INDUSTRY 4.0:

The impact of technological change on the Engineering Construction Industry

This report was produced by Pye Tait Consulting on behalf of the Engineering Construction Industry Training Board.
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CONTENTS

Technologies and processes currently used by employers

42%

Digital technologies - such as big data, data visualisation, augmented reality and virtual reality

27%

3D and 4D printing

26%

Automation – such as robotics and Artificial Intelligence

Business impacts expected over the next three years

81%

Improved business efficiency

65%

Improved precision

55%

Increased profit margin

55%

New business opportunities

20%

Increased headcount

9%

Reduced headcount

> *"Technology is a major driver of change across the engineering construction industry and will impact on all sectors – from oil and gas, to renewables to pharmaceuticals. With the industry set to grow by 33,000 jobs in the next decade, we must ensure the workforce is future proofed. This means making sure companies can recruit new talent with advanced digital skills and upskilling the current workforce in the use of new technologies, so that employers can maximise the opportunities Industry 4.0 presents"*
>
> ***Chris Claydon, CEO ECITB***

Skills challenges in adopting new technologies

19%
Workforce lacks the skills to adopt them

14%
Lack of readily available training courses

16%
Training courses are not at the cutting edge of industry needs

Business challenges in adopting new technologies

34%
Lack of time to make big changes

30%
Lack of finance/resources

24%
No Challenges

20%
Don't see as immediately relevant to our business

Impact of technology on demand for job roles over the next three years

↑ 59%
Engineering and science professionals

↑ 62%
Engineering-related technicians

↑ 53%
Skilled mechanical, electrical, instrumentation and electronic trades

Base: 585 employers. Source: Pye Tait Consulting LMI survey for ECITB, 2018

EXECUTIVE SUMMARY

This report examines the impact that technology might have, or is already having, on the employment environment of the engineering construction industry (ECI). It explores how the industry and individual sectors are responding to the emergence of new technology, methods and processes and the implications for skills. It also looks at change in demand for roles and the challenges in implementing new technologies.

The fieldwork was conducted between July and October 2018 via initial scoping telephone interviews with ten industry stakeholders, a telephone survey with 829 ECI employers ('surveyed' employers) and those in the supply chain, 50 in-depth follow-up telephone interviews ('interviewed' employers), and in-depth discussions with a small sample of training providers (8). This research was supplemented by a desk review of sector-specific reports.

The ECI is facing a number of drivers of change. These include: climate change and related environmental legislation, diversification of business models towards renewable energy, continuing focus on efficiency and effective project delivery.

The industry is also facing technological change as a result of new materials, digitalisation, automation, robotics, artificial intelligence, and related disruptive technologies (cf. Bibliography, Appendix 1 and the separate Annex).

Such technologies will create new types of jobs, enable new ways of working, and prompt an increasing need for cross-sector transferability of skills, alongside a constant pressure for innovation and productivity.

To take one area, the increasing use of big data and analytics is predicted to create over 40,000 jobs in roles such as data analysts, infrastructure engineers and solution architects between 2017 and 2020. In order to harness these emerging technologies and the skills they require, the ECI will need to adapt.

Findings from the research:

- While surveyed companies operating in the ECI acknowledge technology is a major driver, the bigger issue, for now, seems to be uncertainty regarding the impact of technology on jobs and productivity (cf. section 2.1). For smaller companies, in particular, this uncertainty comes from a view that investment in technology is challenging and not always for them or that technological advances will simply introduce themselves organically as they have in the past. Uncertainty around Brexit has also given pause to fresh investment in technology. A quarter of surveyed employers feel there are no challenges at all and one fifth do not see any relevance to their business in implementing new technologies. By far the largest stated challenge in adopting new technologies, however, is a lack of time or resources (64%). More research is needed to ascertain correlation between allocation of time and resources and the view that technologies will introduce themselves organically, or are not relevant to the business.
- According to the survey, four in ten (42%) employers already use digital technologies such as Big Data, Augmented Reality or Virtual Reality (AR and VR). This is higher in sectors such as nuclear (51.5%) and in Scotland (49.2%). Besides sector-specific technologies, these same technologies are rated by surveyed employers as those likely to have the most impact over the next three years. In contrast, modularisation (for example, off-site manufacturing) and low carbon technology are seen as having a lower significance in terms of impact on the industry and are currently used by less employers (20% and 15% respectively). The use of 3D and 4D printing is most prevalent in food and drinks sector, with 48% of employers surveyed making use of this technology. Working with advanced materials, is predominantly seen in the chemical and pharmaceutical sectors, with 48% of employers in each sector currently using these.
- Eighty-one percent of surveyed ECI employers expect possible improvements in efficiency and precision as a result of the use of such technologies. Fifty-five percent of employers surveyed expect to see improvements in profit margins and business opportunities. Interestingly, only 9% of surveyed employers believe that headcount will be reduced as a result of increasing use of technology. There is a similarly, albeit less, conservative view that headcount will increase (20%) as a result of increasing use of technology.
- Over 43% of employers already experience difficulties in recruiting engineering and science professionals due to a shortage of skill[3]. This may well be the driver behind the 52% and 63% of surveyed employers in the ECI predicting engineering-related technicians and engineering and science professionals to be in most demand in three years as a direct result of new technologies and processes.
- A sector-specific report on oil and gas (cf. section 2.4.1) regarding the impact of technology on skills and job roles, expects to see many tasks being managed remotely in on-shore facilities. OPITO (Offshore Petroleum Industry Training Organisation) notes that, of their five job families, 'engineering' and 'projects' will only be marginally affected with a less than 10% likelihood of displacement by disruptive technologies in comparison with technical roles such as drilling.

1 CEBR, 2016, *The value of big data and the internet of things to the UK economy*
2 TechUK, 2016, *The UK's big data future: Mind the gap*
3 ECITB, 2019, *The Engineering Construction Industry Labour Market Outlook*

- On the subject of training and technology (cf. section 2.2), employers say that generic training is much easier to find than technology-related training relevant to specific types of work. One possible explanation for this is a time lag between the provision and knowledge in the training sector of emerging technologies. Providers confirm that the ECI faces significant technological transformation, such as developments in robotics and automation. However, providers struggle to integrate these changes into their training as they lack the funding to acquire the related equipment. This same funding issue affects the ability to attract staff skilled and knowledgeable in the related technological disciplines. This links to a view among surveyed employers (19%), that the workforce lacks the skills to adopt new technologies, and may point to a need to conduct training in such a way as to equip learners with more general technological skills.

Introduction

The Engineering Construction Industry Training Board (ECITB) is the statutory body for the Engineering Construction Industry in Great Britain. Responsible for setting skills, standards and qualifications for the development of the workforce, it is important that ECITB gathers robust and up-to-date primary data on the workforce, taking into account current and future needs.

In April 2018, Pye Tait Consulting was commissioned by the ECITB to carry out detailed research and analysis into the skills needs of the industry. This research – in addition to the separate main report on the Labour Market Outlook, – also examines current and future technologies used in the engineering construction industry (ECI), and their impact on the labour market and the industry as a whole.

The objective of this report, therefore, is to produce an in-depth overview of the status and impact of new and emerging technologies with respect to the skills and workforce profile of the ECI.

The report looks at the main technological trends affecting the ECI and examines the broad skills implications of all of these technologies. It does this by presenting the survey and interview findings and reports on the industry's perceptions on how these technologies impact on job roles, the demand for job roles in the next three years and what challenges they may face in implementing new technologies. Research reports, articles and other sources supplement this with intelligence on the different sectors that utilise engineering construction contractors. This additional desk-based intelligence is largely captured within section 2.4 on the key sectors of the ECI.

Part I:
Technological trends and the impact on skills

1.1 Industry 4.0

The Fourth Industrial Revolution, or Industry 4.0, does not depend on just one technology. It is driven largely by a range of specific technological developments, including, high-speed Internet, Artificial Intelligence (AI) and automation, the use of big data analytics, and cloud technology. It also involves the adoption of cyber-physical systems like the Internet of Things (known as IoT)[4].

One immediate implication of this on the ECI is the potential convergence of the digital and physical worlds, such as the transformation of the traditional linear, sequential supply chain operations to more of an interconnected, open system of supply operations. Company leaders will need vision and a higher level of digital engagement; management structures will need to be agile as companies will need to reinvent their capabilities faster than ever before to stay ahead[5]. The heart of the anticipated change lies in digitalisation and its associated technologies, but it will also require cultural change within companies and a new way of thinking about business. Employees will need to have greater awareness of new technology and their entire working approach will need to be digitally-focused. Digitisation also brings with it a whole new range of issues, including cyber threats to which operations and assets are highly vulnerable.

A 2016 EEF report 'The 4th Industrial Revolution: A Primer for Manufacturers' identified upskilling and retraining as significant to properly realise the benefits and counter the threats of Industry 4.0[6]. The World Economic Forum (WEF) predicts that creativity will become one of the top three skills workers will need[7], along with complex problem-solving, and critical thinking. Change will drive demand for certain job roles including:

- Automation Engineer;
- Controls Systems Engineer;
- Data Scientist;
- Equipment Systems Engineer;
- IT Solution Architect;
- Project Designers and Managers;
- Robotics Engineer;
- User Interface and User Experience Designer;
- Validation Engineer.

The global 'smart factory' market is expected to expand at 13.2% per annum[8] and, alongside any gains from more effective processes and systems of working, engineering construction supply chain companies will be in increasing demand to create, install and maintain such infrastructure.

As a result of digital technologies already changing society and working practices in significant ways, it is predicted that a number of semi-skilled, skilled and professional jobs will follow.

The oil and gas skills body, OPITO (Offshore Petroleum Industry Training Organisation), expects the recruitment of 10,000 workers in new, and in some cases presently non-existent roles - such as robotics, remote operations, or data management - between 2018 and 2035. To prevent skills shortages, OPITO recommends the up-and re-skilling of the existing workforce, harmonisation of standards and work practices across the energy sector and new programmes and courses to equip the future workforce with skills in new and emerging technologies, prioritising cooperation between training providers and the industry.

McKinsey, in their 2017 report 'Jobs Lost, Jobs Gained: Workforce Transitions In A Time Of Automation', discuss and analyse the occupations that will grow, those that will decline/disappear and others that simply cannot be envisioned right now[9]. A Boston Consulting Group (BCG) survey of UK managers in 2017 showed the degree of preparedness and planning of the UK industry for digitalisation. UK managers see new skills requirements but anticipate fewer skills are needed than in Germany or France– (a chart summarising the findings is in Annex - Appendix 1)[10]. Similarly, the2017 McKinsey report estimated the impact of automation on performance gains and labour substitution[11].

In short, research indicates that Industry 4.0 will be characterised by digitalisation, automation and related disruptive technologies, all of which will profoundly impact the ECI and its subsectors, including offshore, nuclear and power generation/renewables. The resulting creation of new types of jobs, the increasing need for cross-sector transferability of skills, and the growing pressure for innovation, increased efficiency, and productivity gains, will result in continuing demand for workforce upskilling and training. Similarly, continuous innovation in the way companies interact with and harness their employees, will be required.

Professor Klaus Schwab, who coined the term 'Fourth Industrial Revolution', believes it will be fundamentally different to previous industrial revolutions, with greater shifts, disruptions and opportunities. He points to the need for leaders to actively embrace these changes and, as a result, change the way in which they think and approach future planning:

> ***"The changes are so profound that, from the perspective of human history, there has never been a time of greater promise or potential peril. My concern, however, is that decision-makers are too often caught in traditional, linear (and non-disruptive) thinking or too absorbed by immediate concerns to think strategically about the forces of disruption and innovation shaping our future."***
>
> *Professor Klaus Schwab, "The Fourth Industrial Revolution"*

4 The IoT is a network of interconnected smart devices that allow each separate device to interact (i.e. send or receive data) from other devices on the network.
5 PWC 2016 Building the digital enterprise
6 EEF (2016) The 4th Industrial Revolution: A Primer for Manufacturers [pdf] p. 11.
7 World Economic Forum 2016 'ten skills you need to thrive in Industry 4.0'
8 Future market insights 2018 Global smart factory overview
9 The Global McKinsey Institute: Jobs Lost, Jobs Gained: Workforce Transitions In A Time Of Automation. 2017

1.2 Disruptive technologies, digitalisation and automation

Disruptive technologies are so called not only because they cut across, disrupt and even destroy existing technologies, but because they bring about significant change in other business systems and processes and can act as a catalyst for social change. The Internet of Things (IoT) is a grouping of smart devices which 'talk' to each other over the internet, e.g. smart fridges tracking out of date groceries, smart heating and cooling systems, even smart cities. For ECI companies, cyber-security will be the key requirement for any interconnectivity – whether at the full IoT level or simply data transfer within Building Information Modelling (BIM). Companies will need not only specialist cyber-security staff to ensure increased security to guard against data theft and sabotage of IoT-connected devices, but all staff will need a level of cyber security awareness to avoid inadvertently putting the company, projects or assets at risk.

Disruptive technologies can often be interlinked and interdependent. As a result, they will almost certainly have a significant impact right across the engineering construction economy. Their impact will be to further drive the movement away from traditional craft and operative skills and towards a need for technicians who can understand, program, and control machines that are computer-controlled, semi-autonomous, or autonomous.

Cross-cutting technologies are sector-neutral; their effects will be felt in the need for higher technical skills across the UK workforce. They can also enhance older technologies in ways which would be hard to predict. In fact, the difficulty of predicting where disruptive technologies will lead is one of their defining characteristics.

Some of their broad characteristics and the potential developments and impact on skills of the main disruptive and sector-specific technologies are headlined here but also described in greater detail in Appendix 1. The Annex with appendices 1 and 2 supplement these headlines with further information on technologies and sectors.

- **Digital Ledgering Technology (DLT) –** uses systems such as blockchain to leverage all forms of data-sharing, particularly down the supply chain and upwards to ultimate users. The key to its success lies in determining a balance between regulation and governance and technical code and legalities.

Blockchain is perhaps the best-known DLT approach. Many experts predict that the use of Blockchain will disrupt traditional working processes in the ECI by enabling a range of associated developments, such as BIM in fully automated, remotely managed and decentralised processes[12].

Blockchain will require an unusual mix of skills – lawyers, engineers, mathematicians, computer experts, corporate management – all collaborating together to harness the technology[13]. Some commentators believe that Blockchain/DLT will jeopardise tasks, such as processing transactions and verifying documentations, and there are still great concerns around data security prior to the use of the blockchain coding. It is this concern that may create specialist digital jobs focussing on encryption and protection to prevent fraud[14].

- **Digitalisation** – Today's applications of digital approaches support new technologies such as automation, artificial intelligence, robotics, drones, and much more. Perhaps the greatest of modern impacts is what is known as 'big data' – the use of digital technologies to gather and harness immense amounts of data and the use of artificial intelligence to combine, assess and analyse those data in incredibly short periods of time.

Digitalisation provides the capacity to visualise thousands of structural components simultaneously across engineering projects ranging from nuclear reactors to wind turbines. This offers unique insights, data-led solutions and perhaps more importantly it potentially enables cross-fertilisation of ideas across different ECI sectors.

The increasing use of big data and analytics is predicted to create more than 40,000 jobs in roles such as data analysts, infrastructure engineers and solution architects between 2017 and 2020[15 16].

The documented benefits of digitisation include increased efficiency, reduced operational costs, fewer human errors; and more powerful data analysis. Innovative digital technologies, such as BIM, along with new materials and processes, will create huge opportunities for boosting productivity and changing the way people work across the ECI.

The UK government committed to the use of BIM and mandated compliance at Level 2 stage for large public projects from April 2016[17]. It has certainly reached the large, early adopters, but has not yet completely filtered down the supply chain[18]. Realisation of these benefits and impact on productivity may be some way into the future.

While some basic skills, such as literacy and numeracy will retain and even increase their relevance in a digitalised work environment, other components of existing skills sets are expected to be made obsolete by digitalisation[19]. Indeed, studies by the Edge Foundation as well as Ernst & Young predict that timeless metaskills such as cognitive flexibility, problem-solving creativity or collaboration will define the skills landscape in the context of rapidly changing technologies[20].

10 *BCG 2017 Is UK Industry ready for the Fourth Industrial Revolution?*
11 *McKinsey Global Institute 2017 Jobs lost, jobs gained: Workforce transitions in a time of automation*
12 *EY (2018) How are engineering and construction companies adapting digital to their businesses?, p.8*
13 *Rand, 2017, Understanding the landscape of distributed ledger technology/blockchain*
14 *https://www.ft.com/content/3a9ef8d8-33d5-11e6-bda0-04585c31b153*
15 *CEBR, 2016, The value of big data and the internet of things to the UK economyAutomation. 2017*

Digitalisation facilitates flexible and remote working, therefore opening up roles to a global talent pool. It could also go some way towards addressing gender imbalances.

- **Robots and automation –** These are often the first technologies cited as replacing humans in the workplace. Using robots can be advantageous for several reasons: it frees people from dirty or unsafe work, it can improve quality of work by reducing errors, and it can cut manufacturing costs significantly. The need for human labour to perform such tasks will inevitably be reduced.

However, as robots become more widespread, there will be an increasing need for people who are capable of designing, installing, operating, and maintaining such systems. At technician level, staff will be needed to program, operate and maintain the equipment. At professional level, the industry will need engineers who can develop systems, write programs, and design the algorithms necessary for bespoke engineering needs.

Companies already use drones to inspect power lines and generation equipment, oil and gas installations, and solar farms. For instance, the Scotland-based company Cyberhawk has provided drone solutions for several oil giants including Shell, Statoil and Maersk Oil, as well as the Scottish energy provider SSE (formerly Scottish and Southern Energy), which has highlighted how applying drone solutions has made inspection data more comprehensive and highly accurate[21]. Apart from subcontracting drone operations, several multinational companies such as Siemens are developing in-house drone solutions[22] while others like ABB[23] and GE[24] have joint ventures developing drone solutions.

The demand for two entirely different skillsets, such as 'data scientists' and 'drone engineers', emphasise the sheer impact and change anticipated in the future. This is reflected in the increasing number of related courses available for learners within the UK: as of 2017, over 110 UK universities across all UK nations offered such courses[25]. Similarly, Colleges in Britain and Northern Ireland, lists 22 colleges offering related courses[26]. Further courses will need to be developed if the expected integration of drones and BIM comes to pass.

In the long term, experts predict that robotics, automation and digitalisation will boost employment, but primarily in the technical and higher professional job grades . Research by the European Economic and Social Committee (EESC) suggests that this trend will affect all economic sectors at those levels and reiterated the growing importance of the technologies discussed in this report[28].

- **Augmented and Virtual Reality –** techniques which permit the user to superimpose a virtual picture upon a real location. In the context of the engineering construction industry, 3D models have been used as visualisation tools for projected finished buildings and installations, in guiding field staff in maintenance activities and many other applications. Individuals or groups of users are then able to "tour" the product or facility before it is constructed.

Augmented and virtual reality, as is pointed out in a recent report on immersive learning in construction[29], has enormous potential to revolutionise training delivery. It also has the potential to transform the perception of industries like engineering construction to young people and investors.

> ***"Immersive learning allows students to be fully involved in an interactive, digital environment. It means trainees can, for example, practice crane manoeuvres, scale wind turbines, or visualise the detailed 3D build of a skyscraper – without leaving the classroom."30***

Most of the research exploring AR and VR has found that it can reduce the time taken to learn, decrease the number of trainee errors, increase the amount learned, and help learners retain knowledge for longer.[31] There are, however, some well-being issues associated with immersive learning, such as simulator sickness.

16 TechUK, 2016, The UK's big data future: Mind the gap.
17 http://bim-level2.org/en/faqs/
18 https://www.ice.org.uk/news-and-insight/the-civil-engineer/july-2017/has-digitals-impact-civil-engineering-really-hit
19 Council of European Employers of Metal Engineering and Technology based Industries 2016
20 The Edge Foundation 2018 Towards a Twenty-First Century Education System
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31 The Edge Foundation 2018 Towards a Twenty-First Century Education System

1.3 Carbon reduction

This subject is becoming more and more complex and diverse with every year. It now runs from efforts to distribute energy support through the construction of highly efficient local gas and biofuel generators, support for well-established renewable technologies such as solar, wind and hydro through to the introduction of low carbon materials, such as new concrete and other energy saving materials.

In 2017, the UK Government presented to Parliament 'The Clean Growth Strategy: Leading the way to a low carbon future'. Specifically, clean growth is defined as "growing our national income while cutting greenhouse gas emissions."[32] The Climate Change Act[33], passed in 2008, committed the UK to reducing greenhouse gas emissions by at least 80 per cent by 2050 (compared to 1990 levels), through a process of setting five-year caps on greenhouse gas emissions termed 'Carbon Budgets'.

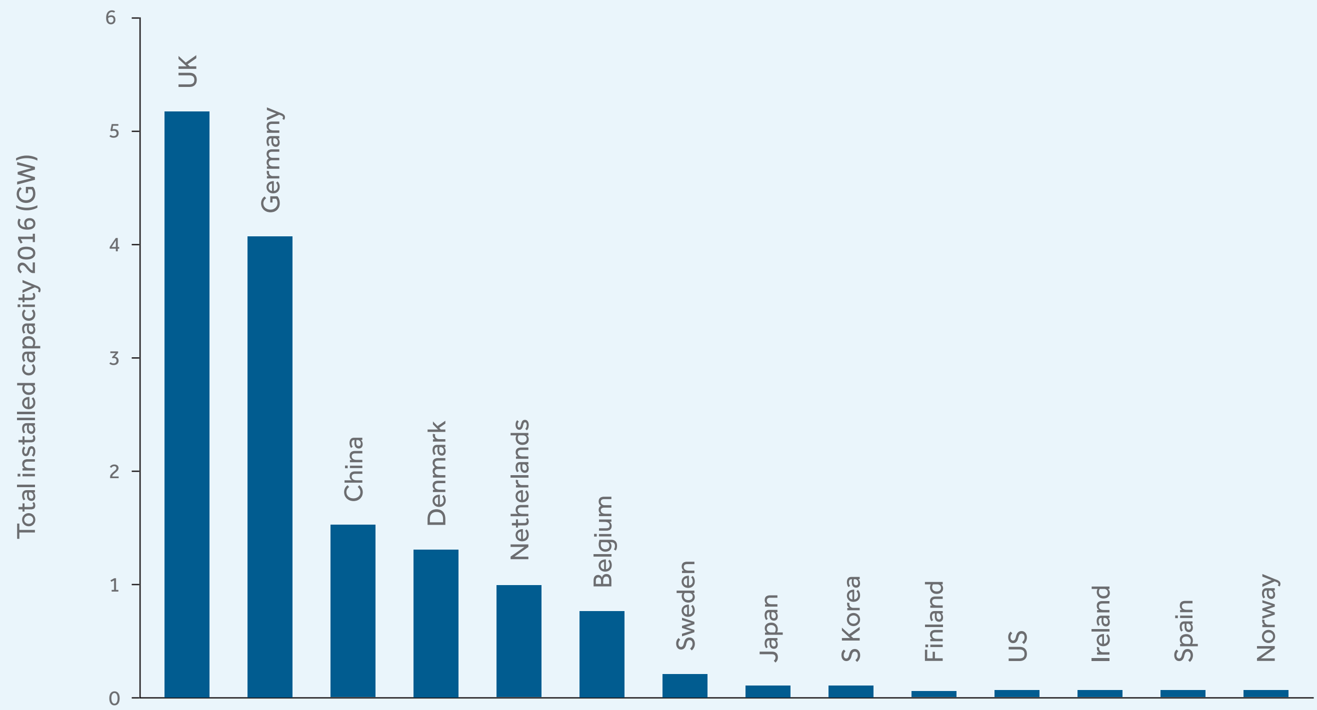
The Government sees nuclear power as the most affordable large-scale, low-carbon energy sources currently available in the UK and recognises its contribution to the diverse and balanced energy mix needed to supply enough electricity to meet the demands of homes and businesses. The Clean Growth Strategy has been partly responsible for the fact that the UK now has the largest installed offshore wind capacity in the world:

The target of delivering clean, smart, flexible power will be achieved in part through the phasing out of the use of unabated coal to produce electricity by 2025.

In recent years, the production of coal in the UK has steadily declined. Imports have overtaken production by a large margin with 694,000 tonnes being produced and 1,559, 000 tonnes imported by the second quarter of 2018[34]. As a consequence, as of 2017, only about 700 workers were still employed in surface and underground coal mining[35].

As referenced in the Labour Market Outlook report, Local Industrial Strategies developed by Local Employment Partnerships (LEPs), city regions, the Greater London Authority (GLA), and UK Government schemes in each of the nations are also driving a strong trend towards different forms of energy generation and conservation. Local generation – sometimes called community energy -– is spreading fast with over 200 schemes currently underway or completed in England alone (including the large 'High Winds Community Energy Society' scheme). Similarly, Combined Heat and Power (CHP) projects are also in strong demand with recent projects including the Leeds Leisure Centre, the new Residential Quay in Newport, as well as many schools and hotels. Some of the projects are based on plant or food waste.

Figure 1 Offshore wind installed capacity by country



The Clean Growth Strategy: Leading the way to a low carbon future (October 2017)

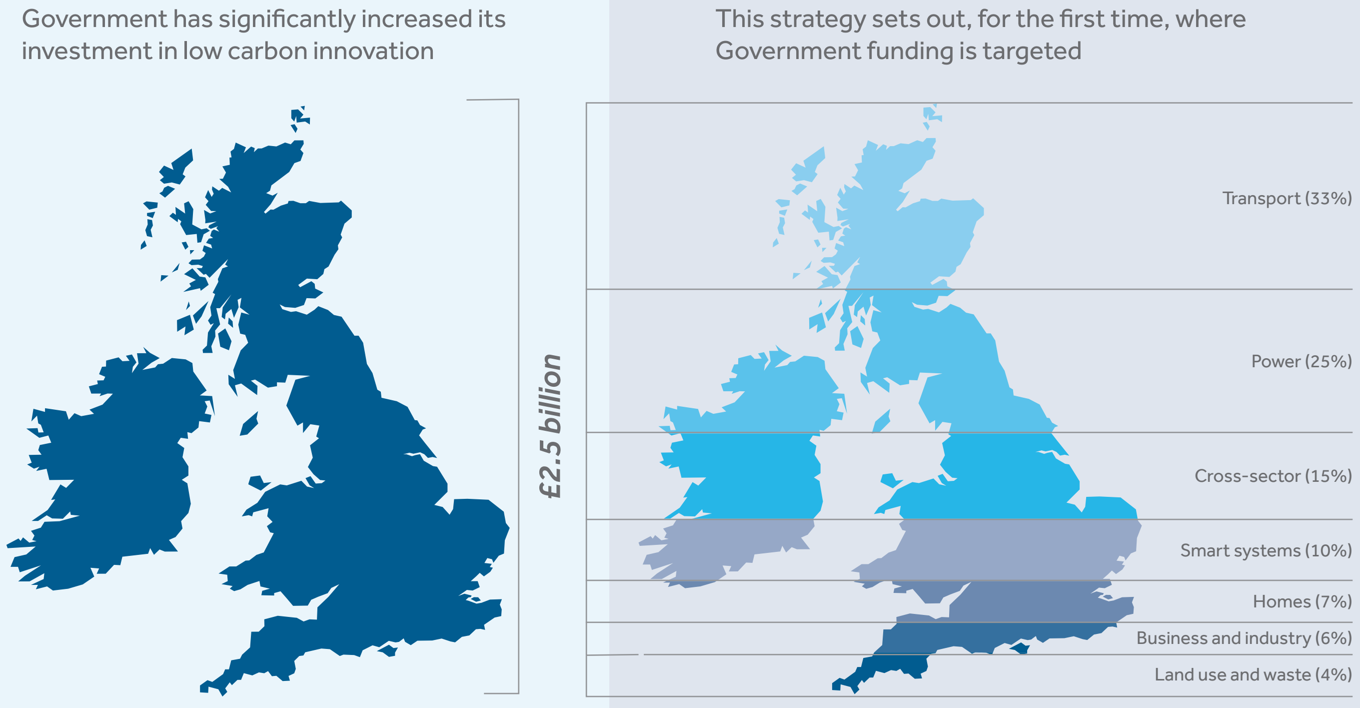
32 BCG 2017 Is UK Industry ready for the Fourth Industrial Revolution?
33 McKinsey Global Institute 2017 Jobs lost, jobs gained: Workforce transitions in a time of automation
34 National Statistics, 2018, Energy Trends: solid fuels and derived gases
35 https://www.desmog.co.uk/2017/10/27/coal-mining-jobs-uk-continue-fall-stats-show

1.4 Materials technology

Allied to the digitalisation and modularisation techniques in use, the integration, investment in and alignment of new materials continues to be hugely important, and key to increasing efficiencies in production. The examples mentioned here herald similar skills implications in their applications and uses. 3D printing for example will ultimately require clear standards to regulate materials, equipment and operators to ensure satisfaction with the quality of materials: a fact brought into sharp relief with the impact of the devastating fire at Grenfell Tower in 2017.

- Graphene is an advanced product that has been around for a long time, but new production methods making it easier to manufacture have allowed industry to find new applications. It is a single-molecule polymer of carbon which is considerably stronger than steel, much more flexible, and extremely lightweight.
- Additive layer manufacturing (ALM), or 3D printing, while initially developed in the 1980s, has gained popularity over the past decade to the extent where 3D Printers are already being sold for home use. The potential uses of ALM in the engineering construction industry are myriad, extending from component production using metal powders to facility building using a combination of processes. Not only can the required items be produced to extremely fine tolerances and accuracy, but components and products can be designed in ways which would be impossible for traditional machinery to construct.
- Self-healing concrete is yet another new material with significant areas of application in the ECI, for instance in the construction and maintenance of nuclear reactors or the construction of nuclear waste storage facilities. The lifespan of concrete can be increased with the use of this new material, which would correlate to a considerable decrease in repair costs. Self-healing concrete uses a mix of self-activating limestone-producing material to fill any cracks before further damage can be done to the structure of the construction[36].
- Fibre Reinforced Polymer or Plastic (FRP) is a composite material that has been used for the last 30 years in the oil and gas industry, including offshore and subsea operations. However, its application to piping systems is recent. FRP solutions can protect piping systems against corrosion in various pressure, temperature and weather environments[37]. More recent studies have demonstrated that the properties of FRP lend themselves to thermal insulation of pipelines, outperforming steel materials[38]. As such, FRP protects pipelines against temperature fluctuations that could increase material fatigue. This leads to significant cost-savings through lower maintenance costs and extended life-span of materials[39].

Figure 2 Government investment in low carbon innovation



The Clean Growth Strategy: Leading the way to a low carbon future (October 2017)

36 https://www.raconteur.net/business/top-ten-construction-innovations
37 https://compositesuk.co.uk/composite-materials/applications/oil-and-gas
38 https://www.ogj.com/articles/print/volume-114/issue-1/transportation/frp-crude-pipeline-shows-thermal-superiority-to-steel.html
39 https://www.moldedfiberglass.com/sites/default/files/docs/MFG_Technical_Design_Guide_FRP_Composite_0.pdf

Part II:
Technological Skills Impact in the ECI

In this section we examine the impact that technology might have, or is already having, on the employment environment of the engineering construction industry. We also explore how the industry is responding to the emergence of new technology, methods and processes and the demand for skills as revealed by desk research and our industry survey with 829 employers, including 50 in-depth interviews.

For the bulk of the ECI, the impact of new technologies will depend on the interplay between the disruptive technologies, the technologies being targeted by the specific sector, the socio-political environment within which the industry operates, and the demands of their customers. For some small companies in the wider ECI seemingly simple tasks, such as electronic signatures, are playing a part in change.

2.1 Technology as a driver of change

For the engineering construction industry, the changes in economic conditions and government policy have been frequent and perhaps relentless, but alongside the impact from climate change and Brexit, it would seem that, on paper, the most challenging and potential changes reside under the heading of 'technology' and its implications.

> ***"There are threats to us because of battery technology and solar and wind coming in, but also opportunities too".***
>
> *Large hydro company*

> ***"New technology has come into the industry, but it's hard to say whether it will create jobs or take some away due to automation".***
>
> *Medium sized engineering construction company*

> ***"We are still miles away from robotics and AI in our field"***
>
> *Medium sized engineering construction*

While companies operating in the ECI acknowledge technology is a major driver of change in industry: the bigger issue seems to be the uncertainty. This falls into two categories: 1) an uncertainty about the impact of the new technology on jobs, and 2), particularly for the smaller companies, the feeling that new technology and investment in it 'is not for us.'

> ***"People tend to take new technology up only when they've no choice. Generally it involves a lot of investment, so they've got to know they will get their money back".***
>
> *(Medium sized engineering company)*

Underpinning this is a view expressed by some, that other industries are being more affected by new technologies than the ECI. They suggest a perception that the industry is not always very technological-focussed and slow to change, although a medium-sized company pointed out that "old-school engineering is being phased out".

Another company summed up this state of mind by explaining that a prevalent view among parts of the industry is "we don't mind innovation as long as it's got a proven 10-year track record".

> ***"Investment in digital infrastructure will be very important, and there's signs of that occurring. The popular term 'Internet of Things' has been going for 10 years but finding applications for digital technology is tricky – there's lots of technology around but few serious applications."***
>
> *ECI Employer In-Depth Interview*

Craig Fox, Business Development Manager.

Furness Engineering and Technology Limited

The major drivers for change will be the ageing workforce and advances in technology.

FETL operate within the oil, gas and nuclear sectors although they work in the niche market of service rather than manufacturing. Things are looking "relatively positive for the coming 3 to 5 years"; as a business they employ 44 people and are working towards moving facilities due to expansion.

Technology is one aspect of their business which they strive to keep up to date with. Craig explains, "we are investing in drones or UAVs (Unmanned Aerial Vehicles) to complete aerial work and in 3D reality". He's seen a dramatic increase in the demand for 3D highlighting that "you can't necessarily walk through a site repeatedly to establish health and safety risks but you can build a 3D version". Craig sees these new technologies as being beneficial in terms of both time and advancement – "things which were once impossible are now possible".

While technology is a major driver for change, Craig has concerns over the impact the ageing workforce will have in the future. As a relatively small business they currently only have one UAV approved pilot who they will inevitably lose and while they are aware of this, succession planning is both costly and time consuming. Craig believes that the ageing workforce is not being addressed sufficiently industry: "It's a long-standing issue which has been going on too long, we'll lose these people along with their knowledge and skills which cannot be replaced".

36 https://www.raconteur.net/business/top-ten-construction-innovations

This uncertainty, mystique or fear of the cost surrounding technology does not appear to have impeded confidence in the future outlook of the ECI, however. As illustrated in the separate Labour Market Outlook, the majority (64%) of surveyed employers are generally confident in the future, explaining that they have seen an upturn in the amount of work and enquiries and have more projects in their order book.

The uncertainty felt by the 16% of employers less confident about the economic outlook arose primarily from the UK's impending exit from the EU rather than from the impact of technology.

Besides automation, digitalisation and robots, survey respondents mentioned a few other specific technologies driving change in ECI/ their businesses. These included battery storage/alternative means of generating and storing electricity, automating welding, and sensor technology.

2.1.2 Technological change

When interviewed, employers were asked about which technologies were emerging to be particularly important, half were unable to provide a specific answer. This was partly because they believed that technological advances would pervade on a more general level across the workforce - i.e. through increasing use of new software, digital processes and devices.

> ***"What I see in the field is that there's not a lot of technological change as welders etc. still go about their jobs in the same way, I don't see any technology changing the way the people in the field operate. In the office and planning and front-end design it's probably completely different, but on the installation and maintenance side it's still the same."***
>
> *ECI Employer In-Depth Interview*

> ***"Sustainability and digital technology I suppose but I'm not really sure on this. We work in a very specific area – unless we build a new bigger vessel things won't change."***
>
> *ECI Employer In-Depth Interview*

> ***"There's enough momentum within the industry to accommodate this [technological change], but the younger ones (20ish) who are going through their last years of their degrees will be working in ten years' time in different sectors of the industry and their roles will change, and there are roles which don't yet exist which will come to the fore. But, like engineering generally, if you look where it's gone in the last 30 years, there's a black and white difference to what facilities and design capabilities and machining technology is used."***
>
> *ECI Employer In-Depth Interview*

Employers are generally very conscious of change and the need to adapt but they are much less aware of the details and the implications. They know that profound changes are approaching but how, when and where are, as yet, unclear.

Leadership skills could be a factor in this situation, as it clear that it is at this level that such decisions on the introduction of and investment in new technologies are to be taken.

The employers who mentioned specific new technologies tended to do so based on the sub-sector of their company. Overall, no one technology stood out, but responses included basic IT through to artificial intelligence, drones, robotics/automation, 3D-modelling, advanced materials, smart systems, 3D-printing, BIM and OSM, augmented and virtual reality (AR and VR), energy from waste, and advances in welding.

> ***"The major area is about making processes simpler and quicker, therefore increasing efficiency. We are using many more automated processes. For example, offshore technicians are communicating through the use of an iPad in real time to share drawings/video etc. for instant communication and efficiency."***
>
> *ECI Employer In-Depth Interview*

According to employers, the industry's current response to technological change is extremely mixed. Only two of the companies we spoke with were strongly positive about the industry's reaction to technological change. Some employers were cautiously optimistic, believing the industry is responding reasonably, or at least as well as might be expected to technological innovations, while others felt that the industry is adapting poorly, or that there is a certain amount of resistance to such change.

Irrespective of employers' stances on this matter, one clear theme emerged from our in-depth interviews: namely, that technology comes at a financial cost and consequently a number of companies, being risk-averse, are wary of significant investment. Those same employers are also very aware that the downside to such an approach is that of being left behind, of missing the boat, and falling critically behind the curve with respect to domestic and overseas competitors.

From a skills point of view some surveyed employers highlighted the need to train technicians and operatives to a point where they can regularly use new technology with ease.

> ***"Maybe the industry has a head in the sand approach. Some workers are resistant to change – hands-on people don't want to change, and some middle-managers are protecting their jobs."***
>
> ***"Not particularly well placed - in the current climate you have to be very brave to invest in anything new and not completely proven."***
>
> *ECI employers in the survey*

Furthermore, there is a less-understood aspect to the problem of coping with change and new technology – human nature.

"Someone's going to get what's left out there in terms of oil [reserves] – the older generation in offshore do tend to be reluctant to share and impart knowledge – especially to new thinkers and the youth embracing technology – their reluctance is due to thoughts of losing their job as a result of sharing their knowledge – it is understandable but needs to be well managed."

ECI Employer In-Depth Interview

42%

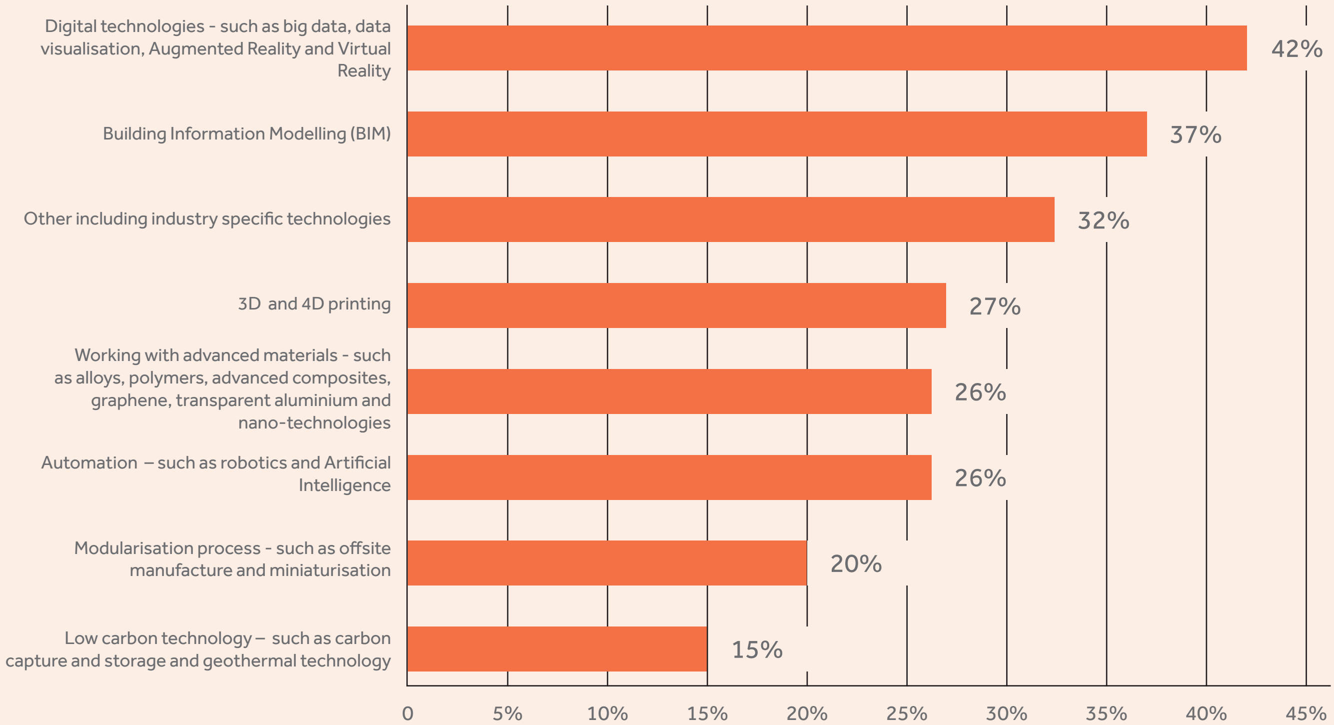
Digital technologies - such as big data, data visualisation, Augmented Reality and Virtual Reality are the currently the most adopted technologies and processes by employers

From desk research and an extensive review of reports (see Appendix 2 Bibliography), and following discussion with the ECITB, the most salient technologies were agreed upon and included in a list as the basis of the key questions posed in the survey of the industry.

These are shown in Figure 3. Provision was made for 'other' responses where needed and analysis of these showed a great variety but are mainly specialist sector technologies such as advanced manufacturing technologies for precision parts in aerospace:

- Computer Aided Design (CAD);
- Computer Numerical Control (for example: housing a range of high-end CNC machine tools that can customise key components at short notice, with agile teams able to slot them into place on cue);
- Laser technologies;
- Materials technology;
- Specialist sector technologies – such as for blade, turbines, composite technologies or air testing.

Figure 3: Technologies and processes currently used by employers



Base: 585 employers. Source: Pye Tait Consulting LMI survey for ECITB, 2018

40 AI techniques and algorithms are already used in many day-to-day technologies such as Siri and Google and if companies' staff are using these types of software they may be unaware that they are encountering AI processes in the search for work-related data.

2.1.3 Technological usage

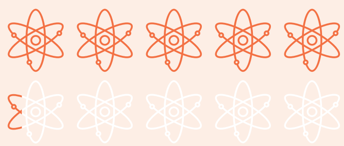
The survey indicates that four in ten employers are already using digital technologies such as big data, AR and VR (42%). This percentage is even higher in Nuclear (Fig. 4). and Scotland (Fig. 5). Some of the technologies are quite specific to certain sub-sectors, therefore it may not be surprising that relatively small proportions are currently using them (e.g. modularisation or carbon capture). Only a quarter of employers say they are currently working with technologies such as robotics and artificial intelligence[40].

This insight has been presented (Fig. 4 and 5) by sector, and then by nation (Fig. 6). These find, for instance, that the nuclear and downstream oil and gas companies lead in the use of digital technologies (52% and 49% respectively).

The food and drink sector sees most prevalent uses of 3D and 4D printing at 48% of surveyed employers, followed by employers in conventional power generation (44%). Use of advanced materials is most common in the pharmaceutical and chemical sectors with 48% of employers in each sector using available technologies, compared to only 27% of employers working in renewables.

The breakdown by nation demonstrates that companies based in Scotland are most likely to use digital technologies (49% compared with only 23% of companies based in Wales). Use of industry specific technologies is most common in Wales (42%), as is use of BIM (46% compared to only 27% in Scotland and 39% in England). Surveyed companies in England appear to use the technologies and processes mentioned in this report the least, with none of the stated technologies and processes reaching use over 39% among surveyed employers.

52%



More than half of all employers in the Nuclear sector are already using digital technologies such as big data, AR and VR

Figure 4: Technologies and processes currently used by employers – by sector (1)

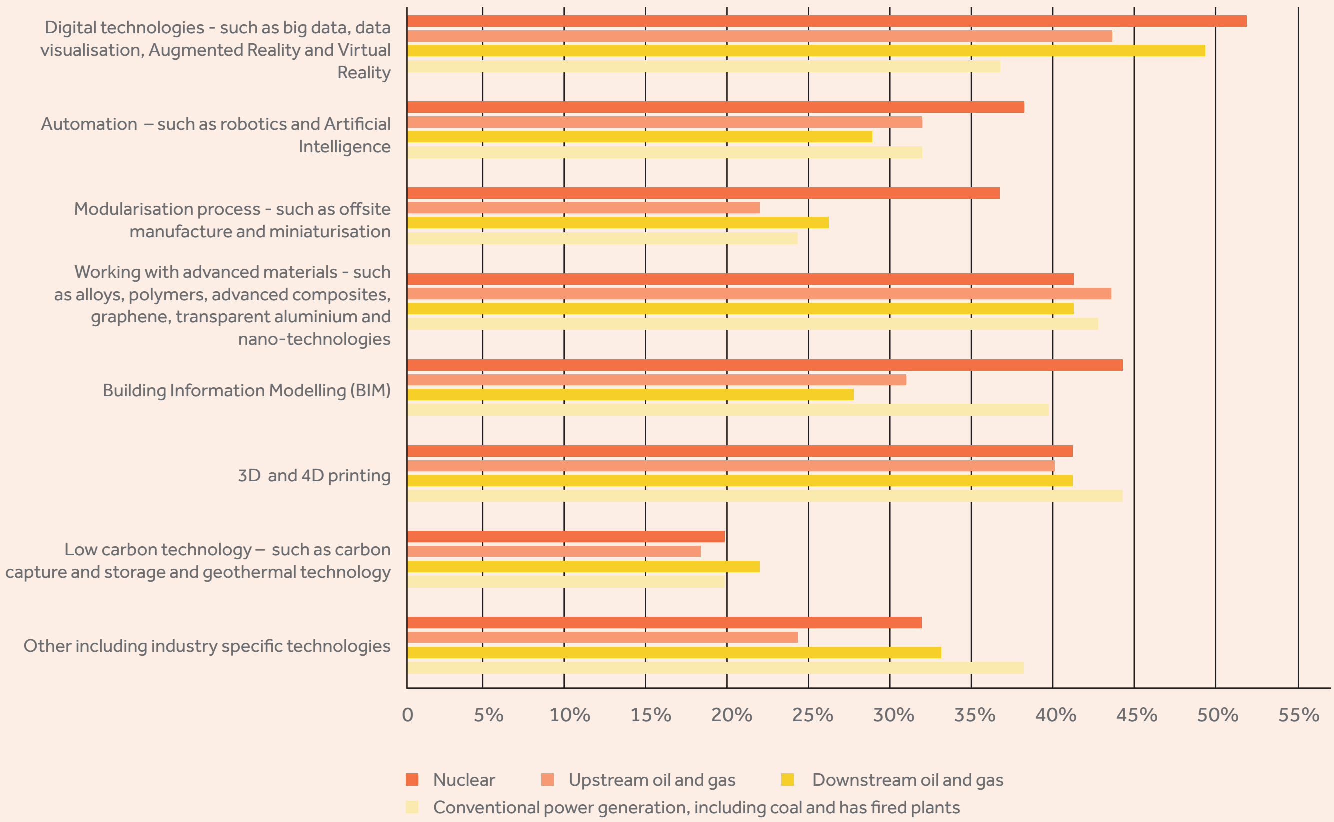
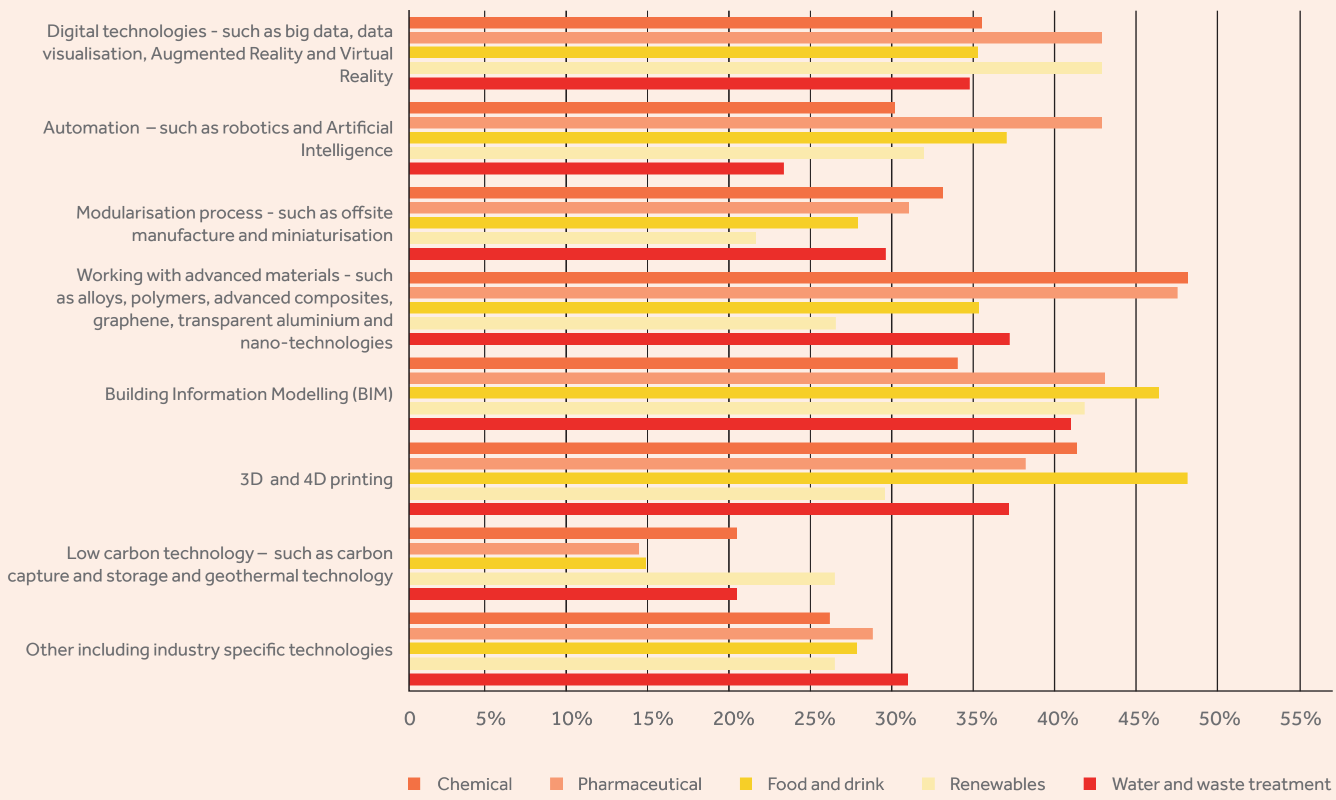
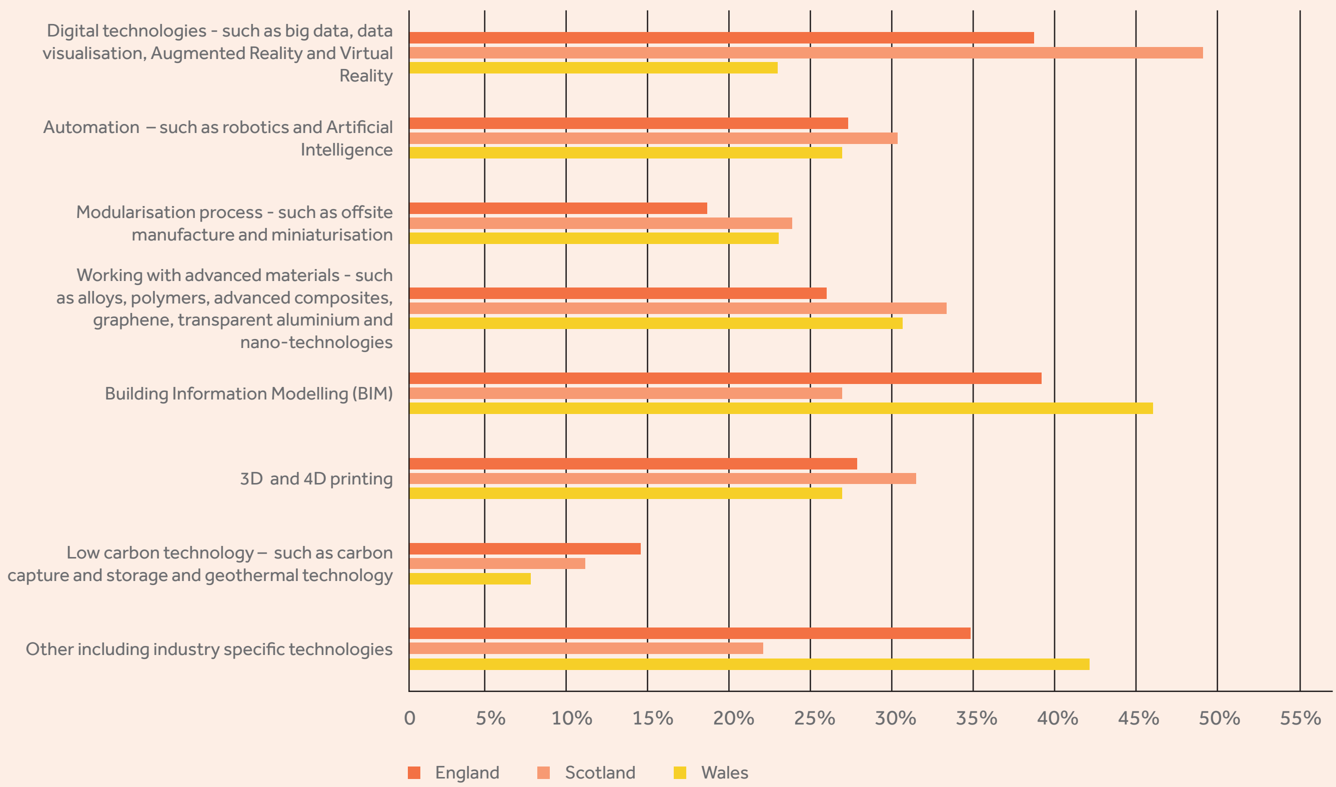


Figure 5: Technologies and processes currently used by employers – by sector (2)



Base: 829 employers. Source: Pye Tait Consulting LMI survey for ECITB, 2018.

Figure 6: Technologies and processes currently used by employers – by nation



Base: 829 employers. Source: Pye Tait Consulting LMI survey for ECITB, 2018.

2.1.4 Impact of new technologies

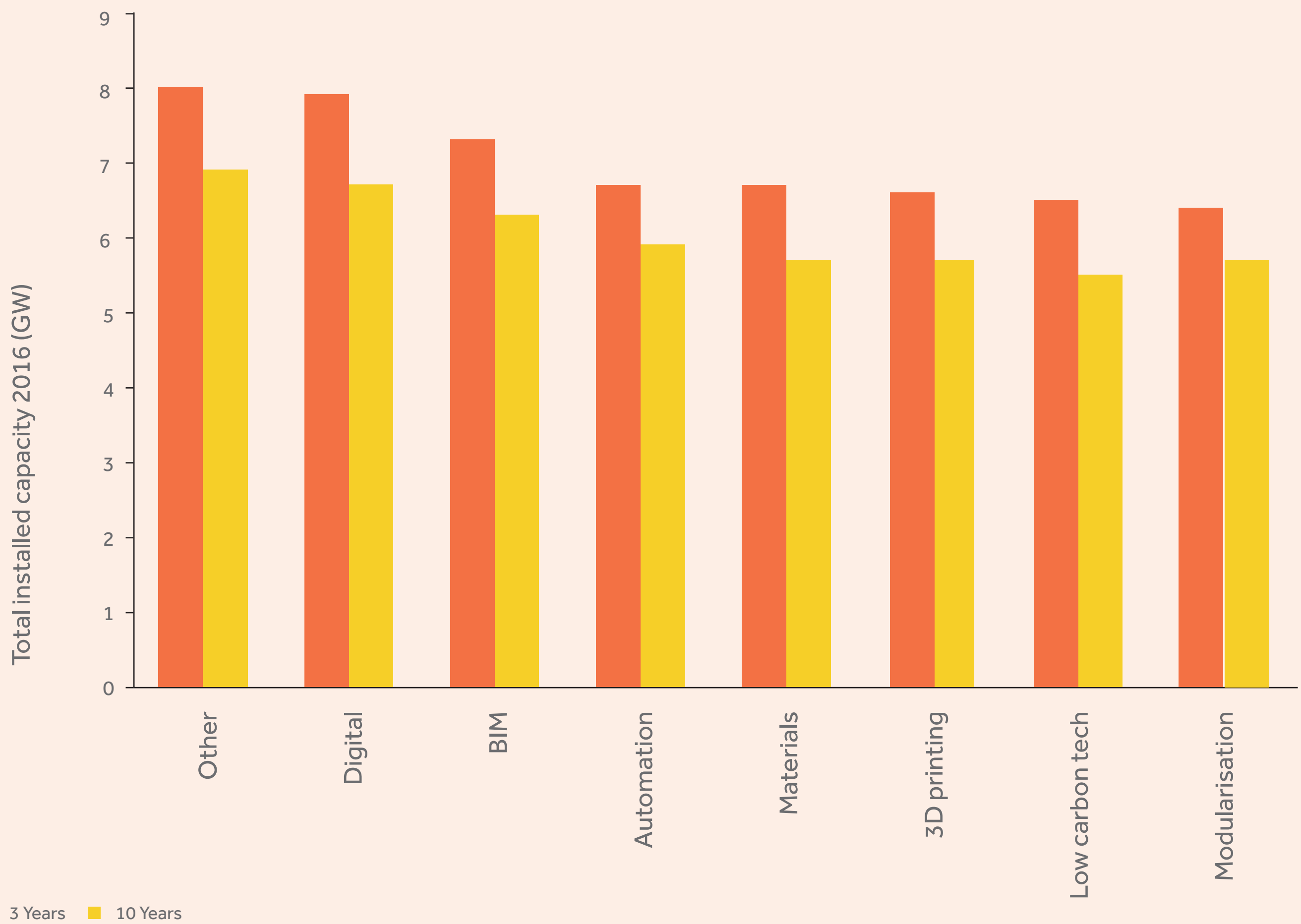
Employers were also asked to rate the expected impact of these same technologies and processes on their business over the next three years and the next ten years from 1 (no impact) to 10 (significant impact). Note that perceptual scoring is relative and should be interpreted within the context at hand. However, generally, people score up to around five for things which they regard as "no/low impact" and between 5 and 7 for things seen as "some impact". A score of between 7 and 8 is "high impact" and 9 or above "very significant impact".

Examining the responses, fig. 7 shows that technologies specific to industry sectors, categorised as 'others', are generally expected to have the most significant impact in the future. These include the increasing use of drones, electro optics and advancements in use of GPS software. Digital technologies (such as AR or VR) and BIM are the technologies next highest scoring; modularisation (for example, off-site manufacturing) and low carbon technology are predicted to have the least significant impact on the industry.

The expected impact of such technologies is predicted to be slightly lower in ten years' time than in three years' time and, on the whole, employers do not expect the ordering of technology impact to alter dramatically over that time period, as can be seen in Table 1.

Employers may rate the impact over the course of a decade as less than over the next three because they anticipate these technologies to already be well entrenched in 10 years (2028). Alternatively, employers may simply be very uncertain and therefore unwilling to score a particular technology higher or lower over the ten year timespan as is borne out to some degree in the in-depth interviews. Another reason is that there may be a large degree of lack of awareness and knowledge involved.

Figures 7: Employers' expected impact of technologies and processes in three and ten years' time



The Clean Growth Strategy: Leading the way to a low carbon future (October 2017)

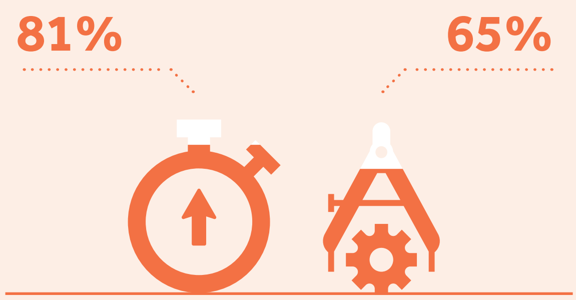
2.1.5 Anticipated impacts of those new technologies

These findings reinforce the broad findings from earlier questions that employers are generally unaware of the ways in which technologies may affect their businesses and – more importantly perhaps, the degree.

The majority of businesses expect new technologies to improve a range of generalised parameters – for example, efficiency and precision (81% and 65% respectively)

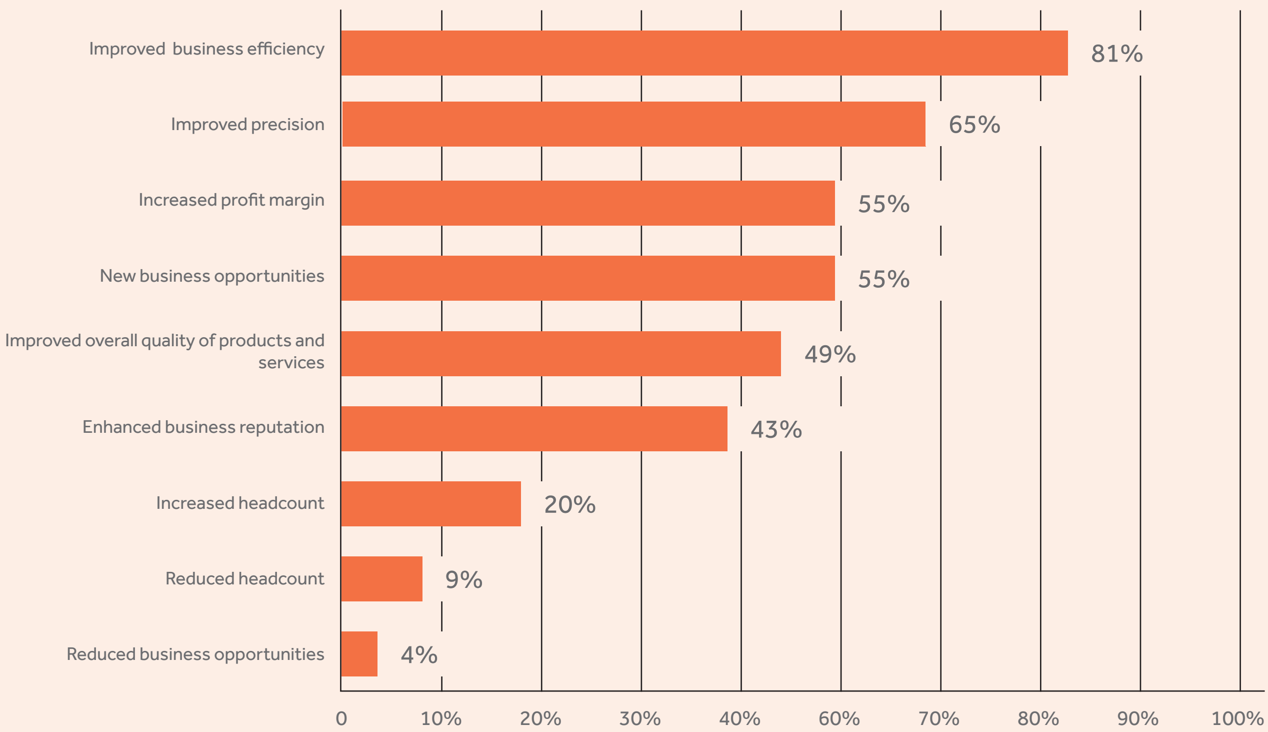
However, improvements in profitability and business opportunities are anticipated but to a slightly lesser extent (55% each). The combination of efficiency and precision is reflected in the majority of sectors and nations, especially oil and gas (upstream) (87% efficiency, 73% precision) and renewables (88% efficiency, 72% precision). There may be a need – alongside other associated research – to evaluate the extent to which genuine understanding underpins these findings.

Positive impacts of new technologies



The majority of businesses expect new technologies to improve a range of generalised parameters – for example, efficiency and precision (81% and 65% respectively)

Figure 8: Business impacts expected over the next three years



Base: 520 employers. Source: Pye Tait Consulting LMI survey for ECITB, 2018.

Analysis of business impact by sector reveals a more interesting picture with regards to headcount than the overall analysis suggests. The largest difference regarding headcount is in water and waste treatment, with 33% of surveyed employers predicting an increase in headcount over the next three years, compared to only 8% who believe that headcount will decrease.

Water and waste treatment is the sector that expects to see the largest increase in headcount, followed by employers in conventional power generation (32%). Employers in renewables expect the largest improvements in precision (88%), followed by upstream and downstream oil and gas (87% and 86% respectively).

Analysis of the business impacts by nation demonstrates that all three nations overwhelmingly expect improved efficiency (82% England, 83% Scotland, 86% Wales). Employers appear positive but cautious in predicting increased business opportunities, with only half of Scottish employers, just over half of English employers (57%) and 67% of Welsh employers believing this will be the case.

This, however, compares to only very small numbers of employers expecting a reduction in business opportunities, with no employers in Scotland expecting this and only 5% of English and 10% of Welsh surveyed employers believing this to be an impact of increased use of technology.

Headcount for the Water and waste treatment sector

Analysis of business impact by sector reveals a more interesting picture with regards to headcount than the overall analysis suggests.

In water and waste treatment 33% of surveyed employers predict an increase in headcount over the next three years, compared to only 8% who believe that headcount will decrease.

Figure 9a: Business impacts expected over the next three years – by sector

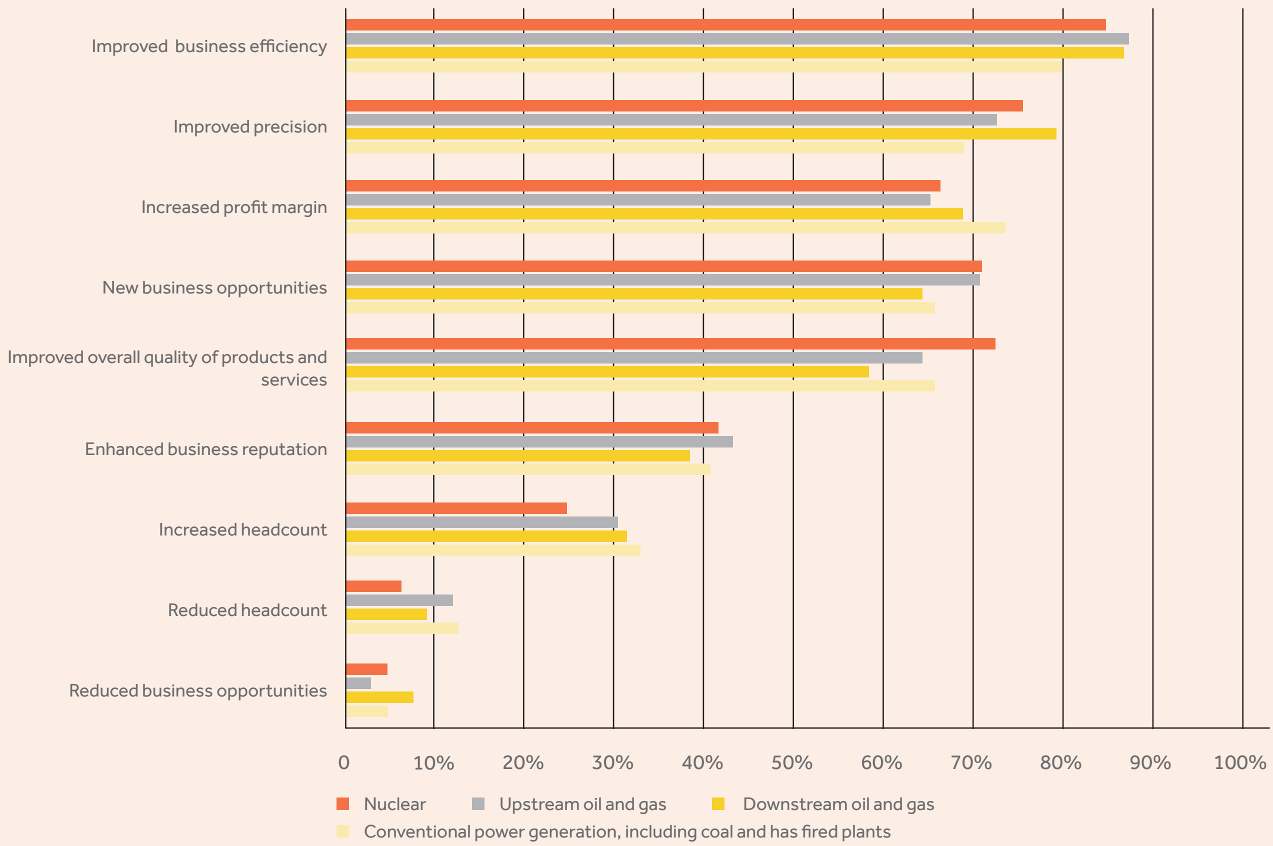


Figure 9b: Business impacts expected over the next three years – by sector

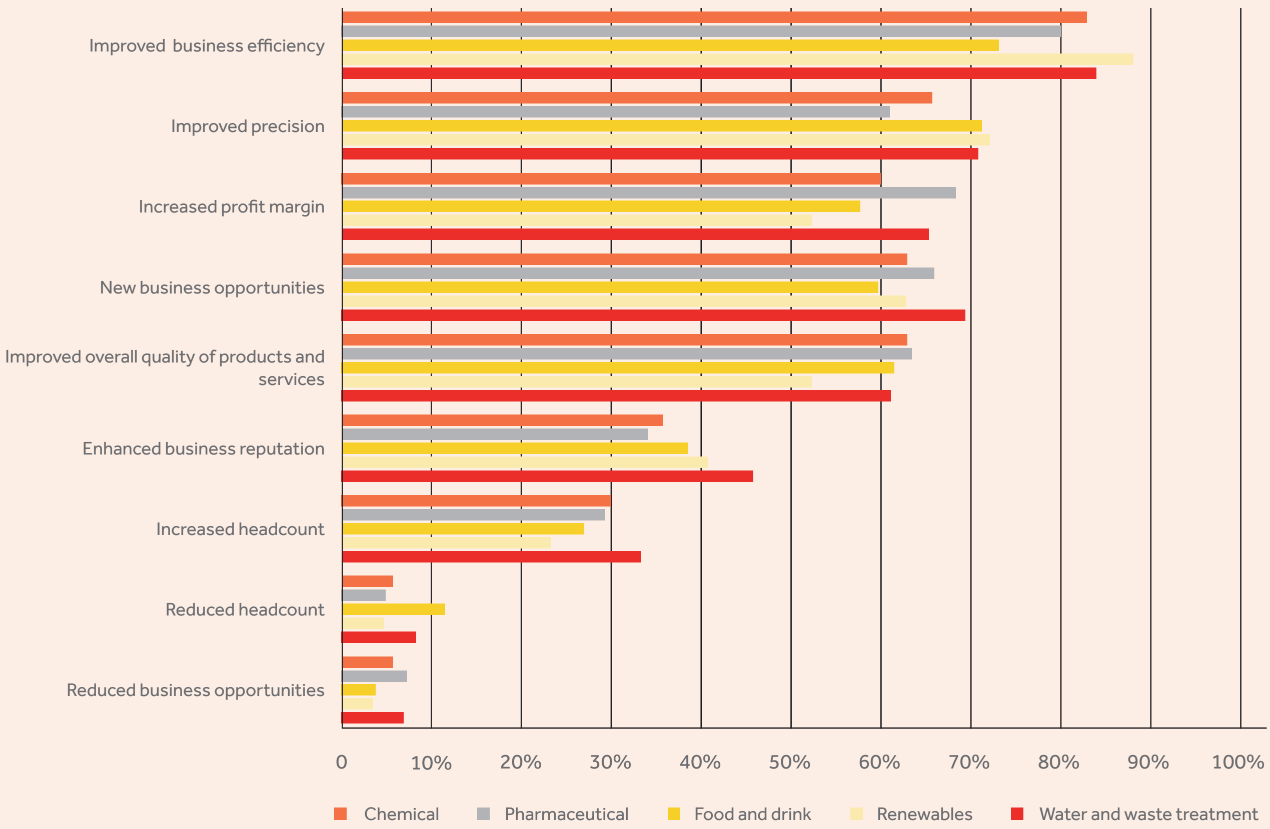
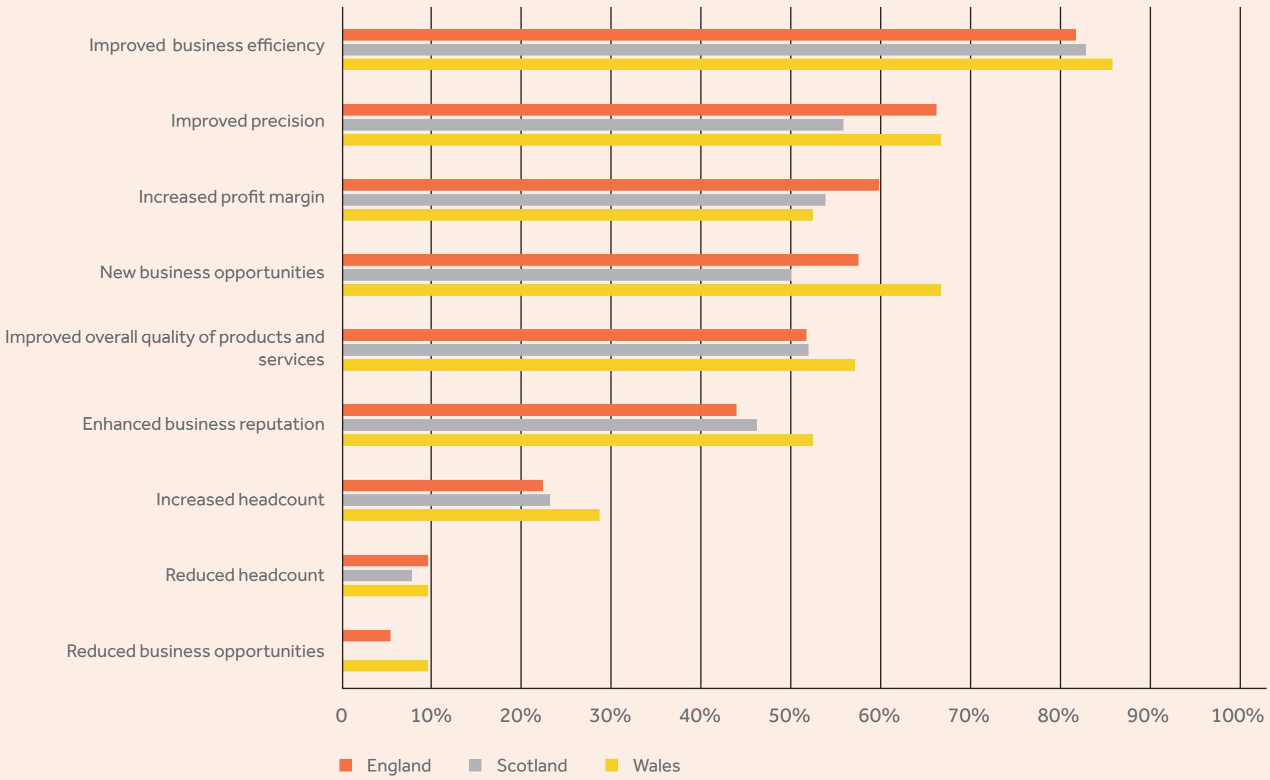


Figure 10: Business impacts expected over the next three years – by nation



2.1.6 Change in demand for roles in implementing new technologies

Table 2 shows the perceptions of ECI surveyed employers about the possible impacts of new technologies on the demand for selected job roles over the next three years. A reduction in demand is not anticipated as a direct result of new technologies and processes.

Demand for business-related directors and managers and business professionals is perceived as remaining pretty much as it is at present (68%).

Other roles, however, are expected to increase in demand. The roles deemed to be most in demand over the next three years are as follows:

- engineering-related technicians - 62% perceived increase in demand;
- engineering and science professionals – 59% increase in demand;
- skilled mechanical, electrical, instrumentation and electronic trades – 54% increase in demand;
- design and draughtspersons – 52% increase in demand;
- project personnel, including expeditors, estimators, cost engineers and planners – 50% increase in demand.

Whilst the demand for the majority of job roles in this survey are expected to either increase or remain the same, expected reductions in demand are very low. The highest expected reduction in demand is in plant and process occupations, construction operatives and design and draughtspersons, but this is only perceived at 6% each.

It is perhaps no coincidence that the top three roles, highlighted in Table 2 are also those which are the most difficult to recruit due to a shortage of available skill. In the Labour Market Outlook report, employers reported having difficulty recruiting for the following roles:

- engineering-related technicians (49%);
- engineering and science professionals (43%), and
- skilled mechanical, electrical, instrumentation and electronic trades (42%).

At the other end of the scale, directors (10%) and business professionals (7%) prove the least difficult to recruit due to skills shortages.

The table below shows the perceptions of ECI employers about the possible impacts of new technologies on the demand for those same three important selected job roles across sectors (Table 3) and nations (Table 4). Engineering and science professional roles are anticipated to be in most demand by all sectors - except pharmaceuticals and water and waste treatment where it switches with engineering-related technicians. This demand for engineering and science professionals is most pronounced in downstream oil and gas and companies in Wales.

Analysis by nation shows that engineering and science professionals are most in demand in Wales (63%) and Scotland (57%), while engineering-related technicians are most in demand in England (63%). Demand for these three job roles is generally expected to increase across all three nations, the only exception being skilled trades in Wales where most employers expect demand to remain static (55%). Reduction in demand is again perceived as very low, with employers in Scotland expecting no reduction in demand at all for engineering and science professionals, and employers in Wales seeing no reduction in demand for engineering related technicians or skilled trades.

Table 2: Impact of technology on demand for job roles over next three years

	Increase	Remain the same	Reduce
Directors and managers of business functions	19%	78%	3%
Project personnel, including expeditors, estimators, cost engineers and planners	50%	47%	3%
Engineering and science professionals	59%	37%	4%
Design and Draughtspersons	52%	43%	6%
Engineering-related technicians	62%	35%	2%
Business professionals	28%	68%	4%
Skilled mechanical, electrical, instrumentation and electronic trades	54%	44%	3%
Construction operatives	41%	53%	6%
Plant/process occupations	38%	56%	6%

Base: 829 employers. Source: Pye Tait Consulting LMI survey for ECITB, 2018.

Table 3: Impact of technology on demand for job roles over next three years – by sector

Sector	Top three job roles impacted by technological advances over three years:	Increase	Remain the same	Reduce
Nuclear	Engineering and science professionals	70%	24%	6%
	Engineering-related technicians	64%	33%	3%
	Skilled mechanical, electrical, instrumentation and electronic trades	60%	39%	2%
Upstream Oil and Gas	Engineering and science professionals	75%	23%	2%
	Engineering-related technicians	68%	29%	3%
	Skilled mechanical, electrical, instrumentation and electronic trades	62%	36%	2%
Downstream Oil and Gas	Engineering and science professionals	76%	22%	3%
	Engineering-related technicians	67%	31%	3%
	Skilled mechanical, electrical, instrumentation and electronic trades	61%	36%	3%
Conventional power generation	Engineering and science professionals	70%	27%	3%
	Engineering-related technicians	64%	34%	1%
	Skilled mechanical, electrical, instrumentation and electronic trades	64%	33%	3%
Chemical	Engineering and science professionals	70%	27%	3%
	Engineering-related technicians	66%	33%	2%
	Skilled mechanical, electrical, instrumentation and electronic trades	53%	46%	2%
Pharmaceutical	Engineering and science professionals	70%	26%	4%
	Engineering-related technicians	71%	24%	4%
	Skilled mechanical, electrical, instrumentation and electronic trades	55%	42%	3%
Food and drink	Engineering and science professionals	70%	27%	4%
	Engineering-related technicians	61%	39%	-
	Skilled mechanical, electrical, instrumentation and electronic trades	53%	45%	2%
Renewables	Engineering and science professionals	71%	24%	5%
	Engineering-related technicians	68%	31%	1%
	Skilled mechanical, electrical, instrumentation and electronic trades	57%	40%	3%
Water and waste treatment	Engineering and science professionals	63%	32%	5%
	Engineering-related technicians	64%	35%	1%
	Skilled mechanical, electrical, instrumentation and electronic trades	58%	39%	3%

Table 4: Impact of Technology on demand for job roles over next three years – by nation

Sector	Top three job roles impacted by technological advances over three years:	Increase	Remain the same	Reduce
England	Engineering and science professionals	60%	37%	4%
	Engineering-related technicians	63%	34%	3%
	Skilled mechanical, electrical, instrumentation and electronic trades	56%	41%	3%
Scotland	Engineering and science professionals	57%	44%	-
	Engineering-related technicians	54%	44%	2%
	Skilled mechanical, electrical, instrumentation and electronic trades	50%	48%	2%
Wales	Engineering and science professionals	63%	29%	8%
	Engineering-related technicians	52%	48%	-
	Skilled mechanical, electrical, instrumentation and electronic trades	46%	55%	-

Predictions vary for the demand in engineers across the ECI as a whole. For instance, one recent study reported that demand for engineers will grow until 2022, with the nuclear sector most in need of skilled workers in roles such as nuclear safety, control and instrumentation, commissioning engineers, site inspection and electrical engineers[41]. However, other reports suggest that demand has been, and will remain, flat. That said, there are predictions that 250,000 workers will require up-skilling or re-skilling by 2024; such new skills will, of course, include digital and technological skills like BIM but it is unclear to what extent the full implications of disruptive technology has been taken into account in these forecasts[42].

More and more companies are appointing 'Directors of Change' and, while many are biased heavily towards change management from an organisational and workforce point of view (that is, the management of existing change and generic preparation for changes in the future), there is potentially a need in sectors such as engineering construction for a more technically-focused role.

Technology Change Directors or Managers would have a more operational responsibility in terms of seeking out and evaluating new technologies (some of which may not be specific to engineering construction) and making recommendations and business-cases to their Boards as to whether, when and how to adopt them.

2.1.6 Challenges in implementing new technologies

When businesses were asked about the main challenges they face in adopting new technologies and processes, the main factors cited were the lack of time to make big changes (34% of employers) and the lack of finance/ resources (30%).

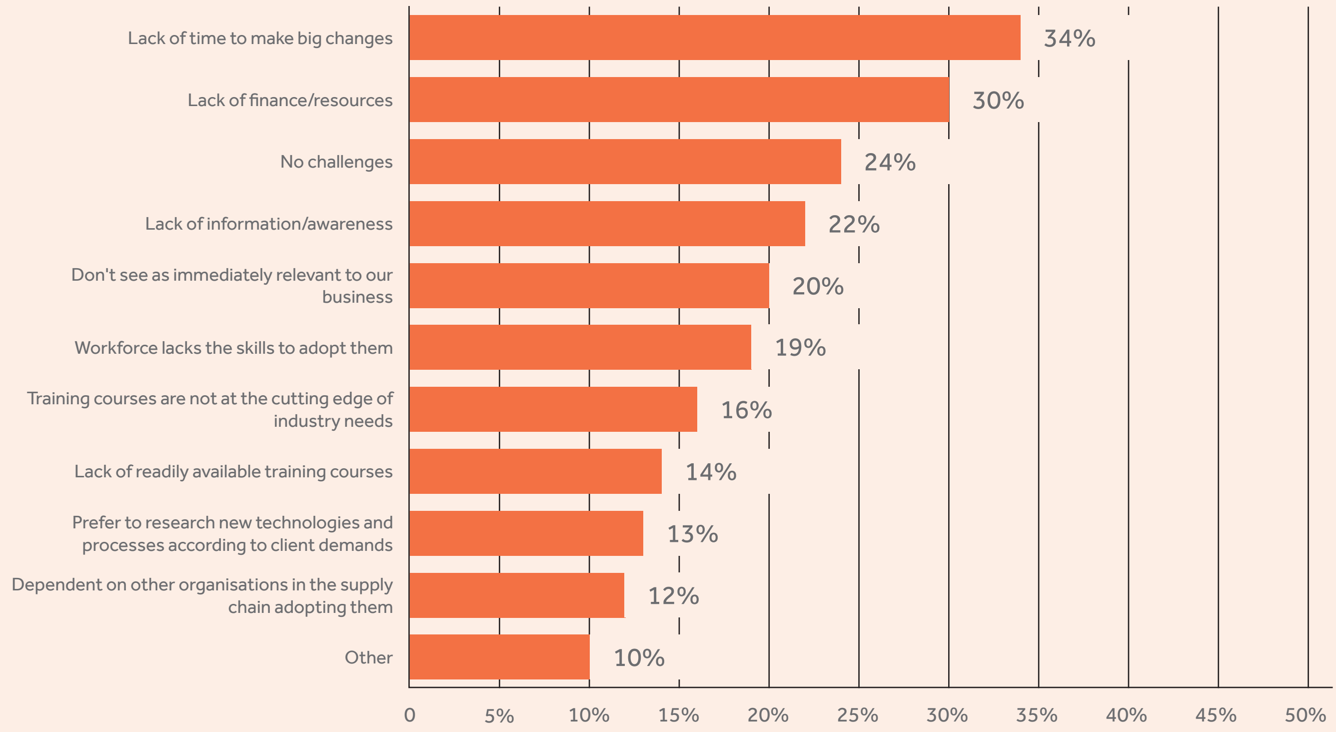
While a quarter of employers feel there are no challenges at all and one fifth do not see any relevance to their business, and the same proportion mention a perceived lack of information. This indicates a considerable lack of understanding within the industry of the potential for new technology and the costs and benefits thereof. A small amount of employers interviewed in-depth also raised concerns about skills shortages, and the need to train operatives to a point where they can regularly use new technology with ease. These views are reflected in the wider survey with 19% of employers citing a lack of skills in the workforce to adopt new technologies, 16% with the view that training courses are not up to date in technologies needed by industry and 14% of employers citing lack of readily available training courses.

The overall analysis demonstrated that the greatest challenge in adopting new technologies is a lack of time; sectoral analysis shows that this is most prevalent in the food and drink sector, with 55% of employers in the sector citing this as their greatest challenge. The nuclear sector feels most strongly that its workforce lacks the skills needed to adopt new technologies (30% of surveyed employers). The greatest lack of awareness of new technologies is in conventional power generation (32%), and this sector also has the greatest perception that there is no immediate relevance of new technologies to the business (35%).

The analysis by nation shows surveyed employers in Wales as most likely to feel the greatest number of challenges in adopting new technologies, particularly in terms of a lack of time to implement changes (49%) and a lack of finance (41%).Employers in Scotland were more likely to cite dependence on organisations in the supply chain adopting new technologies (23%), whilst the largest number of employers citing no challenges were based in England (24%).

41 ECITB, 2018, *Engineering Today: The supply and demand for engineers in the UK*
42 Infrastructure and Projects Authority, *National Infrastructure Delivery Plan 2016-2021*

Figure 11: Challenges in adopting new technologies



Source: Pye Tait Consulting LMI survey for ECITB, 2018.

Figure 12: Challenges in adopting new technologies – by sector (1)

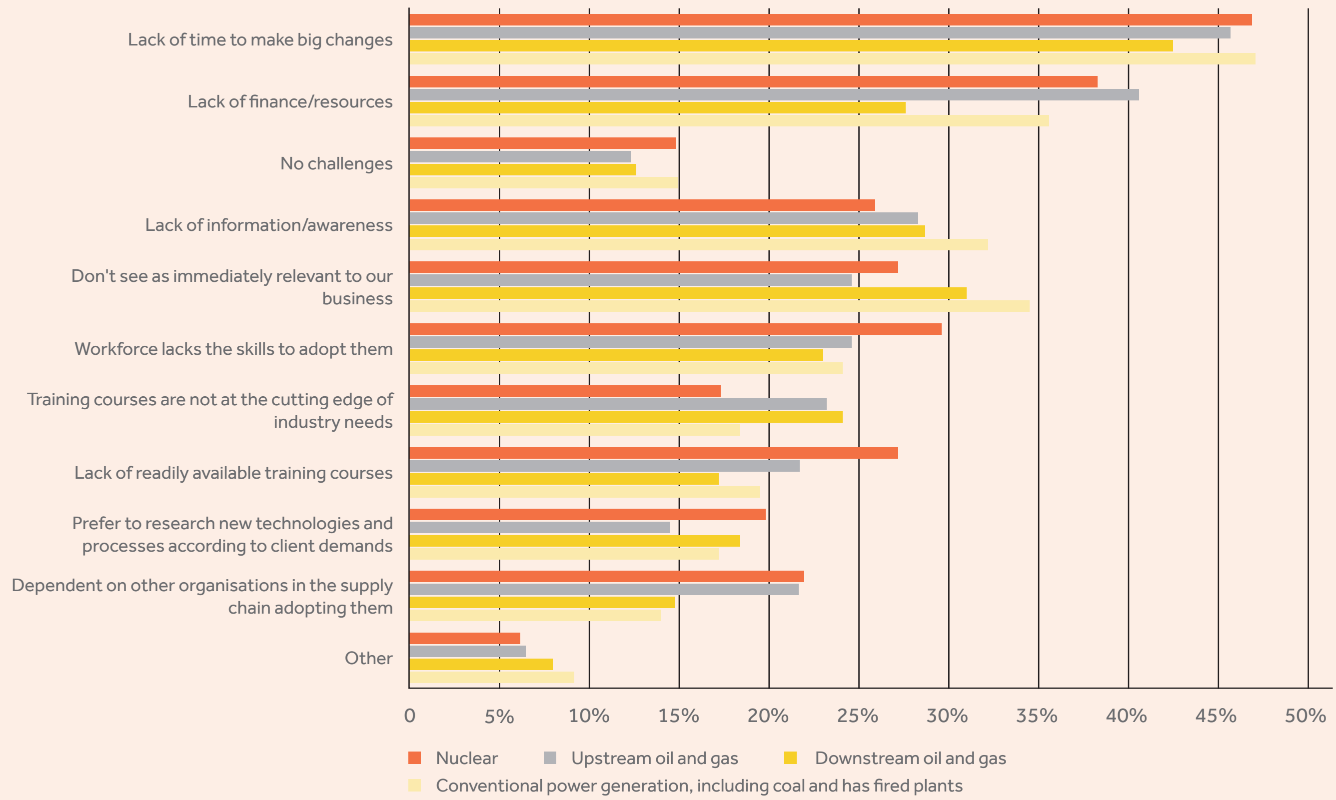


Figure 13: Challenges in adopting new technologies – by sector (2)

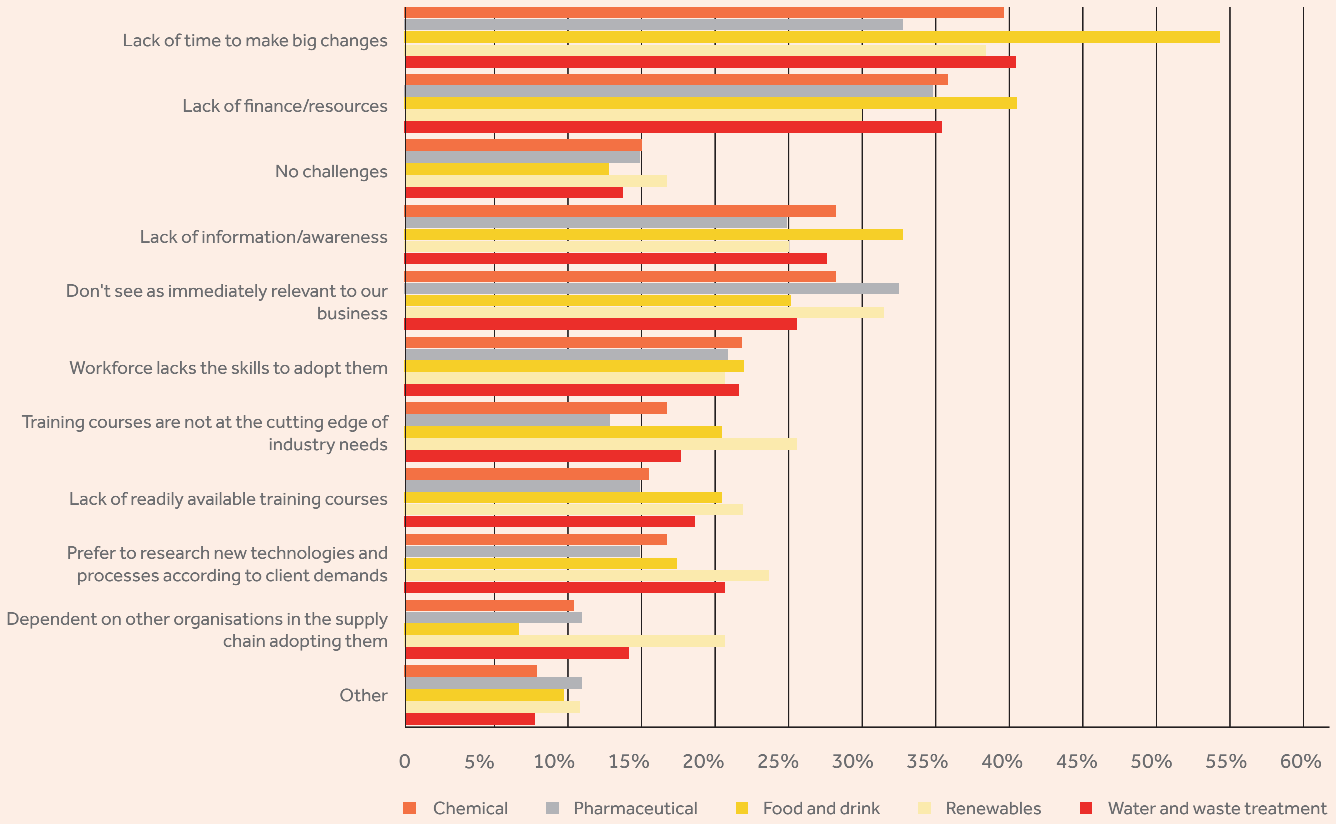
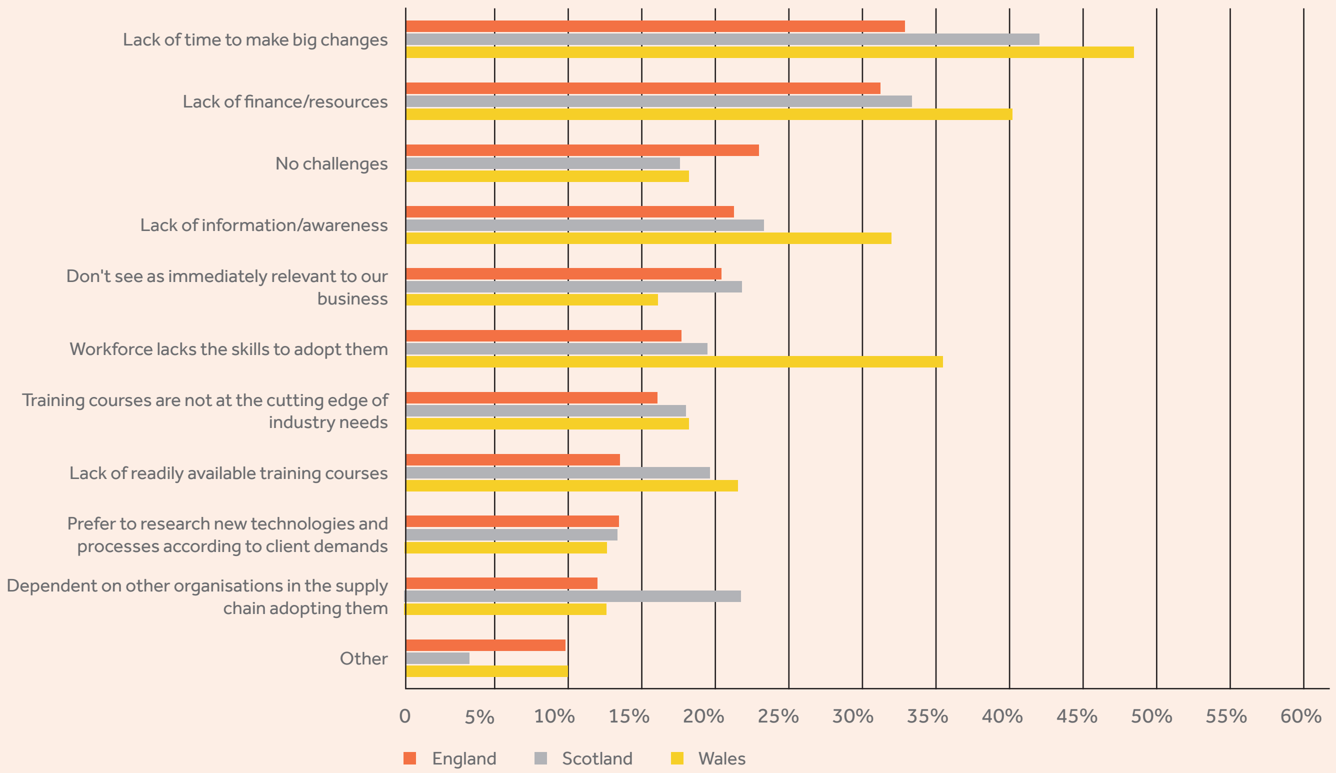


Figure 14: Challenges in adopting new technologies – by nation



2.2 Training provision and technology

Employers in the survey pointed to a reasonable degree of concern about education and training provision.

In their view, providers, through no fault of their own, are in many cases not as up-to-date in technology and skills as the employers would wish; this is further supported by around one third of those employers interviewed in-depth who also expressed some dissatisfaction. Their main concerns with provision related to general and widespread issues that are not specifically tailored to engineering construction, but aspects such as insufficient training of young people to replace retirees, the costs to the business such as the trainee being away from the business, and relevance of the training to the business.

On this last point some complained about being able to find much generic training but insufficient technology training relevant to their type of work. 3D modelling was cited by many as an area where they anticipate a need for skills, prompting more training and therefore funding. One company felt that further education is trying to be all things to all people and lacks focus. Another felt that the main issue is the time lag involved with technology permeating through training development and delivery.

> *"We hear about placing emphasis on the tech aspects of education, but this will take a long time to filter through. The status of technical training is still low."*
>
> *ECI Employer In-Depth Interview*

The discussions with a limited number of further/higher education providers in the ECI confirm that the industry is facing significant technological transformation. While emphasising developments in robotics and automation, education and training providers are more concerned about present funding resources, which in turn results in challenges in getting access to emerging technologies for training purposes and upskilling the teaching workforce. With average salaries being lower in the FE/HE sector than the industry standard, providers also face difficulties attracting and keeping tutors.

Three of the eight provider respondents gave general information about the need to train young people in the use of 'hands on' skills as well as ensuring creativity and flexibility with regard to adapting new technologies. The main concerns of the providers centred on general funding issues for new technology equipment, which makes training of new technologies difficult. In addition, further funding would be needed to offer competitive salaries that could attract talent from the industry.

Other ECITB research similarly points to data manipulation and big data analysis becoming more common and, with change happening so rapidly, employers are struggling to keep up-to-date to continually reskill workers[43].

David Robinson, Director, L A Design

Investment - in technology and in people - is required amidst shifting industry expectations and perceptions

L A Design is a small industrial design and product development consultancy. David feels the outlook for the engineering construction industry is rather uncertain. "Uncertainty around Brexit has given hesitation to fresh investment. My concern is the lack of investment in manufacturing for economic production; there's more investment in China and India now, and there's a slight lethargy perhaps in the UK; it requires big investment."

Such investment might be targeted at new and emerging technologies. Up to now these have perhaps lacked meaningful use in businesses, but David believes that change is afoot: "Investment in digital infrastructure will be very important, and there are signs of that occurring. Augmented reality, virtual reality and simulation are all great communication tools and they're moving away from novelty value to finding genuine applications, like remote servicing and analysis."

To get the most from technology, a sufficiently skilled workforce is required, and David feels more could be done in the education system to bridge the gap between theoretical and practical knowledge. "There's been a very strong focus on learning digital tools, but there's a bit of a reality gap between digital tools and real-world examples; not everything can be done by putting a finger on a screen. Putting some industry experience back into the education system could be beneficial: being able to apply these skills to real-world activities does take time."

Softer skills are equally important to success in business, and David believes younger people can lack these. "They're dialled into the latest technologies, but this comes at the expense of more pragmatic knowledge like economics, working to a budget – dull things like that – or the importance of relationship management. Without those, no matter how skilled you are, things can fall apart quickly. That's experience, not education."

Expectations have also shifted around the way in which work is conducted. David comments: "The location of a business is increasingly irrelevant, as so much work is performed remotely with desktop sharing. Now there's an expectation to work remotely, or a great deal of it without face-to-face contact, though I'm not sure that's always healthy. Digital mobility has become more important than physical mobility." David has faced challenges on this issue of digital literacy, notably with more experienced people in the industry who are apparently resistant to embracing change. "There are still some very skilled people who would be more useful if they could embrace some newer technology, but they struggle or are afraid of it. It's difficult to invest in someone who's reluctant to change. There are lots of things that could enhance what they do, but there's a bit of a fear factor."

43 ECITB, 2018, Grants Consultation, Summary of Results
44 Opito, 2018, UKCS Workforce dynamics 2018-2035; p.4, p.11; p.15
45 Opito, 2018, UKCS Workforce dynamics 2018-2035 p.3; p.10
46 https://www.hartenergy.com/exclusives/new-oil-177195?utm_source=Internal&utm_medium=Reccomended%20Content&utm_campaign=reccoengine&utm_content=new-oil-1720651
47 https://www.ogj.com/articles/2018/07/woodmac-32-billion-to-be-spent-on-decommissioning-worldwide-in-5-years.html

2.3 Sector technological skills impacts

2.3.1 Oil and Gas

As part of a detailed review, the oil and gas industry body, OPITO, predicts a growing separation between expertise and execution in job roles most in demand. With new technologies in augmented reality, simulation and real time information sharing, many tasks will in the future be managed remotely from onshore facilities. This is envisaged as resulting in growing demand for a future workforce skilled in data science and engineering, data analytics and management, data systems and governance, data security, artificial intelligence, remote operations, robotics, and new materials[44].

The technical roles in the oil and gas sector include chemical/process, electrical, mechanical, naval/marine engineering. Together they represent 73% of all jobs with the remaining 27% engaged in supply management, procurement and HR, etc. OPITO classifies the sector's workforce into 23 job families and has estimated the likely disruptive impact of technological transformation on skills and the nature of the roles carried out. In its analysis, the only sector-specific job family that will be significantly affected with a risk of over 40% of activity displacement will be drilling/wells. They anticipate that other sector-specific roles such as operations and technicians will be moderately affected, while engineering and projects will only be marginally affected with a less than 10% likelihood of displacement. Conversely, non-sector specific roles such as finance, logistics or data management are predicted to be highly affected[45]. Job characteristics within the sector's job families will also change with the risks of automation and digitalisation.

Although not immediately of great impact in numerical terms, the increasing use of sub-surface drones and robots will not only lessen the need for human divers and manned submarines, but will also increase industry demand for digital technicians and analysts. Remote sensors and drones will also increase the amount of raw data coming into companies and, hence, the need for technicians. In addition, by reducing costs and (possibly) making a larger number of gas and oil wells accessible the process may further increase the numbers required of such staff.

However, despite growing cross-cutting trends towards digitalisation, only 5% of data gathered is actually used in the industry. Nevertheless, 54% of companies have reported that they are making efforts to harness digital technology[46].

Skills and workforce demands in this sector will also be partially driven by the needs of decommissioning projects. The UK accounted for 16% of all oil fields that ceased production between 2013 and2017 and up to 700 fields could cease production from 2018 to 2023, depending on raw material prices[47]. Spending on decommissioning increased by 48% in 2017.

Decommissioning is expected to be a growing market for the industry, with up to £47bn (2016 prices) needed by 2050 for decommissioning projects on the UK Continental Shelf[48]. In the medium term, around 349 projects (e.g. ageing platforms, etc.) are to be decommissioned in the North Sea between 2017 and 2025. Over this period, approximately £17bn will be spent on decommissioning with the largest share (£8.3bn or 49%) of the expenditure concentrating on plugging and abandonment (P&A)[49].

Over the next ten years, a further 100 platforms and 7,500 kilometres of pipeline in the UKCS will be subject to decommissioning[50]. Envisaging a yearly decommissioning expenditure of £2.5-2 billion over the next decade, the Oil and Gas Authority has introduced a decommissioning cost reduction target of 35% together with related benchmarks. With the industry gaining more experience in this field, the overall decommissioning cost for all assets in the UKCS has already decreased from £59.7bn top £55.7bn in 2016 prices[51].

2.3.2 Nuclear

In the context of the UK Industrial Strategy, the UK Government published the 2018 Nuclear Sector Deal, which aims to boost the industry by investing £200m. This includes £32m for an advanced manufacturing program and to promote gender diversity in the workforce with a target of increasing the proportion of women working in the sector from 22%-40%[52].

A large part of the workforce in the nuclear industry is due to retire in the coming years, with an average worker's age of 54. Between 2017 and 2021, workforce demand is set to increase from approximately 88,000 to over 100,000. Overall, an intake of 7,000 FTE per year is predicted. This will have large skills implications but potentially for the positive if the younger generation coming through have accepted and are ready for the impact of technological impact.

A previous ECITB report revealed that specific skilled occupations, such as high integrity welders and specialist lifting technicians, were in high demand due to the length of training and the small labour pool of qualified workers[53]. Mechanical and electrical engineers were also highlighted as being in demand. All these roles are particularly vital for the nuclear industry, especially so with the construction of Hinkley Point C. They also mirror the latest findings in the 2018 report that technically skilled roles are the most difficult to recruit.

Similar to other ECI sectors, the nuclear energy industry is on the brink of a major digital transformation. At the surface, this means being affected by new UK government regulations in construction. In 2013, the UK government published a new vision for the UK's nuclear industry– 'The UK's Nuclear Future' - in which the use of BIM in the nuclear sector is being promoted

48 *OGA (2016), Technology Strategy, p.10*
49 *Oil & Gas UK (2017), Decommissioning Insight, pp.5-11*
50 *https://oilandgasuk.co.uk/wp-content/uploads/2017/03/Stefan-Ricketts.pdf*
51 *https://www.ogauthority.co.uk/news-publications/news/2018/cost-of-uk-oil-and-gas-decommissioning-is-reducing/*

52 *Nuclear Skills Strategy Group, 2017, Nuclear workforce assessment 2017 summary, p. 6-8; House of Commons Briefing Paper (November 2018), New Nuclear Power, p.22*
53 *ECITB, 2015, LMI report*
54 *HM Government, 2013, The UK's nuclear future p.45*

To this end, the Government set-up the working group 'BIM4Nuclear', enabling developers to apply the technology to the nuclear sector and to ensure its application in the full supply chain.[54]

This initiative ties in with the Government's requirement of BIM use for all public procured projects from 2016. This means that BIM skills will be essential in the construction and planning of nuclear power plants.

In addition, major digital transformation processes are expected regarding the operation, performance enhancement and maintenance of nuclear power plants. For instance, the major French operator of nuclear power plants, Energie de France (EDF) is developing related digital solutions involving big data management, artificial intelligence, a virtual power plant generated by digital twinning and remote access to central operational and safety functions[55]. As critical infrastructure and being of growing importance to the UK low carbon energy security, nuclear power plants are a prime target for cyberattacks. Indeed, in 2017, several nuclear power plants in the United States were targeted by a cyberattack, while in the same, the decommissioning process of the Chernobyl Plant was disrupted by ransomware[56]. Furthermore, increased need for skills in robotics has been confirmed for managing the UK's nuclear waste stockpile in the future, deemed unsafe for humans as well the decommissioning of the UK's ageing nuclear reactor fleet[57].

The 2019 Global Energy Talent Index (GETI) report confirms that operators in the industry are planning to upskill the existing workforce for new technologies. In addition, this means a lower need for nuclear specialists, resulting in more openness in the sector to hire workers with a non-nuclear background[58]. The updated Strategic Plan of the Nuclear Skills Strategy Group in the UK confirms that: "…developments in robotics, machine learning and general applications of modern electronic process control are likely to change the skill profile and the working practices of the nuclear workforce"[59]. However, the plan, produced in close coordination with the Nuclear Innovation and Research Advisory Board (NIRAB), does not yet identify any clear links between new technologies and future skills sets. Thus, from the UK perspective, the nuclear sector, while recognising the importance of new technology, is at present more focused on immediate workforce needs, such as ensuring numbers are to complement by 2021. Nevertheless, the above examples point to a trend of a workforce with a more generic, non-sector specific, skills-set with a solid grounding in digital and automation technologies as well as cybersecurity, which may have an effect on the workforce composition.

2.3.3 Offshore wind power/Renewables

As of 2018, around 10,000 workers are directly employed in the UK offshore wind power sector.

This number is estimated to increase to 36,000 by 2032. Scotland will experience the largest growth in employment (+6,400), followed by East of England (+6,150), Yorkshire & Humber (+5,750) and the North East (+4,050). Employment demand will be strongest for technicians and engineers, with an estimated additional requirement for 10,200 by 2032.

It is not expected that decommissioning of old facilities will result in a workforce growth. Broadly speaking, the entire electricity sector is facing skills shortages, with 12 of 13 related occupations in the sector presently on the UK's Shortage Occupation List[60]. Critical skills areas needed for the future offshore wind industry alone include engineers, asset managers, project managers, and general leadership skills.

As fossil fuel use decreases and renewable energy use becomes ever more common, the demand for skilled engineers in the energy sector will increase. There is increasing focus on energy storage surrounding renewable technologies, like solar and wind power, with pumped hydro and advanced batteries at the top of the list. However, regardless of progress on battery storage, forecasts suggest that advances in both coverage and technology will drive the demand for skilled engineers in the renewables sector[61 62].

In the wider renewables sector, shortages[63] persist and in many different types of engineering roles, for example: design engineer, commissioning engineers, protection engineers, proposals engineers and control engineers are just some of the shortages predicted in the UK Shortage Occupation List.

Corresponding data for the other renewable energy sectors were not available, however the broader skills implications for the electricity sector will affect these sectors in a similar way.

Similar to the nuclear sector, the renewable energy sector acknowledges the profound implications of technological innovation. Again, big data, robotics, artificial intelligence and cybersecurity are seen as pivotal factors for the sector's future transformation.

Overall, this sector is more immediately concerned with medium-term skills gaps and skills shortages[64], particularly in the STEM sector, dominated by engineering (55%). Regarding soft skills, problem-solving (27%) and process management (24%) are viewed as most pressing[65]. As such, a long-term strategy that streamlines education and skills training in line with sector needs is called for, but future skills developments are thus far only hinted upon and recognised as a future challenge[66].

55 *https://energiforskmedia.blob.core.windows.net/media/23875/digital_performance_enablers_edf_morilhat.pdf*
56 *https://www.pwc.com/us/en/industries/capital-projects-infrastructure/asset-classes-sectors/nuclear-power-industry/nuclear-cyber-security.html*
57 *https://www.themanufacturer.com/articles/university-of-birmingham-establishes-national-centre-for-nuclear-robotics/*
58 *GETI, The Global Energy Talent Index Report 2019, pp.80-81*
59 *NSSG, Strategic Plan Update Winter 2018, p.16*
60 *Energy & Utility Skills, 2018. Skills and labour requirements of the UK offshore wind industry p.30*
61 *National Grid, 2017, Enhanced frequency control capability*

The UK Government's Artificial Intelligence Sector Deal announces investment of £93m in artificial intelligence and robotics for the offshore and nuclear energy sectors as well as "£406m in skills, with a focus on maths, digital, and technical education"[67].

There is, however, generally no clear link to sector-specific future skills sets. Nevertheless, it can be presumed that members of the future workforce will need to have been trained in the application of the above technologies.

2.3.4 Pharmaceutical industry

According to the Association of the British Pharmaceutical Industry (ABPI), as of 2016, the UK's pharmaceutical workforce consisted of 63,000 workers, of which 24,000 worked in Research and Development[68]. The recent survey by the APBI of 2015, indicated that respondents were concerned about skills shortages amongst graduates entering and working in the sector. This was explained as a result of a relatively low number of STEM graduates in the UK.

On the other hand, few respondents reported skills shortages in non-graduate occupations, which comprise the majority of the workforce. Other concerns included soft-skills such as communication or team-working[69].

The sector will be heavily impacted by automation and robotics and will require significant new entrants skilled in big-data and other related digital technologies.

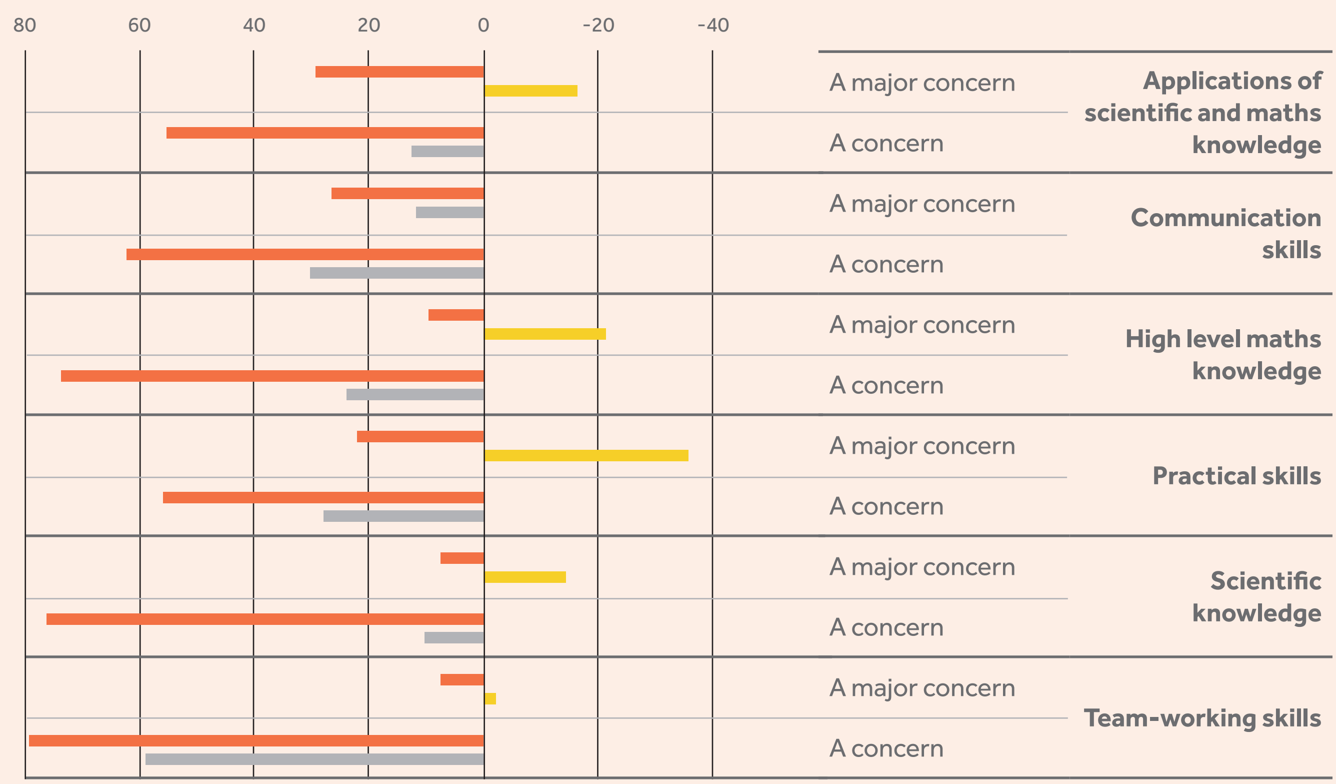
2.3.5 Chemical industry

As of 2016, the UK chemical sector directly employed 99,000 workers[70]. The sector is highly dependent on STEM skills and faces problems to fill technical and professional roles. This includes a shortage of science and engineering skills.

For Scotland in particular, a shortage of apprentices in the sector has also been reported. In general, the sector has to compete with other sectors in which STEM skills are very important[71].

Much of the requirements for the ECI elements will, as with food and drink, focus on design and draughting, process engineering, construction, new materials, robotics, and to a lesser extent big data.

Figure 15: Percentage of respondents rating each competency as a concern or a major concern



Source: ABPI, Bridging the skills gap in the biopharmaceutical industry

62 Engineering UK, 2018, *The state of engineering*
63 Energy & Utility Skills Partnership, 2018, *Many Skills One Vision, EU Workforce Renewal and Skills Strategy: 2020. (electricity-specific),*
64 CEDEFOP, 2018, *Skills for green jobs: an update, United Kingdom*
65 GETI, *The Global Energy Talent Index Report 2019, pp.80-81*
66 CEDEFOP, 2018, *Skills for green jobs: an update, United Kingdom*
67 HM Government, 2018 *Industrial Strategy Artificial Intelligence Sector Deal, p.7*
68 *https://www.abpi.org.uk/facts-and-figures/uk-pharmaceutical-market/biopharma-employment-figures-in-uk/*
69 *https://www.abpi.org.uk/media/1365/skills_gap_industry.pdf, p.33-34*
70 *https://www.parliament.uk/documents/commons-committees/Exiting-the-European-Union/17-19/Sectoral%20Analyses/7-Sectoral-Analyses-Chemicals-Report.pdf, p.3*
71 *https://www.skillsdevelopmentscotland.co.uk/media/35667/chemical_sciences_digital_skills_investment_plan.pdf*
72 *https://www.fdf.org.uk/publicgeneral/FDF-GT-Exec-Summary.pdf, p.3*
73 *http://natwest.contentlive.co.uk/content/food-and-drink-sector-faces-labour-shortage;*
74 *https://www.fdf.org.uk/publicgeneral/FDF-GT-Exec-Summary.pdf, p.7*

2.3.6 Food and Drink

Overall, the food and drink sector in the UK employs 400,000 people[72]. One third of the UK food and drink workforce is due to retire by 2024, resulting in a shortage of 140,000 workers. In terms of skills, 30.8% of employees are low-skilled, 36.7% are semi-skilled, requiring experience and training and 32.5% are skilled or highly skilled at graduate or PhD level[73].

Low skilled roles usually include food preparation and logistics and are considered easy to fill. On the other hand, for technical, engineering and research and development roles, the sector faces significant problems in attracting talent. The sector is predicted to face increased automation and use of robotics, which will increase upskilling needs of the workforce[74].

Conclusions

This research identifies the main drivers for change in the ECI. They rest on the bedrock of rapid digitalisation, but it is hard to predict how the many technologies and combinations of technologies will affect any specific sector within the broad ECI environment.

What we know is that:

- Radical change is happening fast and its effects are difficult to predict, as pointed out in many global research reports on Industry 4.0. This change will create new types of jobs, increase the need for cross-sector transferability of skills, and add to pressures for innovation, increased efficiency, and productivity gains. All of this will result in continuing demands for workforce upskilling and training and continuing innovation in the way companies harness their workforce and skills.
- The new technologies and their impacts are not well understood across the ECI, especially among smaller and medium sized companies where costs and benefits are equally poorly appreciated. While 85% expect that new technologies will improve business efficiency and precision, nearly a quarter of employers do not expect to be facing any challenges when it comes to adopting new technologies and processes. Very few employers mentioned the need to increase cyber awareness overall in their companies to protect operations or assets as a result of the incoming radical technological change.
- In summary, the extensive array of potential new technologies and the confusing variety of applications, may result among some employers in a tendency to avoid the issue. This might be justified internally because investment in advanced systems and technologies is too expensive and that important changes come to the fore as time goes by and will be adopted organically.
- Engineering-related technicians and engineering and science professionals are the roles which will be in most demand in three years, as industry implements new technologies. These roles are also the hardest to recruit because of a general skill shortage. This is a common picture across the majority, if not all, sectors that ECI contractors operate within.

The potential benefit to industry of adopting new technologies is unquestionable. However, this report identifies an urgent need to improve understanding of the fundamentals, significance and cost-benefits of embracing innovation. This reveals a need to provide industry with expert advice and guidance around investment and implementation.

Appendix 1: PESTLE for Engineering Construction Industry

What follows is a PESTLE analysis of the EIC sector which focuses on technological change but also takes into account other equally important factors impacting the sector. Each has been developed with respect to a specific area of technology – digitalisation, automation, modularisation, renewable technology, digital disruptive technologies, and materials.

To this extent it mirrors the main themes of the cross-cutting disruptive technologies and those of the sector technologies discussed in Part III. It is intended as a series of examples and is not comprehensive[75].

Digitalisation	
Politics	There is strong political will and support in this area. The Industrial Strategy and the National Infrastructure Plan are committed to a move to a more digitalised nation. There is some sense that we have fallen behind other advanced nations in this area over the last 5-10 years. In USA there is the IIC (Industrial Internet Consortium) a collaboration of industry, government and academic institutions exploring the digitalisation of manufacturing. "Industrie 4.0" is a German, government-led collaboration of academia and industry with the same objective, and there is a similar collaboration in Japan called the IVCI – Industrial Value Chain Initiative.
Economics	Though life costs of buildings are predicted to be reduced by between 20% and 30% due to smart systems that are enabled by BIM and the digital twin concept there is little evidence that anyone has yet realised these savings in the real world (although the National Building Specification (NBS) is monitoring the situation and has said that cost savings of 15%-20% are attainable).
Social	The use of good visualisation may support the case for developments and assist in gaining support for new buildings and facilities. Financial savings if realised by individuals are a good example of the benefits but there are others, ease of access to services, environmental concerns and better integration of the services we have come to accept as essential such as telephone coverage and internet access are others. Concern among the general public about waste and carbon usage may drive further technological development (e.g. renewables) even where the newer alternatives are delivered at higher financial cost than the previous technologies).
Technologies	These have been discussed in detail in this report but include a range of digital-based technologies such as IoT (Internet of things including the industrial internet of things (IIOT)), Smart Meters, BIM, Data Visualisation, Virtual Reality, Augmented Reality, Digital Twinning, Robotics and Drones, and possibly Quantum Computing.
Legal	Data protection and cybersecurity are the two obvious issues raised. The Centre for the Protection of National Infrastructure (CPNI) are the experts in this area and recognise significant threats to national infrastructure. The application of data-sharing and big-data analysis may also require attention in the light of GDPR and electronic privacy regulations.
Environmental	Energy efficient buildings and services are the obvious benefit but there are issues of concern such as the use of heavy metals in electronics and the ability to recycle materials at end of life. Recycling is a major objective of the UK government at present.
Skills	Clearly there will be need for more electronically-biased technicians and the digital skills that will support them. That need may not result in less mechanically biased trades, but it may lead to development of multi-disciplinary occupations. Data gathering, management and analysis skills will become more in demand as will those centred around digital design, networks and telecommunications. Big data analysis, programming, coding and cyber-security will probably spawn new or vastly amended job roles and specific technologies such as drones/ROVs, robots, and AR/VR applications will also require new specialisms. The most profound implication is the consequent need for revised training and education courses – and for them to be kept up to date.

75 The original analysis was developed by Chris Mann, former Head of Technology at ECITB and it has been expanded and enhanced as a result of this study.

Automation	
Politics	Politically this is a difficult area due to the possibility of job losses and even of social disruption due to lower skilled occupations becoming obsolete in a relatively short period of time. Automation is necessary to improve productivity in the industry, but automation may well result in job losses, or at the least a jobs transformation with a loss of low skills positions but an increase in high skilled positions to maintain the automated equipment.
Economics	Moravec's Paradox may apply here (that high level thinking actually requires much less computational power than motor-skills). Computers are good at doing fast computation and repetitive tasks but replicating motor-skills and learning is much more difficult. From an industry point of view, the key is at what point costs encourage investment in automation. Could it be Brexit (with its potential limitations on cheap manpower), or could it be a tipping point in margins for other reasons. Importantly the automation of office processes such as project controls, accounting and purchasing sits firmly in this trend and will become more prevalent with the expansion of artificial intelligence of the various types. The Internet of Things and blockchain could accelerate the drive towards automation by reducing the costs of linking and controlling machines.
Social	The biggest transformation is likely to be a reduction in jobs or significant change to existing occupations towards operator/maintainer type roles. That is countered by a likely improvement in the sector's safety record as one obvious benefit of replacing people with machines is the limited exposure to risk. However, the speed of change is a major consideration here. Social cohesion may be endangered if automation puts large numbers of lower-skilled people out of work in a short space of time. The huge loss of secretaries, typists and telephonists occurred over a period of probably forty years and there are now far more females in the labour market than before, But, if large numbers of semi-skilled workers are made redundant quickly (e.g. bricklayers, plasterers, joiners, etc.) the social consequences could be more severe.
Technologies	Automation will require most of the technologies discussed in the main report, but will encompass Robotics, Drones (both aerial and sub-sea), Artificial Intelligence, Process Automation (computer controlled and autonomous), Autonomous vehicles, Human Augmentation, etc.
Legal	Cybersecurity will be a serious issue but there are also issues of liability around autonomous vehicles and drones.
Environmental	Similar concerns as for digitalisation.
Skills	There is likely to be a move towards skills centred on maintenance of machines their design and manufacture. Utilisation of machines in dangerous or hazardous environments may lead to a significant maintenance burden. Monitoring and inspection tasks are likely, at least in the short term, to fall to people until the technology is well proven. Data analytics and AI skills are essential but the question arises as to who will need them, will engineering contractors employ individuals with these skills or will it just be clients and specialists companies? Outsourcing of such skills will involve different risks and benefits but there will certainly be a need for at least a proportion of the technical workforce to be capable of understanding and monitoring automated systems.

Modularisation	
Politics	Politically there is support for a move to a more manufacturing centric construction industry. The Farmer Review led to the obvious conclusion that house and office block building is just not efficient enough as evidenced by the very small margins. The failure of Carillion may be a catalyst for change. The value to the ECI is not so clear cut and to some extent modularisation is already widely practised but miniaturisation - to enable wider use of modularisation could be key to progress.
Economics	Manufacturing offsite is a far more predictable science but the economics are not simple. Modularisation requires significantly more effort at the front-end design stage and considerably more effort in logistics. What is a 'module'? Scale is important. Is there a sense in which modularisation may be a half-way-house remedy? If the economics and scale of DLM increases in attractiveness, much of the rationale for modularising buildings and structures may disappear.
Social	Modularisation is potentially one way of solving the housing crisis. Faster, better insulated and serviced buildings. Advantages for the ECI are not so clear. Modularisation has been used extensively for offshore platform builds, out of necessity, but how easy is it to construct a nuclear power plant in modular form and would it reduce construction time or disruption? Small Modular Reactors still require considerable groundworks for safety and containment reasons and the regulatory authorities are unlikely to respond quickly in this area due to the impact of getting it wrong. Direct social impacts may well be neutral, in the sense that many workers not required onsite will be required in factories. The balance is not yet clear.
Technologies	Offsite Fabrication is not a new technology but a different production process but the ECI will probably require Miniaturisation and possibly robotics and technologies such as BIM. AR/VR, drones and LiDAR plus significant data sharing and communications systems.
Legal	Response times for regulatory change are likely to be slow in the ECI and even in civils and housing post Grenfell.
Environmental	Potentially here is where some of the greatest benefits could be realised. It is far easier to control emissions for example in a predictable factory setting than on a construction site. Better design is likely to lead to more energy efficient buildings but there is possibly an offset given the additional logistics footprint and additional energy usage for robots and other assembly machinery.
Skills	The move to a more manufacturing-centric workforce is likely to lead to an increase in the use of Lean techniques, greater multidisciplinary skillsets and an emphasis on design. Logistical trades will be more in demand and on-site skill sets are likely to be reduced to assembly, testing and commissioning. Project management skills will probably need to be refined and amended.

Renewable and alternative energy	
Politics	Considerable political will and commitment to drive these technologies. The Climate Change Act commits to a reduction in greenhouse gasses of at least 80% of the 1990 levels by 2050 and it is likely that this may well be brought forward where possible. The Climate Change Committee's (CCC) report Building a Low Carbon Economy advises how that might be achieved. Under the Infrastructure Act 2015 the CCC has an additional duty to advise the UK Government on the environmental issues of exploiting shale gas and laid out considerable uncertainty regarding the compatibility of pursuing this route with meeting the commitment, concluding that on the planned scale of petroleum exploitation the two policies were incompatible. Although subsidies have been reduced the UK government is still driving for more renewable energy but is taking the view that public support will only be forthcoming where the technology offers definite economic benefits over and above financial and environmental costs (e.g. Swansea Bay).
Economics	The economics of renewables are rapidly changing and investment in energy storage that is likely to advance the emerging battery technology is significant. Solar PV costs have halved in the last couple of years and landowners are investing. In January 2018 Farming Online reported "on the smaller scale 30kW up to 100kW PV installs, we are seeing typical payback periods ranging from 4 to 6 years". We are in the position where a consistent base load for the national grid is likely to be provided by nuclear and combustion sources with renewables, which are less predictable, steadily increasing their share. Storage is key to the ultimate transfer to an entirely renewable grid system The economics of offshore wind are still contentious and newer technologies may overtake the existing pylons and aerofoils.
Social	People are slow to change and the cheaper viable sources of power such as onshore wind are not popular due to their obvious visible presence. Nuclear is enjoying a resurgence in the UK but is extremely expensive. On the plus side there is a strong ethical and moral sense that moving to renewables is the right thing to do as a nation in the long term. There are still of course those who believe man-made climate change is a myth and therefore the taxes associated with fulfilling the policy are wrong. Their voice is small in the UK (unlike the US) but populist movements have surprised us before and could frustrate progress.
Technologies	Nuclear Solar Wind Tide Energy Storage
Legal	There is a legal commitment enshrined in UK Law, but that legal commitment is associated with our EU membership and could be revoked with enough political will – unlikely though.
Environmental	Intrinsic in the trend but there is a strong push politically and socially towards a green circular economy that energy is clearly a part of.
Skills	Many of the skills are those already prevalent in the industry but there may well be a move to more multi-disciplinary workforces which requires fewer personnel moving around to the various, often difficult to access, sites. Increasing use of drones and robots for monitoring, repair and maintenance and data-links and analysis for oversight should also be considered – reducing human maintenance time (and risk).

Digital Disruptive	
Politics	Politically governments are slow to respond to disruptive technologies and there are periods of extreme uncertainty and volatility around them as understanding grows. This trend is often referred to as 'Uberisation' and the many disputes that companies have had with authorities across the globe illustrates how bureaucracy is resistant to the trend.
Economics	These technologies are disruptive by intent and the model they generally set out to change is the economic one. Blockchain, for example, opens the possibility of removing a whole range of middle men from transactions perhaps even to the extent of making tier 1 contractors redundant. But blockchain approaches have significant additional applications in data-sharing, supply-chain collaboration, design, BIM, and much more and the economic implications are potentially greater than blockchain used for financial transactions.
Social	Often these disruptive technologies are grasped by the young and tech savvy and are purposely brought to the fore rapidly which makes them difficult to predict. Businesses are also beginning to appreciate the security and collaborative aspects of blockchain and the applications are growing rapidly.
Technologies	The underlying technologies similar to Blockchain are driving a number of obvious innovations such as Cryptocurrencies, Crowd funding, and Tokenisation, but are also leading to significant savings for business in data-sharing, a more efficient and effective BIM, and Smart Contracts.
Legal	Often there are no laws or regulations in early adoption and things like tax, liability and jurisdiction take time to be established. Individual companies are beginning, however, to use the technology and there is no legal aspect to this.
Environmental	Often poorly understood; what is the environmental impact, for example, of the proof of work model that underpins a cryptocurrency's transaction record on a blockchain? Some estimates reckon that Bitcoin's CO_2 footprint is more than 1 million transatlantic flights per year. The problem is in the energy usage of tens of thousands of separate computers working 24/7 across the world. The system is hyper-secure but extremely carbon heavy.
Skills	Various, but lawyers and technologists generally have the skills needed by companies looking to adopt any of these models as early adopters.

Materials Technology	
Politics	Political considerations here are centred around sustainability and the environment. Polymers are advancing rapidly but there is serious concern related to pollution by long-life-cycle plastics of all kinds. Recyclability is key, and manufacturers are trying to show that their products can be used in an environmentally responsible way by establishing facilities to recycle their own products. One huge political concern is the carbon-cost of concrete. Nano technology is emerging but there is little understanding of the wider environmental effect of nano particles that are let loose in the environment. The Grenfell inquiry will bring the use of materials in construction into sharp focus over the next year or so.
Economics	Many of the new materials are incredibly expensive to produce. Graphene for example, even in small flakes, costs several thousand pounds for a square centimetre although scientists at Glasgow University recently revealed that they had found ways to cut this cost by a factor of ten. The value gained by use is key. Nano-technology offers huge potential benefits, but R&D costs are very high. The most likely near term uses that demonstrate clear value at relatively little cost are composites and alloys that reduce weight and decrease maintenance requirements. Some of these could utilise 3D printing approaches.
Social	As mentioned in the political section, there is considerable concern around the use of plastics, so designers and constructors will be expected to clearly demonstrate the value of using these materials over more traditional types unless clear recycling plans are set in stone prior to construction. The life cycle of these materials is likely to come more to the fore with the increase in North Sea and Nuclear decommissioning. Questions around environmental leakage of pollutants, unexpected consequence of some of these advanced materials will be at the forefront of early adopters' minds. Expensive (currently), carbon rich materials such as self-healing concrete may well acquire acceptability due to their longer life expectancy and lower maintenance costs.
Technologies	Alloys Polymers Self-healing concrete Nano-technology Nano-laminates Composites, e.g. Fibre Reinforced Polymers/Plastics Graphene Transparent aluminium Ceramics 3D printing
Legal	As with anything new and innovative the law and regulations are often slow to catch up. Grenfell will undoubtedly cause changes to the way construction of any sort approves and regulates new materials. 3D printing will require clear standards to regulate materials, equipment and operators if regulators and insurers are to be content with the quality of product, and self-healing concrete will require considerable regulatory testing before it can be used widely.
Environmental	Closely linked to both social and political concerns. Some of the more cutting-edge technologies emerging such as polymers, hybrids and Nano are going to have to clearly demonstrate their safety in the long term.
Skills	Most of the skills to develop these material technologies fall outside of the industry but new techniques for welding, joining, connecting, attaching, applying coatings etc will emerge and will need responding-to in a timely manner. 3D printing is one area that offers the potential for significant benefits to remote engineering operations and the skills required are high level. The development of clear standards and regulations for 3D printing are in some ways the major existing obstacle to adoption. The more prevalent application of Fibre Reinforced Polymer (FRP) as a viable and cost-effective alternative to seamless steel, implies upskilling or training the workforce. This will have to include training in the installation, maintenance, damage assessment and repair of equipment, structures or pipelines, etc. featuring that material.

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