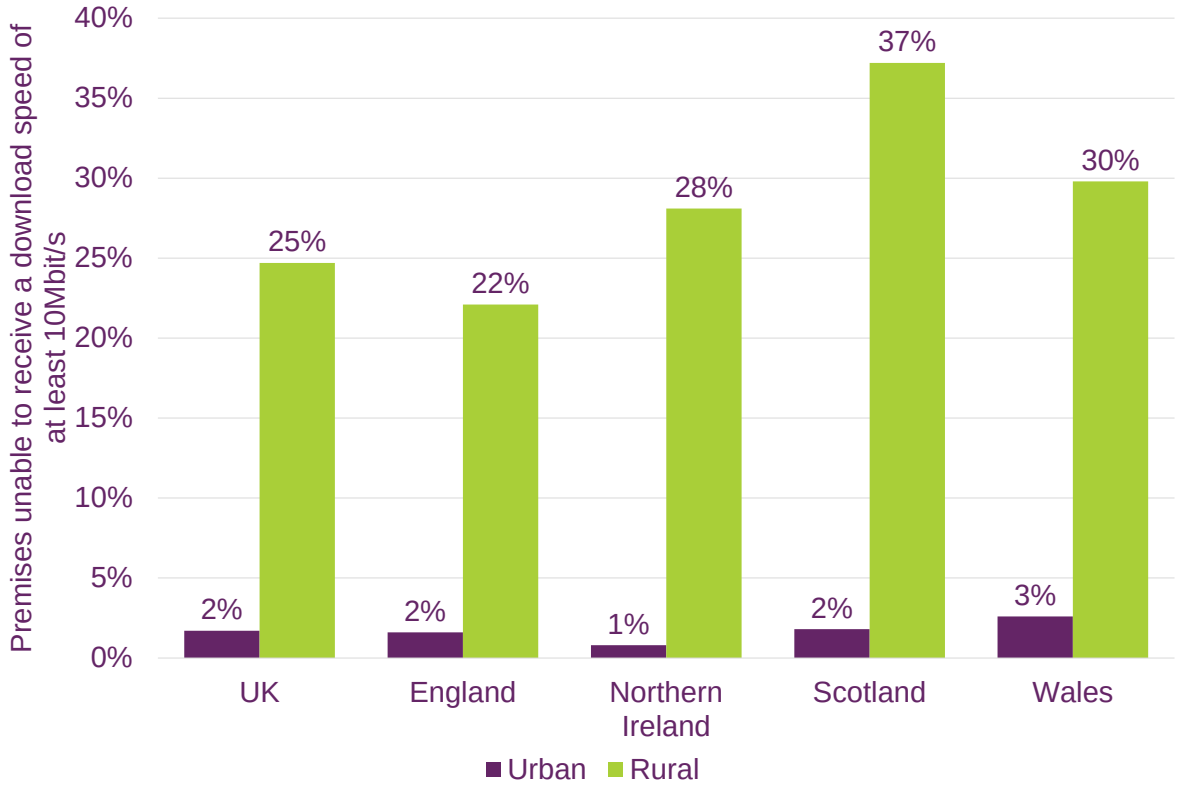
Many consumers remain unable to access broadband with acceptable speeds

4.28 Despite the increase in coverage of superfast services, many homes and small businesses still are unable to receive broadband speeds that are adequate to reliably perform a range of common online activities. Almost a quarter of a million UK premises, around 1% of the total, cannot get a download speed of more than 2Mbit/s and over 600,000 premises cannot get 5Mbit/s.

4.29 As Figure 9 shows, the problem is particularly bad in rural areas. One of the main reasons for poor broadband speeds in rural areas is the length of the connection to the property. Rural properties are often further from the exchange or street cabinet than in urban areas and, for copper-based telephony networks, the longer the connection, the slower the speeds are likely to be due to attenuation of the broadband signal.

4.30 Around 1.4 million, or 5%, of UK premises are unable to receive a download speed greater than 10Mbit/s. We continue to regard this as the minimum download speed required to fulfil the basic needs of the average UK household. As Figure 9 shows, a much higher proportion of premises unable to access a connection speed of at least 10Mbit/s are in rural areas, and across the UK 25% of rural premises (approximately 960,000 premises) are unable to receive download speeds greater than 10Mbit/s. Government programmes, such as those administered by Broadband Delivery UK (BDUK), are helping to address the problem of poor broadband coverage, in particular in rural areas. We expect to see improvements in the coverage of faster services over the coming 12 months.

Figure 9: Many premises are unable to receive a download speed greater than 10Mbit/s, especially in rural areas



Source: Ofcom analysis of operators' data

Why are broadband speeds lower in rural areas?

The distance between the premises and the exchange has an impact on the quality of service received, and in particular the speed of a consumer's connection. Consumers who live in less densely populated parts of the UK are more likely to live further from the exchange, and therefore achieve lower broadband speeds.

The resistance of copper wire increases with the length of the wire, so speeds decay as the distance between the premises and the exchange increases. Speeds typically start to decrease between 1 and 2km from the exchange and are reduced considerably at distances more than 3.5km.

FTTC-based broadband uses optical fibre to the cabinet and therefore the length of copper wire is reduced. It can currently support superfast speeds up to 80Mbit/s. However, as some copper wire remains between the cabinet and the premises, there can be some decay in speeds for customers located a long way from a cabinet. Customers further than 300m from a cabinet can expect their speeds to be less than half the maximum possible.

However, most consumers who live too far from the cabinet to receive superfast broadband may still benefit from the upgrade at the cabinet, as the reduction in the length of the copper access line will improve their broadband speeds.

4.31 There are some consumers that are connected to FTTC networks but do not currently receive superfast speeds. Many of these premises are found in rural areas, where the distance between properties and street cabinets can be higher than those in urban areas. Despite the cabinet being upgraded to fibre, the long copper lines between the cabinet and the premise results in reduced speeds.

4.32 We estimate that around 3%, or 780,000, premises in the UK are connected to FTTC networks but cannot receive superfast speeds. The situation is broadly similar in England, Scotland and Wales, where around 3% of premises are affected in this way. However, Northern Ireland has a much higher proportion of such lines; around 7% of premises in the nation as a whole and 16% of rural premises are connected to FTTC networks but do not receive superfast speeds. This is because Northern Ireland has a relatively large number of dispersed rural properties, needing longer lines to connect them to street cabinets.

Broadband coverage remains relatively poor for many small businesses

4.33 The UK's 5.5 million small and medium enterprises (SMEs)[19] constitute 99.3% of all UK private businesses, account for 60% of private sector employment and 47% of business revenue[20]. Providing all SMEs with access to superfast broadband services is vital for improving efficiencies of business and providing equal opportunities to participate and utilise the benefits of a digital economy.

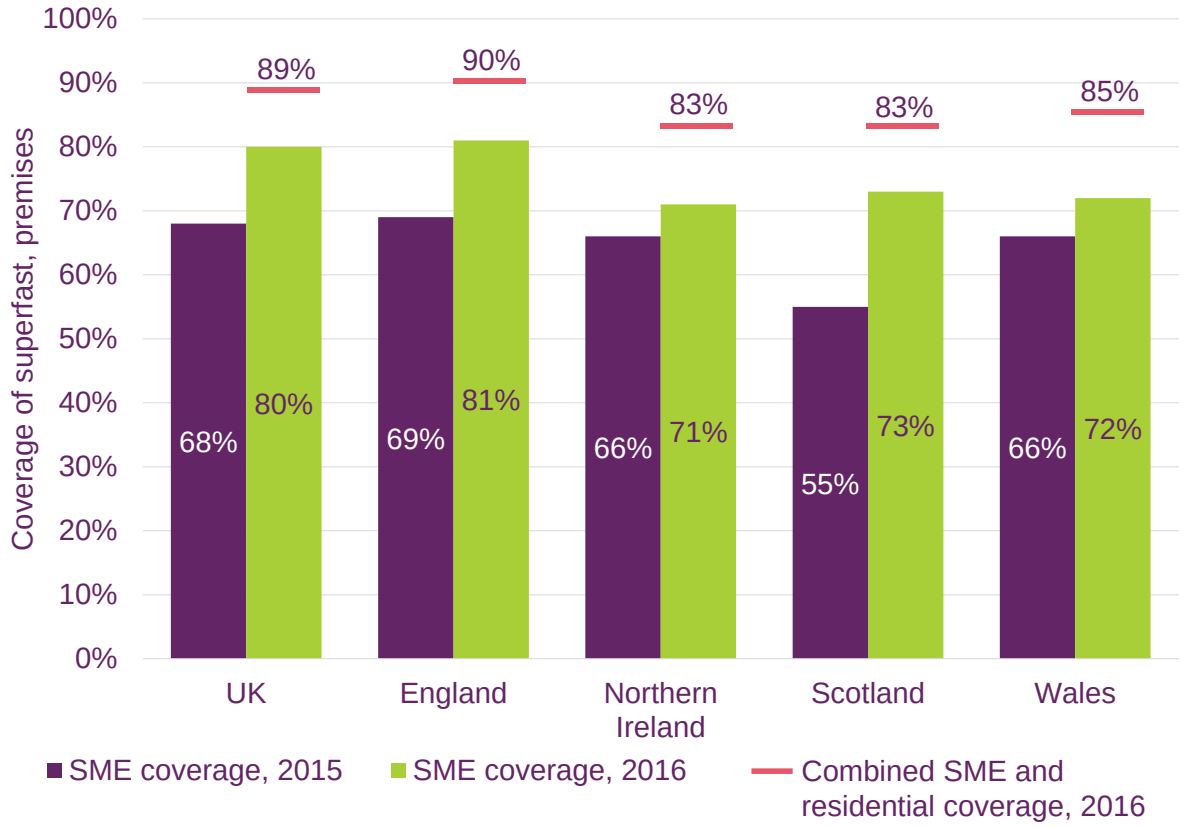
4.34 We have analysed the availability of superfast broadband delivered to 2.4 million SMEs with at least one employee (i.e. not including sole traders)[21]. We have compared coverage of SMEs against the average, split by geography, shown in Figure 10.

[19] Defined as businesses with fewer than 250 employees. In this report we use the terms “SME” and “small business” interchangeably.

[20] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/559219/bpe_2016_statistical_release.pdf

[21] This year we have used a more detailed dataset that identifies more active SMEs (around 2.4 million) than the dataset we used last year (that identified around 1.3 million). As a result, accurate year-on-year comparisons cannot be made and should be considered an indication of broad changes in coverage.

Figure 10: Superfast coverage for SMEs has increased but still lags the population as a whole



Source: Ofcom analysis of operators' data

4.35 Superfast coverage for SMEs has increased to around 81% of premises (1.9 million), up from 68% in equivalent analysis last year. Across the UK, SMEs still experience lower coverage of superfast services than the population as a whole. For example, only 82% of SMEs in England have access to superfast services, compared to 90% of all premises in the country. We note, however, that some SMEs may have access to alternative sources of connectivity, such as within *incubator centres*, i.e. shared facilities intended to help SMEs become established.

4.36 SMEs in Northern Ireland, Scotland and Wales experience relatively low levels of superfast coverage, compared to the UK as a whole. This reflects the lower availability of superfast broadband in these areas overall. More generally, many SMEs are based in rural areas or in business parks, areas that to date have not been targeted for network upgrades.

4.37 Overall, around 8% of SMEs (190,000) in the UK are unable to access broadband services with download speeds of 10Mbit/s or higher, compared to around 5% of all premises. Most of these SMEs are in rural areas, where over 130,000 SMEs receive less than 10Mbit/s.

4.38 Operators are continuing to upgrade, or to deploy entirely new, networks and we expect the availability of superfast broadband to further increase for SMEs, and for all consumers more generally. Looking ahead to the coming year, we estimate that additional, planned network deployments will reduce the number of UK SMEs that are unable to receive superfast services from around 20% today to 10% (around 240,000 businesses) by the end of 2017.

Superfast coverage in business parks is lower than in the rest of the country

4.39 We estimate that around 15%, or 340,000, of the 2.4 million SMEs that we have analysed are located within areas, typically business parks that include no residential premises. As the deployment of superfast broadband services has, to date, been driven by demand from residential customers, many of these areas currently have little or no coverage of these services.

4.40 Across the UK a whole, around 67% of SMEs in business parks (230,000) have access to superfast broadband. This compares to 80% of SMEs throughout the country and 89% of the wider population. Coverage in the individual nations' business parks is broadly similar to the UK average, apart from in Northern Ireland, where 83% of SMEs in business parts have access to superfast services.

4.41 Given the lower availability of superfast services in business parks, the actual speeds delivered to SMEs in these areas is lower than in the country as a whole. We estimate that the average speed of broadband connections in business parks is 24Mbit/s, compared to 38Mbit/s for SMEs as a whole.

Improving the coverage of broadband services for all

4.42 While the coverage and speed of broadband services across the UK have continued to increase, many consumers and small businesses are still unable to get online with acceptable speeds and quality of service. A quarter (25%, or 960,000) of premises in the UK's rural areas cannot get download speeds greater than 10Mbit/s. Even in the UK's towns and cities, where coverage is typically high, there are still some consumers that cannot get fast speeds; almost 1.7 million urban premises cannot receive superfast services and over 410,000 cannot receive download speeds greater than 10Mbit/s.

4.43 We expect the situation to improve over the coming years as operators, both large and small, continue to invest in their networks to both improve the reach and speed of broadband services. There are also a number of ongoing public policy initiatives that are intended to improve superfast broadband availability in areas that may otherwise not be covered by commercial deployments.

4.44 The largest of these programmes is the UK Government's intervention under the Broadband Delivery UK (BDUK) initiative, which aims to deliver download speeds of 24Mbit/s or more to 95% of the UK by the end of 2017. Based on our analysis, we estimate that, as of June 2016, 90% of UK premises (almost 26 million) are covered by broadband services at this speed.

4.45 Even with these current commercial deployments and public policy initiatives, there will still be some UK premises that will lack access to superfast services at the end of 2017. Below we examine a proposal from the UK Government for a broadband Universal Service Obligation (USO), intended to extend the availability of a broadband service to all homes and businesses. We also summarise some recent or emerging technology developments that could improve broadband speeds for all consumers.

Between 1.4 and 3.5 million premises may fall within the broadband Universal Service Obligation

4.46 Ofcom has been asked[22] by the Department for Culture, Media and Sport to provide technical analysis and recommendations to support the design of the broadband Universal Service Obligation (USO).

4.47 The Government has said that its ambition is for a download speed of 10Mbit/s to be available to all on reasonable request. We have published a detailed report[23] on the USO which examines how the provision of USO could work in practice. It also considers how the specification of the USO could affect both the number of premises that are eligible and the costs that could result in meeting the specification if the Government makes a decision to implement it.

4.48 Currently around 5% of premises cannot receive a download speed of 10Mbit/s, a figure which has come down significantly over time - it was 15% in 2014. While small in percentage terms, it should be remembered that 5% represents around 1.4m premises that are currently unable to receive a download speed of 10Mbit/s. Furthermore, as we showed in Figure 9 on page 19, a far greater proportion of rural premises are unable to receive a speed of 10Mbit/s than urban premises, and Wales, Scotland and Northern Ireland have a greater proportion of premises unable to do so.

4.49 However, the number of premises could rise if, for example, the threshold also took upload speeds and other factors into account. One option would be to extend the specification above to include properties that *can* get a download speed of greater than 10Mbit/s, but have an upload speed of less than 1Mbit/s, as well as other technical measurements that can affect a consumer's broadband experience. In this scenario, we estimate that around 2.6 million premises may fall within the USO's technical specification. If Government were to choose a superfast option (30Mbit/s), we estimate that around 3.5 million premises could be in scope.

Technology continues to evolve to meet the demand for higher speeds

4.50 The physical characteristics of full fibre networks mean that they are best placed to deliver reliable, ultrafast speeds both now and for the foreseeable future. Other technologies are emerging, however, that could play a complementary role in delivering broadband where full fibre networks are not available. They include:

4.50.1 **G.fast**: Openreach is partnering with Huawei and Nokia to support its planned rollout of this technology to over 10 million homes and businesses across the UK by 2020. The technology has been trialled in two areas of the UK, and a trial extension to more areas has been announced for early 2017[24]. G.fast has the potential to deliver download speeds up to 330Mbit/s over Openreach's existing copper-based network.

4.50.2 **Long range VDSL**: This emerging technology, also currently being trialled, has the potential to deliver superfast speeds over longer distances than can be achieved using current fibre to the cabinet (FTTC) technologies. In

[22] https://www.ofcom.org.uk/__data/assets/pdf_file/0027/53676/dcms_letter.pdf
[23] https://www.ofcom.org.uk/consultations-and-statements/category-1/broadband-uso-cfi
[24] https://www.openreach.co.uk/orpg/home/updates/briefings/ultrafastfibreaccessbriefings/ultrafastfibreaccessbriefingarticles/nga200216.do

theory, download speeds of up to 40Mbit/s and upload speeds of up to 10Mbit/s could be delivered using this technology to premises that currently receive much lower speeds due to the distance to their serving VDSL cabinet.

4.50.3 **Next generation cable**: Virgin Media is in the process of upgrading its network and is beginning to offer services with download speeds of 300Mbit/s. Later versions of the technology used could support, in theory, download speeds of up to 10Gbit/s and upload speeds of up to 1Gbit/s[25].

4.51 The above technologies are all related to the evolution of fixed broadband networks. However, wireless networks can also play an important role in delivering broadband services. In London and Swindon, for example, Relish provides a fixed wireless broadband service based on 4G technology that is capable of delivering superfast speeds. The Swindon project is part of a BDUK programme to evaluate "fixed wireless" solutions for superfast and the programme also includes equivalent projects involving Airwave and Quickline elsewhere in the country.

4.52 Satellite broadband is another wireless approach that is currently being used to deliver broadband to some parts of the country that are hard to reach with the above terrestrial technologies. Current satellite broadband services use geostationary satellites (which, like those used for satellite TV, stay at a fixed point in the sky) and can offer near universal coverage. A number of companies operate satellites that are used to provide broadband services to users in the UK including Avanti Communications, Eutelsat and SES. These offer download speeds of up to 20Mbit/s, depending on the satellite and package selected. Services are usually offered to consumers via a service provider rather than directly by the satellite operator.

4.53 The next generation of satellite broadband services are expected to provide superfast speeds and better overall performance than existing geostationary satellite broadband services. These services are likely to be available from 2020.

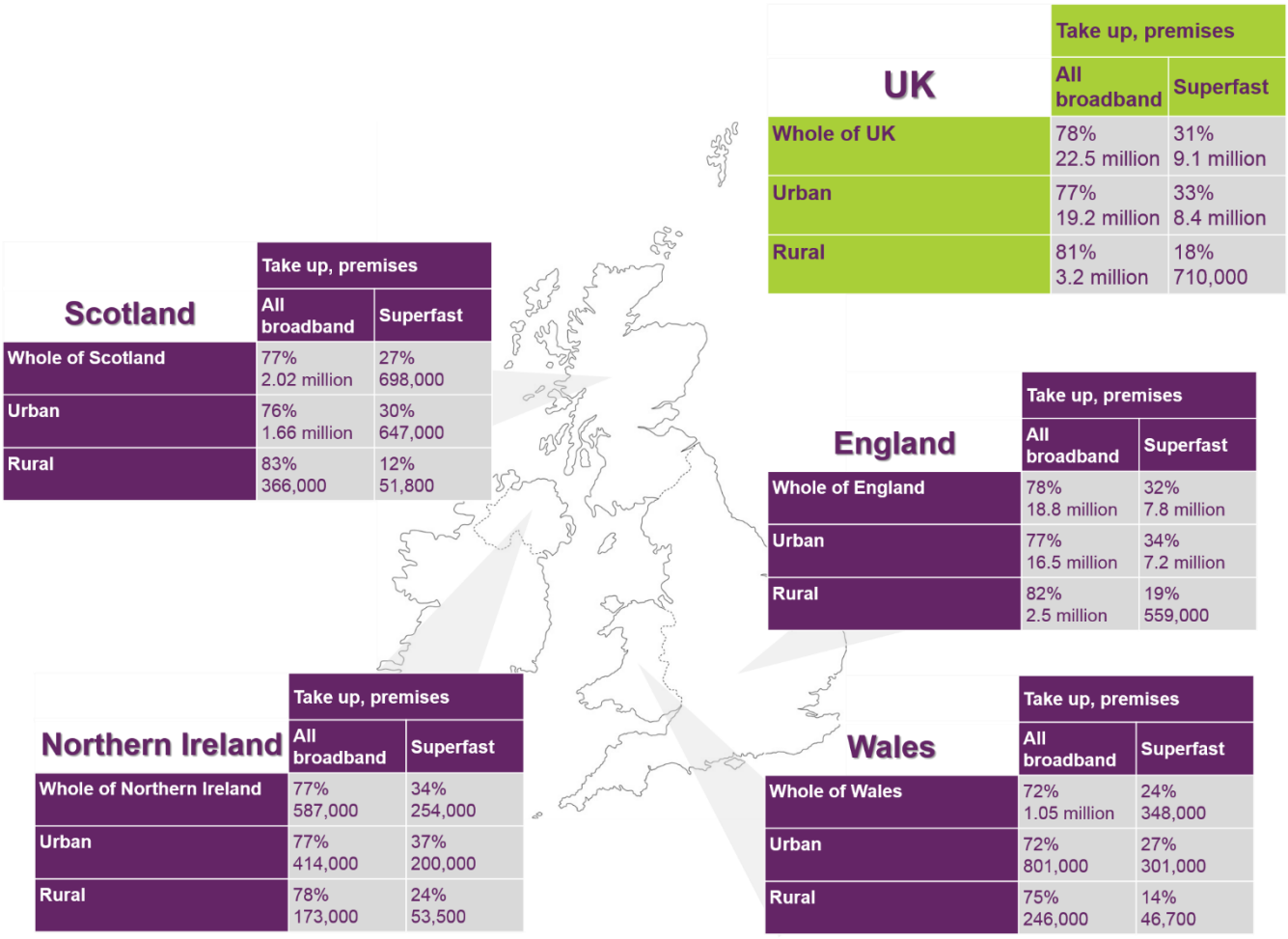
Increased coverage and take up of superfast services means that consumers are using more data

4.54 In the UK, 31% of premises (9.1 million) now have an active superfast broadband connection. This is an increase from 27% in 2015. Nine out of 10 of these properties are in urban areas, which reflects the higher levels of superfast coverage in towns and cities.

4.55 Around 22% of UK premises (6.5 million) have not taken up any fixed broadband product at all, down slightly from 24% in 2015. Take up of broadband is lowest in Wales where almost 28% of the population have not subscribed to broadband services.

[25] See the commentary on DOCSIS3.1 and other cable futures in http://www.libertyglobal.com/pdf/public-policy/Liberty-Global-Policy-Series-Connectivity-for-the-Gigabit-Society.pdf

Figure 11: Take-up of broadband services across the UK



UK	Take up, premises	
	All broadband	Superfast
Whole of UK	78% 22.5 million	31% 9.1 million
Urban	77% 19.2 million	33% 8.4 million
Rural	81% 3.2 million	18% 710,000

Scotland	Take up, premises	
	All broadband	Superfast
Whole of Scotland	77% 2.02 million	27% 698,000
Urban	76% 1.66 million	30% 647,000
Rural	83% 366,000	12% 51,800

England	Take up, premises	
	All broadband	Superfast
Whole of England	78% 18.8 million	32% 7.8 million
Urban	77% 16.5 million	34% 7.2 million
Rural	82% 2.5 million	19% 559,000

Northern Ireland	Take up, premises	
	All broadband	Superfast
Whole of Northern Ireland	77% 587,000	34% 254,000
Urban	77% 414,000	37% 200,000
Rural	78% 173,000	24% 53,500

Wales	Take up, premises	
	All broadband	Superfast
Whole of Wales	72% 1.05 million	24% 348,000
Urban	72% 801,000	27% 301,000
Rural	75% 246,000	14% 46,700

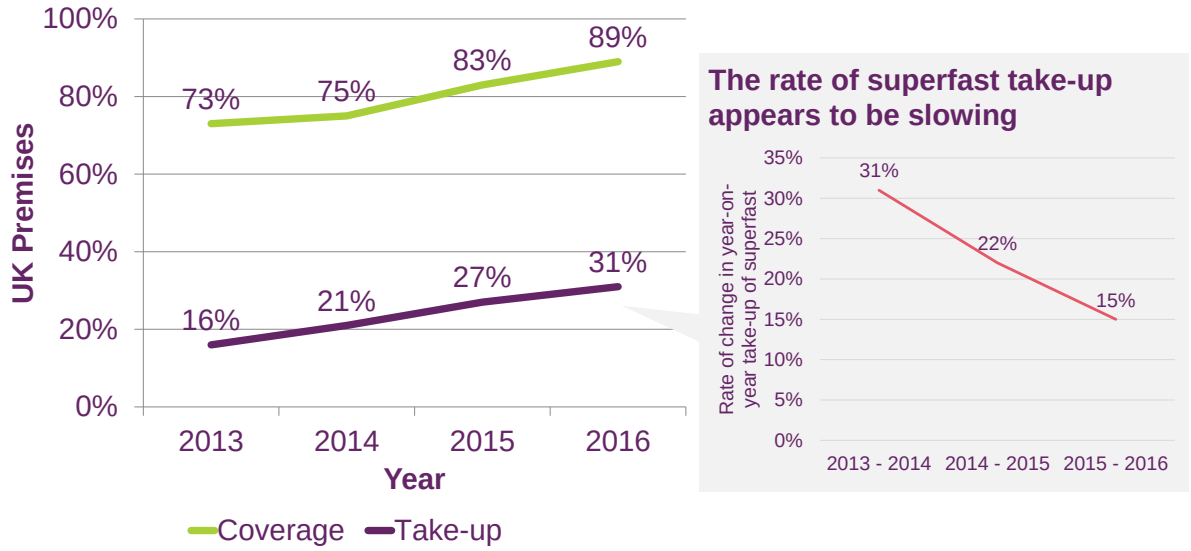
Source: Ofcom analysis of operators' data

Take up of superfast broadband remains lower than availability

4.56 While take up of superfast broadband services has continued to increase, it remains relatively low; 89% of UK premises are able to receive superfast services, but only 31% have active superfast broadband connections.

4.57 Figure 12 shows how coverage and take up of superfast broadband has increased over the past three years. The rate that new subscribers are migrating from basic broadband services and adopting superfast services appears to be slowing, dropping from 31% in the year to 2014, to 15% over the past year.

Figure 12: Take up of superfast broadband has tracked the increase in coverage, but remains significantly lower



Source: Ofcom analysis of operators' data

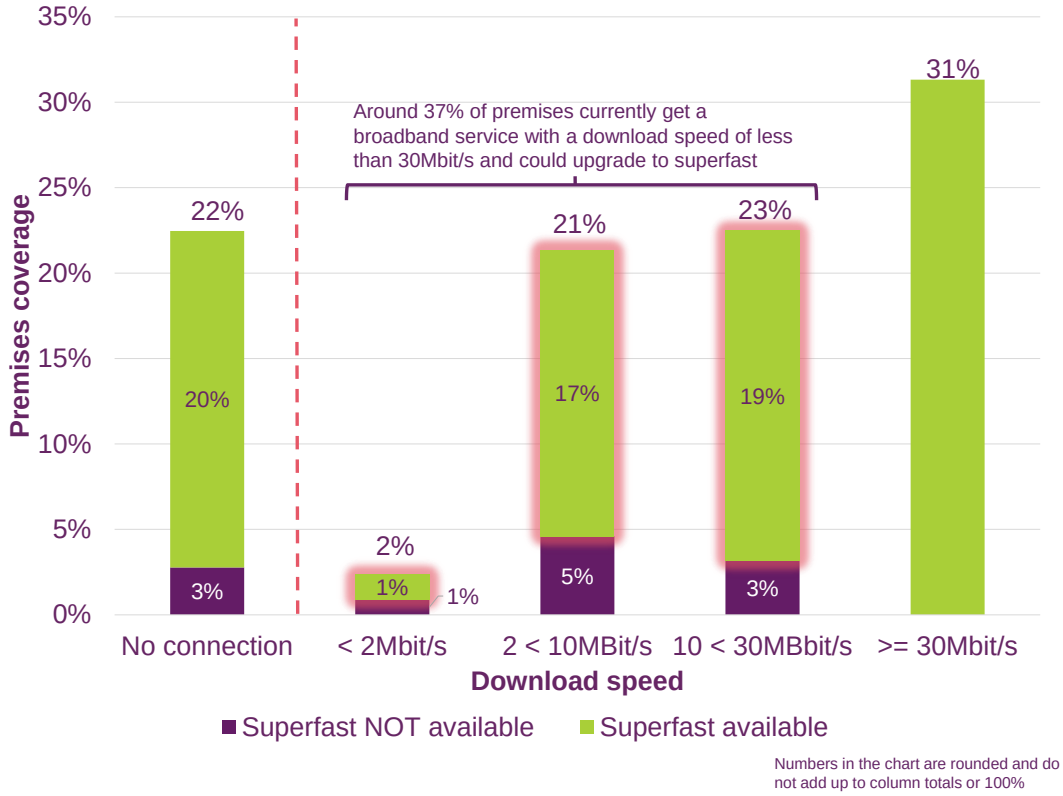
4.58 Some consumers may be unable to take up superfast broadband because these services are not yet available at their property. On the other hand, some consumers with slow broadband could upgrade to superfast, but have not yet done so.

4.59 Figure 13 shows the take up of broadband services grouped by download speed and indicates the extent to which superfast services are available to consumers with those broadband speeds. It shows that around 37% of premises currently get a broadband service with a download speed of less than 30Mbit/s and could upgrade to superfast.

4.60 It is not clear from this data why some consumers are choosing not to take superfast services where they are available and further market research is needed. In order for superfast broadband take up to continue growing at the same rate as it has in the past, providers may need to consider new approaches for attracting customers, including articulating its benefits more clearly and lowering prices further.

4.61 Just less than 0.1% of UK premises (27,000) have taken up a service offering download speeds of 300Mbit/s or more. This relatively low level of take up is understandable, given current low levels of coverage. However, take up has increased significantly since 2015, when we reported that just 0.003% of UK premises had subscribed to these services.

Figure 13: Over three quarters of premises with standard broadband could get superfast broadband



Source: Ofcom analysis of operators' data

The average download speed of active connections has increased, but upload speeds have remained static

4.62 The growth in take up of superfast broadband has led to an increase in average speeds across the UK. The average download speed of all active connections in the UK is now 37Mbit/s, an increase of 28% from 29Mbit/s in 2015. Speeds are lower in rural areas, where there is a lower availability of superfast services. The average download speed in the UK's rural areas is just 21Mbit/s, although this still represents an increase on the speed last year, which was 13Mbit/s.

4.63 Download speeds have also risen for those consumers that subscribe to superfast services. The average download speed of superfast services in the UK is now 74Mbit/s, up from 65Mbit/s in 2015. We do not yet have sufficient data to estimate the average speeds of ultrafast or full fibre services, but will explore ways to calculate this in future reports.

4.64 While download speeds have increased, upload speeds have remained static. This may restrict the quality of experience for some popular online services that require good upload, as well as download, speeds, such as social media sites and cloud backup services. The average upload speed of all broadband services has increased

by just 7% to 4Mbit/s over the past year, while the average upload speed of superfast services has remained the same at 8Mbit/s.[26]

4.65 The average download speed of 37Mbit/s reflects both the speeds available to consumers and their choice of package; if consumers were to choose faster packages, the average speed would rise. We estimate that the average download speed would rise to around 132Mbit/s if all consumers subscribed to the fastest available broadband service at their property.

Faster broadband speeds lead to more data being consumed

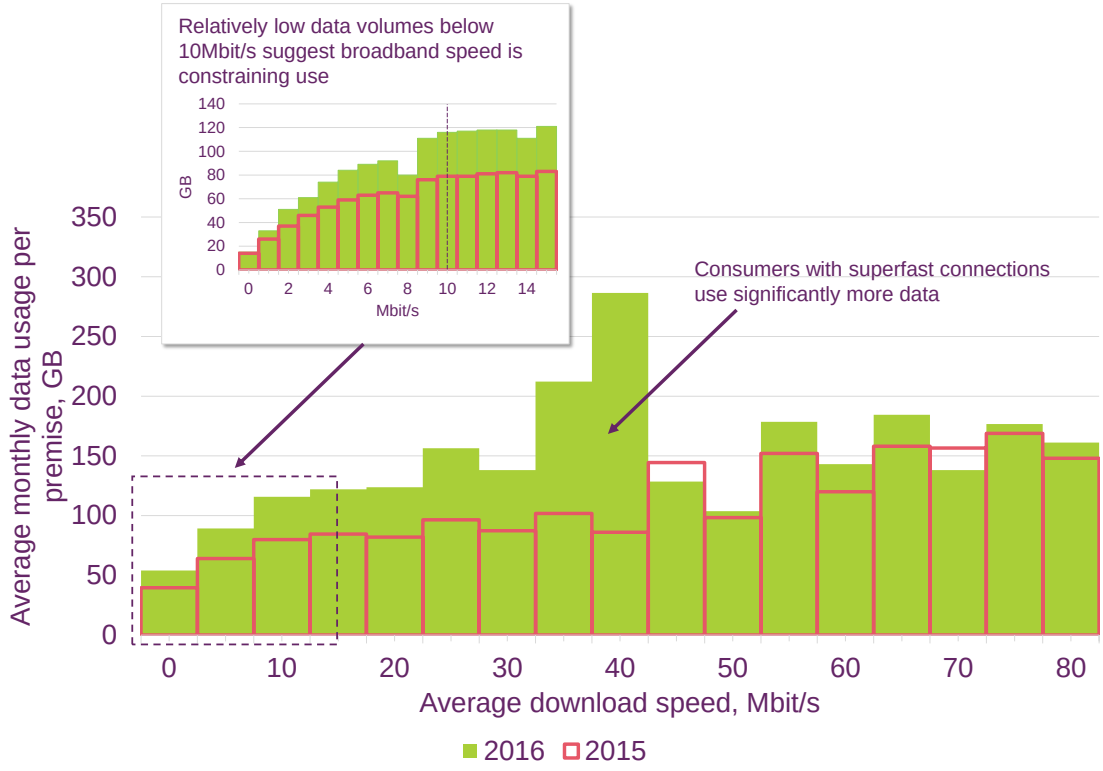
4.66 Consumers who take up superfast broadband will find that the faster download and upload speeds will enable them to use a much wider range of multimedia applications than they could with slower connections. They include:

4.66.1 Online video services, such as You Tube, iPlayer and Netflix. These services offer video for download or streaming in standard, high and, increasingly, ultra-high definition formats;

4.66.2 Video calling services, such as Skype or Apple's FaceTime; and

4.66.3 Cloud-based services for back-up of data or sharing content with friends or colleagues.

Figure 14: Users with faster broadband connections tend to use more data



Source: Ofcom analysis of operator data

[26] This asymmetry of download and upload is a feature of both DSL and DOCSIS technology implementations currently. The degree of asymmetry can be reduced but this is normally at the expense of reducing download speeds. Future technologies may suffer less from this problem.

4.67 On average UK households consumed 132GB of data per month over the past year, up from 97GB in 2015. Figure 14 shows that, on average, more data per household is being consumed for all broadband speeds. As in previous years, there is evidence that households with higher speed connections are consuming significantly more data, especially those with superfast speeds.

4.68 Users with broadband speeds of around 40Mbit/s appear to be consuming very high volumes of data. We believe that this is evidence of an increase in the consumption of online video. Services such as the BBC's iPlayer, Sky's Now TV and Netflix are increasingly popular and are integrated into smart TVs and set-top boxes. Consumers are often unaware that content they access via these services is delivered over their broadband connection as they are intended to deliver a seamless viewing experience.

4.69 In addition, many video services are also available on smartphones and tablets. This means that content could be streamed to multiple devices within a home simultaneously, adding to the overall volume of data consumed.

4.70 We might also expect the impact of video on demand services to be reflected in higher average data volumes for broadband connections faster than 40Mbit/s. This is not apparent from Figure 14. In the case of Virgin Media's customers, many of whom are on a package with a download speed of 50Mbit/s or higher, this could be explained by some on demand video services being delivered over the cable TV connection, rather than the broadband connection.

4.71 Figure 14 also shows that the average usage per household drops notably for connections with speed less than 10Mbit/s. This may be evidence that users would use more data if their connections were faster.

Measuring the broadband speeds consumers actually receive

4.72 One of the most commonly used ways to describe the performance of broadband connections is speed and, in particular, download speed. However, there are a number of ways to express broadband speed, as shown in Figure 15:

4.72.1 **Headline speed** is the speed at which a particular broadband service is the maximum speed available by at least 10% of the customer base. It is normally preceded by the words "up to".

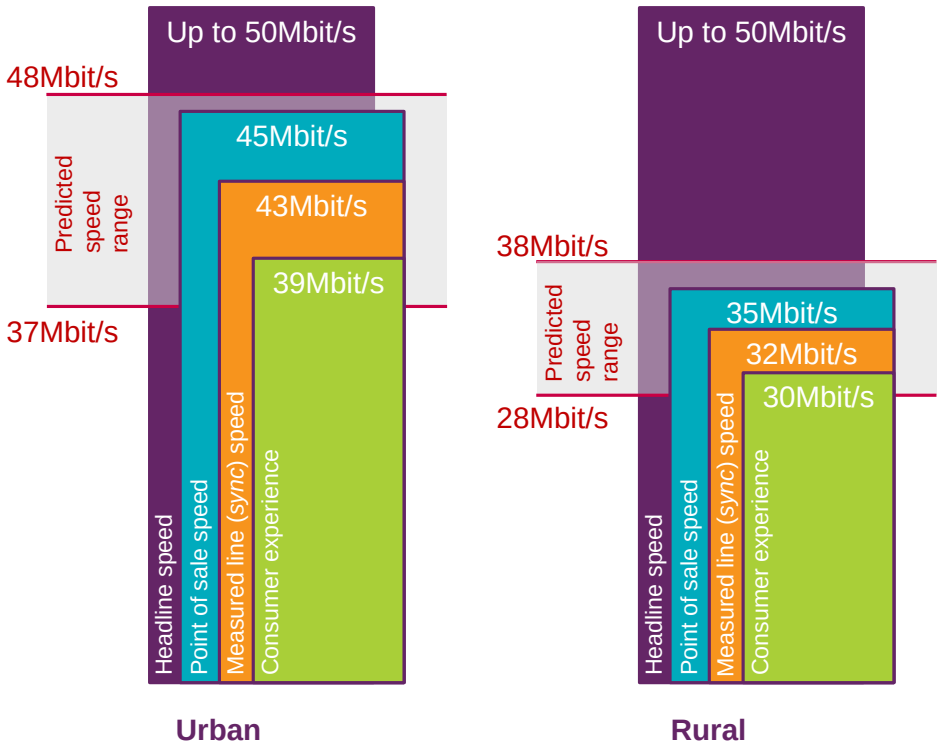
4.72.2 **Point of sale speed** is the estimated speed that a customer is quoted before they purchase the broadband service for the first time. Signatories of the Broadband speeds Code of Practice undertake to give this estimated speed, normally in the form of a range, although it can also sometimes be a point estimate. Specifically, this constitutes an estimate of the max speed a customer will be able to experience on his or her individual line. The speed is based on a technical assessment of factors such as the length of the line to the customer's property, which could affect the performance of the line. As a result, the point of sale speed is often lower than the headline speed

4.72.3 **Measured line, or sync, speed** is the maximum rate at which the line connecting the customer's property to the street cabinet or exchange can operate. In many cases, ISPs are able to measure this speed and this data is provided to us as part of preparing this report. Sync speeds can be lower than the point of sale speeds as a result of local technical factors, such as

interference on the line, which are difficult to predict when calculating the point of sale speed; and

4.72.4 **Consumer experience speed** is the measured speed that the consumer actually experiences during the course of using the broadband service. This is measured through a panel based methodology using SamKnows "Whiteboxes" that are connected to panellists' routers. This does not include any Wi-Fi measurements, and indicates the speeds that may be experienced if a consumer was to connect their device to the router with an Ethernet cable. The consumer experience speed is likely to be lower than the sync speed because it is an end-to-end measure of performance, i.e. it also takes into account the speed of the ISPs backhaul and core network.

Figure 15: Illustration of different ways to express broadband speed



Speeds are illustrative only and are not based on actual measurements

Source: Ofcom

4.73 Consumers may receive slower speeds than they expect, because of the factors described above. In addition, the difference between headline and consumer experience speeds may be greater in rural areas than in urban areas because factors such as longer line lengths.

Investigating broadband performance using physical measurement units

4.74 Each year we publish a report on the performance of residential fixed broadband services[27] as part of our work to monitor the UK communications industry. The objective of this research is to provide better information about the *actual performance* (i.e. the measure of consumer experience described above) of UK

[27] https://www.ofcom.org.uk/research-and-data/broadband-research/home-broadband-performance

residential fixed broadband connections to inform Ofcom's policy making and help consumers make better-informed purchasing decisions.

4.75 This section of the Connected Nations report uses data collected by our research partner, SamKnows Limited (SK), in September, from a panel of volunteers. The panel is selected to be representative in terms of a number of factors, including geographic location, broadband connection technology, internet service provider (ISP) and broadband package.

4.76 Volunteers are required to connect a hardware measurement unit (a “whitebox”) to their broadband router. These units run tests that measure various metrics that help determine the user experience of various online activities. The software is configured to identify other network activity and not to run tests when such activity was detected. This avoids compromising results by running tests at a time when bandwidth was being used by other internet-connected devices in the household (including those using a Wi-Fi connection).

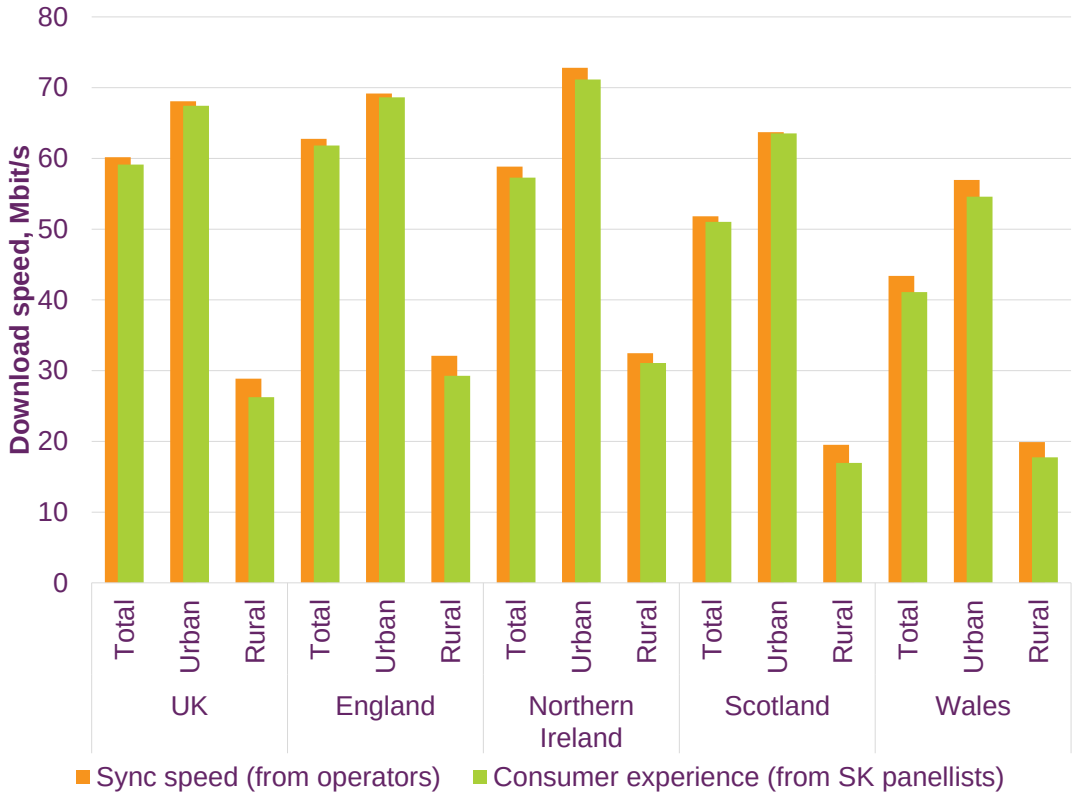
4.77 We carried out analysis to match the sync speed data collected from fixed network operators for the purposes of preparing this report, to the data collected from SK panellists across the month of September 2016. This matching process has allowed us to compare the two data sets across download and upload speed metrics.

4.78 We would not expect the results of the two data sets to match exactly, given the differing timescales of the data and that one data set contains sync speed data and the other consumer experience data. However, comparing the values will highlight the extent of any systemic difference between sync and consumer experience speeds, and whether this difference varies between urban and rural properties.

4.79 Figure 16 shows a comparison of the download speeds of each data set, split by nation and rurality. As we illustrated in Figure 15, when comparing consumer experience speeds to sync speeds there is some disparity between the two measures. Across all panellists, measured consumer experience speeds were around 2% lower than the sync speeds, rising to a 5% difference for those panellists in Wales.

4.80 This disparity is more pronounced in rural areas, which could suggest that speeds in these areas are lower than they could be under ideal conditions due to the amount of available backhaul, impeding optimal performance. For example, consumer experience speeds for panellists in the UK’s urban areas were just 1% lower than sync speeds; whereas, in rural areas, the difference was 9%. For panellists in the rural areas Wales and Scotland the difference was greater, 11% and 13% respectively.

Figure 16: Comparison of sync and average consumer experience speeds, for only those premises with a SK measurement unit



Source: Ofcom analysis of operator data / SamKnows

4.81 We are aiming to continue analysis between these joined data sets and will endeavour to include further analysis in the UK home broadband performance report planed for publication in H1 2017.

Section 5

Mobile voice and data services

5.1 Mobile services are playing an increasingly important role in our daily lives. This means consumers increasingly expect their mobile devices to work reliably wherever they are, whether at home, at work, or on the move. In this section we provide an update on the levels of mobile voice and data coverage achieved in different parts of the UK as of June 2016, and the total amount of mobile data being consumed. We also discuss the minimum levels of mobile signal needed to make a good quality voice call and how these relate to the mobile operators' geographic coverage targets for voice call services.

5.2 The key highlights are:

5.2.1 **4G roll-out:** All four operators are in the middle of a major 4G rollout programme, which provides in some locations similar connection speeds to those of fixed networks. To date the rollout of 4G services has primarily focussed on providing higher speed services to users in cities and towns. As they are rolled out more widely, it is likely that 4G landmass coverage will continue to increase to at least match the coverage of earlier generation 2G and 3G services. Some operators have also enabled voice calling on their 4G networks, which together with voice over Wi-Fi, are helping to increase the number of places where consumers can make and receive voice calls.

5.2.2 **Mobile data growth:** In the past year, mobile data consumption per subscriber has grown at a rate of 49%. Although still growing, this is less than last year's growth rate of 64%. It is almost identical to the data growth rate on fixed networks. The volume of data carried over mobile networks remains a small proportion (around 4%) of data carried over all networks.

5.2.3 **More needs to be done to extend mobile coverage to all of the locations consumers want to use their mobile devices**. There are two main reasons why additional steps are likely to be needed to meet future consumer expectations on mobile coverage.

5.2.4 Firstly, the additional coverage improvements resulting from commercial investments by mobile operators in new network infrastructure will reach a plateau.

5.2.5 Secondly, the existing geographic voice call coverage targets in licences, requiring 90% landmass coverage by the end of 2017, are based on lower mobile signal levels than those we have found to be necessary from our field testing work to deliver a good consumer experience. This means that when these targets are met, good geographic landmass coverage is likely to be below 90%.

Our assessment of coverage is representative of how consumers use their mobiles

5.3 In this report, we provide mobile coverage numbers based on the mobile signal levels we have found to be necessary to provide a good consumer mobile experience.

These relate to the areas shown in green on our interactive maps[28]. We also show on these maps areas in amber and red where a mobile signal is available but is likely to provide a less reliable consumer experience.

5.4 In previous years, we have reported on mobile coverage in terms of the number of premises where a signal can be received outdoors. We will continue to report on outdoor coverage in this way but, from this year, our focus will be on reporting on mobile coverage in a way that we believe better reflects how and where consumers use their mobile phones – both indoors and outdoors.

5.5 For **indoor coverage**, we will report on the percentage of premises where a good mobile signal is likely to be available indoors. This metric is useful to describe the coverage that a consumer will experience when using their phone at home, at work or in a shop. It is more challenging to deliver reliable mobile coverage indoors than outdoors, as walls, buildings and doors reduce the strength of, or even block, mobile signals as they pass through.

5.6 We will report on **outdoor coverage** in three ways:

5.6.1 **Geographic coverage**, which represents the percentage of landmass where good coverage is likely to be available. This metric is useful to describe the coverage that a consumer will experience when using their phone outside or on the move between outdoor locations;

5.6.2 **Coverage on the transport network**, which focuses this year on roads. This metric represents the percentage of distance covered by the road network where a good mobile signal is likely to be available inside the car. This metric is useful to describe the coverage that a consumer will experience when using their phone while travelling in a vehicle and not using a car kit with an external antenna. Next year we also aim to report on coverage on the rail network;

5.6.3 **Outdoor premises coverage**, which represents the percentage of premises where a good mobile signal is likely to be available outdoors. This metric is still commonly used by operators and we will continue to report on coverage in this way to aid comparisons.

5.7 The levels of mobile coverage in this report are based on data supplied by the operators which has been scaled to indicate where a good consumer experience is likely to be available. This scaling is based on our own field testing of the minimum mobile signal levels needed for a good consumer experience. These signal levels are generally higher than those used in existing mobile operator licence obligations and, as a result, levels of coverage shown in this report are generally lower than the target coverage levels set out in these obligations.

5.8 While our use of these metrics make it more difficult to compare our coverage figures with those from other sources, we believe that using these metrics is important for two reasons:

5.8.1 **They offer a more realistic view of current coverage levels.** Figures for coverage expressed in terms of outdoor premises tend to be higher than those for indoor or geographic coverage. Presenting information in terms of

[28] http://maps.ofcom.org.uk/check-coverage

outdoor premises can be potentially misleading for consumers, who may feel that their actual experience of coverage does not correspond to the relatively high coverage figures presented. Additionally, and as mentioned above, expressing coverage in terms of outdoor premises does not reflect the locations where the majority of consumers use their phones most; and

5.8.2 **They provide an important baseline against which future improvements in coverage can be measured.** Several current public policy initiatives are targeting improvements in coverage by requiring operators to achieve agreed levels of indoor and geographic coverage by certain dates. By reporting on mobile coverage in terms of geographic and indoor coverage, it is easier to identify the progress being made towards meeting these coverage targets. In addition, the use of Ofcom's scaling of the mobile coverage data provided by operators to show where good reliable coverage is available provides a useful benchmark for the actual improvements being delivered by these initiatives, and the improvements any new coverage improvement initiatives should be aiming to achieve.

5.9 In the remainder of this section, we summarise the levels of coverage from all operators for both mobile voice and data networks, i.e. we consider an area or property to be in coverage if a mobile signal can be received from all operators. In addition, we highlight the coverage of 4G networks, given operators' ongoing focus on deploying these networks.

5.10 In order to facilitate year on year comparison, we are using data collected in June 2016 to calculate coverage. We note that since this data was collected, further network deployment is likely to mean that coverage levels have continued to increase. Our coverage checking tools[29] use the most up-to-date mobile coverage data.

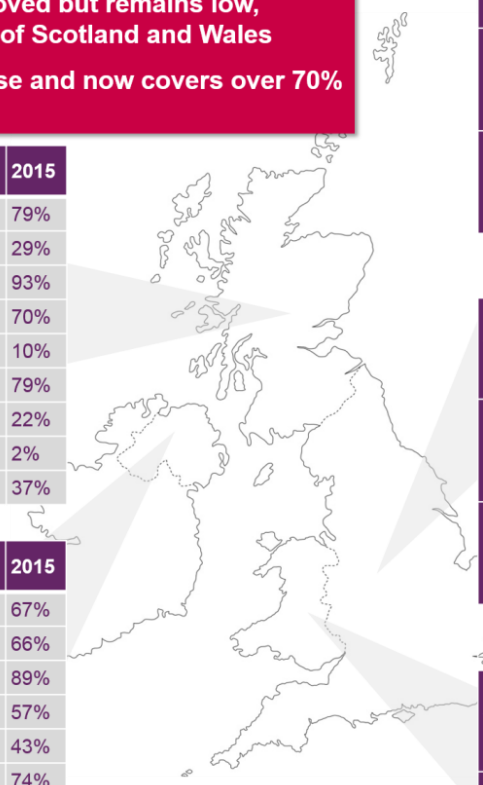
Status of mobile coverage across the UK and in the nations

5.11 Figure 17 summarises the mobile coverage available in the UK and constituent nations from all operators, for voice, data and 4G networks.

[29] https://checker.ofcom.org.uk

Figure 17: Summary of mobile coverage from all UK operators

- **Consumers can use their phones for voice calls inside almost 90% of UK premises and data services inside around 80% of UK premises**
- **Outdoor coverage has improved but remains low, especially in the rural areas of Scotland and Wales**
- **4G coverage continues to rise and now covers over 70% of UK premises indoors**



Scotland		2016	2015
Voice	Indoor premises	84%	79%
	Outdoor geographic area	36%	29%
	Outdoor premises	95%	93%
Data	Indoor premises	75%	70%
	Outdoor geographic area	21%	10%
	Outdoor premises	87%	79%
4G	Indoor premises	62%	22%
	Outdoor geographic area	12%	2%
	Outdoor premises	76%	37%

Northern Ireland		2016	2015
Voice	Indoor premises	80%	67%
	Outdoor geographic area	81%	66%
	Outdoor premises	95%	89%
Data	Indoor premises	70%	57%
	Outdoor geographic area	71%	43%
	Outdoor premises	90%	74%
4G	Indoor premises	64%	37%
	Outdoor geographic area	60%	17%
	Outdoor premises	86%	46%

UK		2016	2015
Voice	Indoor premises	89%	85%
	Outdoor geographic area	66%	58%
	Outdoor premises	97%	96%
Data	Indoor premises	80%	77%
	Outdoor geographic area	52%	38%
	Outdoor premises	93%	88%
4G	Indoor premises	72%	28%
	Outdoor geographic area	40%	8%
	Outdoor premises	86%	46%

England		2016	2015
Voice	Indoor premises	91%	87%
	Outdoor geographic area	84%	77%
	Outdoor premises	98%	97%
Data	Indoor premises	82%	81%
	Outdoor geographic area	72%	57%
	Outdoor premises	95%	91%
4G	Indoor premises	76%	31%
	Outdoor geographic area	60%	11%
	Outdoor premises	90%	50%

Wales		2016	2015
Voice	Indoor premises	73%	65%
	Outdoor geographic area	52%	46%
	Outdoor premises	90%	88%
Data	Indoor premises	57%	47%
	Outdoor geographic area	27%	17%
	Outdoor premises	76%	67%
4G	Indoor premises	34%	10%
	Outdoor geographic area	13%	2%
	Outdoor premises	53%	20%

Coverage is for all operators, i.e. the percentage of premises or geographic area where there is likely to be a signal from all operators. Coverage levels for individual operators may be higher.

Source: Ofcom analysis of operator data

Mobile delivery technologies

There are currently three generations of technology used to deliver mobile services to consumers in the UK.

2G was the first digital mobile technology, launched in the UK in 1992. It is used to deliver voice, text services and low-speed data services. 2G services are delivered by O_2, Vodafone and EE.

3G is a later generation of digital mobile technology, launched in 2003, and provides typical download speeds of over 5Mbit/s. 3G supports voice, text and data services, and services are operated by O_2, Vodafone, EE and Three.

4G is the latest generation of mobile technology, launched in 2012, and provides typical download speeds of over 10Mbit/s, with some services able to deliver significantly higher. These services are operated by O_2, Vodafone, EE and Three. There has been a significant roll-out of additional 4G services by all operators over

the past year. Three and EE have also upgraded their 4G networks to support voice services. Other operators may introduce similar services over the coming months.

When we report on mobile coverage, we often focus on the services offered by networks, rather than the technologies themselves. This is because the latest generation of mobile phones support all of these technologies and if, for example, a 3G network is unavailable, the phone will automatically switch to a 2G network to make the call. We therefore report on voice and data services.

The coverage of **voice services** is determined by the combined coverage of 2G and 3G networks, plus the 4G voice networks operated by EE and Three. The coverage of **data networks** is determined by the combined coverage of 3G and 4G networks.

5.12 The coverage of voice services has increased over the past 12 months, with 66% of the UK's geographic landmass having coverage from all operators, up from 58% in 2015. Indoors, voice services from all operators are now available within 89% of the UK's premises, up from 85% in 2015. The increase in voice coverage has been driven by both increases in 3G coverage and the deployment of 4G voice services.

5.13 The coverage of mobile data networks has also improved, but remains lower than voice coverage. 52% of the UK's geographic landmass has mobile data coverage from all operators, up from 38% in 2015. Around 82% of UK premises can receive a mobile data network signal from all operators indoors, up from 77% in 2015.

5.14 Geographic coverage of both voice and data networks is lower in Scotland and Wales than other parts of the UK. This is because a greater proportion of their landmass is rural, and mobile coverage is more difficult to provide in these areas than urban areas on a commercial basis due to their lower population density.

5.15 Operators are continuing to increase the coverage of their 4G networks. All operators now provide some 4G coverage to the UK's major cities and coverage is beginning to reach into smaller towns and some rural areas. Around 40% of the UK's landmass is now covered by a 4G signal from all operators, up from just 8% a year ago. In-building 4G coverage has also increased significantly; 72% of UK premises can now receive a 4G service from all operators indoors, compared to just 28% in 2015.

5.16 4G coverage has increased the most in Wales and Scotland, with both countries experiencing a six-fold increase in geographic coverage. However, overall coverage levels are still low, with only 12% and 13% of landmass in Scotland and Wales respectively covered by 4G networks from all operators.

5.17 The information on coverage levels in this chapter is based the mobile signal strength data provided to us by all mobile operators in June 2016. Operators are continuing to upgrade their networks and deploy new base stations. It is therefore possible that coverage levels may have increased since this data was collected. For example, we note that in November EE switched on 700 4G sites[30] which use spectrum at 800MHz. This spectrum is particularly well suited to providing coverage over wide areas and deep into buildings. These and other recent improvements will be reflected

[30] http://newsroom.ee.co.uk/ee-calls-on-industry-to-get-clear-on-coverage-as-it-covers-5000-square-kilometres-of-4g-not-spots-overnight/

in the next report. In addition, our online coverage checker[31] uses the most up-to-date information provided by operators.

5.18 We explore the coverage of mobile voice and data networks in more detail below.

Some 4G networks have been upgraded to support voice calls

Until recently, the 4G networks deployed in the UK only supported high speed data services; in order to make or receive a voice call, a mobile phone connected to a 4G network needed to automatically switch to a 2G or 3G network, switching back to the 4G network once the call is complete.

However, in the past year EE and Three have upgraded their 4G networks to support voice calls, using a technology known as 4G Voice or VoLTE. Combined with the ability, supported by all operators, to make voice calls over Wi-Fi, this development means that consumers should be able to make and receive phone calls in more places than before.

In calculating voice coverage, we include data from the 2G and 3G networks of all operators, plus the 4G networks of EE and Three. We understand that Vodafone and O_2 are undertaking trials of 4G Voice and could include their networks in the future.

Coverage of mobile voice services

5.19 Operators mostly use their 2G and 3G networks to provide voice services. EE and Three have upgraded their 4G networks to also support voice services and an increasing number of handsets are compatible with this new technology. Figure 18 shows the coverage of mobile voice services for each operator in the UK.

Figure 18: UK coverage for each operator's mobile voice services

	O_2 (2G, 3G)	Vodafone (2G, 3G)	EE (2G, 3G, 4G)	Three (3G, 4G)
Indoor, premises	96%	95%	96%	95%
Outdoor geographic, landmass	78%	82%	80%	76%
Outdoor, premises	99%	99%	99%	99%

Source: Ofcom analysis of operator data

5.20 In the case of EE and Three, the activation of 4G voice services on their networks has helped improve voice coverage[32], but for slightly different reasons. EE's 4G network is the most mature amongst the operators in the UK and enabling 4G voice on this network offers their customers an additional means to make and receive calls. EE provides an indoor mobile voice service to 96% of UK premises, but this falls to 94% of premises if their 4G coverage is disregarded and only their 2G and 3G networks' coverage is included.

[31] https://checker.ofcom.org.uk

[32] We are currently undertaking further field testing work to more firmly establish the minimum 4G signal level needed to provide reliable 4G voice call coverage.

5.21 For Three, the benefit is mainly derived from their use of lower frequency spectrum at 800MHz for some parts of their 4G network. The characteristics of this frequency band make it good at covering wide areas and, in particular, penetrating deep into buildings. Three's use of their 4G network takes their geographic voice coverage to 76% of UK landmass, as opposed to 70% of landmass if they only used their 3G network. The difference is even more pronounced with indoor coverage, with 95% of UK premises covered if 4G is included, compared to just 86% of premises if only their 3G network is used to deliver voice.

5.22 We can expect some further improvement mobile voice call coverage with the further deployment of voice-enabled 4G networks by all operators, in particular those operating in the 800MHz spectrum band.

Coverage of mobile data services

5.23 Operators mostly use their 3G and 4G networks to provide higher-speed mobile data services to their customers; 2G networks are only capable of supporting lower-speed data connections and we exclude them from this assessment of coverage. Figure 19 shows the coverage of mobile data services for each operator in the UK.

Figure 19: UK coverage for each operators' mobile data services, based on combined 3G and 4G coverage

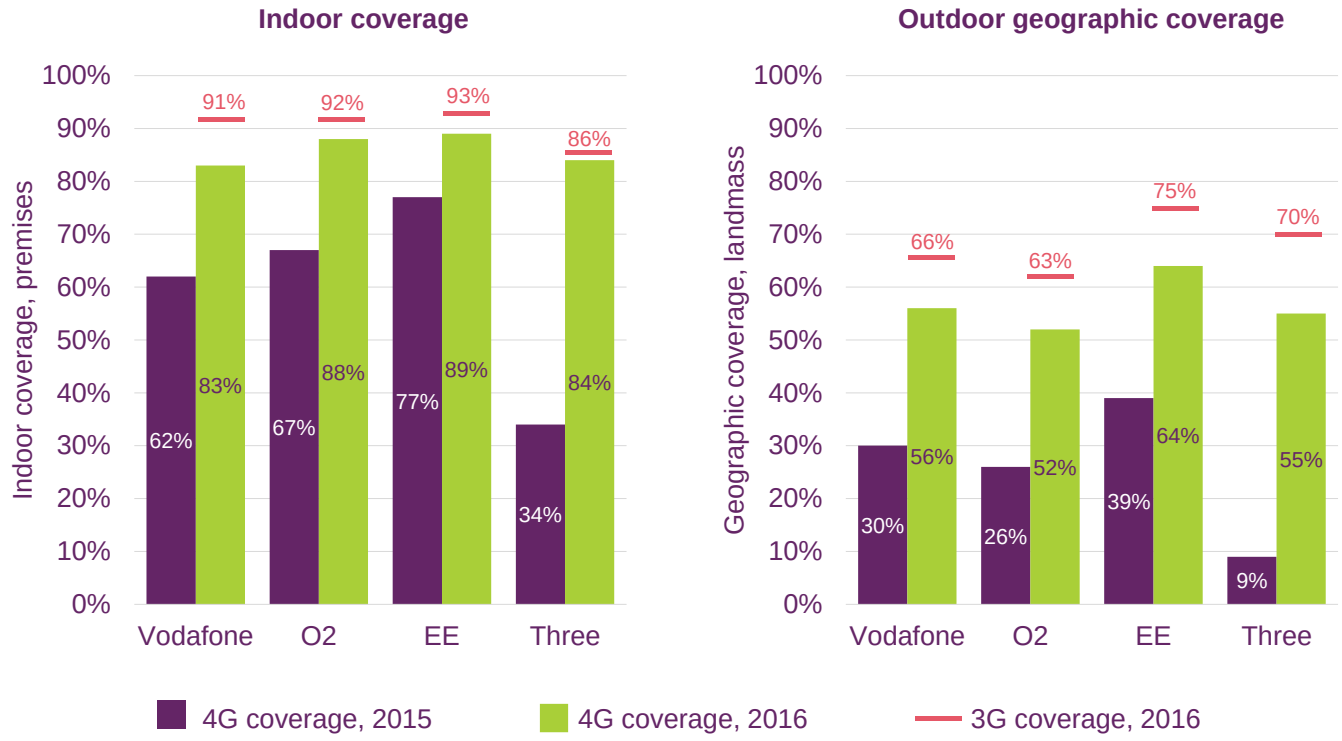
	O_2	Vodafone	EE	Three
Indoor, premises	92%	92%	95%	87%
Outdoor geographic, landmass	63%	66%	76%	70%
Outdoor, premises	96%	97%	99%	97%

Source: Ofcom analysis of operator data

5.24 3G networks have been deployed in the UK since 2003 and their levels of coverage are relatively high, compared to more recently deployed 4G networks. The coverage of mobile data services is, therefore, largely determined by the level of 3G coverage. However, this will change as operators continue their 4G network deployment, especially where those networks make use of spectrum at 800MHz, which is better suited to covering large areas and reaching deep into buildings.

5.25 Coverage of 4G services has increased significantly over the past year as all operators continue to roll out these networks. Each operator now provides indoor coverage to over 80% of the UK's premises, offering levels of coverage similar to their more mature 3G networks. Geographic coverage is lower, with operators' 4G networks covering between a half and two thirds of the UK's landmass.

Figure 20: Coverage of 4G networks has increased over the past year



Source: Ofcom analysis of operator data

Coverage of mobile services on the transportation network

5.26 Consumers spend a significant amount of time travelling on the roads or on trains and frequently experience poor coverage. This may be because these roads or railway lines pass through rural areas, tunnels or cuttings, where mobile signals are weak or totally blocked. In urban areas, the problem could be because too many people are trying to use the network at the same time.

5.27 Being able to communicate on the move is important to consumers. Yet providing reliable coverage across the transportation network can be challenging. This year, as in previous years, we report on the coverage of mobile networks across the UK's road network. We have also undertaken some research to understand levels of mobile coverage on key train routes.

Mobile coverage on roads

5.28 Good mobile coverage is important for road users. For workers on the move it provides a vital means to stay in contact with colleagues and customers; it allows drivers or pedestrians to call for help in an emergency; and, increasingly, it will connect vehicles and roadside sensors as part of the emerging Internet of Things.

5.29 As Figure 21 shows, coverage on A and B roads reflects levels of geographic coverage and is relatively low. Just 62% of the UK's network of A and B roads is covered by a voice service from all operators. Data coverage is even lower, at just 45% of the A and B road network. Coverage is worst in Scotland and Wales, which reflects the relatively low levels of geographic coverage in these countries. Voice calls are only possible on around 40% of Scotland and Wales' network of A and B roads.

5.30 Coverage on motorways is better, as these major roads are often targeted by operators at an early stage of network deployment. 97% of the UK's motorway network is covered by voice services from all operators, with motorways in the nations similarly well covered for voice. Data coverage on motorways is lower, but still significantly better than A and B roads; 83% of the UK's motorway network is covered by a data service from all operators.

Figure 21: Mobile coverage on many roads is poor

	A and B roads, % road network		Motorways, % road network	
	Voice coverage	Data coverage	Voice coverage	Data coverage
UK	62%	45%	97%	83%
England	72%	55%	97%	85%
Northern Ireland	59%	43%	92%	74%
Scotland	39%	25%	95%	75%
Wales	40%	22%	97%	89%

Source: Ofcom analysis of operator data
Note: For in-car coverage, we assume that the mobile phone is used within the vehicle. Coverage would be better if a car kit with an external antenna were used.

Mobile coverage on trains

5.31 As explained in the box below, mobile coverage inside train carriages can be poor for a combination of reasons. The apparently obvious approach of simply deploying more base stations to cover all of the rail corridor may not an effective solution in all cases, and would certainly be high cost.

Why is mobile coverage on trains often so poor?

While the coverage of mobile networks continues to improve in many places, many of us still experience the frustration of dropped calls and poor speeds when trying to use our mobile phone on a train. Why is delivering reliable mobile coverage to train passengers so difficult?

One reason is the location of the tracks. Intercity railway tracks often pass through rural areas, where levels of coverage tend to be lower than in urban areas. However, consumers often experience dropped calls and slow data speeds even in dense urban areas, such as around railway stations. This is more likely caused by the mobile networks lacking the capacity to deal with high numbers of users simultaneously. In addition, many railway tracks are laid in deep cuttings and tunnels, which are difficult and costly to cover with standard network base stations.

The construction materials used in some newer trains also contribute to poor coverage. In particular, the train windows are sometimes coated in a metallic film or mesh. While this has the desired effect of helping to regulate the temperature within the train, the coating also weakens or blocks mobile signals from passing through.

5.32 Consequently, the train industry (Network Rail and the Train Operating Companies or TOCs) have been working on a number of different approaches to improving connectivity as the rail travelling public's expectations have risen. Some TOCs have deployed repeater technology, but these have tended only to improve matters for customers of a single mobile operator and do not solve the problem of deep cuttings and tunnels, or lack of coverage.

5.33 More generally, many TOCs, particularly those running the main long distance routes have installed Wi-Fi systems into their rolling stock, providing internet connectivity to the travelling public via on train gateways, provided by specialist service providers, that use either satellite or, now more commonly, mobile coverage. These solutions also do not provide contiguous coverage because of the tunnel and cutting problem and lack of mobile coverage and capacity in some areas. Additionally, these services have typically been provided on a "pay as you go" basis and have not supported voice connectivity. The latter point is becoming less of an issue with increasing adoption of Wi-Fi calling functionality by the operators, and this functionality is likely to be widely available and commonly used by most consumers within a few years.

5.34 Government has taken a keen interest in these developments and recently announced that the Department for Transport is proposing a new set of conditions on TOC franchises that will deliver free Wi-Fi services to travellers on all of the main routes, both long distance and commuter, over the next few years. The aim is to provide uninterrupted coverage along the entire route with sufficient capacity to meet the basic internet access and voice connectivity needs of the normal passenger loads, based on actual route data. The requirement specified per passenger will increase over time to meet increases in expectation and usage.

5.35 The approach taken is technology agnostic as far as "backhaul" solutions providing connectivity to the on train gateways are concerned. Additional operator capacity targeted at the rail corridor is one approach already being deployed on the Chilterns line through an agreement between Arriva and EE. Other radio spectrum, aside from that licensed to mobile network operators, could potentially be used and Ofcom would welcome further dialogue with the TOCs and their service partners on these issues.

5.36 In order to meet the goal of service contiguity, access to facilities close to or on the rail corridor will also be necessary for any backhaul solution deployed. The planned reforms to the Electronic Communications Code contained in the Digital Economy Bill will facilitate this but it is envisaged that Network Rail, as the rail corridor landowner, will also play a key role in providing a range of active and passive services to the service providers, particularly with regard to deploying solutions in tunnels.

5.37 Ofcom is already planning additional service monitoring activity to assess the effectiveness of these measures and will remain in active dialogue with Government, the rail industry and service providers to ensure their success.

Challenges remain in delivering mobile coverage in rural areas and to consumers on the move

5.38 Mobile operators face a number of challenges in delivering high levels of geographic coverage. Many of these result from the challenges associated with installing mobile network equipment in very rural areas, and include:

5.38.1 **Terrain**, e.g. steep mountains make it harder to reliably deliver mobile signal coverage deep into valleys;

5.38.2 **Policy**, e.g. planning restrictions on where mobile base stations can be built, especially in areas of natural beauty; or

5.38.3 **Practical factors**, such as difficulties in securing and maintaining a reliable power supply for the base station.

5.39 As a result of these, and a commercial focus by mobile operators on first deploying networks where population density is highest, levels of mobile coverage in rural areas are significantly lower than in urban areas. Figure 4 below shows the voice service coverage from all operators in rural areas.

Figure 22: Coverage of voice services from all operators in rural areas

	Indoor	Outdoor	
Rural areas in	Premises	Geographic	Premises
UK	50%	64%	84%
England	53%	83%	88%
Northern Ireland	52%	80%	86%
Scotland	41%	35%	71%
Wales	32%	50%	66%

Source: Ofcom analysis of operator data

5.40 The figures in Figure 21 highlight two important themes of rural coverage:

5.40.1 Firstly, indoor coverage of voice services across the all of the UK's rural areas is poor, with only 50% of premises in these areas served by all operators; and

5.40.2 Coverage is particularly poor in Scotland and Wales, both in terms of indoor and geographic coverage.

5.41 We have published alongside this document an update to our Economic Geography report[33], which is a more detailed analysis of the factors that affect the provision of mobile coverage. The decision to offer mobile coverage in a particular area is essentially a commercial judgement by the operators. Profitability will depend on the likely demand for mobile services and the costs of providing these services. Based on actual coverage data provided by operators, we can observe that there are generally more areas in London that have full 3G and 4G coverage than the UK average while the opposite is true for areas within Scotland and Wales.

5.42 This may create the perception that certain parts of the UK are 'under-served' in terms of the level of 3G or 4G coverage that they receive. However, a region may have below-average coverage in part because it is less densely populated or has more challenging terrain than other regions.

[33] https://www.ofcom.org.uk/research-and-data/multi-sector/economic-geography-2016

5.43 We have used regression techniques to examine how much of the regional variation in 3G and 4G coverage can be explained by differences in the demand and cost factors. Applying this technique, we find that once factors such as population density, population composition, topography and whether the locality is urban or rural are taken into account, the probability of good 3G coverage is relatively similar between different parts of the UK. This indicates that much of the variation that we see in coverage can be explained by these factors. However, there would appear to be other factors that are specific to the East of England, Scotland and Wales that negatively affect coverage. Further work will be needed to understand the reasons for this.

5.44 In the case of 4G, there remains a considerable amount of unexplained regional variation particularly in the West Midlands, East of England, the South West, Wales and Scotland. However, 4G roll-out is ongoing and this only represents a snapshot of a dynamic environment. Over time, as 4G networks mature, we would expect that the amount of unexplained regional variation may become smaller, as it has for 3G.

Mobile coverage obligations

5.45 Licence obligations to meet particular coverage levels are also playing a role in helping extend mobile coverage. In December 2014 the UK Government signed a binding agreement with the four network operators to improve mobile coverage. This agreement, since reflected in a licence obligation, guarantees coverage of a mobile voice service from each operator 90% of the UK's land mass by 2017.

5.46 This agreement uses a different definition of coverage to the one we use in this report. In particular, it is based on a lower mobile signal level requirement. This lower signal level relates to a lower likelihood of reliably being able to make a call when there are localised signal blockages by trees, buildings and other obstructions. Hence when this agreement is met it will correspond to a geographic mobile coverage level of between 80 and 85% based on the definitions used in this report, depending on the frequency bands used by each operator to provide voice services[34]. We intend to report in more detail on the progress being made by mobile operators in meeting their geographic mobile coverage licence obligations in Q1 2017, using more up to date coverage data from the operators[35].

5.47 As with voice services, licence obligations are also playing a role in improving the coverage of data services. O_2 has a coverage obligation in its Wireless Telegraphy Act licence, requiring it to provide indoor coverage to 98% of UK premises by the end of 2017. Other operators have indicated their intention to match this level of coverage over the same timescale.

The increase in 4G coverage is helping to drive consumers' demand for mobile data

5.48 Data consumption on mobile has increased to 106PB per month with the data per active connection per month now over 1GB (Figure 23); this is a ten times increase

[34] Unless the operators exceed their licence commitments.

[35] We estimate that as of June 2016, based on the lower minimum mobile signal level requirements used in their agreements, the level of geographic mobile voice call coverage achieved by the different operators for the purposes of their agreements are: O_2 – 89%, Vodafone – 93%, EE – 85%, Three – 78%.

over five years. The increase in 4G coverage, as shown in Figure 20 on page 40, has been instrumental in facilitating data consumption growth across the UK.

Figure 23: Mobile data use continues to increase

Traffic Type	June 2016	June 2015	June 2014	June 2013	June 2012	March 2011
Active Connection (millions)	83.6	83.7	83.2*	82.7	82.2	81.1
Total data uploaded/downloaded (GB, millions)	105.5	72.9	44.3	28.9	19.7	9.0
Data per active connection (GB)	1.26	0.87	0.53	0.35	0.24	0.11

Source: Ofcom analysis of Mobile Network Operator data and Connected Nations Report 2015[36]
Note: * figure from March 2014

5.49 Data traffic distribution is roughly in line with population distribution across the UK, as can be seen in Figure 24. England has the highest 4G coverage in the UK and, with just under 93PB, it accounts for 88% of the total data traffic generated in a month. The 2016 data traffic in England has outstripped the total data traffic in the UK for 2015.

5.50 Wales has the lowest 4G coverage in the UK and accounts for 3% of data traffic generated in a month, ahead of Northern Ireland, as a result of higher population. With regards to Northern Ireland, it has the second best 4G coverage in the UK, but only accounts for 2% of the total data traffic generated in a month.

Figure 24: Share of data traffic and population between UK nations

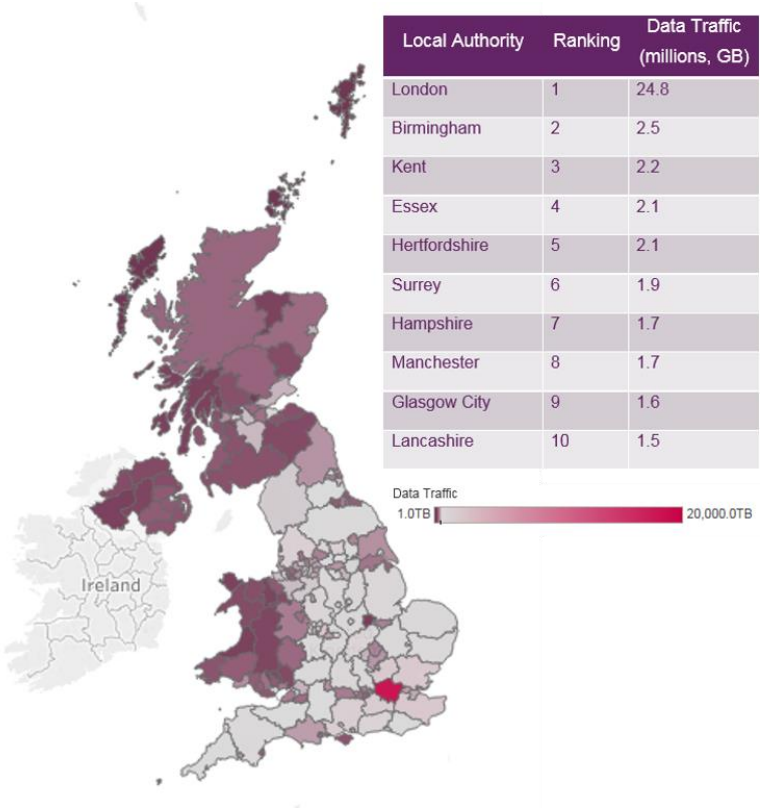
Nation	Data Traffic (GB, millions) (%)		Population (millions) (%)[37]
	2015	2016	Mid-2015
England	64.0 (88%)	92.7 (88%)	54.8 (84%)
Northern Ireland	0.8 (1%)	1.8 (2%)	1.9 (3%)
Scotland	5.4 (7%)	7.6 (7%)	5.4 (8%)
Wales	2.7 (4%)	3.4 (3%)	3.1 (5%)
UK	72.9	105.5	65.1

[36] https://www.ofcom.org.uk/research-and-data/infrastructure-research/connected-nations-2015
[37] ONS estimates of UK population: https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationestimates/bulletins/annualmidyearpopulationestimates/mid2015

Source: Ofcom analysis of Mobile Network Operator data.

5.51 Figure 25 shows the distribution of data traffic by local authority. Data consumption in London is 24.8PB per month, which accounts for almost a quarter (23.5%) of the total UK data consumption. The second highest local authority by data traffic consumption is Birmingham with a tenth of London's data traffic consumption. The least data traffic is consumed in the local authority of the Isles of Scilly.

Figure 25: Data traffic heat map at each local authority[38] and top 10 local authorities by data traffic



Local Authority	Ranking	Data Traffic (millions, GB)
London	1	24.8
Birmingham	2	2.5
Kent	3	2.2
Essex	4	2.1
Hertfordshire	5	2.1
Surrey	6	1.9
Hampshire	7	1.7
Manchester	8	1.7
Glasgow City	9	1.6
Lancashire	10	1.5

Source: Ofcom analysis of Mobile Network Operator data

5.52 A greater proportion of data is being delivered over 4G networks. Given the faster download speeds of the technology, and its ability to handle high demand applications such as streaming HD video. In 2016, 60.2% of the total data traffic was delivered over 4G networks (63.5PB), in comparison to 39.3% on 3G network (41.5PB). This means that 50% more traffic is carried on 4G than on 3G.

[38] An interactive version of this map is available: https://www.ofcom.org.uk/research-and-data/infrastructure-research/connected-nations-2016/interactive

Figure 26: UK data traffic by technology type for each nation

	Data Traffic (GB, millions) (%)			
	2G	3G	4G	Total
England	0.4 (76%)	35.7 (86%)	56.4 (89%)	92.7 (88%)
Northern Ireland	0.02 (3%)	0.67 (2%)	1.1 (2%)	1.8 (2%)
Scotland	0.07 (13%)	3.4 (8%)	4.24 (7%)	7.6 (7%)
Wales	0.04 (8%)	1.71 (4%)	1.72 (3%)	3.4 (3%)
UK	0.53 (0.5%)	41.5 (39%)	63.5 (60%)	105.5

Source: Ofcom analysis of Mobile Network Operator data

5.53 The table in Figure 26 highlights the marked difference between 3G and 4G data traffic across nations except Wales, where the data traffic for 3G and 4G are particularly close. Wales has relatively low 4G coverage, compared to the UK as a whole and as shown in Figure 17; as a result, the data traffic delivered over 4G networks is relatively low.

Where and when consumer uses data plays an important role in the experience

5.54 Coverage is perhaps the most important factor in determining the consumer's quality of experience. Despite data traffic and coverage continuing to increase (as shown in Figure 17 and Figure 23), the quality of experience of a single consumer is affected by a range of factors, including whether they are indoors or outdoors, close to or far from a base station and whether they are moving. The service consumers receive will also be influenced by factors outside of their control, such as how many others are trying to use the network at the same time.

5.55 In Figure 27, we analyse data traffic in the busy hour. Each base station has a different busy hour; this is the hour in which the greatest data traffic is downloaded. Consumer quality of experience may be affected in the busy hour, and they may experience slower download speeds as more people are using the network.

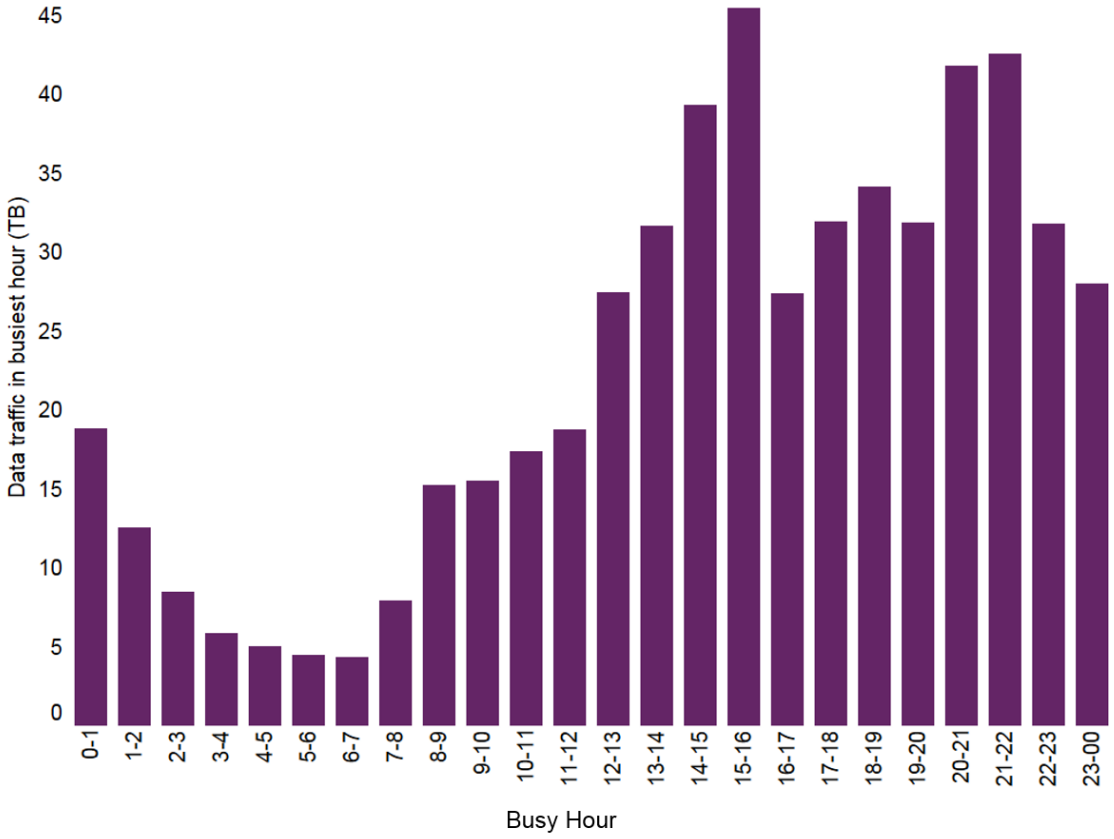
5.56 Our analysis of the data traffic carried in busy hours shows that 15:00 – 16:00, across the month, is the hour in which the most data is downloaded and uploaded across the UK, nevertheless the use of data never switches off. The 15:00 – 16:00 slot coincides with the end of the school day, and analysis of Digital Day data[39] shows a peak for smartphone reach for 11-15 year olds at 3-5pm.

5.57 Consumers at different hours and locations may have a lower quality of experience. Base stations can have their busiest hour across any of the 24 hours of a day. For

[39] http://www.digitaldayresearch.co.uk/

example, busy hour for some sites surround the O_2 arena in London is between midnight and 01:00 as events finish around that time.

Figure 27: Average busiest hours for data traffic in the UK



Source: Ofcom analysis of Mobile Network Operator data

Section 6

Internet Access Services

Overview

6.1 The fixed and mobile services discussed in the preceding two sections of this report are used predominantly for the delivery of internet access services. In this section we touch on some of the issues relating to how these services link consumers to the online services and content they wish to access and, in particular, on the increasing role of regulators and policy makers in ensuring that these services operate in an equitable and open way.

6.2 These services now constitute the majority of traffic delivered over access networks and consumers have become increasingly reliant on them for both economic and social activity. As a result, consumers are becoming increasingly concerned about the quality of their internet connection, in addition to the performance of the more traditional services such as voice telephony. Policy makers have recognised this and taken steps to ensure that all sources of content continue to be generally available to all end users and that particular services or classes of service are not unduly favoured unless justifiably necessary.

6.3 In this section we report on how Internet Service Providers (ISPs) are supporting the delivery of internet services over their networks, including how they manage the flow of data over their networks and how they interconnect with other ISPs, content delivery networks and the wider internet. We also touch on how the new regulatory regime for internet access services aimed at ensuring "net neutrality" is being delivered.

6.4 The highlights are:

6.4.1 **A major package of new regulatory obligations coupled with complementary enforcement powers for regulators is in the process of implementation**. This will result in greater transparency in how ISPs manage traffic, market their services and contract with customers.

6.4.2 **ISPs have already been improving the information they provide to consumers about the use of traffic management on their networks as part of a voluntary Code of Practice administered by the Broadband Stakeholder Group (BSG)[40]**. Current traffic management practices in widespread use have minimal or no impact on most users on fixed networks but, given the fixed capacity and variable demand in specific parts of mobile networks, may have an appreciable effect on mobile users during peak periods in busy areas.

6.4.3 **The amount of internet data being delivered to consumers by major video content providers continues to increase**. The use of content delivery networks (CDNs[41]) also continues to increase: internet content is increasingly being served from caching servers embedded in the ISPs' access networks and provided by the content providers.

[40] See http://www.broadbanduk.org/policies/the-open-internet/open-internet-code-of-practice-2016/
[41] Akamai, Google, Amazon, Netflix and the BBC.

6.4.4 Larger-scale ISPs are progressively **introducing support for the latest IPv6 internet addressing system**;

6.4.5 The **lack of security of Internet of Things (IoT)** and other low cost internet connected devices is leading to their being targeted by malware and their use to launch distributed denial of service (DDoS) attacks, increasing concerns over security of personal data.

EU Regulation on Net Neutrality

6.5 In April of this year, the EU Telecoms Single Market (TSM) Regulation on net neutrality rules came into force in the UK. The regulation introduces new rights for consumers and places certain obligations on ISPs. These rules were introduced to address concerns that ISPs might manage traffic on their networks in ways that would limit competition and innovation, which in turn could lead to consumer harm.

6.6 The rules impose requirements on ISPs in terms of how they can manage traffic on their networks and place transparency obligations on informing consumers how they do so. The rules also place an obligation on regulators to closely monitor and ensure compliance with the rules.

6.7 The relevant provisions in the EU regulation are:

6.7.1 **Article 3** sets out end-user rights to "access and distribute information and content, use and provide applications and services, and use terminal equipment of their choice" when accessing the internet. It imposes specific obligations on ISPs intended to secure this outcome. The obligations cover traffic management practices and commercial aspects relating to internet access services such as the provision of "zero-rated"[42] content.

6.7.2 **Article 4** imposes a range of specific transparency obligations on ISPs in relation to the speed and quality of their services. It also introduces requirements about the handling of complaints and the circumstances under which consumers have rights of redress when an internet access service is unsatisfactory.

6.7.3 **Article 5** requires regulators to monitor and ensure compliance and to report annually to the European Commission on compliance and on the general quality of internet access services. It also reinforces regulators' powers to impose quality of service obligations on ISPs.

6.7.4 **Article 6** requires member states to introduce an effective penalties regime for non-compliance.

The duties on regulators

6.8 In order to provide clarity and guidance to the regulators on their obligations, BEREC, the Body of European Regulators for Electronic Communications, published guidelines in August of this year to National Regulatory Authorities (NRAs) on the implementation of net neutrality. NRAs have a range of new tasks under the Regulation, which fall into two groups.

[42] An online content service is “zero-rated” on an internet access service when use of that content service does not count against the data cap applying to the internet access service.

6.9 Firstly, monitoring and reporting on compliance with the Regulation and the quality of internet access in the country. NRAs must "closely monitor" the quality of internet access, and ISPs' compliance with the obligations in the Regulation, specifically:

6.9.1 The transparency obligations for ISPs to provide additional information in contracts about the broadband speeds - the minimum, maximum, normally-available and advertised speeds for fixed services; the estimated maximum and advertised speeds for mobile services; to handle consumer complaints about these issues, and provide remedies/redress when necessary.

6.9.2 To ensure that ISPs do not limit end-users' ability to: access and distribute information and content; use and provide applications and services; and use terminal equipment of their choice, irrespective of the end-user's or provider's location or the location, origin or destination of the information, content, application or service, via their internet access service.

6.10 Secondly, enforcement of ISP compliance with the Regulation:

6.10.1 NRAs must enforce the Regulation, investigating complaints or potential breaches identified in the course of monitoring compliance. They may require ISPs to change their practices and impose sanctions in the event of serious breaches.

6.10.2 NRAs must also report annually to the Commission on these issues, with the first report due in June 2017.

6.11 Ofcom will continue to maintain a close dialogue with industry to ensure that the appropriate balance is struck between restricting ISP practices, in order to protect innovation in online services, and allowing ISPs to evolve their networks and the range of internet and non-internet services they offer – whilst avoiding harming incentives to invest and ensuring the Internet remains an open and innovative environment.

Implementation actions

6.12 Ofcom currently has an on-going programme of work that is in line with the requirements of the EU Regulation. This programme includes reviewing the voluntary Broadband Speeds Code, and establishing a process to discharge our obligations with regard to the measurement and reporting on the quality of Internet Access Services (IAS).

6.13 Article 4 requires ISPs to ensure that any contract which includes IAS specifies the following:

6.13.1 How traffic management measures could impact on the quality of IAS, the privacy of end-users and the protection of their personal data;

6.13.2 Any impact of fair usage policies, data caps and specialised/managed services on IAS;

6.13.3 Important broadband speeds for both fixed and mobile networks; and

6.13.4 The circumstances under which consumers should be able to exercise their rights of redress, and the remedies available to them, when an internet access service (IAS) is unsatisfactory.

6.14 ISPs also need to have transparent and efficient procedures for handling complaints about such matters.

6.15 Ofcom is currently checking the compliance of the UK's main ISPs' residential consumer contracts in relation to the impact of traffic management on the quality of the IAS and on privacy and the protection of personal data.

6.16 We already have an active monitoring and enforcement programme covering providers' obligations under General Condition 14.4 in relation to complaints handling, including for IAS. We will continue to actively monitor communications providers' (CPs) compliance with these obligations, considering formal enforcement action if breaches are identified.

6.17 We will be revising the Broadband Speeds Codes of Practice for businesses and residential consumers. We aim to strengthen the Codes and ensure that speed information given at point of sale and after sale is in line with the specification of the TSM regulation and consistent across CPs. This will ensure more realistic estimated speed measures are given to consumers, as well as an easier route to redress. The Codes will provide guidance to CPs on the interpretation of the TSM regulation in the UK. We are currently engaged in discussions and workshops with CPs and aim to consult on the revised Codes and guidance in summer 2017.

6.18 In this context, it is worth noting that the Advertising Standards Authority (ASA) recently published research into consumers' understanding of broadband speed claims made in adverts[43]. The study was commissioned following growing concerns that consumers were misled by adverts for broadband services citing headline speeds that customers did not actually receive.

6.19 The research found that speed is an important factor for a significant proportion of consumers who are making decisions between providers. However, levels of knowledge and understanding of broadband speeds vary, and are low overall with many not knowing what speed they need to carry out daily online tasks

6.20 Most understand that the higher the number in the advertisement, the higher the speed of the service, but many are unclear on what this means for them and what speed they would likely achieve. Despite that uncertainty, most consumers believe they are likely to receive a speed at or close to the headline speed claim when, for many, that is not likely to be the case

6.21 As a result, the ASA is reviewing its guidance to advertisers on broadband speed claims. A report will be published in spring 2017. Ofcom will work with the ASA to ensure consistency of approach.

Traffic management practices

6.22 Traffic management is a necessary aspect of ISPs' network management practices. Better controlling the flow of traffic across an ISP's network by using traffic management (TM) can benefit consumers by improving the performance of their broadband connections at peak times. However, there are concerns that through their use of it, ISPs might manage traffic on their networks in ways which can cause consumer harm or limit online innovation. These potentially harmful practices may

[43] See https://www.asa.org.uk/News-resources/Media-Centre/2016/ASA-calls-for-a-change-in-the-advertising-of-broadband-speed-claims.aspx#.WDxjtX2uggE

include ISPs restricting or 'slowing down' subscribers' access to specific online content, in order to further their own commercial interests, or attempting to charge CPs to access their subscribers. Practices such as these can stifle innovation, be considered anti-competitive and could restrict freedom of expression.

6.23 In light of this, Ofcom has required ISPs to be fully transparent in what they do in this regard, to ensure that consumers can make informed decisions. Before the coming into force of the European Union Telecoms Single Market (TSM) Regulation, ISPs in the UK were already subject to a regulatory obligation[44] to be transparent with consumers about their TM practices. There is an industry-wide code of practice explaining how they should comply with this obligation (the Traffic Management Transparency Code of Practice[45]) which requires that each ISP publish a table summarising its TM policy for each package on offer. These tables have been available on signatories' websites since July 2011.

6.24 In late 2013, Ofcom conducted research on consumer awareness and use of the TM information provided by ISPs. It found that, while the information provided by ISPs was largely accurate and understandable, consumer awareness of TM generally was low. Following this, during 2014 we worked with ISPs to help them improve the impact of the information they provide, with a focus on improving consumer awareness and usability.

6.25 This work, pursued via the BSG Open Internet Forum has resulted in voluntary agreement by the ISPs that they adopt a common approach to defining the traffic management techniques they deploy. The ISPs now provide introductory information explaining their policies and the impact of these policies on their services, and have updated their websites to include glossaries of technical terms.

6.26 We review these key facts indicators and report on them each year as part of this report. Our conclusion is that, broadly, transparency about TM practices has improved, and in general TM policies are less restrictive than they were a few years ago.

6.27 For many fixed networks, TM policies are rarely if ever invoked, although CPs do publish what they would do if networks are congested to ensure adequate performance for time critical applications. Virgin Media continues to apply TM to very heavy data users as part of its demand management policy during busy periods

6.28 Mobile networks also now generally claim not to use TM unless congestion becomes an issue, but this can happen both as a result of normal "time of day" variations in overall loading and as a result of more random increases in users and consequent traffic in particular geographic areas and the cell sites that serve them. They also use data caps and speed limits as another means of managing demand, which may have a much more fundamental impact on the customer experience

6.29 Ofcom continues to explore how best to assess and measure the mobile broadband consumer experience. The "Smartphone Cities, Measuring 4G mobile broadband and voice performance" report[46] that is being published concurrently with this report looks

[44] General Condition 9.2e

[45] http://www.broadbanduk.org/wp-content/uploads/2013/08/Voluntary-industry-code-of-practice-on-traffic-management-transparency-on-broadband-services-updated-version-May-2013.pdf

[46] https://www.ofcom.org.uk/research-and-data/broadband-research/smartphone-cities/december-2016

at how each of the MNO networks performs in a number of major urban areas. In addition to average speed measurement and key web service delivery performance, it has established that generally users in all of the cities can expect to receive more than 2Mbit/s for 90% or more of the time. Whilst this seems likely to deliver a good quality of experience for users, it does emphasise that congestion and, hence, TM can have a significant impact during peak periods or other congestion episodes.

6.30 As mobile networks, and the customers who use them, complete the transition to a fully 4G environment, voice services will be delivered using 4G voice or VoLTE technology, as discussed in Section 5. Since voice will now be transported as any other data service session, ensuring prioritisation during busy periods or localised congestion will become more important, particularly for calls to the emergency services. Ofcom will continue to monitor TM application in this context to ensure voice service quality is maintained.

Internet interconnection trends

6.31 As part of our information requests to communications providers, we asked them how they connect their customers to the rest of the internet. In previous years we have used this information to review and report on the nature of the connection arrangements used by ISPs to deliver internet content.

6.32 Interconnection can be defined as a business relationship where there is an exchange of customer traffic, between administratively separate Internet networks. As referred to in last year's report, there are many different ways in which ISPs can exchange their customer's traffic with each other. These include transit, public and private peering and the deployment of CDNs.

Peering

6.33 With peering, both parties tend to meet at a carrier neutral location known as an internet exchange point or IXP. At this exchange they are able to connect either directly or via the exchange's equipment. The latter is often known as public peering, the former as private peering, this term also being used to describe interconnection at one or other of the parties own premises.

6.34 In the case of public peering each ISP pays its own costs for connecting into the exchange's switch. In the case of private peering there are many commercial alternatives available to them, which in many cases may depend on the ratio of traffic exchanged between the two parties.

6.35 In the situation where the ISPs exchange traffic within a given ratio they cover their own interconnection costs, as the relationship is mutually beneficial and is considered a "balanced" peering.

6.36 With larger content providers, the ratio between the traffic sent by each of the peers is now typically relatively high and very different from the 1:1 ideal of "balanced" peering, as a content provider such as Netflix sends a significantly larger volume to the ISP's customers than *vice versa*.

6.37 Generally, in the scenario where the amount of traffic exchanged between the ISPs falls outside of the agreed ratio, the ISP responsible for sending excess traffic is likely to have to pay for the excess, as the relationship could be considered as being more beneficial for only one party. This change has led to a "settled" peering model, where billing is based on the out-of-ratio traffic.

6.38 However, in time this trend may reverse, with the increase in cloud computing and other consumer oriented and services that involve bigger uploads, the traffic flowing upstream to some content providers may tend more toward a balanced ratio. This is likely to result in further adjustments to commercial arrangements with both parties sharing the costs more evenly.

Transit

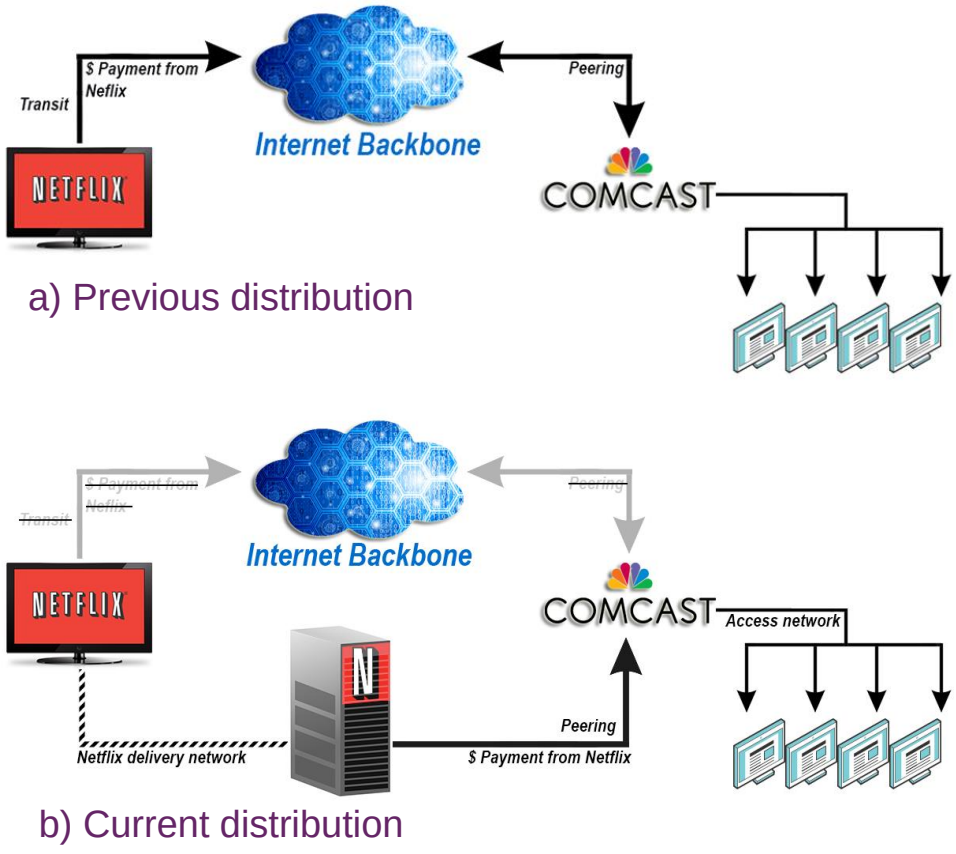
6.39 Transit is when a party pays for access to either all possible destinations in the Internet, or only within a geographic region i.e., destinations with the UK only. The commercial details may include the volume of traffic exchanged or where the customer commits to maintaining a minimum volume.

Content Delivery Networks and caching

6.40 Over the last year, and as we have reported in previous years, both the number of transit and peering connections have been decreasing whilst the deployment of Content Delivery Networks and associated caching has been noticeably increasing.

6.41 Some of the largest content providers now operate their own delivery networks, which must interconnect with ISPs in order to deliver content to consumers. They can do this either by paying a transit network, which itself connects to the ISP, or by interconnecting directly as shown in Figure 28. Direct interconnection is cheaper (for the content provider) for the delivery of large volumes of data

Figure 28: Changing approaches to interconnection



Source: Ofcom

6.42 Particularly in the US, these 'direct' interconnection agreements between ISPs and content delivery networks have led to allegations that ISPs are attempting to become *gatekeepers*, extracting a charge from content providers to allow them to access the ISPs' subscribers. The allegations are particularly prominent in those countries (like the US) where there is limited competition among ISPs, and hence the negotiating position of content providers is seen to be weaker.

6.43 In fact, these arrangements are arguably no different from traditional network operator interconnection negotiations and arrangements that have always existed. We have no reason to believe that UK ISPs are abusing their position to extract payment from content providers.

6.44 In particular, we note that Netflix's CDN arrangements, and those of other leading content providers, are now being further extended into the access provider's own network using 'caching servers'. Caching servers are CDN servers which can be placed within the ISP's network or on a third-party network, storing the most popular content. This removes the need for the ISP to connect to the original source of the content every time a customer requests it.

6.45 There are many reasons why this approach may be preferred. The local delivery of content can result in better delivery times to the consumer, which may translate to a better quality of experience, and so is often a preferred option for content providers. This approach further reduces transit or backhaul connectivity costs, and can also improve the customer experience by reducing the likelihood of data congestion in these parts of the network. The commercials in this model are likely to include location services and port-based pricing.

6.46 This evolution is explored further in an academic paper called "Open Connect Everywhere: A Glimpse at the Internet Ecosystem through the Lens of the Netflix CDN[47]" published this year by a team at Queen Mary University of London. This notes, in particular, how Netflix as a content provider has moved to operating its own CDN whilst generally relying on third party cloud storage and, increasingly, caching servers it embeds in ISP networks. The variability of its network interconnection scenarios reflects the very differing network topologies and traffic flows in different markets.

6.47 Many CDN providers are now measuring and reporting on the performance of their content through each ISPs network. The publishing of this data on their websites may also influence how ISPs choose to interconnect with them.

Overall trends

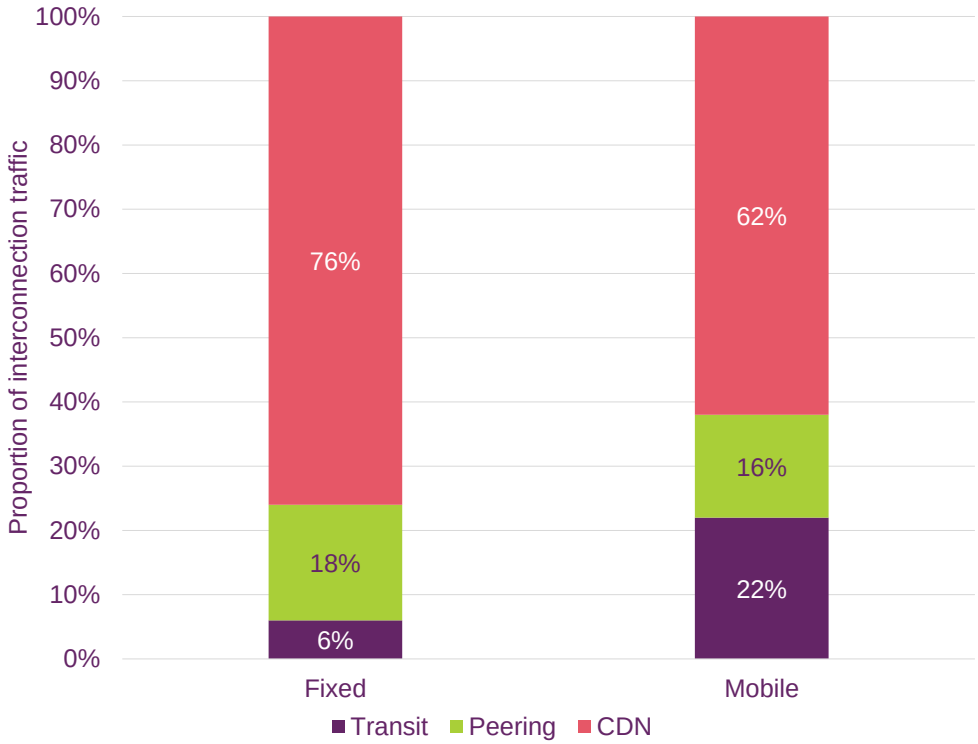
6.48 Last year we noted an increasing use of content delivery networks (CDNs) and direct connections between the access providers and the providers of content and services, and a reducing use of transit and public peering arrangements to deliver internet content.

6.49 This trend has continued - volumes of traffic across the interconnection points between the main ISPs and the internet core, other ISPs and the main providers of content have increased by around 45% since last year.

[47] See http://www.theregister.co.uk/2016/06/22/boffins_map_netflixs_open_connect_cdn/ and http://eecs.qmul.ac.uk/~boettget/mapping-netflix-coseners16.pdf

6.50 As Figure 29 shows, CDN connectivity is an even bigger proportion of the overall traffic than before, although there are notable differences between content providers. Generally, mobile networks have a lower proportion of CDN delivered traffic, probably reflecting the lower consumption of streamed video through devices connected directly to the mobile networks (as opposed to Wi-Fi).

Figure 29: Breakdown of fixed and mobile interconnection traffic



Source: Ofcom analysis of operators' data

Further progress on migrating to IPv6

6.51 The availability of IPv6 to consumers is progressing. IPv4 address ranges are nearing exhaustion and new service deployment is inevitably going to increase the demand for unique, publicly accessible addresses that only the IPv6 regime can deliver. This will, in particular, facilitate the deployment of the Internet of Things (IoT).

6.52 According to the Akamai IPv6 Adoption[48] table, the UK is currently in 10th place in a list of countries who have adopted IPv6. However, compared to last year, most of the major ISPs have now launched IPv6 services to those customers who want it, building on the IPv6 support they already had in their core networks.

6.53 For example, Sky has progressively enabled "dual-stack[49]" IPv6 for approximately 90% of its customers by upgrading the firmware in existing routers. A small percentage of the remainder will need replacement routers as the existing units will

[48] https://www.akamai.com/uk/en/our-thinking/state-of-the-internet-report/state-of-the-internet-ipv6-adoption-visualization.jsp

[49] Dual-stack means that those with IPv6 addresses will be able to access both IPv4 and IPv6 sites. This is important as much of the Internet is still on IPv4 only.

not support IPv6. BT is adopting a similar path with their integrated Home Hub routers being mainly IPv6 compatible with a firmware upgrade that is shortly being rolled out.

The Internet of Things - is security an afterthought?

6.54 Recently there have been a number of security breaches where Internet of Things (IoT) devices have been hijacked and used to create distributed denial of service (DDOS) attacks. One particular attack rendered Akamai helpless when they were unable to mitigate the effects of the attack on a target they were providing hosting and network security services for, and the website had to be shut down[50]. In the wake of these attacks, the security, or lack thereof, associated with IoT devices is gaining public interest.

6.55 As the adoption of IoT technologies continues to increase, the threat of security breaches is likely to rise, particularly as some IoT device manufacturers are not currently implementing particularly effective security measures into their products and, in many cases, do not have entirely convincing approaches to firmware upgrades and patching in the light of emerging threats.

6.56 In some cases, the most fundamental problems with these devices can be partly attributed to the default passwords not being changed, thereby allowing hackers to remotely gain access and install malware on them. These infected devices are then used directly or indirectly to launch DDoS attacks.

6.57 The lack of security with these devices may also have an impact on the consumer's privacy, with hackers being able to gain access to personal information. Depending on the IoT device they have, it may reveal personal data related to their health, or their habits of when they leave and arrive home, leaving them vulnerable to higher insurance costs or targeted burglary.

6.58 Many creators of IoT devices, who are not security minded, may be unaware of how vulnerable their products are to cyber-attacks. The GSMA[51] has produced security guidelines on how developers of IoT devices can incorporate security safe guards into their products.

6.59 As the deployment of IoT continues, Ofcom will work to ensure that industry addresses the need to protect the consumer from data exfiltration and other exploits. This could involve educating consumers on how best to protect their devices and personal information.

6.60 The past year has seen a 34% increase in the number of IoT devices individually connected to mobile networks (with a dedicated SIM card) in the UK, as shown in Figure 30 below. The amount of IoT traffic carried over the mobile networks is steadily increasing. However, as the volume of traffic generated by IoT devices is very small, this remains only a small proportion of traffic overall. Figure 30 does not include those IoT devices that are not connected to mobile networks, such as those connected via short range links (e.g. Bluetooth) or wide area low power networks (such as Sigfox).

[50] http://www.networkworld.com/article/3123672/security/largest-ddos-attack-ever-delivered-by-botnet-of-hijacked-iot-devices.html
[51] http://www.gsma.com/connectedliving/future-iot-networks/

Figure 30: Number of connections and proportion of total data traffic for IoT devices connected to mobile networks

	2016	2015
M2M (IoT) connections	6,999,287	5,212,304
Change	34.3%	28.2%
Average proportion of M2M data to total traffic	0.23%	0.16%
Change	44%	78%

Source: Ofcom analysis of operator data

Section 7

Security and resilience

Overview

7.1 As consumers and businesses become even more dependent on communications services, our duties with regard to network resilience become increasingly important. Overall, whilst network failure incidents are not significantly increasing in volume or impact, underlying changes in network technology have implications for consumers that need an appropriate regulatory and policy response. This section summarises the major security and resilience issues that were reported to Ofcom over the past year and the key issues that need addressing in the near future.

7.2 Key themes are:

7.2.1 The majority of security incidents reported relate to **voice services**, often affecting consumer access to the 999 emergency services;

7.2.2 The majority of incidents are caused by the **failure of hardware components, the loss of power supply or by software bugs**;

7.2.3 Incidents with an impact above one million customer-hours are uncommon, and are often the result of a **unique and unexpected threat to security**;

7.2.4 The next few years will see a fundamental change in how voice telephony services are delivered, **as obsolete PSTN[52] legacy systems are replaced by new VoIP[53] solutions**. This process will bring benefits to users but it is important that it is managed in a way that minimises disruption to consumers. We outline a number of key principles that should be followed to ensure minimum disruption for consumers and businesses: that providers must communicate the migration process clearly to their customers and that no voice service users are worse off after the technology change, either financially or functionally.

7.2.5 Mobile networks are increasingly important both as the main general communications channel for many users and the first choice for calls to emergency services. In this context, **the current level of resilience of mobile networks, particularly to mains power outages, is an increasing concern**. There will be a need for more focussed activity in this area involving Ofcom, Government and industry as part of the programme of securing and making key elements of critical national infrastructure more resilient.

[52] Public Switched Telephony Network
[53] Voice over Internet Protocol

Our role in security and resilience

Ofcom and providers of communications networks and services are subject to certain requirements[54]. These include requiring operators to appropriately manage security risks, to minimise impacts on consumers and to report any breaches of security or network failures to Ofcom.

We first published guidance on the full range of security requirements in May 2011 and updated that guidance in August 2014. We are in the process of updating the guidelines[55]. The guidance sets out our expectations for a risk-based approach to the management of security. It highlights appropriate sources of industry best practice and details our incident reporting requirements.

Aside from these specific requirements, digital terrestrial television (DTT) operators have an obligation[56] to meet high standards of reliability and to provide us with an annual report on transmission performance.

Reported fixed and mobile incidents

7.3 The majority of security incidents reported relate to voice services, often affecting consumer access to the 999 emergency services

7.4 In the past year, 581 security incidents were reported to us by fixed and mobile providers. The vast majority of reports were from fixed providers regarding disruption to telephony services (including 999 access) for fewer than 10,000 customers and for less than one day. Incidents with a wider impact, which affect tens of thousands of customers, are less common. Reporting data also show that incidents are more likely to occur in, or near, large population centres.

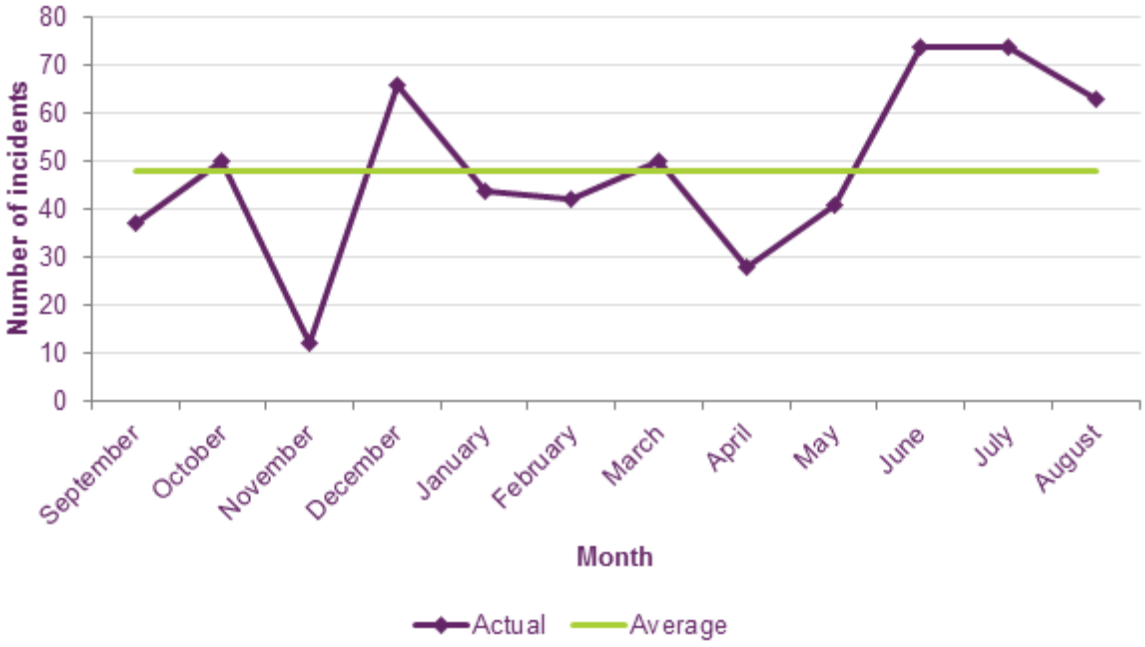
7.5 Figure 31 summarises the number of incidents reported each month between September 2015 and August 2016. The monthly variation could be the result of seasonal factors such as weather or school holidays. We continue to monitor for trends over time.

[54] In accordance with Article 13a of the Framework Directive, sections 105A-D of the Communications Act 2003 place requirements on providers and Ofcom regarding the security and resilience of communications networks and services.

[55] http://stakeholders.ofcom.org.uk/binaries/telecoms/policy/security-resilience/ofcom-guidance.pdf

[56] http://stakeholders.ofcom.org.uk/binaries/broadcast/guidance/techguidance/tv_tech_platform_code.pdf

Figure 31: The number of incidents reported between September 2015 and August 2016



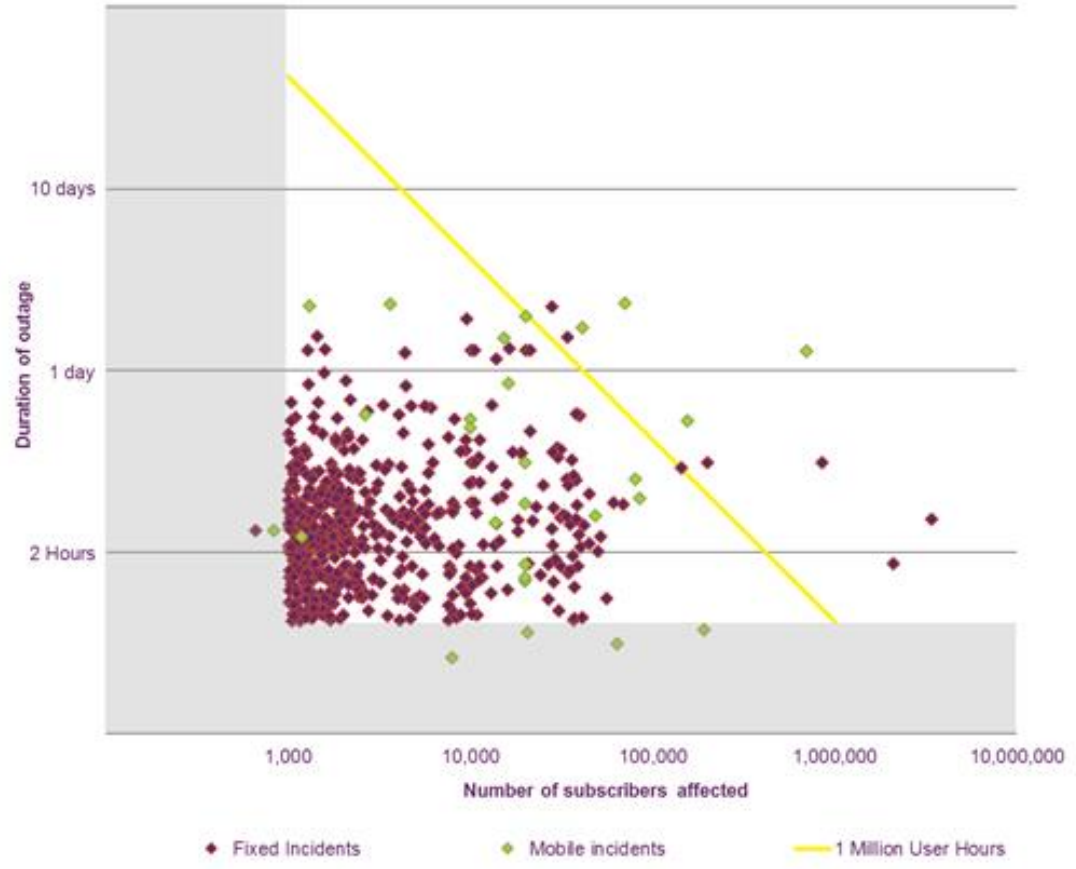
Source: Ofcom analysis of operator data

Scope of Ofcom reporting guidance/ framework

7.6 Ofcom's guidance provides quantitative criteria, or thresholds, against which a provider can gauge the impact of an incident and determine if it should be reported. The most critical is the 'emergency services access' threshold which applies to incidents that affect voice access to the emergency services for 1000 customers, for one hour. There will be incidents that occur but which are not reported to us, since they do not have 'significant impact' as defined in relevant guidance.

7.7 We measure the impact of an incident in 'customer-hours'. This is the product of an incident's duration and the number of consumers affected. While customer-hours is not the only metric by which incidents may be measured, it provides a useful basis for comparison. Figure 32 shows the customer-hours impact of the 581 incidents reported to Ofcom.

Figure 32: The impact of incidents reported to Ofcom, between September 2015 and September 2016



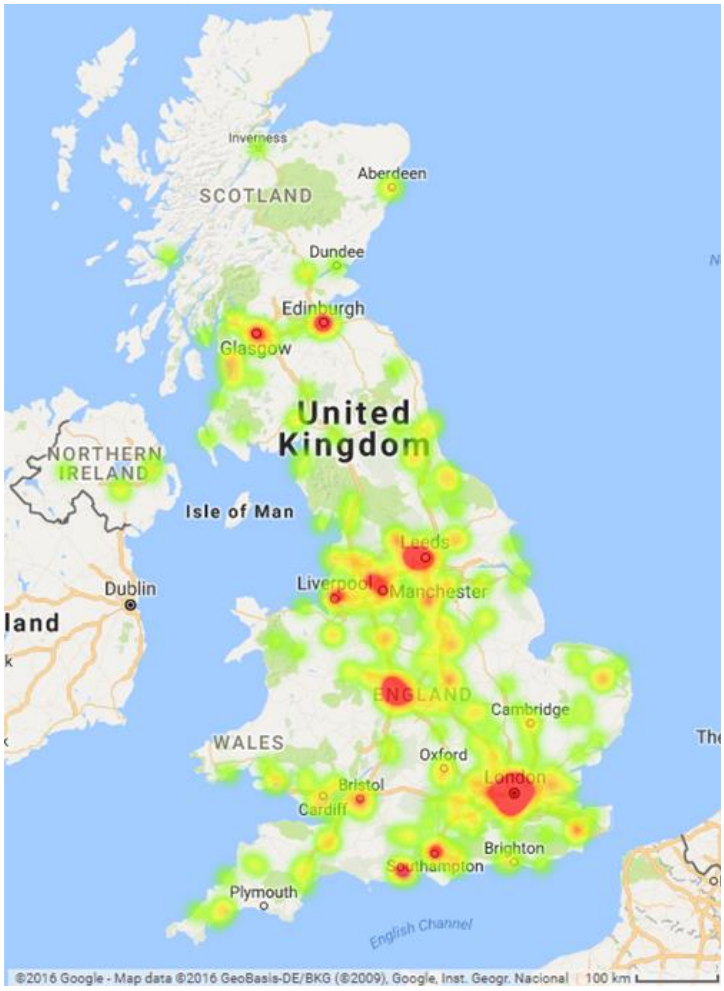
Source: Ofcom analysis of operator data

7.8 The majority of incidents have a relatively low customer-hours impact and are reported under the 'emergency services access' threshold.

7.9 Of the 581 reported incidents, 548 affected fixed networks and 33 affected mobile. The difference between these figures is explained by the emergency roaming agreement in place between mobile operators. This means that mobile operators have significant resilience in place for emergency service availability and therefore do not report often under the 'emergency services access' threshold.

7.10 Our revised guidance, published in August 2014, places a particular emphasis on receiving more incident reports from the mobile sector, given the growing importance of mobile services to consumers.

Figure 33: Heat map showing the distribution of incidents throughout the UK



Source: Ofcom analysis of operator data

7.11 Figure 33 shows how the 581 incidents are geographically distributed across the UK, and reveals that there is a correlation between incident frequency and population density. Where population densities are higher, a higher concentration of network equipment, or assets, is required to provide services.

7.12 It is logical to expect that where there are more assets, there is a greater likelihood of incidents. However, our minimum incident threshold of 1,000 end-users affected may result in some rural incidents not being reported.

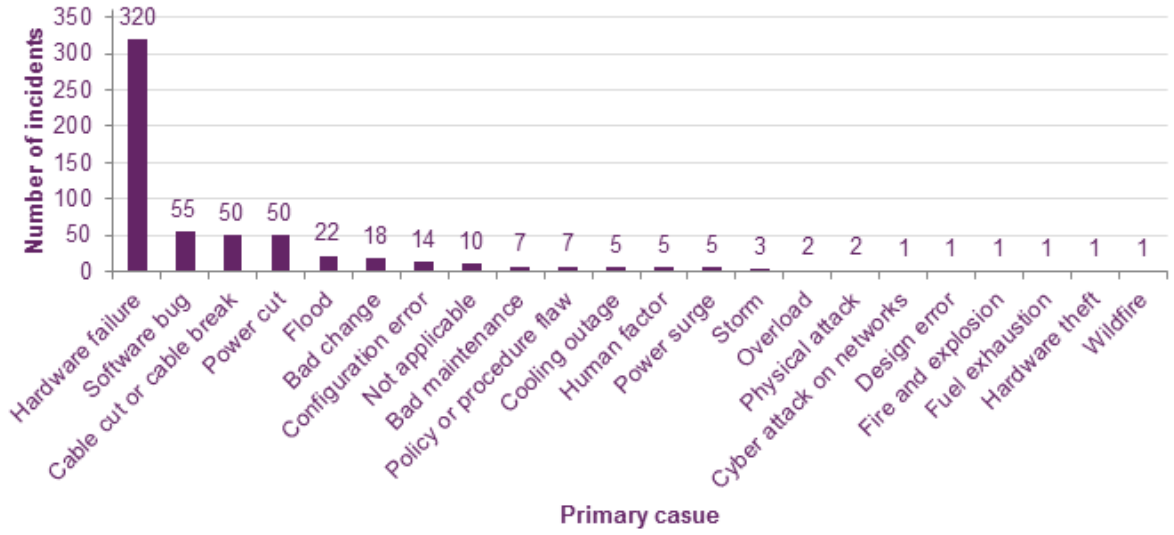
The majority of incidents are caused by the failure of hardware components, the loss of power supply or by software bugs

7.13 Establishing the root causes of incidents is central to understanding risks to the security and resilience of networks and services. System failure is overwhelmingly the root cause of significant network incidents; over 89% of reported incidents fall into this category. This includes hardware and software failures, and the failure of systems, processes and procedures.

7.14 The remaining categories are human error, natural phenomena (which includes severe weather) and malicious actions, which were responsible for 5%, 5% and <1% of the reported incidents, respectively.

7.15 Figure 34 shows that incidents were reported against a wide range of primary causes[57] 'Hardware failure' is the most common primary cause, followed by 'software bug', 'power cut' and 'cable break'. Together these causes account for over 80% of the incidents that are reported to us.

Figure 34: Primary cause of incidents reported to Ofcom, September 2015 to August 2016



Source: Ofcom analysis of operator data

Incidents with an impact above one million customer-hours are uncommon, and are often the result of a unique and unexpected threat to security

7.16 The European Union Agency for Network and Information Security (ENISA) is a centre of network and security expertise for the EU. ENISA provides guidance[58] on the reporting of security incidents. This includes the requirement for national regulatory authorities, such as Ofcom, to report annually on incidents with a significant impact; this is defined as those incidents with an impact above one million customer hours.

7.17 In the reporting period of September 2015 to August 2016 there were 10 incidents which met this threshold: three affected mobile networks and seven affected fixed networks. System failure is still the main root cause, at 70%.

[57] We categorise the root and primary cause of reported incidents according to the taxonomy provided in the ENISA Article 13a Technical Guideline on Threats and Assets, https://resilience.enisa.europa.eu/article-13/guideline_on_threats_and_assets

[58] ENISA Technical Guidance on Incident Reporting. https://resilience.enisa.europa.eu/article-13/guideline-for-incidentreporting/Article_13a_ENISA_Technical_Guideline_On_Incident_Reporting_v2_1.pdf

Evolution of voice services

The way that voice services are being delivered is changing

7.18 Internet-based providers such as Skype and WhatsApp are already offering consumers low-cost calls, usually coupled with additional features such as messaging or photo and video sharing. Many businesses are exploiting the reduced costs and enhanced capabilities of voice-over-IP (VoIP) technology. In response, traditional communications providers are looking to improve the services that they offer.

7.19 At the same time, the Public Switched Telephone Networks (PSTN) that have traditionally delivered voice services are coming to the end of their economic life. Globally, it is becoming increasingly difficult to maintain them, as the availability of spare parts and the engineering knowledge to effect repairs reduces.

7.20 Different communications providers are at different stages of managing this process:

7.20.1 BT is planning to fully migrate customers off its PSTN network by 2025 and is currently trialling the first IP-based voice services that will replace those offered by the PSTN. It is expecting to start piloting a range of new services in late 2017 leading to a full commercial launch thereafter.

7.20.2 Virgin Media is deploying fibre to the home under Project Lightning between now and 2019 and we can expect it to move to the adoption of IP voice services to replace its current PSTN based offering.

7.20.3 KCOM expects around three quarters of its network will have ultrafast capability by the end of 2017 under its Project Lightstream. Consequently, we would expect introduction and increasing adoption of IP voice services over roughly the same timetable.

7.20.4 TalkTalk and Sky both already operate an IP-based voice network, albeit still using analogue transmission over the LLU copper connections it buys from Openreach. With the increasing adoption of superfast services, both may choose to migrate customers to “broadband voice”, using the experience gained in the full fibre trial they are undertaking in York with CityFibre.

7.21 The UK is not alone in this process. Internationally, operators are also considering strategies for this “PSTN switch off”. An Ofcom-commissioned study for the 2014 Infrastructure Report noted that Verizon and AT&T in the US are looking to migrate customers, as are various European countries (e.g., Germany). More recently, the Body of European Regulators for Electronic Communications (BEREC) has published a report of case studies on migration to voice over IP across Europe[59].

Migration to new services will bring consumer benefits

7.22 Moving voice services to broadband, away from traditional delivery, means that new voice services will have different characteristics. New services can support new features and new functionality.

[59] http://berec.europa.eu/eng/document_register/subject_matter/berec/reports/6486-berec-report-case-studies-on-migration-from-potsisdn-to-ip-on-the-subscriber-access-line-in-europe

7.23 The evolution of voice services lowers barriers to entry to the provision of primary fixed voice and messaging services, and the cost of providing the service will fall to very low levels. We may see more companies enter, with better prices and more innovation; for example, intelligent call-blocking to combat nuisance calls, redirection and measures to improve digital inclusion. Using voice over broadband for fixed voice-only consumers may also help achieve 'universal broadband' by default. If connections to all homes are broadband-enabled even if only to allow an IP-based voice service, it should be possible to quickly (and potentially remotely) enable data services on demand to any household.

In many cases, the consumer experience will be largely unaffected

7.24 It is important that migration itself does not cause disruption. Migration will work best where people migrate voluntarily, and where operators' migration strategies rely on developing new services which make it attractive to move. The BEREC report on migration across Europe found there tended to be fewer issues with the migration process where it was customer-driven.

7.25 For many, migration to voice over IP will be voluntary. Consumer and business use of voice services is already changing, as more people use mobile voice services instead of fixed, and as a number of users, especially businesses, are already choosing to move to voice over IP. In new-build housing developments, where providers are already deploying full fibre broadband services, residents are already using VoIP, as there is not a copper wire over which to deliver a voice service.

7.26 For those who have and use a fixed telephone line within the home, PSTN migration should result in little noticeable change, both in terms of the consumer experience, and of the steps required to make the change. For consumers who already use a broadband connection for data services, it should be a relatively simple matter of moving their existing telephones from the PSTN to their broadband connection, via an adapter or suitable broadband router. Below, we consider those consumers who do not already have a broadband connection.

However, there are challenges to managing migration for some consumers

7.27 Whilst switch off should have few implications for the majority of consumers, for others there may be important challenges which require careful consideration.

7.28 There are 3.2m voice-only consumers in the UK. For these customers, broadband technology will need to be installed in the home in order for fixed telephony services to continue. While this technology may be capable of supporting telephony and broadband, it may have only the telephony elements of the service activated, depending on customer requirements and demands. Alternatively, customers who want voice-only services may be offered a telephony-only router.

7.29 Where required, voice services can be delivered to consumers in a manner that looks just like traditional telephony, and consumers may not even be aware that the underlying connection is now broadband. We estimate that it will be particularly important for around a half of voice-only customers to continue to benefit from a service that is delivered in a manner that they recognise as fixed telephony.

For businesses, outstanding compatibility issues need to be resolved

7.30 There are a number of non-voice legacy applications which run over the PSTN which are typically used by business customers. These include the use of fax machines and

dial-up modems (for point of sale card readers for example) as well as point to point connections for industrial purposes such as process monitoring.

7.31 BT's previous work to move to broadband-based voice services during the 2005/6 21CN programme identified a number of the relevant issues which we are aware still exist today[60]. This programme revealed that there were a number of applications which depended on technical characteristics of legacy networks beyond basic delivery of voice, such as way that the PSTN handles signalling tones in the network. As the industry again looks to make this migration, it is clear the process will need to take into account the needs of these specialist service providers and end users.

7.32 Ofcom has addressed similar issues during other technology migrations. For example, we are overseeing an effective migration away from analogue leased lines used for critical applications such as the protection against overload conditions in the National Grid or to control water supplies. We have already publicly signalled that these are approaching end of life, and are actively monitoring migration to modern equivalent services.

Resilience in emergency situations is a particular concern for Ofcom

7.33 One of the highest profile concerns about PSTN switch off is the ability of individuals to make 999 calls within the home during a power outage. Traditional telephones on fixed lines provided this capability, because they are powered from the local exchange. IP-based services require an alternative solution – typically some form of battery backup in the home and for any electronics in the access network, or a fall back solution such as the ability to send calls over a mobile network when power to the fixed network fails. Ofcom's initial conclusions from the Strategic Review of Digital Communications[61] stated that we will "assess what operators are doing on a case-by-case basis, provided the technical solution delivers a level of protection equivalent to that provided by traditional means".

7.34 In this context, it is important to note that two thirds of calls to emergency services are now made on a mobile phone. Of the remaining third, it is likely that the majority are made on cordless phones, which also do not currently work during a power outage. Nonetheless, there remains a significant minority of people for whom the capability for the landline to continue to work during a power cut could offer a lifeline in an emergency.

7.35 PSTN switch off also raises concerns about other services which may be required in an emergency. Certain social care devices, such as personal alarms, have traditionally run over the PSTN. The calls that these devices make can traverse a number of different networks between source and destination, and as some of these intermediate networks migrate to IP-based technologies, interoperability issues are beginning to manifest.

7.36 The scale of these problems may increase as widespread migration of networks from traditional to IP-based technologies increases. However, as network technologies are evolving, so too are the services and devices that run over them, in order to become more IP-compatible, and therefore able to offer additional functionality and features. The providers of such services have already engaged with Ofcom and with their CPs

[60] Many of these were identified in our NGN consultation: https://www.ofcom.org.uk/__data/assets/pdf_file/0016/43018/main.pdf
[61] https://www.ofcom.org.uk/__data/assets/pdf_file/0016/50416/dcr-statement.pdf, February 2016

regarding migration, to ensure that services can remain operational or are superseded in good time before PSTN switch-off occurs.

Consumer protection principles Ofcom will apply during migration

7.37 We have set out above that it is important that migration itself does not cause disruption. It is important that Ofcom is satisfied that proposed migration processes will not result in bad outcomes for consumers and businesses. Fundamentally we are seeking to ensure that migration does not result in undue disruption to customers, and that they are no worse off, either financially or functionally, as a result of it.

7.38 As such, we will seek to uphold the following principles during any such migration:

7.38.1 Emergency services access should be provided by all voice services in accordance with the relevant General Conditions (GCs). Note that these GCs are currently being reviewed, and we expect to publish revised Conditions in Spring 2017.

7.38.2 Technical solutions for ensuring reliable operation of new voice services, for example during localised or widespread power outages, should provide levels of protections equivalent to that provided by traditional means. We will assess the suitability of such solutions on a case-by-case basis, taking into account the technical limitations and customer usage of both the traditional and new services.

7.38.3 New voice services will maintain existing protections for vulnerable consumers in a manner which is appropriate for the technology they employ and their usage.

7.38.4 Equivalents to the current social phone tariffs and rules on the sensitive handling of debt will be applied to future voice services where appropriate.

7.38.5 Before and during any planned withdrawal, providers of existing voice services will work with third party service providers which rely on them, in order to minimise end customer disruption. In particular, voice service providers should make all reasonable efforts to ensure their changes do not cause excessive disruption to services used by vulnerable customers, such as personal alarm systems.

7.38.6 Providers of traditional voice networks must give reasonable notice to their wholesale customers of any intention to withdraw relevant voice services, or to replace them with alternatives based on different network technology.

7.38.7 Customers who do not migrate on a voluntary basis should be no worse off than they were before migration.

7.38.8 Vulnerable consumers must receive any assistance they require for the migration process and continue to receive a service they recognise as a telephony service.

Ofcom will need advance sight of operators' plans for migration

7.39 In order to ensure migrations proceeds in line with the principles set out above, there are a number of particular areas where Ofcom expects to have early sight of operators' planned approach.

7.40 Firstly, implications for the end user experience:

7.40.1 Prior notification to end users - how will users be notified and when?

7.40.2 The migration process - what form will this take, both for customers who move voluntarily, and those who do not?

7.40.3 Replacement services - what alternative options will be offered to consumers and businesses? In particular, for consumers, what replacement service will be offered to BT Basic customers?

7.40.4 Consumer access services - what is the migration process for access services, such as text relay?

7.40.5 Pricing - how will replacement services be priced? It is essential that voice-only customers do not face additional costs as a result of moving to VoIP.

7.41 Secondly, implications for emergency services:

7.41.1 Emergency access obligations - to what extent will the current requirements (free access, caller location, prioritisation) apply to new services, including over-the-top (OTT) services, i.e. services delivered over the internet?

7.41.2 Power resilience of replacement services - for how long will services continue to work during power outages, or by what other means would access to the emergency services be possible?

7.41.3 General resilience of replacement services - what level of resilience can be expected?

7.42 Thirdly, implications for downstream service providers:

7.42.1 Third party providers - how will these providers be consulted with ahead of migration? How will it be ensured that end customers are aware of the changes and their options in good time?

7.42.2 Alternative service providers - what will be the impact on competition?

Ofcom will work with industry to prepare for PSTN switch off

7.43 We understand that preparation for PSTN switch off will necessarily involve complicated dialogue, involving a wide range of parties, both across the telecoms industry and beyond. As such, we recognise that there will be a need for co-ordination, which will likely require a new, specific forum to ensure that discussion can progress efficiently and effectively.

7.44 The responsibility to ensure that migration does not result in disruption to end users lies with industry. Ofcom has an important role to play in setting out our expectations for switch off, whilst it is industry's role to set out how this will be achieved. Ofcom will monitor industry's progress, and enforce specific obligations in due course, as the process takes place.

Mobile network resilience

Mobile services are increasingly used as the first choice and the last resort

7.45 As discussed above, the way that fixed voice services are delivered is changing and this raises particular concerns in relation to emergency services access, and more general communications during emergencies, particularly for vulnerable customers. Already though, fixed voice has made way to mobile voice as the primary mechanism used to contact the emergency services. We have also seen that in major emergencies native and "over the top" services on mobile networks are playing an essential role in allowing people to continue to communicate effectively and obtain information. This will soon include the communications systems used within the emergency services, as they move away from their current dedicated wireless network onto the public mobile network.

7.46 These trends shift the role of mobile services from desirable to essential. Major outages, such as those caused by the UK winter floods of 2015, have raised concerns about the resilience of mobile networks, and this issue is likely to become more prominent over time.

This places requirements on both coverage and reliability

7.47 Understanding and improving mobile coverage is rightly an area which has received significant attention. However, coverage alone is not enough to discharge the role mobile services now play; services also need to be reliable in order to be available to perform their essential functions when required.

7.48 In common with fixed network operators, mobile operators take steps in the design and operation of their networks to ensure they are reliable. The mobile nature of the service provides additional levels of resilience, for example offering the possibility of a customer relocating to avoid a localised failure or perhaps taking advantage of overlapping coverage from adjacent cells in order to maintain service without doing anything at all. In the UK, calls to the emergency services can also be made from any other available network if the customer's own network is unavailable.

Mobile networks are more vulnerable to widespread power outages than legacy fixed networks

7.49 The resilience to a loss of mains power is very different between fixed and mobile networks. The customer equipment used with fixed voice services requires an external source of power in order to operate. In the case of the cordless phone basestations used in most homes, this comes from the customer's own mains power, and so the ability to make a phone call will immediately be lost if the customer's home experiences a power cut. Traditional "wired" phones however, receive their power over the copper phone line that connects them to their network provider. Virgin Media supplies this power from its street cabinets and BT from its exchanges, the former typically having batteries capable of maintaining service for several hours, and the latter's back-up power typically sufficient for power cuts lasting several days or more.

7.50 Mobile handsets have their own power and will continue to operate until they next need charging. However, the extent to which the network itself will continue to operate during a power failure is variable. The central, or "core" network elements which can affect the services of a large proportion of an operator's customer base typically have similar protection to fixed networks, lasting several days. However,

individual base stations may have little or no ability to offer service during power cuts, but this varies by operator and by individual base station. Some base station locations impose practical limitations on aspects such as size, weight, noise generation and environmental impact which can limit the ability to install back-up power. In other cases, the operator may simply decide the cost of installing and maintaining additional back-up power is not justified.

7.51 The features such as mobility, emergency call roaming and overlapping base station coverage make it difficult to represent the relative levels of reliability between fixed and mobile services in a simple fashion. However, the evidence from recent winter storms suggests that when there is a widespread loss of mains power, mobile voice services typically suffer more than fixed voice. Although in practice many households will lose fixed voice service because their cordless phones rely on mains power, they do have the option of keeping a corded pone for such situations. In contrast, even if a mobile customer can keep their handset charged, there is little they can do if the network has failed due to power loss.

7.52 As the role of mobile services as the primary communications channel for many customers increases, a significant investment in the networks will be required if their vulnerability to loss of mains electricity is to be reduced.

7.53 As part of a project on cross sector resilience undertaken by the United Kingdom Regulators Network (UKRN)[62] and led by Ofcom, we identified this vulnerability in what is becoming an increasingly important element of the UK's "Critical National Infrastructure". Government has been working with industry to understand how this can be rectified, and the scope and scale of the network changes needed. It is vital that this work is progressed and brought to fruition.

[62] See http://www.ukrn.org.uk/wp-content/uploads/2016/07/2015AprCSR-Phase1Report.pdf

Section 8

The continuing evolution of television

8.1 The means by which television services are distributed and consumed have continued to evolve over the last year. Increasingly, broadcast and broadband delivery technologies are being brought together by more sophisticated consumer receiver equipment to provide consumers with a hybrid viewing experience. There has also been a continuation of the move towards higher resolution, more *life-like* TV formats, with UHD (Ultra High Definition) content now available on some broadcast and broadband delivery platforms.

8.2 In this section we set out three key themes:

8.2.1 **The live consumption of TV channels remains popular with viewers:** Viewing of live TV (i.e. broadcast TV content watched at the time of transmission) represents over 80% of viewing and is being complemented by an expanding range and capability of catch-up modes (digital video recorder and online).

8.2.2 **There has been a significant increase in both the number and sophistication of hybrid broadcast/broadband TV platforms:** Hybrid TV platforms are continuing to develop, including the launch of Freeview Play on the DTT platform. These platforms are seamlessly merging broadcast and online content into one consumer experience, where the viewer becomes 'abstracted' from the actual means of delivery.

8.2.3 **The majority of consumers can receive HD and the first Ultra-High Definition (UHD) services are now available:** 59% of households now access HD services and approximately 30% of TV sales support HD and UHD[63]. UHD Blu-ray discs are available, and satellite and online distribution of UHD content has started. HD and UHD services require higher connection speeds, limiting their reach to households with higher speed broadband connections.

Consumers are able to view TV from a growing range of sources

8.3 Consumers in the UK receive digital television from a number of providers:

8.3.1 **Satellite:** TV services over satellite are available through platforms such as Sky's pay-TV service, or at no cost through Sky's UK viewing card, and through Freesat, which is available for a one-off digital receiver cost.

8.3.2 **Cable:** Virgin Media makes TV available over its cable network and passes 44% of UK homes. It has set a target to increase the coverage of its cable network by 4 Million homes and, once implemented, this is expected to increase cable TV coverage to around 65% of UK premises.

[63] Many of these models also support the new High Dynamic Range (HDR) standard, which gives TV pictures greater contrast and more vibrant colours.

8.3.3 **Digital Terrestrial Television:** A wide range of free-to-air channels is available via an aerial, accessible through Freeview and through hybrid boxes (Freeview Play, Now TV and YouView).

8.3.4 **IPTV:** A number of different providers, including BT, Now TV, TalkTalk and Plusnet deliver linear broadband TV services. Synapse TV and Connect TV offer a range of IPTV channels linked from slots on the Freeview electronic programme guide (EPG). Channel related catch-up content is also delivered online (supplementing DVR use) and on-demand non-catch-up content is available from a wide variety of providers including Netflix, Amazon Prime, and YouTube.

8.4 The coverage of the different: national, commercial, regional and local DTT multiplexes is shown in Figure 35 and Figure 36 below.

Figure 35: Coverage of DTT national, interim and local services

Multiplex	Standards	Bit rates (Mbit/s)	Coverage, premises
PSB1 (BBC A)	MPEG2 / DVB-T / 64QAM	24	99%
PSB2 (D3&4)	MPEG2 / DVB-T / 64QAM	24	99%
PSB3 (BBC B)	MPEG4 / DVB-T2 / 256QAM	40	99%
COM4 (SDN)	MPEG2 / DVB-T / 64QAM	27	~90%
COM5 (Arqiva A)	MPEG2 / DVB-T / 64QAM	27	~90%
COM6 (Arqiva B)	MPEG2 / DVB-T / 64QAM	27	~90%
COM7	MPEG4 / DVB-T2 / 256QAM	40	~76%
COM8	MPEG4 / DVB-T2 / 256QAM	40	~76%
LTVMux	MPEG2 / DVB-T / QPSK	9	~54%*

Source:Ofcom

** Local coverage from 21 currently on air stations, of 34 granted licences*

Figure 36: Coverage of DTT regional services

Multiplex	Standards	Bit rates (Mbit/s)	Regional coverage
NIMux	MPEG2 / DVB-T2 / QPSK	9.8	~71%†
GIMux (Manchester)	MPEG2 / DVB-T / 16QAM	18.1	~55%‡

Source:Ofcom

† *Expressed as a percentage of households in Northern Ireland*

‡ *Expressed as a percentage of households in Greater Manchester*

Figure 37: UK coverage of Digital satellite TV and Virgin Media cable broadband

Platform	Availability	Notes
Digital satellite TV	98%	Relates only to the ability to achieve a necessary line of sight path to the satellite and does not include other factors that can affect coverage including: access in multi-dwelling units where it is not feasible to install a dedicated household satellite dish and there is no internal wired distribution system for satellite, and the need for planning permission in some locations.
Virgin Media cable broadband	45%	Proportion of premises able to receive Virgin Media cable broadband services, June 2016

Sources:Ofcom and operators

The ways in which consumers watch TV are evolving

8.5 Live TV remains by far the most popular way of viewing TV, but continues to decline slowly each year.

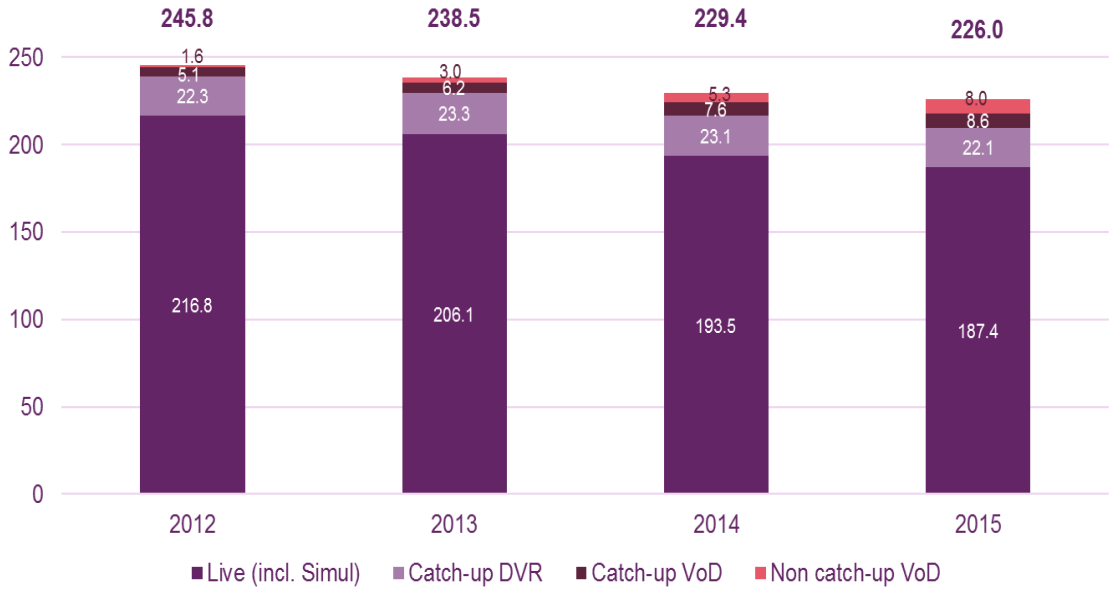
8.6 However, there has been an increase in the use of TV channel related catch-up services, through both digital video recorders (DVRs) and online sources such as the BBC iPlayer and All 4.

8.7 Non catch-up video on demand (VoD) viewing continues to increase, albeit from a low base.

8.8 Overall, there has been a continuing decline in the amount of time spent watching long-form video content. The Digital Day 2016 survey[64] shows that this decline is commensurate with a rise in the use of a variety of alternative media services including social media, games and short form video content.

[64] The Digital Day findings are in section 1.4 from pages 15-29 of CMR 2016. https://www.ofcom.org.uk/__data/assets/pdf_file/0024/26826/cmr_uk_2016.pdf

Figure 38: Average daily viewing minutes across all devices for live TV, catch-up DVR, catch-up VoD and non-catch-up VoD.



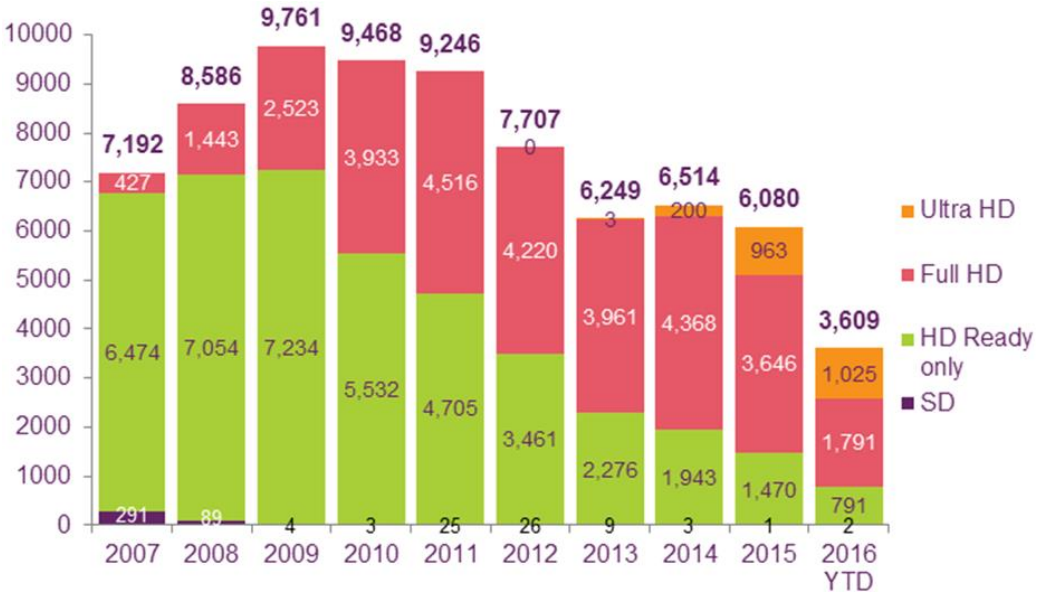
Source: 3 Reasons estimates (including BARB data). Base: all devices, long-form professional audio-visual content. Live includes simulcast. Excludes physical consumption (e.g. DVDs) and short-form.content. DVR data is based on a 7 day playback period.

The majority of consumers are able to receive HD services, and the first UHD services are now available

8.9 Sales of HD compatible sets represent over 99% of new set sales (Figure 39Figure 39), and UHD compatible sets now represent 30% of new set sales. Sales of SD sets continue to decline and are now almost insignificant: a decision by Freeview that from 2017 only HD sets will be permitted to carry the Freeview brand logo is likely to mean that nearly all new DTT sets will be HD capable.

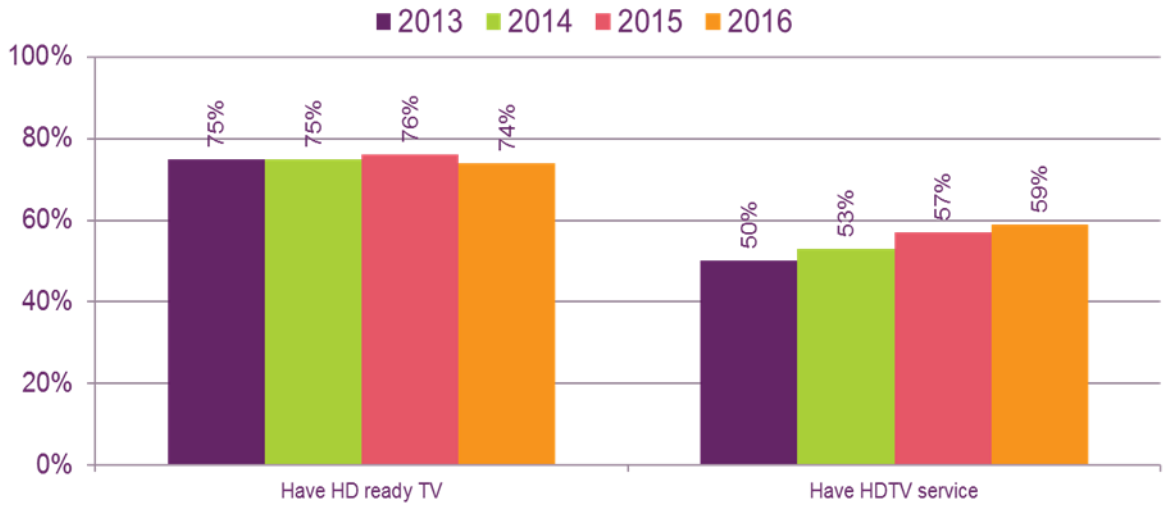
8.10 59% of all TV households are now accessing HD services (Figure 40). This figure is likely to grow further as more consumers replace existing SD sets with HD capable sets.

Figure 39: Sales volume share of receivers, by technology (000's)



Source GfK: sales volumes of SD, HD Ready, Full HD and UHD receivers

Figure 40: Take-up of HDTV sets and HD services, smart TVs and DVRs.



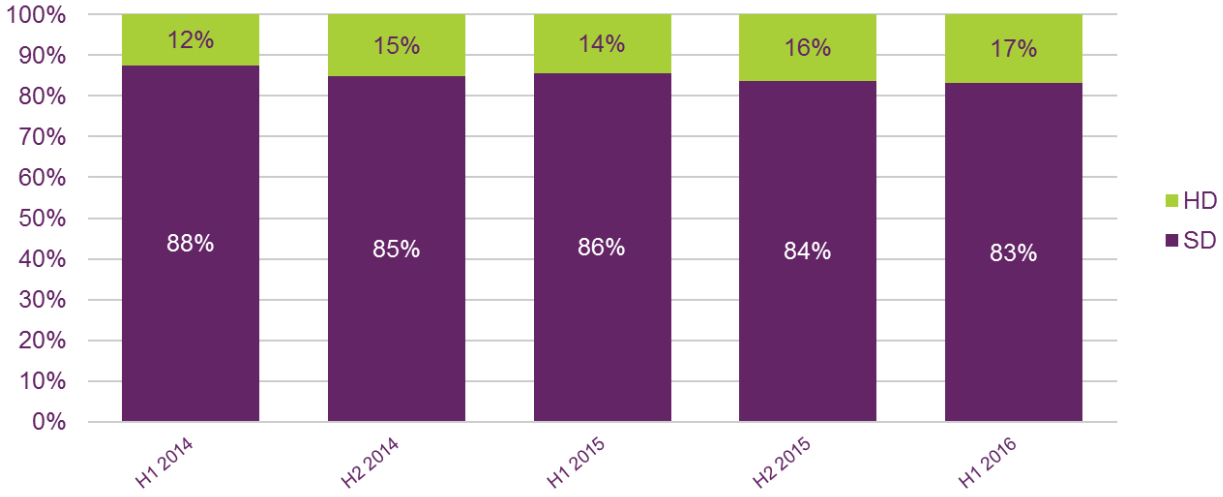
Source: Ofcom Technology Tracker, data as at Q1 2013-2014, then H1 2015-2016.
Base: All adults aged 16+ with a TV in the household: 2013 (3661), 2014 (3635), 2015 (3616), 2016 (3606)

8.11 Overall, viewing of the HD versions of the main five PSB channels continues to grow slowly (see Figure 41) and now accounts for 17% of viewing. There is a notable disparity between the amount of HD viewing of some PSB channels. For example, the HD viewing of BBC One is at 11% and BBC Two at 33%.

8.12 For a number of potential reasons the viewing of PSB channels in SD remains strong, including: the higher position of SD services in the electronic programme guide (EPG), relatively small differences between the perceived quality of SD and HD

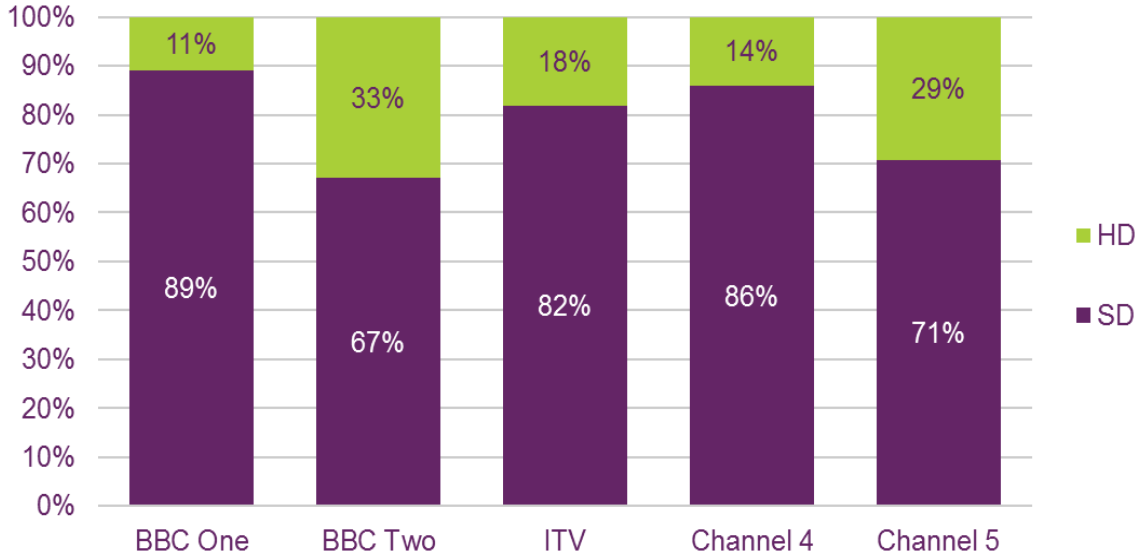
services, and a lack of regional opt-outs in some HD services. Figure 42 shows the average proportion of viewing of SD and HD for the main five PSBs individually.

Figure 41: Average contribution of viewing of SD and HD for the main five PSBs combined, by half year January 2014 – September 2016



Source: BARB. Individuals 4+ with HD available in the home. Average proportion of viewing of the HD channels for BBC One, BBC Two, ITV, Channel 4 and Channel 5 combined.

Figure 42: Average contribution of viewing of SD and HD January – September 2016



Source: BARB. Individuals 4+ with HD available in the home. Not all available HD channel services are separately reported and so we have used the main five PSBs for our analysis (their combined share of total broadcast TV viewing in 2015 was 51%)

8.13 The last year has seen a significant increase in the number of UHD (4K) capable devices and sales of UHD TVs have now reached 30% by volume of the market. UHD content is available on UHD Blu-ray disc; via Satellite from Sky (through Sky Q's silver's red-button - covering 124 games in the 2016/17 Premier League); and online through BT's Ultra HD YouView box and Amazon's Fire TV. The latest DTG (Digital Television Group) D-Book specification, released in November 2016, provides for online UHD content.

8.14 There have been, as yet, no announcements of UHD services on DTT.

A number of trends are driving up IPTV viewing

8.15 As we set out in Section 4, the amount of data use on fixed networks has grown by 36% over the past year, driven in large part by video. A number of distinct trends suggests that video traffic will continue to grow over fixed networks:

8.15.1 **Increased take-up of broadband services:** The majority of households have a TV or set top box connected to the internet. Research conducted by media consultancy 3 Reasons at the end of 2015 shows that around 62% of UK TV homes had a TV connected to the internet via a set top box or a smart TV. This figure increases further if devices such as games consoles and dongles are included.

8.15.2 **Growth in hybrid TV services:** The growing range of hybrid broadcast/broadband services and devices is likely to further increase the consumption of broadband TV services. In addition, the improving ease of use of these services supported by better user interfaces and a more seamless integration of broadcast and online content are making it easier and more beneficial for viewers to access on-demand connected TV services.

8.15.3 **Growth in online catch-up TV viewing.** Catch-up TV is a significant and growing mode of viewing - fuelled by DVRs, connected boxes and smart TVs. And, as more catch-up viewing is carried out online, the demands for internet bandwidth and capacity are likely to grow further.

8.15.4 **Growth in other online TV services.** The use of non-catch-up video on demand services also continues to grow. For example, the proportion of adults watching short online video clips (e.g. YouTube and Vimeo) per week has risen from 20% in 2014 to 25% in 2016[65].

8.15.5 **The use of subscriber video on demand (SVOD) is also growing.** For example, more households are subscribing to discretionary video-on-demand services such as Netflix, Now TV and Amazon Prime[66]. However, subscription video-on-demand services are, on the whole, complementing rather than replacing conventional TV[67].

8.15.6 **Finally, there is a growing take up of linear IPTV services.** Linear internet TV (IPTV) services, such as BT TV and Now TV, are continuing to add customers, competing with existing pay-TV platforms such as Sky and Virgin Media, particularly at the low-cost end of the market.

8.16 As consumers move onto faster 4G and 5G mobile services it is expected that video viewing on mobile phones will continue to increase, but it is an open question as to

[65] See page 16 of the UK Communications Market Report 2016 https://www.ofcom.org.uk/__data/assets/pdf_file/0024/26826/cmr_uk_2016.pdf
[66] 27% of all UK households had a subscription service to at least one of Netflix, Amazon Prime or Now TV in Q3 2016 according to the BARB Establishment Survey.
[67] See pages 64-65 of the UK Communications Market Report 2016 *https://www.ofcom.org.uk/__data/assets/pdf_file/0024/26826/cmr_uk_2016.pdf*

whether the majority of this viewing in the future will be of live TV services or on-demand content.

Implications of changing viewer behaviour for broadband infrastructure

8.17 As discussed in Section 4, the vast majority (99%) of broadband connections are, in principle, now capable of delivering IPTV in standard definition, since they have a speed of above 2Mbit/s.

8.18 Currently, a broadband connection speed of at least 2Mbit/s is needed to deliver an SD video stream, from 6 to 8Mbit/s for an HD stream, and from 20 to 25Mbit/s for a UHD stream. In practice higher headline broadband speeds than these may be needed to achieve a good consumer experience. This might be because other services might be being accessed at the same time over the broadband connection, or the headline connection speed is not available all of the time due to congestion in the internet delivery chain.

8.19 The new and more efficient HEVC (High Efficiency Video Coding) compression standard is helping to reduce the connection speeds needed to deliver video. This standard is being used to deliver the new UHD services available from Amazon Prime, BT, Netflix and YouTube. Despite the use of this more efficient compression standard, BT currently recommends that a connection speed of at least 44Mbit/s is needed to access its UHD sports services.

8.20 If HEVC is more widely utilised for IPTV, it could also reduce the connection speeds required to deliver SD and HD services.

Implications of changing viewer behaviour for broadcast infrastructure

8.21 Viewers are starting to embrace higher resolution, more life-like TV services, and the use of internet connectivity to access a wider range of content at times that are more convenient to them. To meet these expectations, TV platforms need to continue to evolve; including:

8.21.1 Enhancing their hybrid DTT/broadband TV offer; and

8.21.2 Upgrading broadcast transmission and transmission standards.

8.22 Some of the improvements are already underway. For example, the Freeview Play service offers consumers easier-to-use IPTV services. Freeview has also announced that the Freeview label will be available only for HD (and UHD) products as of 2017, and the latest D-Book specification will support UHD IPTV services. Sky has similarly launched its Now TV platform which integrates DTT and IPTV services, and its Sky Q platform which integrates satellite and IPTV services, and which supports UHD.

8.23 An improved selection of HD channels on DTT made possible in part by two interim DTT multiplexes which have widened the range of HD services on the platform. HD services use more efficient compression and transmission technology (MPEG4 and DVB-T2) which provide more channel capacity and which can, therefore, effectively expand DTT capacity for other services in the future.

Annex 1

Methodology

A1.1 Sections 4 and 5 of this report use new data gathered from the largest operators in each sector, as well as information already held by Ofcom. For fixed networks, we used input from the four largest networks, KCOM for services in Hull and smaller network providers. In the case of mobile networks, we gathered data from all four main network operators.

Figure 43: List of operators that provided data on network availability

Name of provider	Types of networks and services
Arqiva	Public Wi-Fi
B4RN	Fixed networks: broadband
BT Group	Fixed networks: voice and broadband, public Wi-Fi
EE	Mobile networks: voice and broadband, public Wi-Fi
Gigaclear	Fixed networks: broadband
Hyperoptic	Fixed networks: broadband
KCOM	Fixed networks: voice and broadband, public Wi-Fi (Hull only)
IFNL	Fixed networks: broadband
O_2	Mobile networks: voice and broadband, public Wi-Fi
Sky	Fixed networks: voice and broadband, public Wi-Fi
TalkTalk	Fixed networks: voice and broadband
Three	Mobile networks: voice and broadband
UK Broadband	Fixed networks: broadband
Virgin Media	Fixed networks: voice and broadband, public Wi-Fi
Vodafone	Mobile networks: voice and broadband Fixed networks: voice and broadband

A1.2 Much of the data presented in this report is based on the analysis of the new data provided by the operators. In this annex we summarise our approach to this analysis.

Fixed broadband networks

Coverage

A1.3 Our data on coverage of fixed broadband services is collected from the three main network operators, BT, KCOM and Virgin Media, and five smaller providers. In 2016 operators were asked to provide data for each address where a service was provided.

A1.4 For the overall coverage of fixed broadband, reported in Section 4, we have identified the number of UK residential and small business premises. This will exclude PO boxes and large organisations. For 2016 we have used a premise base of 29 million.

A1.5 We use premises data from the OS Addressbase Premium dataset[68] (May 2016 version), OS Addressbase Islands dataset[68] (May 2016 version). This is combined with additional geographic classifications from the ONS National Statistics Postcode Lookup (NSPL)[69] (Feb 2016 version) and to Urban and Rural categories derived from the Locale classification (Feb 2016 version)[70].

A1.6 Where we report on the availability of superfast broadband for SMEs, we have used an address match process to link our premise base to a business classification. For 2016 our SME premises base, with between one and 249 employees is 2.4 million. Data is based on the Blue Sheep Business Universe[71].

A1.7 The availability of address-level data allows us to create a comprehensive data set describing the characteristics of all available services and all operators present at premises across the UK. Many operators provided a unique property reference number (UPRN), a common identifier available for use in the UK. Other operators provided address information that would need to be processed and linked to our premise base. Over 45 million records were received from across all operators and 99% of our premise base were matched using a UPRN or building address reference. For coverage this provides a base denominator of 28.8m premises.

A1.8 Each operator provides information on the technology available together with predictions of download and upload speeds. After the address matching process these characteristics are assigned to each premise that enables further detailed analysis to be undertaken. We are able to adjust thresholds for our analysis to investigate different patterns of provision. For coverage we have used the maximum predicted download speed available at a premise to determine the broadband category a premise is represented in.

A1.9 We use 10Mbit/s because our data suggest that an average sync speed of 10Mbit/s is where data use begins to appear to not be constrained by speed. We use 30Mbit/s because this is our threshold, and the European Commission's threshold for superfast broadband.

[68] https://www.ordnancesurvey.co.uk/business-and-government/products/addressbase-products.html
[69] http://www.ons.gov.uk/ons/guide-method/geography/products/postcode-directories/-nspp-/index.html
[70] http://www.bluewavegeographics.com/images/LOCALE_Classification.pdf
[71] http://www.allmapdata.com/products/digital-map-data/business-poi/blue-sheep-poi/

A1.10 In previous years Ofcom collected data from operators on the percentage of premises in each postcode unit that could receive a service above a specified threshold. This required Ofcom to estimate the degree of operator overlap in each postcode and would lead to an over or under-estimate of the number of premises covered by a service. The use of address-level data means that a more accurate and comprehensive analysis is now available, however, this will not be directly comparable to previous analysis.

Take-up, speeds and data use

A1.11 We gathered data from the main fixed broadband internet service providers (BT, KCOM, Sky, TalkTalk, Virgin Media and Vodafone) on both their retail services and the services they provide to other ISPs as a wholesale service. Three smaller operators also provided data on the customers they serve.

A1.12 Our analysis of broadband speeds is based on the information provided by these ISPs regarding the sync speed of each active line. This gives a measure of the maximum possible connection speed achievable between the ISP's access network and the consumer premises. Line speed measurements are typically a few Mbit/s lower than sync speed measurement, and they typically vary throughout the day depending on the level of congestion in the ISP's network.

A1.13 This data was collected at the address-level and by line identifier and involves a more complex matching process. In addition to matching records via the UPRN or address to our premise base, we also need to match wholesale providers including BT, Sky, TalkTalk and Vodafone) to the BT Openreach infrastructure using either a line identifier (where these are common) or via address matching. Of the 24 million records representing take-up, 93% (22.5m) were matched using a UPRN or address matching process. Fewer than 1% (181,000) of records could not be matched to a premise, whilst the remaining 6% were matched by postcode approximation.

A1.14 A premise is considered in our take up analysis if any line associated with that premise has a measured speed greater than zero.

A1.15 We set certain speed thresholds in some of our analysis, of 2Mbit/s, 10Mbit/s and 30Mbit/s. We include any ADSL/ADSL2+/VDSL modem sync speed below 2.2Mbit/s in our assessment of sub-2Mbit/s broadband, as some data is used in protocol overheads and so is not available to the end-user. We do not apply a margin to 10Mbit/s or 30Mbit/s because these thresholds are derived differently.

A1.16 We use 10Mbit/s because our data suggest that an average sync speed of 10Mbit/s is where data use begins to appear to not be constrained by speed. We use 30Mbit/s because this is our threshold, and the European Commission's threshold for superfast broadband.

A1.17 Our analysis of data use is calculated from the amount of data downloaded and uploaded on each line as reported by operators. We also collected data on the total data use between the hours of 6pm and midnight, to assess data use at 'peak times'. Our analysis considers all lines where the amount of data downloaded was greater than zero.

A1.18 The analysis of overall traffic mix and encrypted traffic is calculated from the individual traffic mix provided by each ISP, weighted by the total data downloaded by customers of that network.

Mobile

Coverage

A1.19 Our data on the coverage of mobile networks were collected from the four mobile network operators, EE, O_2, Three and Vodafone as 100m x 100m pixels referenced against the OSGB[72] grid system, for their coverage in June 2016 for 2G ,3G and 4G networks. Premises coverage is calculated from a base of 1.6 million postal delivery points, taken from the OS Addressbase Premium dataset[73] (May 2016 version), OS Addressbase Islands dataset (May 2016 version)[73]. This totals to 29 million premises.

A1.20 In addition, geographic identifiers are added from the ONS NSPL (Feb 2016 version)[74] and urban and rural categories are added from the Locale classification (Feb 2016 version)[75]. Roads data is taken from Ordnance Survey Meridian and LPS OSNI datasets. We set the following signal strength thresholds when estimating coverage.

	Metric	Outdoor	Indoor and in-car
2G	RxLev	-81dBm	-71dBm
3G	RSCP CPiCH	-100dBm	-90dBm
4G	RSRP	-115dBm	-105dBm
Voice (2G, 3G+4G)	RxLev, RSCP CPiCH & RSRP	-81 dBm, -100 dBm & -115 dBm	-71 dBm, -90 dBm & -105 dBm
Data (3G+4G)	RSCP CPiCH & RSRP	-100 dBm & -115 dBm	-90 dBm & -105 dBm

Source: Ofcom

A1.21 We apply the above technology-specific thresholds to each of 100m x 100m pixels to determine whether a sufficiently strong signal is available to successfully make a phone call or send or receive data. These pixels are aggregated to provide an estimate of either the landmass or the number of premises that are covered by the corresponding mobile technology.

Data use

A1.22 We also gathered data on the amount of data uploaded and downloaded on each mobile cell in these networks.

[72] Ordnance Survey of Great Britain (OSGB) Coordinate System
[73] https://www.ordnancesurvey.co.uk/business-and-government/products/addressbase-products.html
[74] http://www.ons.gov.uk/ons/guide-method/geography/products/postcode-directories/-nspp-/index.html
[75] http://www.bluewavegeographics.com/images/LOCALE_Classification.pdf

A1.23 The analysis of overall traffic mix and encrypted traffic is calculated from the individual traffic mix provided by the four network operators, weighted by the total amount of data downloaded by customers of that network.

Femtocells and public Wi-Fi

Femtocells

A1.24 The mobile network operators that have more than 1000 femtocells on their networks provided information on the postcodes where these femtocells are located.

Public Wi-Fi

A1.25 Our data on public Wi-Fi was gathered from the main providers of this service (Arqiva, BT, KCOM, O2, Sky and Virgin Media). These public Wi-Fi providers reported on the total data downloaded and uploaded at each of their public Wi-Fi access points, and the postcodes of these access points.

A1.26 Where they were able to do so, operators also provided information on the proportion of data downloaded and uploaded on 2.4GHz and 5GHz Wi-Fi.

Internet

A1.27 We collected data from fixed internet service providers and mobile network operators about the nature of their internet interconnection (peering, transit or CDN), the capacity of that connection, the total volume of data through that interconnection in June 2015 and the physical location of that interconnection.

A1.28 From this, we calculated the proportion of traffic by each type of interconnection for each CP and weighted this by the total data used by their customers, to estimate the overall mix of internet interconnection traffic.

Urban and rural classifications

A1.29 In 2016 we have used the Locale[76] classification to identify premises as being in an urban or rural area. Locale is a third-party data source based on the analysis of 2011 census output areas (OAs). Each OA is assigned to one of seven Locale Groups using a combination of Government conurbation definitions, population density at the OA- and postcode sector-levels, urban sprawl boundaries, OS roadmaps and additional visual inspection. The Locale classification was previously used by Ofcom in 2014 and earlier reports.

A1.30 Each postcode is assigned to a postcode unit so that the Locale urban and rural classification can be matched to premises by their postcode. For mobile analysis, each postcode centroid is assigned to its nearest OSGB coordinate at a resolution of 100m. Then each pixel can be assigned an urban or rural flag based on matching this co-ordinate to the 100m x 100m pixels used for mobile analysis. Where multiple postcodes exist in a single 100m x 100m pixel, the category with the highest number of premises associated with it is used.

[76] http://www.bluewavegeographics.com/images/LOCALE_Classification.pdf

A1.31 In last year's report Ofcom used the rural/urban classifications developed by DEFRA, NISRA and The Scottish Registry Office to produce urban/rural splits. Figures in the Connected Nations 2015 report using urban or rural categories are not directly comparable to this report. However, we have also re-classified any 2015 figures used in this report to the Locale categories to allow direct comparisons.

Annex 2

Glossary

2G Second generation of mobile telephony systems. Uses digital transmission to support voice, low-speed data communications, and short messaging services.

3G Third generation of mobile systems. Provides high-speed data transmission and supports multi-media applications such as video, audio and internet access, alongside conventional voice services.

4G Fourth generation of mobile systems. It is designed to provide faster data download and upload speeds on mobile networks.

Access network An electronic communications network which connects end-users to a service provider; running from the end-user's premises to a local access node and supporting the provision of access-based services. It is sometimes referred to as the 'local loop' or the 'last mile'.

ADSL Asymmetric Digital Subscriber Line. A digital technology that allows the use of a standard telephone line to provide high-speed data communications. Allows higher speeds in one direction ('downstream' towards the customer) than the other.

Backhaul The part of the communications network which connects the local exchange to the ISP's core network

BARB Broadcasters' Audience Research Board compiles audience measurement and television ratings in the UK. It is jointly owned by the BBC, ITV, Channel 4, Channel 5, Sky and the Institute of Practitioners in Advertising.

Base station This is the active equipment installed at a mobile transmitter site. The equipment installed determines the types of access technology that are used at that site.

BDUK Broadband Delivery UK

Blu-ray A digital optical disc technology capable of storing HD (High Definition) and, with Ultra HD Blu-ray, UHD (Ultra High Definition) resolution television.

Broadband A data service or connection generally defined as being 'always on' and providing a bandwidth greater than narrowband connections.

CDN Content Delivery Network - Networks of servers based in many geographic locations designed to improve the speed and quality of content delivery by routing requests to the closest server.

CGNAT Carrier Grade Network Address Translation - a technique that makes it possible to use fewer public IPv4 addresses to support more subscribers.

Core network The central part of any network aggregating traffic from multiple backhaul and access networks.

DCMS Department for Culture, Media and Sport.

DOCSIS Data Over Cable Service Interface Specification. It is a standard for the high speed transmission of data over cable networks.

DSL Digital Subscriber Line. A family of technologies generally referred to as DSL, or xDSL, capable of transforming ordinary phone lines (also known as 'twisted copper pairs') into high-speed digital lines, capable of supporting advanced services such as fast internet access and video on demand. ADSL and VDSL (very high speed digital subscriber line) are variants of xDSL).

DTT Digital Terrestrial Television. The television technology that carries the Freeview service.

DVB-T Digital Video Broadcasting – Terrestrial. A combination of technologies used to carry standard definition television. DVB-T2 is nearly twice as efficient, and is key to the carriage of HD channels

DVB-T2 Digital Video Broadcasting – Terrestrial 2. A new, more efficient combination of technologies used to carry standard definition television.

DVR Digital Video Recorder (also known as a PVR – Personal Video Recorder). A digital set-top box including a hard disc drive or other storage technology which allows the user (or the service provider) to schedule recordings and download content, and the user to pause and rewind live TV.

ENISA European Network and Information Security Agency - a European Union agency responsible for cyber security.

Femtocell A small base station, typically installed indoors to improve indoor mobile coverage. A residential femtocell uses the consumer's broadband connection to offload the mobile data onto the fixed network.

FTTC Fibre to the Cabinet. Access network consisting of optical fibre extending from the access node to the street cabinet. The street cabinet is usually located only a few hundred metres from the subscribers' premises. The remaining segment of the access network from the cabinet to the customer is usually a copper pair.

FTTP Fibre to the Premises. A form of fibre optic communication delivery in which the optical signal reaches the end user's home or office. Also known as full fibre broadband.

HD or **HDTV** High-definition television. A technology that provides viewers with better quality, high resolution pictures.

HDR High Dynamic Range television. The ability to display a far greater range of contrast, with deeper blacks and brighter highlights.

HEVC High Efficiency Video Coding. The latest generation of video compression, allowing television programmes to be represented by around half the data required by MPEG-4.

IP Internet Protocol. This is the packet data protocol used for routing and carrying data across the internet and similar networks.

IPTV Internet Protocol Television. The term used for television and/or video signals that are delivered to subscribers or viewers using internet protocol (IP), the technology that is also used to access the internet. Typically used in the context of streamed linear and on-demand content, but sometimes for downloaded video clips.

IPv4 The fourth and most widely used version of the Internet Protocol. It defines IP addresses in a 32-bit format, which looks like 111.111.111.111

IPv6 The successor to IPv4. It uses 128-bit addresses, increasing the number of possible addresses.

ISP Internet Service Provider. A company that provides access to the internet.

LINX London Internet Exchange. A not-for-profit membership organisation that provides peering services to Internet Service Providers.

LTE Long Term Evolution. This is 4G technology which is designed to provide faster upload and download speeds for data on mobile networks.

M2M Machine to Machine. Wired and wireless technologies that allow systems to communicate with each other.

MNO Mobile Network Operator, a provider who owns a cellular mobile network.

Modem Sync Speed The modem sync speed represents the highest possible speed at which data can be transferred across the line.

MPEG the Moving Picture Experts Group produces standards for digital video and digital audio compression, which are used to reduce the amount of data required to carry television pictures.

Multiplex Multiple signals or streams of information carried together in the form of a single, complex signal. The separate signals are then recovered at the receiving end.

Not-spot An area which is not covered by fixed or mobile networks.

Peer to Peer (P2P) A distributed application that uses end users' computers as nodes to deliver service applications.

Peering A mutual agreement between two network providers to exchange traffic, either in private or via a public peering exchange.

PSTN Public Switched Telephone Network. The network that manages circuit switched fixed line telephone systems.

QAM Quadrature Amplitude Modulation. A means of combining and recovering signals with different phases and amplitudes.

RIPE NCC Europe and the Middle East, Réseaux IP Européens Network Coordination Centre - The Regional Internet Registry with responsibility Europe, the Middle East and parts of Central Asia. It oversees the allocation and registration of IP addresses in these areas.

RIR Regional Internet Registry. Provide blocks of IP addresses to telecommunications companies and Internet Service Providers within an allocated region.

SD Standard Definition television.

SIM Subscriber Identity Module. A SIM is a small flat electronic chip that identifies a mobile customer and the mobile operator. A mobile phone must have a SIM before it can be used.

Smartphone A mobile phone that offers more advanced computing ability and connectivity than a contemporary basic 'feature' phone.

Superfast broadband Broadband services that deliver download speeds of at least 30 Mbit/s.

Transit This is a paid for connection used by Internet Service Providers (ISP) for bandwidth from a provider of core internet connectivity. It is used to provide connectivity to data hosted on services where the ISP does not have a direct peered connection.

UHD Ultra high-definition television, providing a resolution of 3840 x 2160 pixels (4K).

Ultrafast broadband Broadband services that deliver download speeds of greater than 300 Mbit/s.

Usage cap Monthly limit on the amount of data that users can download, imposed by fixed and mobile operators for some of their packages.

VDSL Very High Speed DSL. A high speed variant of DSL technology, which provides a high headline speed through reducing the length of the access line copper by connecting to fibre at the cabinet.

VOD Video-on-demand. A service or technology that enables TV viewers to watch programmes or films whenever they choose to, not restricted by a linear schedule (also see 'push' VOD and 'pull' VOD.

VoIP Voice over Internet Protocol. A technology that allows users to send calls using internet protocol, using either the public internet or private IP networks.

VoLTE Voice of LTE, also known as 4G voice. A service that allows voice calls to be made over 4G networks

Wi-Fi A short range wireless access technology that allows devices to connect to a network through using any of the 802.11 standards. These technologies allow an over-the-air connection between a wireless client and a base station or between two wireless clients.

xDSL The generic term for the Digital Subscriber Line (DSL) family of technologies used to provide broadband services over a copper telephone line.

ROYAL ACADEMY OF ENGINEERING

Engineering the Future

Engineering an economy that works for all

INDUSTRIAL STRATEGY
Green Paper response

April 2017

Engineering an economy that works for all

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Green Paper response

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:

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- Chartered Institution of Highways & Transportation
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- 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
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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.

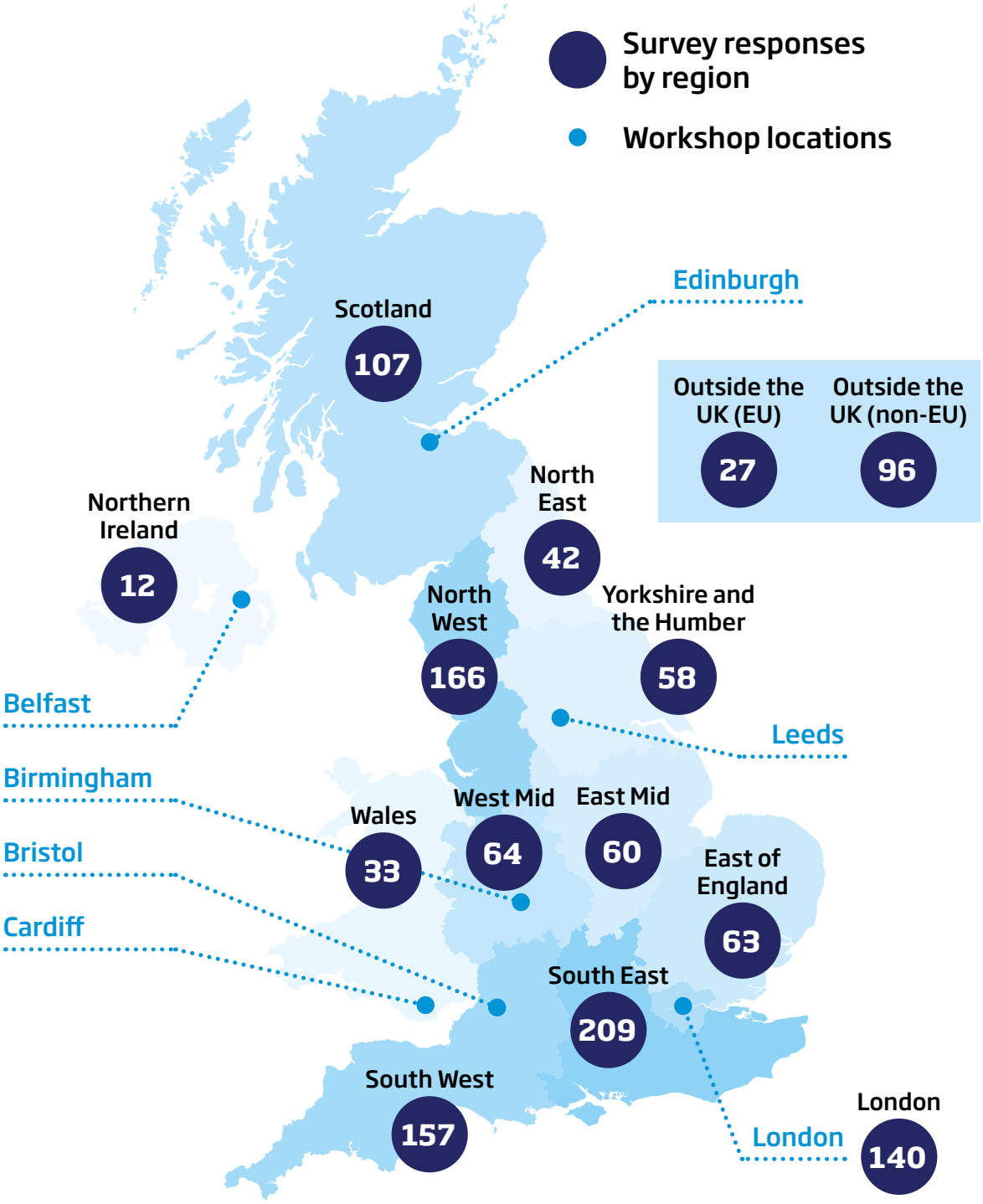
There was a fair spread of organisation size from large businesses (65%) to micro businesses (17%), medium-sized businesses (11%) and small businesses (7%), as well as between private sector businesses (57%), government and public bodies (7%), academia (7%), charities (2%) and research and technology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

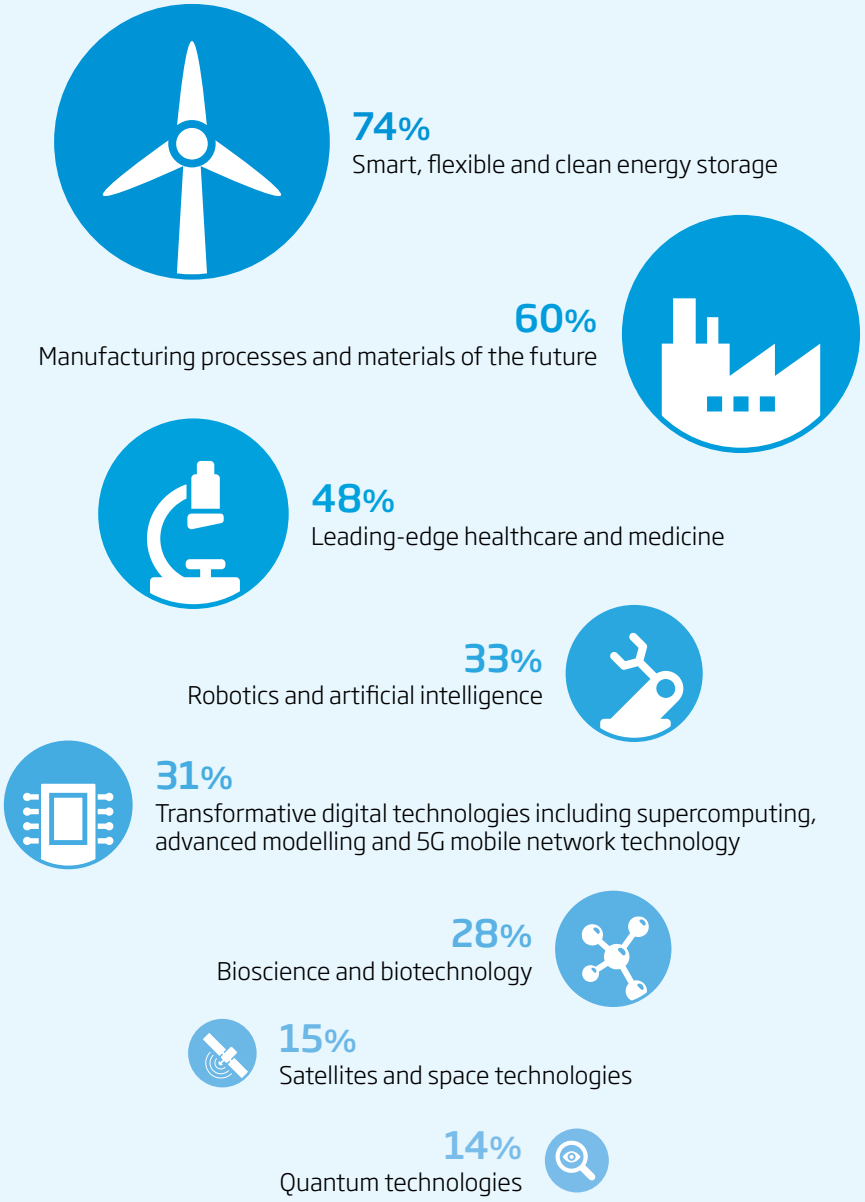
Survey respondents were asked to prioritise the top three challenge fund areas as proposed in the industrial strategy Green Paper. The top three areas cited overall were: smart, flexible and clean energy storage; manufacturing processes and materials of the future; and leading-edge healthcare and medicine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

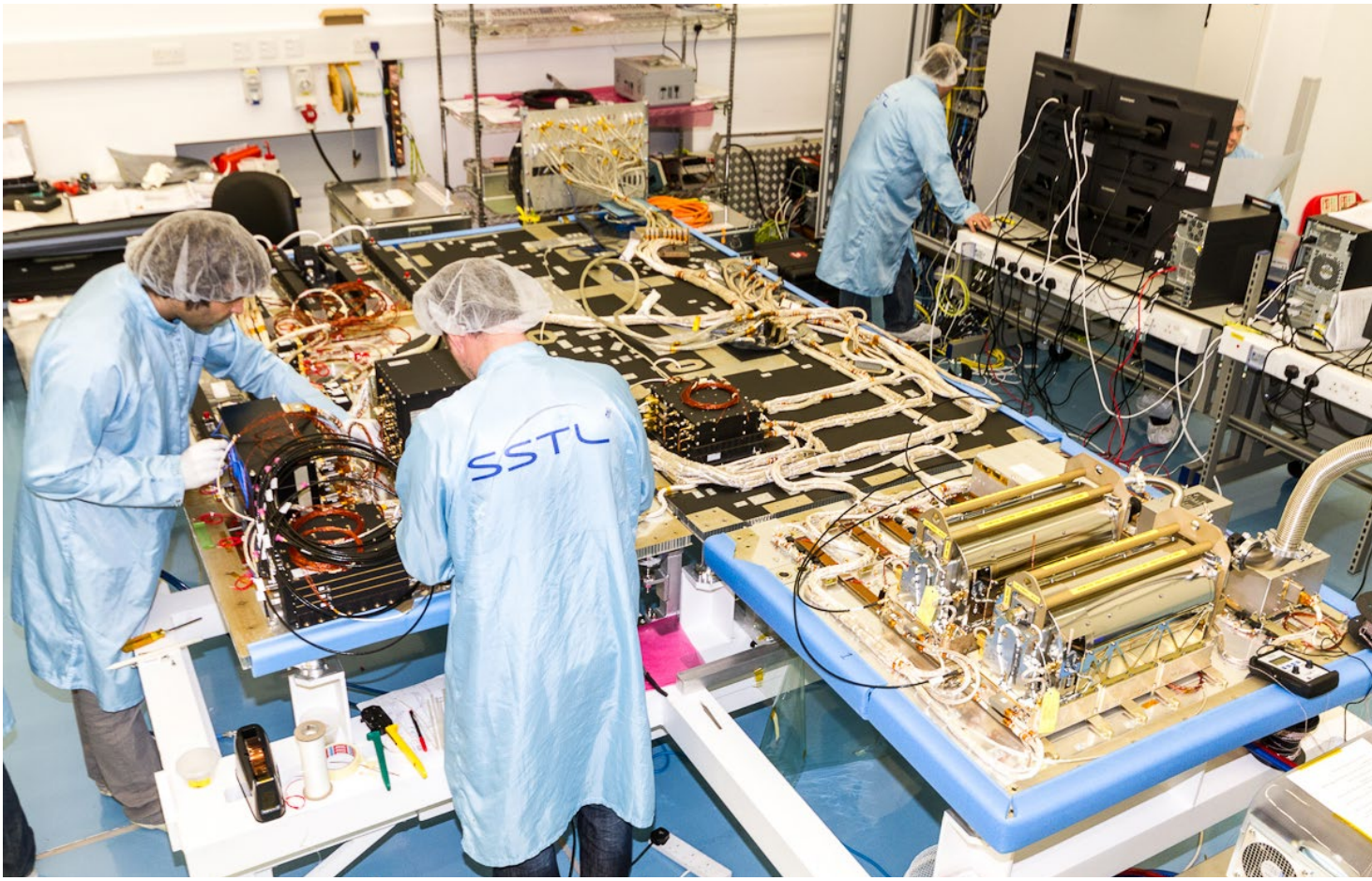
- physical infrastructure already exists – or is being developed
- there may already be relevant skills in the local workforce (for instance, because of the industrial heritage of the area or previous specialist activity)

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

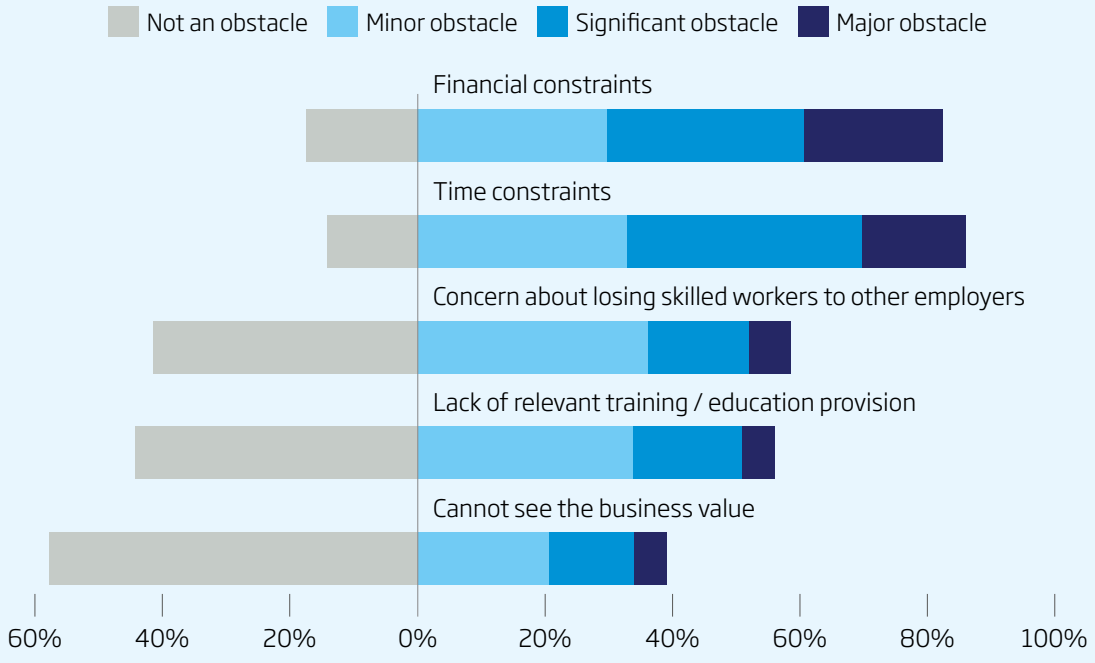
The engineering profession has always been strongly supportive of CPD. The speed of technological change, as well as the growth in global competition, make this an ongoing imperative for UK engineering in order to maintain a leading position internationally.

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

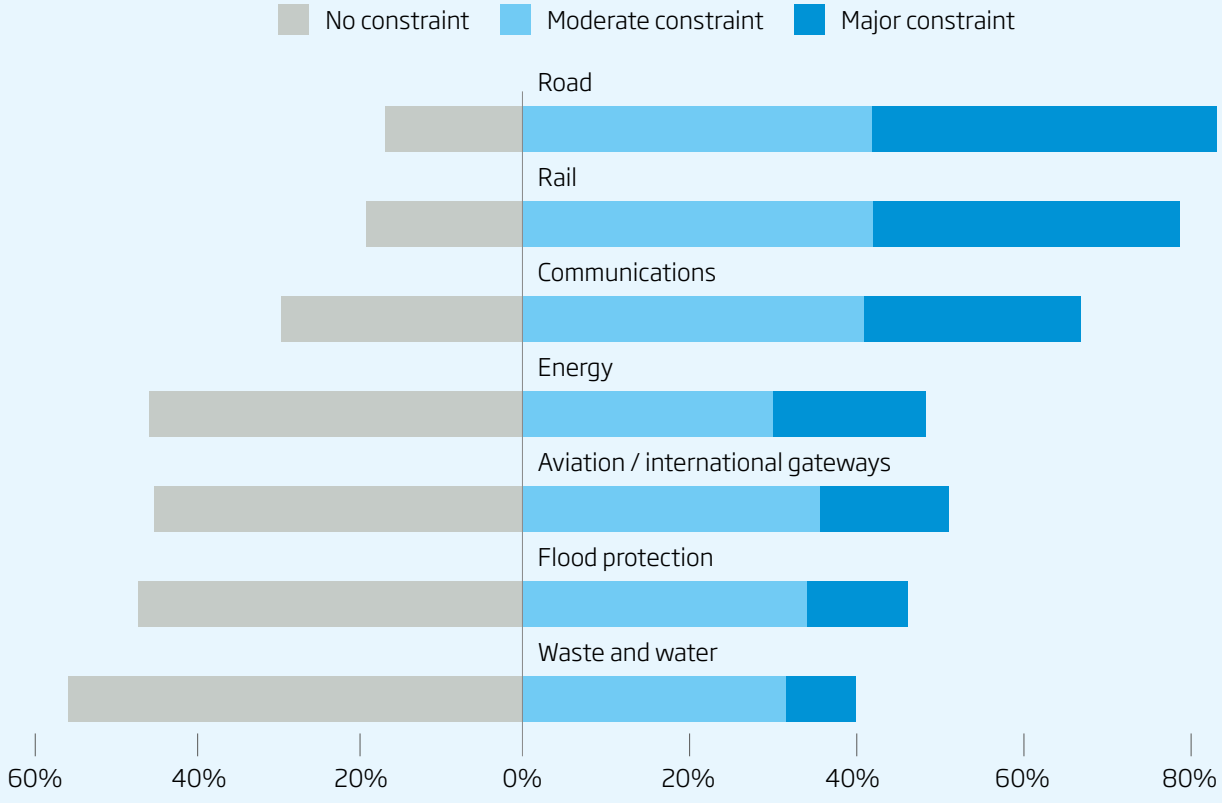
Private investment in infrastructure (Q15)

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).

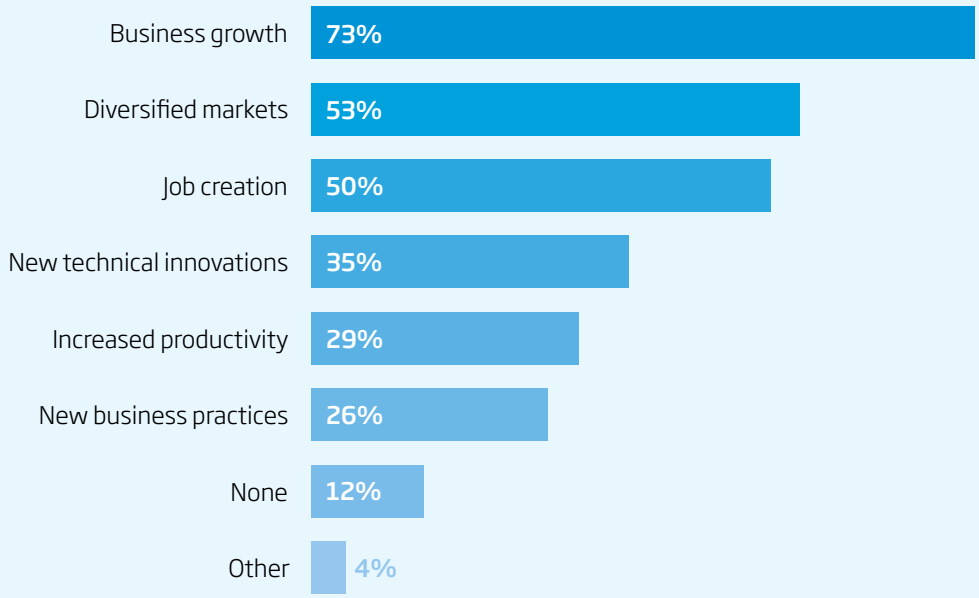
Effectively communicating this multitude of benefits to companies that are considering beginning exporting may provide the encouragement needed for firms to enter the export market.

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.

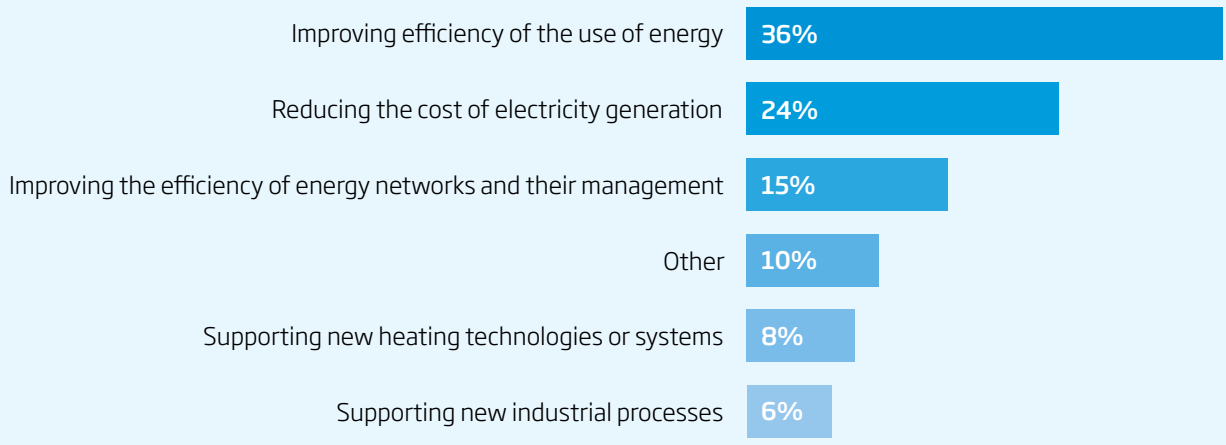
Existing international protocols for the measurement and verification of energy-saving projects are widely used to underpin investments using energy performance contracting models. It is conceivable that the introduction of an Energy Saving Incentive (ESI) scheme that pays out for demonstrated energy 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

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[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

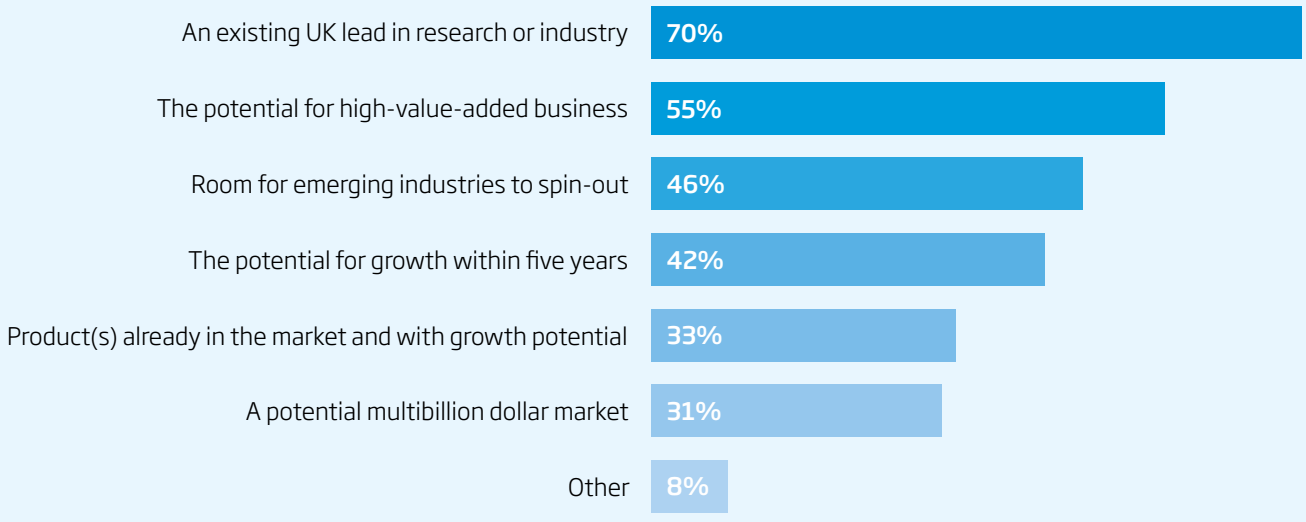
- Tax relief and incentives
- Simplification of R&D tax credits for micro businesses
- Increase in public investment in R&D

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.

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.

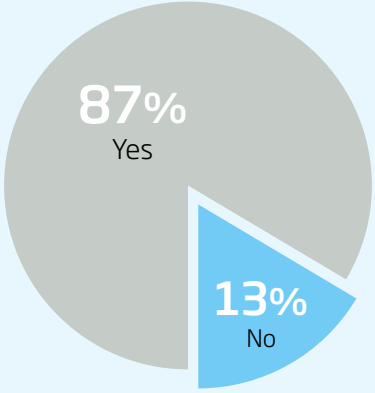
The need for resilience and reliability is also critical. An increasingly significant proportion of other infrastructure now depends on effective telecommunications and any loss of service through either deliberate or accidental breach could have potentially catastrophic social or economic consequences. 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.

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.

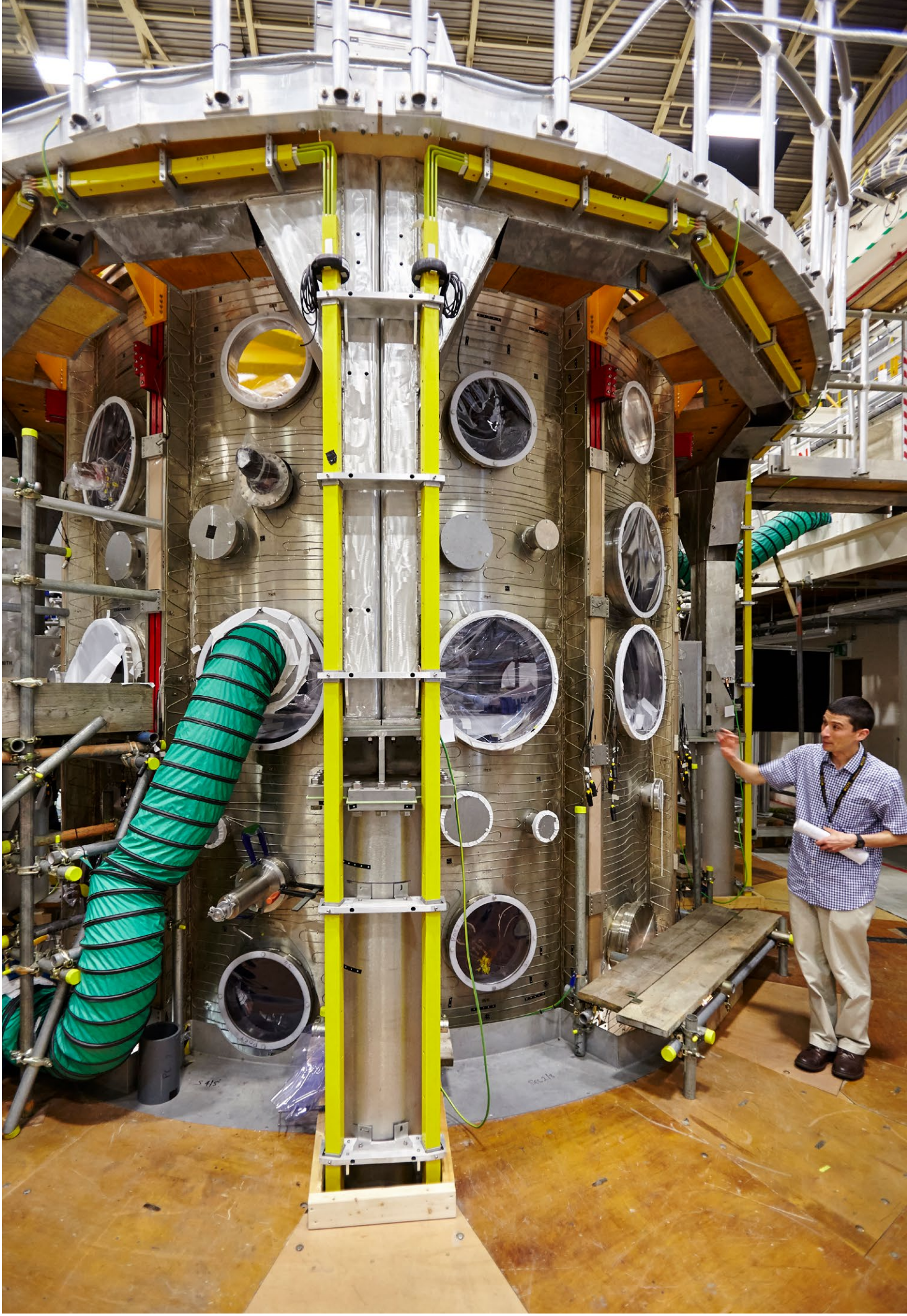
7.5 There is an opportunity for the UK supply chain to play some part in the development of small modular nuclear reactors; however, this will be likely to need some form of catalytic activity from government and a clearer focus from the industry on commercially viable solutions, notably those that minimise 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.



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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