UK COMMISSION FOR EMPLOYMENT AND SKILLS

Sector insights: skills and performance challenges in the advanced manufacturing sector

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Sector Insights: skills and performance challenges in the advanced manufacturing sector

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Foreword

The UK Commission for Employment and Skills (UKCES) is a publicly funded, industry-led organisation providing leadership on skills and employment issues across the UK. Together, our Commissioners comprise a social partnership of senior leaders of large and small employers from across industry, trade unions, the third sector, further and higher education and all four UK nations.

Our vision is to create, with industry, the best opportunities for the talents and skills of people to drive competitiveness, enterprise and growth in a global economy.

Over the next three years our ambition is to see industry in the UK create "ladders of opportunity" for everyone to get in and on in work. This means employers improving entry routes into the labour market for young people, ensuring the existing workforce has the skills businesses need to compete and individuals need to progress, and deploying those skills in a way that drives productivity and growth. This is a collective agenda for employers working in partnership with government, trade unions, education providers, industry bodies and local organisations.

Our Research

Our research mobilises impartial and robust national and international business and labour market research to inform choice, practice and policy. We aim to lead the debate with industry to drive better outcomes for skills, jobs and growth.

Our ambition is to cement the UK Commission's reputation as the 'go-to' organisation for distinct high quality business intelligence, and communicate compelling research insights that shape policy development and influence behaviour change.

In order to achieve this, we produce and promote robust business intelligence and insights to ensure that skills development supports choice, competitiveness and growth for local and industrial strategies.

Our programme of research includes:

- producing and updating robust **labour market intelligence**, including though our core products (the Employer Skills Survey (ESS), Employer Perspectives Survey (EPS) and Working Futures Series);

- developing an understanding of what works in policy and practice through **evaluative research;**
- providing research **insight** by undertaking targeted thematic reviews which pool and synthesise a range of existing intelligence.

Our research programme is underpinned by a number of core principles, including:

- providing **business intelligence**: through our employer surveys and Commissioner leadership we provide insight on employers' most pressing priorities;
- using evaluative insights to identify **what works** to improve policy and practice, which ensures that our advice and investments are **evidence based**;
- adopting a **longer term, UK-wide, holistic perspective**, which allows us focus on big issues and cross cutting policy areas, as well as assessing the relative merits of differing approaches to employer engagement in skills;
- providing **high quality, authoritative and robust data**, and developing a consistent core baseline which allows comparison over time and between countries and sectors;
- being **objective, impartial, transparent and user-friendly**. We are free of any vested interest, and make our LMI as accessible as possible.

We work in strategic partnership with national and international bodies to ensure a co-ordinated approach to research, and combine robust business intelligence with Commissioner leadership and insight.

The overall aim of this project is to examine the skills and performance challenges in the advanced manufacturing sector in the UK, with a specific emphasis on a selected number of key occupations. In addition, the research assesses employer engagement with and use of national occupational standards.

This project forms part of a wider suite of sector labour market intelligence (LMI) research undertaken by the UK Commission. The overall aim of the programme is to examine skills and performance challenges across a range of industry sectors of critical importance for the UK economy.

Sharing the findings of our research and engaging with our audience is important to further develop the evidence on which we base our work. Evidence Reports are our chief means of reporting our detailed analytical work. All of our outputs can be accessed at www.gov.uk/government/organisations/uk-commission-for-employment-and-skills

We hope you find this report useful and informative. If you would like to provide any feedback or comments, or have any queries please e-mail info@ukces.org.uk, quoting the report title or series number. We also welcome feedback on Twitter.

Lesley Giles

Deputy Director

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Executive Summary

Overview of the research

This report examines skills and performance challenges facing the advanced manufacturing sector with an emphasis on the mix of skills needed in specific occupations, as well as employer awareness of and engagement with National Occupational Standards (NOS). This project forms part of the Sector Insights research undertaken by the UK Commission for Employment and Skills (UKCES). The overall aim of the programme is to examine skills and performance challenges across a range of industry sectors of critical importance for the UK economy.

This study focuses on five key occupations that are prevalent in advanced manufacturing industries, and which represent a cross-section of skills levels:

- production managers and directors in manufacturing;
- biological scientists and biochemists;
- production and process engineers;
- metal working production and maintenance fitters;
- assemblers of electric and electronic products.

Key findings

The advanced manufacturing sector

Advanced manufacturing is broadly described as manufacturing that is 'intensive in its use of capital and knowledge and requires a high level of technology utilisation and Research and Development (R&D)' (UKCES, 2012). This can apply to all manufacturing industries, but is most commonly associated with medium- and high-tech industries.

The Annual Business Survey estimates that there were approximately 29,000 advanced manufacturing enterprises operating in the UK in 2013, comprising around 23 per cent of the total number of manufacturing enterprises (128,000). These enterprises generated over £72 billion of GVA in 2013 (Annual Business Survey, 2014). The number of advanced manufacturing enterprises has declined slightly in recent years, but their share of GVA has largely remained constant, indicating a degree of consolidation in the sector, alongside growth for some employers.

A high proportion (44 per cent) of the advanced manufacturing workforce holds high-level qualifications (qualifications at Level 4 and above). This is a much higher proportion than for manufacturing as a whole (31 per cent) and slightly higher than for the economy as a whole (41 per cent).

Although manufacturing employment as a whole is expected to decline up to 2022, recent forecasts have predicted that advanced manufacturing is expected to grow significantly in the coming years, particularly in Western Europe.

Skills and performance challenges in the sector today

Advanced manufacturing is widely reported as an area of significant potential growth for the UK economy (UKCES, 2013; BIS 2010a). There are a range of key drivers shaping the performance of the sector, most of which have a skills dimension. They include:

- translating innovation into growth;
- increasing investment in Research and Development (R&D);
- meeting low carbon policies and legislation;
- maximising export opportunities;
- taking advantage of potentially transformative enabling technologies.

The sector is heavily-influenced by developments relating to advanced manufacturing technologies, such as:

- the growing ‘computerisation’ of production processes, as well as the prevalence of Computer-Aided Design (CAD) and bespoke software solutions;
- an increase in the resources required to test and inspect new products, as more complex materials and smaller components are used in production processes;
- a shift to shorter production runs and more tailored products, which is being driven by customer demand and facilitated by new manufacturing techniques such as 3D printing and plastic electronics.

Future Skills

Employers perceive that these changes will continue to significantly impact on the skills required from workers in the key occupations:

- **Production managers/directors in manufacturing:** Employers report that the workload of this occupation has increased as new, more complex materials and the growing use of smaller components have made quality assurance more labour-intensive. In addition, there is an increasing focus on business skills to identify new sources of funding and to appraise the benefits of new technologies. Employers, particularly SMEs, report experiencing skills gaps in the business aspects of the production manager role. Some employers expect that, in future, these jobs may have to split into two distinct roles. One role will focus on quality assurance and regulation, while the other will focus on the design aspects of the job. In addition, within large Original Equipment Manufacturers (OEMs), the role may also become more focused on supply chain management, purchasing, contract negotiation and large-scale project management.

- **Biological scientists and biochemists:** Employers anticipate that new digital technologies will make clinical trials less labour intensive, which will likely mean that workers in the future will be investing more time in R&D to develop new products. Although demand for biological scientists and biochemists will increase, not all these jobs will be created in the manufacturing sector. Some will be created in research facilities in universities, which are increasingly working in partnership with employers. The growing importance of R&D in advanced manufacturing is increasing demand for new entrants with higher degrees and specialisms. For a few employers, the industrial manufacture of biological products is also requiring workers to develop new skills in managing the production line and optimising production. Employers report experiencing difficulties recruiting new entrants with the appropriate research skills in the UK and, consequently, some were recruiting from abroad.
- **Production and process engineers:** Employers suggest that the increasing complexity of the production method (shorter, more varied production runs and more complex machinery) and growing use of sub-contracting may require production and process engineers to possess increased skills in project management and maintaining quality across multiple manufacturing sites. Production engineers are increasingly required to be proficient in a range of design packages and bespoke software. Most employers reported experiencing difficulties recruiting production and process engineers with appropriate practical skills. However, some employers believed that they were managing to overcome some of these issues by taking on more apprentices.
- **Metal working production and maintenance fitters:** Employers report that the use of computer-controlled machines is increasing the need for software skills and the ability to adapt to new machines. It is anticipated that software development skills will become an increasingly important part of maintenance fitters' role. In addition, some employers expect the role of maintenance fitters to become more service-focused as manufacturers outsource more complex machine calibration and system setting to specialist machine

maintenance companies. Laser technology was also reported to be an important development in simplifying metal cutting, which has required workers to develop skills in operating cutting machines safely.

- **Assemblers:** Employers report that assembler roles are expected to decrease in future, as the use of laser cutting tools and growing automation of production lines will mean that new products require less preparation and can be more easily assembled. However, this would be balanced by an increase in jobs for technicians to operate machine tools. The data suggests that there is a greater need for 'IT literacy' for assemblers to work with new production machines and components. Employers are generally willing to train staff 'on-the-job, but some had experienced difficulties in recruiting staff with appropriate attitudinal skills.

Current and future interest in occupational standards

The 2014 UK Commission's Employer Perspectives survey indicates that manufacturing employers have a slightly lower than average awareness of National Occupational Standards (NOS). Most employers interviewed were not aware of NOS; but, when pressed, employers generally understood that key sector training, such as apprenticeships, were based on a consistent set of national standards.

As a performance management tool, NOS were considered a useful starting point, but generally required tailoring before they could be applicable to employers' work environments. This was largely because the standards did not necessarily refer to specific machines, or always reflect the fluid and overlapping nature of job roles in the sector.

NOS were, however, generally considered to be a crucial tool in ensuring consistency in training standards, particularly apprenticeships. This creates a tension between low- and high-specificity NOS. The former is widely considered important by employers for training, as it ensures the focus is on general skills that can be applied to different technologies. As some employers noted, the pace of technological advances in manufacturing means that specific machinery soon becomes obsolete and new technology takes its place.

As a consequence of these factors, relatively few of the employers interviewed used NOS to develop performance management tools. However, NOS use is not always visible to employers. For example, recruitment companies and other specialists are increasingly being asked to develop job descriptions and may be using NOS to develop their products, although employers would not necessarily be aware of this.

Suggested actions

- Employers need to invest in upskilling and developing their existing workforce to ensure that they are capable of taking advantage of new technologies.
- Universities and vocational training providers also need to ensure that technology skills are embedded at the heart of a wide range of STEM-related programmes, alongside leadership and management and supply chain management skills.
- Some employers report that offering apprenticeships has enabled them to address skills and performance challenges, as well as helping to recruit production and process engineers. Other employers within advanced manufacturing could assess the benefits of offering apprenticeships, and ensure they have clear pathways in place to enable progression to higher-level technical and professional roles.
- Managers in advanced manufacturing should explore ways to take ownership over their own continuing professional development and ensure that they have the space and learning opportunities.
- Continued investment by government in collaboration between HE and industry is likely to be worthwhile in the context of industries that need to mitigate risk in order to pursue business development / innovation.
- There may also be a role for government to help foster those links and support the development of skills and knowledge beyond traditional industry silos, and to conduct more research to examine good practice in engaging SMEs in R&D and disseminate this widely across the sector.

1 Introduction

ICF Consulting was commissioned in November 2014 by the UK Commission for Employment and Skills (UKCES) to research the skills and performance challenges facing the advanced manufacturing sector. This report draws on primary research with employers and secondary analysis of labour market and skills information.

1.1 Background and aims of the study

The UKCES is a publicly funded, industry-led organisation providing leadership on skills and employment issues across the UK. Together, its Commissioners comprise a social partnership of senior leaders of large and small employers from across industry, trade unions, the third sector, further and higher education and across all four UK nations. Its vision is to create, with industry, the best opportunities for the talents and skills of people to drive competitiveness, enterprise and growth in a global economy.

Innovative and insightful research is central to UKCES' role as a prime source of knowledge on how skills drive enterprise, create more and better jobs and deliver economic growth. Its programme of sector research includes a series of Sector Skills Insights reports (published in 2012), which focus on skills needs in specific sectors; and a rolling programme of sector-specific studies. The first round of these covered the role of technology in driving high-level skills in the digital, off-site construction, aerospace and automotive industries. The second addressed skills and performance challenges in the logistics and wholesale and retail sectors. The third round examines sector skills and performance challenges, with an emphasis on the mix of skills needed in specific occupations, as well as employer awareness of and engagement with National Occupational Standards (NOS).

This report focuses on the advanced manufacturing sector. It:

- synthesises evidence on the sector's labour market to identify the outlook for jobs and skills;
- identifies major trends affecting the sector and how the mix of skills needs is likely to change over the next decade in response to these;
- investigates employers' perceptions of the skills needs of five specific occupations, and the challenges employers have in meeting those needs;
- discusses current awareness of, engagement with and interest in National Occupational Standards in developing the sector's workforce;
- draws out the implications for skills supply and workforce development.

In order to identify common skills issues across sectors, the projects in this third round of the sector insights programme shared a common methodology where appropriate. This included: a review of existing literature and data from the UK Commission's Employer Skills Survey, Employer Perspectives Survey, and Working Futures labour market projections; and consultations with sector bodies and sector employers. The focus on five key occupations represents a change from past UKCES sector studies, and reflects UKCES's interest in assessing market demand for National Occupational Standards, as well as an opportunity to build on previous sector research and delve deeper into the operation of specific sector labour markets.

1.2 Study methodology

The research adopted a mixed-methods approach. Existing sector data and literature on skills and performance issues was supplemented with primary research with employers and stakeholders to explore experiences and perceptions of the sector.

The research was conducted in three stages. There was a short **scoping stage,** during which research tools were developed and the five key occupations were selected[1]. The selection of occupations was based on a review of literature and analysis of the Labour Force Survey (LFS) [2].

The **fieldwork stage** took place during January and February 2015. During this stage, 53 employer interviews were conducted, each focusing on one of the five selected occupations. Interviews were conducted with 48 unique employers across the UK, which included 40 SMEs and eight large employers. The number of interviews conducted by occupation are presented in the Table 1.1:

Table 1.1 Interviews conducted

Occupation	Interviews conducted
Production managers and directors of manufacturing	12
Biological scientists and biochemists	6
Production and process engineers	11
Metal working production and maintenance fitters	10
Assemblers of electric and electronic products	14
Total	53

[1] The five occupations selected for the study were Production managers and directors of manufacturing; Biological scientists and biochemists; Production and process engineers; Metal working production and maintenance fitters; and Assemblers of electric and electronic products

[2] Further details of the selection approach for the five occupations is included in Chapter 3

In parallel to the employer interviews, secondary data sources and literature were also analysed. Key data courses included: the UK Commission's Employer Skills Survey; the Labour Force Survey; Working Futures, Annual Business Enquiry (ABS); and the Annual Survey of Hours and Earnings (ASHE). The literature used for the research is listed in the bibliography.

In the **reporting stage** the findings from the research were analysed. These findings were then tested with four sector stakeholders: Semta, Cogent, the Automotive Industrial Partnership and the Advanced Manufacturing Research Centre Training Centre (based at the University of Sheffield). The research also consulted the BIS sector teams.

1.3 Report structure

The report is structured as follows:

- Chapter 2 sets out the definition of the sector and the drivers affecting advanced manufacturing;
- Chapter 3 sets out the selected lead occupations;
- Chapter 4 describes the characteristics of the sector today;
- Chapter 5 presents the future skill needs of the sector;
- Chapter 6 sets out findings relating to the role of occupational standards;
- Chapter 7 presents the conclusions and recommendations.

2 The advanced manufacturing sector

Chapter summary

This chapter sets out the definition of advanced manufacturing used in the study, and presents some of the key drivers influencing the sector.

This report defines advanced manufacturing primarily in relation to the manufacturing industries identified by Eurostat (2013) as high tech or medium-high tech. This includes the pharmaceuticals, automotive, aerospace, chemicals and electrical/electronic industries.

Advanced manufacturing is widely reported to be an area of significant potential growth for the UK economy (UKCES, 2013; BIS 2010a). There are a range of key drivers shaping the performance of the sector, including:

- Accessing finance to bring new products and technologies to market, which is increasing the focus on business development skills among senior managers.
- Increasing investment in R&D, which is stimulating demand for highly skilled graduates and increasing collaboration between research centres and industry.
- Meeting low carbon policies and legislation, which is increasing investment in energy-efficient technologies and driving research in lightweight materials.
- Maximising export opportunities, which is considered a major growth opportunity for UK manufacturers.
- Taking advantage of potentially transformative enabling technologies, such 3D printing, composites and robotics, which could potentially transform the sector.

2.1 Definition of the sector

Advanced manufacturing is broadly described as manufacturing that is ‘intensive in its use of capital and knowledge and requires a high level of technology utilisation and Research and Development’ (UKCES, 2012). This can apply to all manufacturing industries, but is most commonly used in technology-intensive industries.

For the purpose of the study, advanced manufacturing has been classified as manufacturing industries defined by Eurostat (2013) as high-tech or medium-high tech. Focusing on these specific industries allows more detailed qualitative and quantitative analysis to take place on skills and performance issues in the sector. In line with the previous sector insights approach, the definition of advanced manufacturing also incorporates scientific research and development[3]. Although this is not a manufacturing industry *per se*, it is generally considered to be an important because it informs R&D in the manufacturing sector, particularly in areas such as biotechnology.

The selected industries[4] are:

- SIC20: Manufacture of chemicals and chemical products;
- SIC21: Manufacture of basic pharmaceutical products and pharmaceutical preparations;
- SIC25.4: Manufacture of weapons and ammunition;
- SIC26: Manufacture of computer, electronic and optical products;
- SIC27: Manufacture of electrical equipment;
- SIC28: Manufacture of machinery and equipment not elsewhere classified (n.e.c);
- SIC29: Manufacture of motor vehicles, trailers and semi-trailers;
- SIC30.2: Manufacture of railway locomotives and rolling stock;
- SIC30.3: Manufacture of air and spacecraft and related machinery;
- SIC.30.4: Manufacture of military fighting vehicles;
- SIC30.9: Manufacture of transport equipment n.e.c;
- SIC32.5: Manufacture of medical and dental instruments and supplies;
- SIC72.1: Research and experimental development on natural sciences and engineering.

2.2 Sector size and key characteristics

The Annual Business Survey estimates that there were approximately 29,000 advanced manufacturing enterprises operating in the UK in 2013, comprising around 23 per cent of the total number of manufacturing enterprises (128,000). These enterprises generated over £72 billion of GVA in 2013 (ABS, 2014).

[3] Specifically SIC72.1 on research and experimental development on natural sciences and engineering
[4] Industries were defined using the 2009 SIC classifications produced by the ONS. SIC comprises 24 divisions that are further disaggregated into groups of activities

From 2008 to 2012 the overall number of advanced manufacturing enterprises dropped by 11 per cent. However, there was significant growth in some advanced manufacturing industries, most notably pharmaceuticals, aerospace and scientific research and development.

In 2013, advanced manufacturing comprised 1.4 per cent of the total number of enterprises in the UK and seven per cent of UK GVA. This proportion of enterprises has declined slightly in recent years, from 1.6 per cent in 2008, but the share of GVA has remained largely constant. This indicates a degree of consolidation in the sector, alongside growth for some advanced manufacturing employers.

There are approximately 1.3 million people employed in the advanced manufacturing industries in the UK (LFS, September 2014). This compares to just over three million employees for the manufacturing sector as a whole, approximately four per cent of total UK employment. Just under three quarters of the advanced manufacturing workforce is male (74 per cent), which is similar to the manufacturing sector as a whole (75 per cent), but the economy as a whole has a more even gender split (53 per cent of workers are men).

The number of people employed in the advanced manufacturing sector has increased slightly in recent years (by 68,000 between September 2009 and September 2014). This is in line with employment growth in the economy as a whole over the same period.

Approaching half of the advanced manufacturing workforce (44 per cent) holds a high-level qualification (qualifications at Level 4 and above). This is a much higher proportion than for manufacturing as a whole (31 per cent) and slightly higher than for the economy as a whole (41 per cent). A lower proportion of workers in the advanced manufacturing sector have no qualifications (five per cent) than in the overall manufacturing sector (eight per cent). The advanced manufacturing share is comparable to the economy as a whole (five per cent).

The average earnings of staff in advanced manufacturing are significantly higher than in manufacturing as a whole. In 2014, the total weekly wage in advanced manufacturing was £582 compared to £516 in manufacturing, a difference of 13 per cent. Average weekly earnings have increased by 11 per cent from 2008, a trend that runs counter to the trend for the UK economy as a whole. This reflects the profile of advanced manufacturing as including a substantial portion of high-skilled, high-value jobs. Earnings in advanced manufacturing are also significantly higher than earnings in the overall UK workforce. They are on average 9-12 per cent higher than the rest of the workforce for the period 2008-2014.

There are significant gender differences in pay across the sector. Female employees in the manufacturing industry as a whole earned an average of £349 (gross weekly pay) during the period 2008-2014, while male employees earned an average of nearly £529. However, female average weekly earnings have increased at over twice the rate of male earnings over this period (21.6 per cent compared to 10.4 per cent). Nevertheless, the UK gender pay gap (based on the median weekly earnings of full time employees) is higher in the manufacturing sector (27 per cent) when compared to the all industry average (18 per cent). Only women working in financial and insurance activities and energy experience a greater gender pay gap (37 and 32 per cent respectively) (Perfect, 2012).

The 2014 Annual Survey of Hours and Earnings suggests that the UK gender pay gap varies across the advanced manufacturing sector: it is lowest in the manufacture of medical and dental instruments and supplies and highest in the manufacture of computer, electronic and optical products. However, these estimates are based on relatively small sample sizes, so should be seen as indicative.

There is a relatively low percentage of women working part-time within advanced manufacturing. This varies across the different sub-sectors (see Table 2.1) but overall less than ten per cent of the workforce within any one sub-sector is comprised of part-time women. This is much lower than sectors such as education and human health and social care, where women working part-time constitute 36 per cent of the workforce.

Table 2.1 Advanced manufacturing sub-sectors by gender and employment type (%).

	Male			**Female**			
Industry Division	**FT***	**PT**	**SE**	**FT**	**PT**	**SE**	**Total**
Manufacture of coke and petroleum; chemicals and chemical products	68	2	1	22	5	2	100
Manufacture of pharmaceuticals	58	1	2	30	6	2	100
Manufacture of metal products	79	2	3	10	5	1	100
Manufacture of computer, etc	69	2	4	20	5	0	100
Manufacture of electrical equipment	69	2	1	21	5	1	100
Manufacture of machinery n.e.c.	78	2	2	14	3	0	100
Manufacture of motor vehicles, etc	81	1	5	11	2	1	100
Manufacture of other transport equipment	85	1	3	9	2	1	100
Other manufacturing	50	6	10	20	9	6	100
Scientific research and development	50	2	7	32	8	2	100

*Source: 2012 Working Futures. Note: Working Futures data is unavailable at 3 digit SIC, therefore the definition of advanced manufacturing used by this table is wider than the definition applied elsewhere in the report as defined in Appendix A. *FT= full time; PT= part time; SE= self-employed*

2.3 Future drivers in advanced manufacturing

Advanced manufacturing is widely-reported to be an area of significant potential growth for the UK economy (UKCES, 2013; BIS 2010a). There are a number of key drivers shaping the performance of the sector:

- translating innovation into growth;
- increasing investment in Research and Development;
- meeting low carbon policies and legislation;
- maximising export opportunities;
- potentially transformative enabling technologies.

2.3.1 Translating innovation into growth

The UK, along with other Western European countries, leads the way in patent applications. Half of all worldwide patents are submitted by employers from Europe, of which just under a fifth originate in the UK (Eurostat, 2014). However, the UK and Europe perform less well in translating these products into new business opportunities. Investment in the new products is significantly lower than among competitors in the USA and Eastern Asia (European Commission, 2013).

A key priority in advanced manufacturing is to increase access to finance and investment to bring new products to market, and embed advanced manufacturing techniques across a range of manufacturing industries (Foresight, 2013). This highlights the connection between the technical science and engineering-based skills required to support innovation and the wider business skills necessary in order to bring new products to market. It also highlights the connection between growth potential and other factors such as public strategies for growth and support for advanced manufacturing that enables this potential to be realised.

The UK Industrial Strategy published in 2013 has identified 11 priority sectors for business and government to work in partnership to promote growth, including aerospace, automotive and life sciences (HM Government, 2014). The strong emphasis on advanced manufacturing industries within the strategy provides not only an indication of the importance of the sector as a driver of growth, but also the specific advanced manufacturing industries considered to provide tangible opportunity for growth. This prioritisation in part reflects areas of strength within the existing UK skills base, but the Industrial Strategy as a whole is explicit about the connection between skills and growth.

2.3.2 Increasing investment in Research and Development (R&D)

The need to continue to invest in new products, in light of increasing worldwide competition, requires significant investment in research and development (EU Skills Panorama, 2014). To meet this need, there is increasing demand for high-quality science and engineering graduates to enter and progress in the sector. While issues relating to the supply of high-level STEM skills can sometimes be characterised in monolithic terms, the increased need for specialisation means that the supply of skills relating to specific subjects (including at post-graduate level) is important.

In particular advanced manufacturing industries, the connection between universities and business goes much further than the supply of new entrants. In the life sciences, for example, there is an almost umbilical relationship between R&D, university-based innovation and industry spin-offs of products developed in higher education.

The institutional infrastructure linking universities and the business community has been further strengthened by Government-funded ‘Catapult’ centres (Technology Strategy Board, 2013). Each centre is a network of research centres to support employers create cutting edge products or technologies. The Catapult centre for High Value Manufacturing (HVM) was created in 2011 and in the 2014 Autumn Statement the Government committed an additional £61m to the centre, which is expected to support around 2,250 manufacturers.

2.3.3 Meeting low-carbon policies and legislation

The Kyoto Protocol and EU 2020 strategy aim to significantly reduce carbon consumption among businesses. The UK is committed to achieve EU targets to:

- reduce greenhouse gas emissions in 2020 to 20 per cent lower than emissions in 1990;
- generate 20 per cent of energy from renewables;
- increase energy efficiency by 20 per cent.

These policy objectives are driving innovation in the use of lightweight materials for the automotive and aerospace sector (UKCES, 2013). In addition, they are also a factor driving employer investment in advanced manufacturing techniques that generate efficiencies in water and energy consumption, as well as minimising waste (Foresight, 2013).

2.3.4 Maximising export opportunities

The advanced manufacturing industries export a higher proportion of goods than the manufacturing sector as a whole. Taking advantage of overseas markets is seen as an important contributor to growth (BIS, 2010b). However, there remain some employers, particularly micro and small SMEs, that experience difficulties in identifying and taking advantage of export opportunities, due to a lack of contacts or networks in overseas markets, as well as a lack of familiarity with different legal and regulatory frameworks (BIS, 2010a). These barriers have a clear skills dimension, and affect the strategic capacity of organisations to grow.

However, it is also important not to assume that all firms in advanced manufacturing industries are targeting export growth – or, indeed, have a plan for growth at all. The strategies pursued (or not) by smaller firms operating in the advanced manufacturing industries will also influence skills demand. This can relate both to growth and innovation. Just are there are advanced technologies in use outside of the industries defined here as 'advanced manufacturing', there are businesses within notionally more advanced industries that lack the capability, capacity or perceived need to harness these technologies.

2.3.5 Potentially transformative enabling technologies

Advanced manufacturing is closely connected to what are known as 'enabling technologies', which provide some of the main sources of innovation for a wide range of industries (European Commission, 2011). These innovations are not confined to the manufacturing sector *per se*, and have potential impacts in sectors as diverse and agriculture and health. However, there are close links with production processes, creating both opportunities and challenges for manufacturing employers.

Looking to the future, one of the issues in trying to make sense of the impact of enabling technologies on jobs and skills is that the pace of technological advancement is fast and unpredictable. There is also a difference between the cutting-edge development of enabling technologies and the widespread application of those technologies.

Relevant current enabling technologies that *could* have profound future implications for advanced manufacturing are summarised in Table 2.2.

Table 2.2 Current enabling technologies that *could* have profound future implications for advanced manufacturing

Technology	Summary
Additive manufacturing	The development of products using digitally-controlled machine tools. Products are built through layering rather than traditional methods of moulding, casting or welding.
Composite manufacturing	The joining of two materials together to produce one material with superior mechanical properties. Composites are increasingly being used to replace metal due to their high-tensile strength and low weight.
Nanotechnology	The manipulation of materials at a sub-atomic level to create new materials. It is used for both organic and non-organic materials.
Plastic electronics	Electronics built using semi-conducting plastic polymers. Diodes and transistors are ‘printed’ on plastic substrates using inks of semi-conducting plastic materials.
Silicon electronics	The development of electronic circuits built on a single layer of single-crystal silicon. It is considered advantageous because it consumes very little power.
Industrial Biotechnology	The industrial manufacture of chemical products using biological rather than oil-based materials.
Robotics and artificial intelligence	The use of machinery to automate parts of the production process. A potential recent development in this area is artificial intelligence, which is software that make decisions on optimising the production process.

Source: SSC Advanced Manufacturing Cluster (2009); European Commission (2011); UKCES, (2013); Foresight (2013)

3 Key occupations

Chapter summary

This chapter outlines the rationale for selecting the five key occupations and provides a summary description of each occupation. The selection of occupations aimed to ensure a mix that broadly mirrored the skills composition of the manufacturing workforce, but was geared towards higher-level skills to better reflect the advanced manufacturing workforce. In addition, the selection was weighted towards larger occupational groups in order to increase the generalisability of the study's findings.

The five key occupations selected for the study were:

- Production managers and directors in manufacturing;
- Biological scientists and biochemists;
- Production and process engineers;
- Metal working production and maintenance fitters;
- Assemblers (electronics and electrical).

There are a diverse range of occupations in the advanced manufacturing sector, with no occupation comprising more than five per cent of the total workforce. Most occupations, with the exception of production managers and directors in manufacturing, are concentrated in a few advanced manufacturing industries.

3.1 Selecting five advanced manufacturing occupations

Occupations were defined according to the Standard Occupational Classification (SOC) at four-digit unit level, the most detailed level of the national classification. The occupations were selected based on the following criteria:

- **Occupational skill level:** To ensure a mix of occupational levels (based on the Major Occupational Group categories) that broadly mirrored the skills composition of the manufacturing workforce, but geared towards higher-level skills to better reflect the advanced manufacturing workforce.
- **The size of the occupational group:** Gearing the selection towards larger occupational groups in order to increase the generalisability of the study's findings, and focusing on the largest occupations within the manufacturing industries (at two-digit level) most closely associated with advanced manufacturing technologies.

Table 3.1 shows the selected occupations.

Table 3.1 The chosen key occupations according to selection criteria

Occupation SOC 4-digit unit group	Industry Rank within SIC Division	Major Occupational Group	Rank (% of Adv Man workforce)
Production managers and directors in manufacturing (1121)	In the top 10 occupations for all advanced manufacturing industries except scientific research and development	Managers, directors and senior officials	1 (4.2%)
Metal working production and maintenance fitters (5223)	• Vehicles and trailers manufacturing (#4) • Machinery manufacture not elsewhere classified (#1) • Other transport (#3)	Skilled trades occupations	3 (3.4%)
Biological scientists and biochemists (2112)	• Scientific research and development (#1) • Pharmaceuticals (#1)	Professional	4 (2.8%)
Production and process engineers (2127)	• Chemicals (#10) • Computer & electronics (#10) • Other transport sector (#9)	Professional	10 (1.9%)
Assemblers (electric and electronic products (8131)	• Computers & electronics (#3) • Electrical equipment manufacturing (#2)	Process, plant and machine operatives	16 (1.5%)

Source: ICF (based on the Labour Force Survey, 2014)

3.2 Overview of the selected occupations

An overview of the selected occupations is provided below. This describes the types of jobs included in each occupational category, as well as the rationale for considering it to be an occupation of interest in the context of advanced manufacturing skills issues.

3.2.1 Production managers and directors in manufacturing

Production managers and directors in manufacturing includes company directors, managing directors and operations directors of manufacturing and engineering firms, as well as owners of manufacturing firms. It also includes operations managers, plant managers and production managers and wide range of specific manufacturing manager roles, such as shift managers, textile managers, and systems managers in printing (ONS, 2014).

Production managers and directors of manufacturing are responsible for embedding new advanced manufacturing techniques and monitoring production to ensure that processes operate effectively and efficiently. Managers also play a key role in supporting organisations to increase exports, a key driver of manufacturing growth (BIS, 2010).

It is the single largest occupational group both for manufacturing generally and in advanced manufacturing specifically. This reflects that it is an occupation that is widely-dispersed across manufacturing industries and the economy as a whole. Indeed, four out of ten manufacturing production managers and directors work for non-manufacturing organisations (see Appendix B, Table B.1).

It appears in the Top 10 occupations by size for most of the advanced manufacturing industries and is one of the three largest occupations in chemicals manufacturing, pharmaceuticals manufacturing and manufacturing of machinery 'not elsewhere classified'[5]. The largest concentration of manufacturing production managers and directors is in the manufacture of fabricated products (the manufacture of weapons and ammunition), which is included in the scope of advanced manufacturing.

3.2.2 Biological scientists and biochemists

Biological scientists and biochemists includes range of scientific roles, such as biological scientists, biochemists, microbiologists, pathologists, forensics scientists and pharmacologists, as well as research scientists, officers and managers working in biochemistry, horticulture, biology, agriculture and zoology (ONS, 2014).

While not a traditional manufacturing occupation (only 11 per cent of the workforce sits within the manufacturing footprint), biological scientists and biochemists is the largest occupation group in pharmaceutical manufacturing and scientific research and development. Outside the manufacturing footprint, it is also a common occupational group in the health, education and agriculture sectors (see Appendix B, Table B.2).

3.2.3 Production and process engineers

Production and process engineering is an engineering profession alongside, but distinct from, civil engineers, mechanical engineers, electrical engineers, electronics engineers and design and development engineers. Focusing on technical aspects of production processes, it includes roles such as planning and quality control engineers / process engineers, chemical engineers, industrial engineers and production consultants / engineers (ONS, 2014).

It is among the ten largest groups in chemicals manufacture, computers and electronics manufacture and the other transport (including aerospace) industries, although still relatively niche even in these industries.

[5] General purpose machinery (engines, turbines), fluid power equipment (hydraulic components etc), pumps, compressors, taps, valves, bearings, gears, ovens, non-domestic cooling and ventilation equipment, lifting and handling equipment, power-driven hand tools etc.

There are fewer than 5,000 production and process engineers in any given industry (see Appendix B, Table B.3). Nevertheless, seven of the top ten industries in which production and process engineers operate are associated with advanced manufacturing. As well as aerospace/other transport, there are also relative concentrations of these workers in the manufacturing of machinery 'not elsewhere classified' and automotive manufacturing.

3.2.4 Metal working production and maintenance fitters

Metal working production and maintenance fitters encompasses a large number of highly-specialised roles relating to the installation and repair of plant and machinery, including erectors, fitters, setters, machinists, repairers, as well as various mechanics roles (e.g. plant mechanics). It also includes engineering trades such as engineering machinists and installation engineers (ONS, 2014).

Metal working production and maintenance fitters are responsible for building machines and equipment for production lines. The occupation is associated with sites of leading edge technology and in vehicle production lines (Semta, 2010). Almost half of the workforce is qualified to Level 3 – i.e. GCE, A-level or equivalent (LFS).

It forms the second-largest occupational group in manufacturing as a whole (around four per cent of the workforce) and the third largest occupation in advanced manufacturing specifically (around three per cent of the workforce). It is the largest occupation within the manufacturing of machinery 'not elsewhere classified'[6] and in the top five occupations by size in both the automotive manufacturing and other transport (aerospace) industries. There is also a concentration of metal working and production maintenance fitters in the manufacture of fabricated products, which includes the advanced manufacture of weapons and ammunition (See Appendix B, Table B.4).

3.2.5 Assemblers of electric and electronic products

Assemblers (electric and electronic products) is part of the wider group of assemblers and routine operatives (including tyre and windscreen fitters and sewing machinists). It includes assemblers of electrical and electronic equipment (component assemblers, radio assemblers and so on), as well as solderers and wirers, technical operators in circuit board manufacture and team leader roles in in the assembly of electrical and electronic equipment manufacture. It is distinguished from the separate group of assemblers of vehicles and metal goods (ONS, 2014).

[6] General purpose machinery (engines, turbines), fluid power equipment (hydraulic components etc), pumps, compressors, taps, valves, bearings, gears, ovens, non-domestic cooling and ventilation equipment, lifting and handling equipment, power-driven hand tools etc

In electronic/electrical manufacturing, assemblers are responsible for using new advanced manufacturing products such as silicon electronics, plastic electronics and nanotechnology to develop electronic components. It has been argued that the capacity of assemblers to use these new materials influences the take-up and success of these new technologies (SSC Advanced Manufacturing Cluster, 2009). In comparison with the UK average, electric/electronic assemblers are more likely to be qualified at Level 2 – i.e. GCSE grade A*-C or equivalent (LFS).

Although not one of the 20 largest occupational groups in manufacturing as a whole, electric/electronic assemblers are the 16th largest group in advanced manufacturing specifically. It is among the top three largest occupations in both the electrical equipment manufacture and the computers and electronics manufacture industries. The only other industry with a concentration of electric/electronic assemblers is the manufacture of machinery 'not elsewhere classified', although it is a fairly niche occupation within that industry (see Appendix B, Table B.5).

4 The sector today

Chapter summary

This chapter presents findings on skills challenges within the advanced manufacturing sector today. It draws on analysis of national data sets, policy literature and interviews with employers.

There are significant changes taking place to occupations in the advanced manufacturing. The general shift to shorter, more tailored products, driven by both customer demand and the availability of more flexible production technology such as 3D printing, is increasing the focus of demand for skills, particularly among production and process engineers and production managers/directors in manufacturing.

The increasing use of design packages and bespoke software in the manufacturing process is also creating demand for greater 'IT literacy' and skills in utilising different software, particularly in CAD/CAM and CNC machining.

Increasing regulation and the growing trend for outsourcing production of more complex products were increasing the importance of the business aspects of the 'production managers/directors in manufacturing' occupation. A few employers interviewed were experiencing skills gaps in this area.

The 2013 UK Commission's Employer Skills Survey suggests that 19 per cent of employers within the advanced manufacturing sector had at least one employee with a skills gap (compared to an all industry average of 15 per cent). Three quarters (75 per cent) of advanced manufacturing employers with at least one employee with a skills gap reported that employees lacked technical or practical skills or job specific skills (compared to an all industry average of 60 per cent).

Employers also report skills shortages for highly skilled professionals, including production and process engineers and biological scientists and biochemists.

4.1 Skills challenges at sector level

The UK Commission's Employer Skills Survey (UKCESS, 2013) sets out the scale and nature of skills challenges reported by advanced manufacturing employers. It also allows advanced manufacturing to be compared against the manufacturing sector and the UK economy as a whole.

4.1.1 Overall vacancies and hard-to-fill vacancies

In 2013, the percentage of employers across the UK reporting at least one vacancy was 15 per cent in the manufacturing sector, the same share as for the economy as whole. In comparison, 19 per cent of advanced manufacturing employers reported a vacancy. Advanced manufacturing employers with vacancies also had a slightly higher average number of vacancies (three compared to 2.5 for both the wider manufacturing sector and the UK economy as a whole).

Advanced manufacturing employers were also more likely to have hard-to-fill vacancies. The percentage of advanced manufacturing employers with at least one hard-to-fill vacancy is nearly double that for the UK economy as a whole (nine per cent versus five per cent). The incidence of hard-to-fill vacancies for manufacturing as a whole is much more in line with the overall UK average. There was also a greater concentration of hard-to-fill vacancies in advanced manufacturing than for the economy as a whole (Table 4.1).

Table 4.1 Hard-to-Fill (HfF) vacancies in the advanced manufacturing sector

Hard to fill vacancy indicators	Advanced Manufacturing	Manufacturing	Total Economy
Number of employers with at least one HtF vacancy	2,100	5,600	89,700
Percentage of employers with at least one HtF vacancy	9%	6%	5%
Percentage of employers with at least one vacancy, who have at least one HtF vacancy	44%	39%	35%
Average number of HtF vacancies per employer	0.2	0.1	0.1
Average number of HtF vacancies per employer with vacancies	1.2	0.9	0.7
Average number of HtF vacancies per employer with HtF vacancies	2.7	2.3	2.1
Total number of reported HtF vacancies	5,700	12,800	189,300
HtF vacancies as a percentage of employment	1%	1%	1%
HtF vacancies as a percentage of vacancies	39%	35%	29%

Source: UKCES Employer Skills Survey, 2013

4.1.2 Skill-shortage vacancies (SSVs)

Nearly 2,000 (eight per cent) advanced manufacturing employers reported a SSV in the UK in 2013, double the rate for the economy as a whole (see Table 4.2). More than nine out of ten (92 percent) hard-to-fill vacancies in advanced manufacturing are SSVs, compared to 77 percent for the economy as a whole. This is only marginally higher than the figure for all manufacturers, indicating that skills shortages are not just focused within the more advanced industries. SSVs represent over third of all advanced manufacturing vacancies compared to just over a fifth of vacancies across all UK industries.

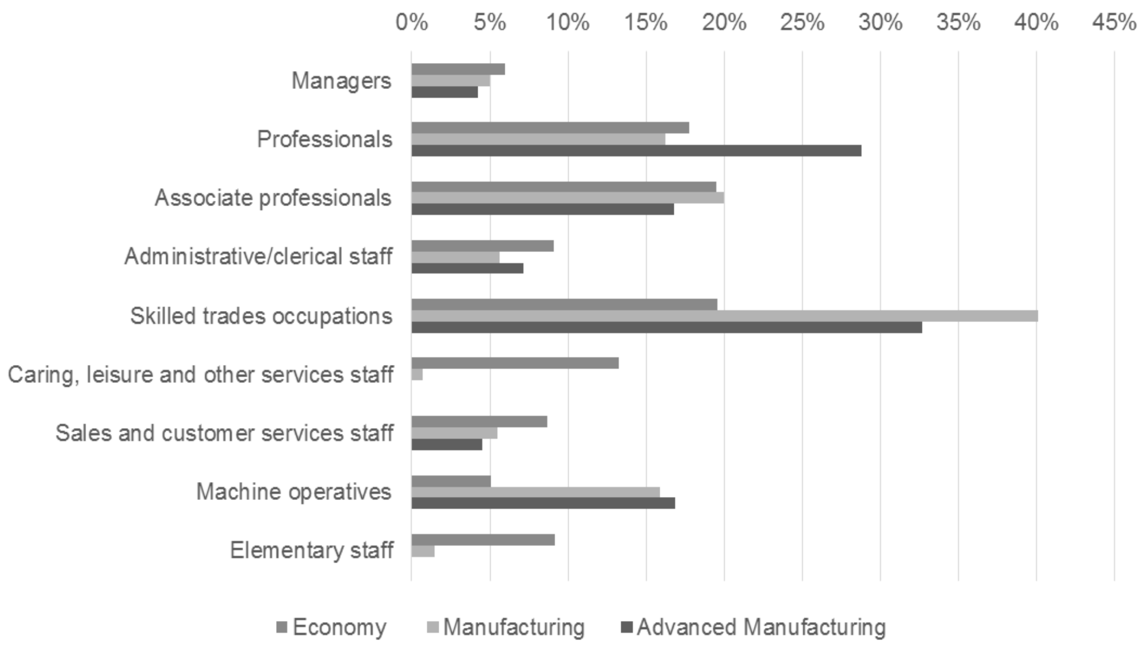
Table 4.2 Skill-shortage Vacancies (SSVs) in the advanced manufacturing sector

Selected skill-shortage indicators	Advanced Manufacturing	Manufacturing	Total Economy
Number of employers with at least one SSV	2,000	5,000	70,500
Percentage of employers with at least one SSV	8%	5%	4%
Percentage of employers with at least one vacancy, who have at least one SSV	41%	34%	27%
Average number of SSV	0.2	0.1	0.1
Average number of SSVs per employer with vacancy	1.1	0.8	0.6
Average number of SSVs per employer with HtF vacancy	2.5	2.0	1.6
Average number of SSVs per employer with SSVs	2.7	2.2	2.1
Total number of reported SSVs	5,300	11,100	146,200
SSVs as a percentage of employment	1%	2%	1%
SSVs as a percentage of vacancies	36%	30%	22%
SSVs as a percentage of HtF vacancies	92%	87%	77%

Source: UKCES Employer Skills Survey, 2013

Figure 4.1 shows the density of SSVs by occupation. This presents the number of SSVs for each occupation as a proportion of the total number of vacancies for each occupation. As such, it controls for the size of each occupational group within the sector. It shows a clear concentration of SSVs among professionals in advanced manufacturing, which is not apparent for manufacturing as a whole.

Figure 4.1 Density of SSVs by occupation



Source: UKCES Employer Skills Survey, 2013

For manufacturing as a whole, SSVs are concentrated within the skilled trades occupations. The density of SSVs for machine operatives is also higher than average in the advanced manufacturing and manufacturing sectors. There is a much greater concentration of technical, practical and job-specific skills issues underpinning SSVs in manufacturing (and advanced manufacturing) than for the economy as a whole (Table 4.3).

Table 4.3 Top reasons for SSVs in the advanced manufacturing sector (as a percentage of employers with SSVs)

Top reasons for SSVs	Advanced Manufacturing	Manufacturing	Total Economy
Technical, practical or job specific skills	80%	78%	63%
Planning and organisation skills	32%	38%	45%
Written communication skills	34%	34%	39%
Customer handling skills	25%	28%	43%
Team working skills	19%	25%	34%

Source: UKCES Employer Skills Survey, 2013

4.1.3 Skills gaps

Nineteen per cent of advanced manufacturing employers report having at least one employee with a skills gap. This is consistent with the manufacturing sector as a whole (18 per cent) and is only slightly higher than the UK economy average (15 per cent). The percentage of staff in both manufacturing and advanced manufacturing (six per cent) who are not fully proficient at their jobs is also in line with the average for all industries (five per cent).

While advanced manufacturing employers are only marginally more likely than average to have employees with skills gaps, the average number of staff members with a skills gap reported by those employers is higher. Across the economy as a whole, employers with a skills gap report that this applies to an average of 5.3 employees. Among manufacturing and advanced manufacturing employers, this rises to 7.7 and 10.3 employees respectively.

Table 4.3 shows that most of the reported causes of skills gaps are similar in advanced manufacturing to the economy as whole. Advanced manufacturing employers are however slightly more likely to report the root cause of skills gaps as being because training is currently only partially completed or because staff are new to the role (Table 4.3). Advanced manufacturing employers are also slightly more likely than other manufacturers and the UK average to take steps to address skills gaps relating to increasing training activity (Table 4.4).

Table 4.3 Main causes of skills gaps among employers, (as a percentage of employers reporting skills gaps)

Main causes of skills gaps	Advanced Manufacturing	Manufacturing	Total Economy
Their training is currently only partially completed	68%	64%	60%
They are new to the role	65%	60%	59%
Staff lack motivation	31%	31%	34%
They have been on training but their performance has not improved sufficiently	32%	29%	31%
They have not received the appropriate training	31%	29%	28%

Source: UKCES Employer Skills Survey, 2013

Table 4.4 Steps taken to address skills gaps, (as a percentage of employers reporting skills gaps)

Steps taken to address skills gaps	Advanced Manufacturing	Manufacturing	Total Economy
Increase training activity/ spend or increase/expand trainee programmes	73%	68%	68%
More supervision of staff	61%	53%	60%
More staff appraisals / performance reviews	47%	43%	51%
Implementation of mentoring / buddying scheme	46%	41%	47%
Reallocating work	37%	32%	37%

Source: UKCES Employer Skills Survey, 2013

The impacts of skills gaps on establishment performance are similar in advanced manufacturing, overall manufacturing and all UK industries. Typically, around half of respondents reported that they increased the workload for other staff. As with skills shortages (UKCESS, 2013), the types of skills that are most likely to require improvement in the advanced manufacturing sector are technical, practical and job-specific skills (Table 4.5).

Table 4.5 Main skills which need improving as reported by employers with skills gaps, (as a percentage of employers reporting skills gaps)

Main skills which need improving	Advanced Manufacturing	Manufacturing	Total Economy
Technical or practical skills or Job specific skills	75%	69%	60%
Planning and organisation skills	52%	54%	57%
Team working skills	43%	44%	44%
Problem solving skills	48%	50%	48%
Customer handling skills	36%	33%	47%

Source: UKCES Employer Skills Survey, 2013

4.1.4 Training activity

In 2013, just under 60,000 manufacturing establishments had provided training over the previous 12 months (Table 4.6). This equates to a higher proportion of employers than for manufacturing as a whole; although the share of advanced manufacturing employers providing training is in line with the UK average.

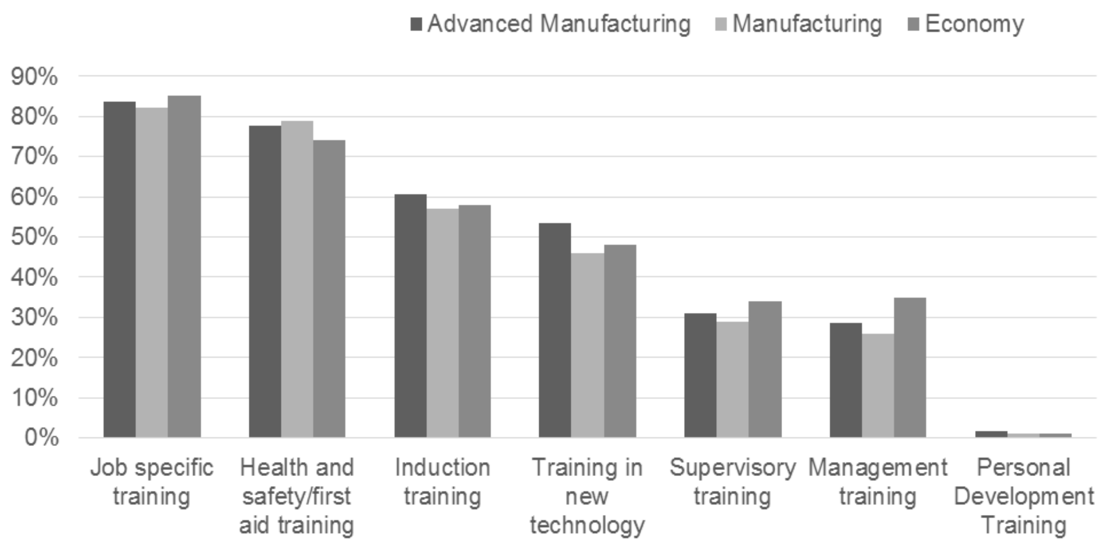
Table 4.6 Training opportunities in the advanced manufacturing sector

	Advanced Manufacturing	Manufacturing	Total Economy
Number of employers providing training in the past 12 months	16,300	58,800	1,147,800
Percentage of employers providing training in the past 12 months	66%	59%	66%
Average number of training days per trainee	4.8	5.4	6.7
Average number of training days per staff member	2.7	2.7	4.2

Source: UKCES Employer Skills Survey, 2013

Among the employers that have trained staff, the balance between on and off-the-job training is similar across advanced manufacturing, all manufacturing and the UK economy as whole. There is also no sector-specific pattern in the type of training offered by employers (Figure 4.2).

Figure 4.2 Types of training offered, 2013



Source: UKCES Employer Skills Survey, 2013

Investment in training among manufacturing employers declined from £3.2bn in 2011 to £2.5bn in 2013 (UKCESS, 2013). This decline is mirrored across the UK economy as whole, although it is of a slightly higher magnitude in the manufacturing sector. Data on training investment for advanced manufacturing employers specifically is not available.

The amount spent on each person that received training declined from £2,850 in 2011 to £2,190 in 2013. This compares to an average spend in 2013 of £2,552 per trainee across the UK economy as a whole. On average a trainee within advanced manufacturing receives 4.8 days of training compared to a UK average of 6.7 days, which suggests that training is more expensive (per day) when compared to the UK average.

4.2 Skills challenges at occupational level

This section presents current skills challenges in each of the key occupations examined in the study.

4.2.1 Production managers and directors in manufacturing

The production managers/directors occupation is common across all types of manufacturing employers. In small employers, production managers/directors in manufacturing are often the owner-manager of the organisation. Consequently, as well as managing the production process, they are also responsible for identifying new business opportunities and sourcing funding. In larger employers, the role of production managers focuses specifically on managing the production line, with some large employers employing over 20 of these workers.

Production managers/directors in manufacturing play a key role in supporting the implementation of advanced manufacturing technologies. They are responsible for embedding new manufacturing methods and monitoring production to ensure that processes operate effectively and efficiently (ONS 2010). In smaller employers, production managers and directors in manufacturing are also responsible for sourcing funding to invest in new machinery or R&D.

Drivers affecting production managers and directors

One of the major reported barriers to the implementation of advanced manufacturing technologies is a lack of awareness among senior managers/directors of the latest industry technologies and their application. This has been noted as a common issue among SMEs (BIS 2010a).

The employer interviews found varying levels of awareness of new technologies. Around a quarter of employers did not have a clear vision of the future of the sector and did not expect to make any changes to their manufacturing process, unless customers requested a particular new product. These employers could be described as largely reactive rather than proactive in identifying new opportunities.

> At the moment we plan to continue doing what we do until our customers tell us otherwise (Small supply chain employer, automotive industry).

In contrast, some employers were forward-looking and demonstrated a willingness to keep up-to-date with new technological developments. These employers had both short-term plans and a long-term vision of how the company needs to advance in the next 10 years to maintain or increase its market share.

> Our sector changes quickly, and we have to keep up to date with developments as we know our competitors are. We have to try to make sure we are always ahead of the curve (Medium-sized employer, electronics and electrical industry).

Introducing new advanced manufacturing methods to a production process also requires a significant upfront investment in R&D and new equipment. Consequently, production managers/directors of manufacturing are increasingly expected to be able to appraise the benefits of new technologies, and be able to articulate the business case for investment (BIS 2010a).

How the production managers and directors role is changing as a consequence of advanced manufacturing technologies

Most employers that were utilising advanced manufacturing techniques reported that the workload and type of tasks production managers/directors in manufacturing perform were generally increasing. This was reported to result from two trends:

- The new, more complex materials and processes being used were increasing the amount of time required to document the production process and complete forms for health and safety and regulatory purposes.
- In addition, the growing use of electronic components and micro-parts made quality assurance and fault-checking more labour intensive. For example, one interviewee reported:

> There has been a major change in how we spend our time on the production line. Five years ago we would spend about two hours producing something and ten minutes checking it and filling in the paperwork. With new technologies like 3D printing, we can now make things in 10 minutes, but because the parts are so complex we then need two hours to check it and document it. This has turned everything on its head (Large employer working in various manufacturing industries).

Skills challenges facing production managers and directors today

Most of the employers interviewed reported few apparent difficulties in recruiting and retaining production managers/directors in manufacturing. The turnover of staff was stated to be low, largely because staff were well-remunerated (often among the highest paid staff in the company). In addition, many employers wanted to promote staff from within the organisation to fill vacancies.

> We generally try to recruit staff from within as it is a way of rewarding people that have been loyal to the company and helped make it successful (Small employer, electronics industry).

Some large employers, however, reported recruiting production managers/directors primarily from outside the organisation. The main consideration for these employers was that new entrants should have experience in managing production in a large organisation. This was felt to be an important skill for production managers because: *"there are a lot of senior manager meetings and internal administration associated with the role – we need someone to come in that that is used to working in that sort of environment".*

A commonly-reported skill challenge among production managers is their knowledge of different manufacturing processes and techniques. Interviewees reported that when new staff are promoted to the role, they tend to have an in-depth knowledge of one or two production methods. To perform the role of production manager effectively, they often require a broader knowledge of other production methods (both in the company and in the supplier chain), so they can identify improvements to existing processes. Employers generally expected production managers to develop these skills through self-directed learning and from learning on-the-job.

In the interviews a few employers reported the need to up-skill production managers so they are capable of performing the HR, finance and business improvement aspects of the role. Staff recruited from within the organisation may not have had experience in conducting these tasks or the skills to perform them effectively.

> Many of our production managers are great at the technical side of the role but struggle with the business side. Because of this, we offer rolling in-house training courses on leadership and management, recruitment and performance management (Medium-sized employer, defence industry).

In the employer interviews, a few SMEs reported experiencing skills gaps in the business aspect of the production manager/director in manufacturing role. These interviewees reported difficulties in being able to identify and access new funding opportunities to improve the production process. As a consequence, new developments have been delayed or postponed:

> We have tried to get a loan to develop a new centre but we keep on getting knocked back. Part of the problem is that what we are trying to do will not create new jobs in the short term, as we will be automating a large part of our production method. This makes it harder to get money from the Government. The private sector is less keen to invest because it is quite risky. We have to be better in getting across the benefits of what we are doing, that we will be developing the entire area (Small employer, electrical and electronics sector).

4.2.2 Biological scientists and biochemists

Biological scientists and biochemists jobs are primarily found in the pharmaceuticals and scientific research and development industries. In these advanced manufacturing industries, employers reported that the role typically involves research, development and the trialling of new products. *"We are scientists, we go out in the field, perform experiments, write reports and pass on information for regulation".*

For a few employers, biological scientists and biochemists were in a leadership role in the organisation. Staff in these organisations played a key role in monitoring the production process and testing new products.

Employer interviewees generally expected biological scientists and biochemists to have a related university degree in pharmacology, chemistry or biology/biological sciences. However, some employers reported promoting technicians to scientist roles, providing they could demonstrate the underpinning analytical and scientific skills to be able to respond to changing products and production methods quickly and efficiency.

Drivers affecting biological scientists and biochemists

Research shows that a key driver influencing the pharmaceutical and life science industries is the general shift towards personalised treatments and health care management service/technical services. This is expected to result in new drug treatments being personalised for individuals or groups based on biomarkers and pharmacogenomics[7] to ensure optimum impact (Skills for Health *et al.*, 2010).

The employer interviews found that the impact of these changes was primarily affecting OEMs in the sector. Very few supply chain employers stated that they saw this as an immediate priority for their organisation, but some believed that it was a key driver for their customers. This may reflect that these are relatively new developments and, consequently, have not yet filtered down to the supply chain.

[7] Detailed knowledge of how genetic variation affects the effectiveness of drugs

Innovation is also a key driver in the sector. The pharmaceuticals sector invests more in R&D than any other business sector (Skills for Health *et al.*, 2010). As patents for recent 'blockbuster' drugs expire, UK pharmaceutical companies were reported to be increasingly investing in the development of new products to maintain or grow their market share.

Employers interviewed tended to consider themselves to be at the forefront of new scientific developments. For example, one employer has worked with a local university to commission research on new products and processes. Most reported introducing new equipment in the last five years (such as High Performance Liquid Chromatography) to improve the efficiency of the production process and reduce waste.

Employers reported that the increasing affordability of camera and sensor technology was affecting the way that clinical trials were conducted. In addition, tailored computer software also allowed the results to be analysed quickly and tested for statistical significance. For example, one company producing new fertilisers now uses a camera linked to a computer to measure the number of planted seeds that have flowered as a result of the new fertiliser, and how much they have grown. In the past, this would have been done by hand.

Nearly all employers expected developments in industrial biotechnology to create new business opportunities. Large-scale biological manufacturing processes enable pharmaceuticals and life science companies to develop new products more cost-effectively than if they solely relied on chemical processes.

The employer interviews suggest that biopharmaceuticals are still at an early stage of development. It is regarded as a key sector development among OEMs, but there is a sense that these changes are not yet affecting the supply chain, which still, by and large, uses chemical-based manufacturing processes.

Across supply chain employers, there does appear to be a shift to more automated production lines. Programmable logic controllers (PLCs) are a particularly widespread new technology that reduce waste in the production of pharmaceutical products.

How the biological scientists and biochemist occupation is changing as a consequence of advanced manufacturing technologies

Around half of employers reported that the increasing importance of R&D was also likely to increase demand for scientific research skills among biological scientists and biochemists. A few reported that they were increasingly looking to recruit new entrants with higher level degrees in order to ensure they have sufficient skills to perform R&D and conduct research independently.

A small number of employers reported that the growing automation of the production process has also resulted in biological scientists and biochemists needing to develop skills in monitoring quality on the production line: *"they are becoming more production and control engineers and less biochemists".* Consequently, biochemists must be able to interpret production data to ensure the process is working effectively. It was felt that this would eventually lead to a need to develop skills in cost control and identifying areas of improvement to the production process.

Skills challenges facing biological scientists and biochemists today

Evidence suggests that labour and skills shortages in professional occupations are quite common in the life sciences and pharmaceutical industries, particularly in scientific and technical areas (UKCESS, 2013; Office of Life Sciences, 2009; ABPI 2008). Research on the life sciences industry specifically found common skills gaps in chemistry, pharmacology and toxicology, drug metabolism, pharmacokinetics, pharmacodynamics and modelling as well transversal skills in mathematics and scientific research (Skills for Health *et al*., 2010; ABPI 2008).

A few of the employers interviewed reported skills gaps in research skills:

> We find that many people are good at conducting experiments on a small scale. However, they have to learn how to do this on a bigger scale and come up with an approach which is efficient enough to be feasible in a commercial environment (Small employer, pharmaceuticals industry).

Interviewees reported difficulties in recruiting new biological scientists and biochemists with sufficient technical and research skills. Among SME interviewees, there is a perception that many potential new entrants want to work for the large pharmaceutical companies and therefore they receive fewer applications for vacancies. The supply chain base is perceived to be significantly less attractive to recent graduates.

There is also a feeling among interviewees that the scientific skills of graduates are in demand from other industries, and consequently many life science graduates gain jobs outside the sector.

> What we do is not very glamorous, and people will need to get their hands dirty. This puts a lot of people off, I think a lot of people would rather work in a nice clean hospital or specialist R&D facility (Small employer, agriculture/bioscience industry).

In advanced manufacturing, research shows the growing demand for investment in R&D is increasing the need for graduates qualified at masters and doctorate degree level (EU Skills Panorama, 2014). Many employers reported that they were having to recruit workers from outside the UK to fill vacancies.

A few employers also reported shortages of expertise above-and-beyond scientific research skills. This relates to the demand for recruits to have a good understanding of the specific sub-sector that the employer works in (which could include agriculture in the case of pesticide manufacturing, or chemical manufacturing). To address this issue, some employers report employing agriculture or chemical engineers, and training them in production methods, as well as developing their scientific research skills.

All employers reported that an important requirement of the biological scientist and biochemist role is to continually develop skills on new technologies or processes, particularly for staff working in R&D. In some cases, this is developed through in-house training. However, it is also expected that staff undertake their own self-directed learning.

> The sector changes quickly so we [biological scientists] need to make sure we keep up-to-date with the new techniques being used. This means reading what is being done by our competitors and what is being done in academia (Small employer, pharmaceutical sector).

4.2.3 Production and process engineers

Production and process engineers are primarily responsible for designing and monitoring the production process. Key responsibilities are typically:

- using Computer-Aided Design and Computer-Aided Manufacturing (CAD/CAM) design tools to develop plans on the production line for products;
- reviewing/monitoring the production process to identify opportunities for improving efficiency or quality;
- implementing quality assurance systems and using tools such as Computer Numerical Control machines to test and review new products (ONS, 2014).

The role of process engineers is particularly important in the aerospace and transport industries, where the use of composites and additive manufacturing increases the need for concessions design and stress tests of new products (UKCES, 2013). It is also essential in plastic and silicon electronics, where new techniques such as inkjet printing of plastics requires stringent quality controls to reduce the risk of errors that could destroy entire production batches (SSC Advanced Manufacturing Cluster, 2009).

Drivers affecting production and process engineers

The main driver reported by employer interviewees to be influencing the role of production and process managers is the general shift towards shorter production runs as customers increasingly demand more tailored products. This is increasing the complexity of the manufacturing process and requiring production to need far more management to optimise performance.

There is an increasing reliance on computer design, which is becoming embedded in many new production machines. Moreover, Computer Numerical Control (CNC) machines are increasingly using more complex software to manage more varied production processes.

Another driver reported by employers to be affecting the occupation is the increasing use of multi-function production machines. These machines provide greater flexibility as they can perform more than one function on the production line. However, they are more expensive to buy and maintain. Some employers have transitioned to the new machines and a few others plan to do so in the near future.

How the production and process engineer occupation is changing as a consequence of advanced manufacturing technologies

The employer interviews suggest a growing demand for production and process engineers as a combination of shorter, more varied production runs and the use of more complex machinery means that employers now need more production and process engineers to manage the production line.

The skills required from production and process engineers have reportedly changed significantly over the last five years. The growing automation of production processes require production and process engineers to be familiar with bespoke software to control the production process. Employers report that, in some cases, production and process engineers require software development skills to control newer, more complex machines.

> Everything now in the production line is controlled by computer software. Every morning we have to set the production runs for the day, then an engineer puts in the designs onto a system. Even faults have to be entered on the computer and are then sent to the manager (Medium-sized employer, automotive industry).

Production and process engineers also need to be proficient in a range of Computer-Aided Design or Computer-Aided Manufacturing (CAD/CAM) software packages. In some cases, the software package can change for a particular client or for a particular machine, which means that production and process engineers need to be able to use more than one package concurrently.

As most new manufacturing machines are now reliant on computer control, production and process engineers increasingly need to have a wide-ranging and high-level IT expertise. For example, to make dental restoration, one lab uses an intraoral scanner to take a digital impression of a patient's mouth, which is then converted, using proprietary software, into a virtual restoration. This is then sent to a 3D printer, which produces a replica of the product. The production and process engineers need to quality assure each stage of the process - the scanned image, the quality of the virtual restoration and the appropriateness of the 3D printing. This requires an ability to analyse what is being produced by computer software and test whether it is working effectively.

Some employers also reported that the quality assurance aspect of the production manager role is also becoming increasingly important. The use of new materials such as composites increases the need for 'stress tests', particularly in the automotive and aerospace sector when they relate to customer safety.

Skills challenges facing production and process engineers today

Most employers reported significant difficulties in recruiting new production and process engineers, particularly in design roles. This was primarily due to a shortage of students in the discipline in college or University. In addition, some employers also reported that new entrants, and particularly graduates, do not always have well-developed practical skills and often require further training before they can be employed on the production line.

> New entrants seem to understand the theory, but don't always have very good mechanical skills for builds. For some it is a very steep learning curve (Small employer, working across various manufacturing industries).

One employer reported fewer difficulties recruiting production and process engineers in Scotland, where jobs created by the oil and gas industry in northern Scotland encourage students to train in engineering. Universities and colleges in Scotland were also believed (by this employer) to provide a wider range of engineering courses.

Employers are increasingly using recruitment agencies to recruit production and process engineers. A few employers stated they have also recently recruited staff from abroad to fill production and process engineering positions as they have not been able to find sufficiently high-quality candidates in the UK.

Within their organisations, employers reported skills challenges in high-quality design skills that allow products to be developed to optimise efficiency while meeting customer requirements. A few employers reported that, while new entrants have the ability to design products using software, some do not have skills in assessing customer needs and in optimising production processes.

> We have lots of people that can draw beautiful 2D and 3D diagrams. However, some people struggle at being able to work out how these products can be created on the production line and the best way of doing this while minimising waste and energy (Large employer, various manufacturing sectors).

A few employers stated that they experienced difficulties in introducing lean and 6-sigma manufacturing techniques[8] because of skills gaps in their organisation. Staff were generally aware of these techniques, but few had the skills and experience in *applying* these techniques to generate efficiencies in the production line. Recruiting specialist staff to conduct these tasks was also found to be difficult: *"these individuals just don't exist in the market".* A few employers have had to employ external consultants to introduce lean and 6-sigma methods to their production line.

There appears to be an emerging trend of employers using apprenticeships to address shortages in production and process engineers. A few employers reported that they had recently used apprenticeships to fill hard-to-fill vacancies to good effect.

> We are very pleased with the apprenticeships we have. They have good practical skills, work hard and are always willing to learn. We hope to take on a few more apprenticeships next year (Medium-sized employer, automotive industry).

An apprenticeship was considered a good route to attract new candidates as on-the-job training helps to ensure that trainees have good practical skills. In addition, they can also be trained on the specific software packages and machinery used by the company during the apprenticeship, which means that once the complete their apprenticeship they will not require further training.

Meanwhile, an interviewee from a trade association within the elastomers sub-sector of the advanced manufacturing supply chain reported that employers find it difficult to access funding to train workers such as process and production engineers. They reported that specialist FE and HE provision for their subsector had declined over the last fifteen years and they were facing challenges filling this gap. The elastomers sub-sector is comprised of many SMEs who report challenges competing with larger employers from other sub-sectors for funding.

4.2.4 Metal working production and maintenance fitters

Metal working production and maintenance fitters are responsible for building machines and equipment for production lines. The occupation generally consists of two distinct roles:

[8] Lean and 6-sigma manufacturing are techniques commonly used to appraise the production process and identify opportunities to minimise waste (including waste created through overburdening workers or the uneven distribution of work).

- Metal workers, who develop products using techniques such as welding, casting and moulding. They are expected to have a high level of practical skills in welding and metal work. Qualifications are often less prized than practical experience in the industry.
- Maintenance fitters, who are responsible for machine installation, testing and fault finding. They are required to have good problem-solving skills, as well as extensive knowledge of the specific materials and equipment that particular metal and electrical trades work with and related production methods.

Drivers affecting metal workers and maintenance fitters

There is evidence that metal working production and maintenance fitters play an important role in supporting the implementation of new advanced manufacturing technologies, particularly around silicone electronics, plastic electronics and composite manufacturing (SSC Advanced Manufacturing Cluster, 2009).

Most employer interviewees reported that a major development affecting metal workers is the introduction of new laser technology and the lower cost of laser machines. Some employers reported introducing laser cutting to the production line and others plan to do so in the near future. Laser cutting allows new products to be developed with cleaner edges that require less preparation for welding. It also enables products to be developed that can be fitted together without welding or joining.

A few employers also planned to introduce 3D printing to develop rapid prototypes of metal components. This significantly reduces the time taken to design and test new products. For new products, employers often need to design specialist tools and machines to produce parts. If the part needs to be changed, then the tools also need to be modified. Rapid prototyping allows the components to be approved quickly and the production equipment to be developed without needing later modifications.

The increasing automation of production lines and growing use of bespoke design software to run production machines is also affecting the role of metal working production and maintenance fitters, reportedly across all advanced manufacturing industries.

How the metal workers and maintenance fitter occupation is changing as a consequence of advanced manufacturing technologies

As with other occupations, most employers reported that the role of metal working production and maintenance fitters has changed due to the increasing use of computer design and programmes in production machines. A range of proprietary software packages are now widely found in production machines. Consequently, metal working production and maintenance fitters are increasingly required to identify and address programming issues that may be affecting the manufacturing process.

However, overall, most of the employers interviewed did not believe the skills required by maintenance fitters were changing significantly. The fundamental component of the role was still the ability to diagnose faults and make corrections using tools. Although the machines change, workers should be able to adapt to these changes, often supported by on-the-job and product manufacturer training.

A few employers reported that among metal workers, the increasing use of laser produced products has in some cases reduced the practical skills required from metal workers. For example, there is less need for welders to use deburring[9] machines to prepare metal for joining. In addition, the growing use of multidimensional cutting is resulting in pre-fabricated products that do not requiring welding. On the other hand, a few employers stated that the use of lasers to produce components require metal workers to have greater knowledge of laser technology, new machinery and safe operating procedures.

Skills challenges facing metal workers and maintenance fitters today

Employers in industries at the forefront of advanced manufacturing developments, such as aerospace, have reported skills shortages in metalworking, welding and fabrication and CNC machine operations (UKCES, 2013). This issue has partly been attributed to the increased complexity of new production methods and challenges of working with smaller, more complex materials.

Most employers interviewed for this study reported few practical skills gaps among the workforce. This was generally because many employed an older workforce that had significant industry experience in metalworking. However, a few employers did report that some members of their existing workforce had difficulty in using more modern CNC machines. This technology has been changing significantly in recent years. Some employers have enrolled workers onto NVQs to address these skills gaps.

[9] Deburring is the process of removing unwanted material from a piece of metal

Some employers did report having difficulties in recruiting maintenance fitters who could demonstrate problem-solving skills and are *‘good with their hands’*. Interviewees were generally keen to recruit engineers, but there were example where employers had also recently taken on individuals who may have worked in other sectors (such as plumbing) and trained them ‘on-the-job’. Demand for maintenance fitters appears to be growing among employers producing high-tech equipment and declining among those that produce more traditional machines. Employers in the latter category are reporting reduced demand for metal working production and maintenance fitters, as the lower cost of producing customised parts has led to many customers replacing component parts rather than repairing them. However, other interviewees reported an increase in demand due to their organisation providing more business services to clients (such as servicing, adaptation, and providing software updates).

Recruitment difficulties were largely consistent across all four UK nations. However, they tended to be more acute in rural areas. Employers reported that this meant they had a smaller pool of potential workers to draw on, and where a local area did not have an industrial history it was difficult to find individuals with the appropriate level of practical and technical skills. Employers also reported difficulties in recruiting new entrants, which they believed was due to a lack of interest in the occupation: *“it is not considered very sexy”.*

Industry-specific qualifications are not always seen as an important requirement for new entrants. In many cases, the knowledge and understanding that workers require is primarily product-specific. Consequently, much of the training is done on-site and employers are primarily concerned that new entrants can demonstrate a significant aptitude to learn and desire to work in the sector.

4.2.5 Assemblers (electric and electronic products)

In electronic/electrical manufacturing, assemblers are responsible for producing products to a design plan. The role traditionally requires craft skills in welding, soldering, wiring, bolting and working to plan (ONS, 2009).

There is a broad spectrum of roles that can be considered part of the assembler occupation. At one end of the scale, the assembler role requires the 'slotting together' of pre-fabricated parts. At the other end of the scale, assemblers are required to use a range of craft techniques to develop circuit boards and equipment, and in some cases develop their own solutions to solve design requirements. This has resulted in considerable variation in the skills required from new entrants. Some employers do not require new entrants to hold particular qualifications in electronics as they train workers on-the-job. However, for more complex assembler roles, employers report requiring new entrants to hold a L3 or L4 qualification in an electronic or electrical discipline.

Drivers affecting assemblers

Sector research (Semta, 2009; Semta, 2011; European Commission, 2009) highlights the potential of new technologies such as silicon electronics, plastic electronics and nanotechnology to significantly affect the electronics and electrical sector. This is resulting in new skills required from workers operating at all levels in the production process.

The increasing growth of manufacturing in niche markets in the medical, oil and gas, aerospace and defence industries is also stimulating innovation (Semta, 2010). In the UK, the growth of high value-added sectors such as pharmaceuticals, automotive and aerospace is resulting in demand for design and higher-level skills across all aspects of the production cycle.

Employers reported that new technological advances are playing a significant role in driving changes in the electronics and electrical industry. For example, most employers stated that they had either recently introduced plastic electronic production to their production line or planned to do so in the near future. Other developments, such as silicon electronics and nanotechnology, are seen as having few applications at present and consequently their impact is limited to a few niche products.

Across the electronics and electrical sector in general, there is also a general trend towards miniaturisation: *'products get 10 per cent smaller each year'*. As a consequence, there is demand for new technologies such as plastic electronics that can reduce the heat usage and weight of a product, allowing it to be fitted in a smaller space. This has been used for products such as security lights, sensors and creating new slim line LCD TVs.

How the assembler occupation is changing as a consequence of advanced manufacturing technologies

Employer interviewees generally reported that the assembler occupation had not changed significantly in recent years despite the increasing use of new technologies, largely because employers are increasingly using supply chains to produce new components and then integrating these new products using traditional craft techniques. Outsourcing the production of new components is often more cost-effective than developing the product themselves, as it does not require investment in new equipment or R&D.

The main change to the assembler role has been in the increasing need for *'IT literacy'.* Workers on the production line are increasingly required to enter information onto IT systems for quality assurance monitoring and to access design documentation. For example, one employer reported introducing touch screen consoles to control the machines on a production line. In addition, whereas assemblers previously recorded information in paper format, they now collect digital production data.

Skills challenges facing assemblers today

The main skills that employers required from assemblers were behavioural skills: a good work ethic; attention to detail; flexibility; and the ability to work well in a team. A Level 3 qualification in electronics is also desirable. However, most employers believed that *'even if they do not have an electronics background, if they have the right attitude we can train them on-the-job'.*

Most employers interviewed had a relatively established assembler workforce and few reported any skills gaps relating to the occupation. Most assemblers are taught the basics of the role in the first four to six weeks, after which most have the skills they require to work on the production line. Although workers occasionally have to get used to new equipment or changes to the role, most employers were able to provide manufacturer training or mentoring, which was generally sufficient to up-skill staff.

When employers have had to replace assemblers, a few reported difficulties in recruiting staff with sufficient practical skills and the right attitude. Although there were usually a high number of applicants, employers reported that some new recruits drop out early as many are not able to work to a consistent standard and pay attention to detail (which it is only possible to assess once an assembler had been trained and left to do tasks independently). Moreover, some workers leave as the role does not always match their expectations.

5 Future skills

Chapter summary

This chapter sets out findings relating to the likely future skills needs of employers in the sector based on interviews with employers within the advanced manufacturing sub-sector and data projections.

Although manufacturing employment as a whole is expected to decline up to 2022, recent international and EU level forecasts have predicted that advanced manufacturing is expected to grow significantly in the coming years, particularly in Western Europe.

Recent projections show that demand for high skilled occupations is expected to increase. The growing complexity of production processes is likely to increase demand for production and process engineers, who will need to dedicate an increasing amount of time to managing production processes over multiple sites.

Employer interviews suggest that the importance of R&D will also lead to increased demand for production and process engineers and biological scientists and biochemists with higher degrees and specialisms. The search for high-performing students is likely to make the UK workforce even more international in nature.

Some roles are expected to change significantly in future. Employers anticipate that the role of production manager and directors of manufacturing may be split into two distinct roles, and in large organisations they will be more outward facing, focusing on supply chain management, purchasing, contract negotiation and large-scale contract management.

The maintenance fitter role may become more service-based, as employers contract more complex machine initialisation and calibration. In addition, workers will also increasingly require software development skills to maintain mainly programme-driven machines.

5.1 Overview

The UKCES Working Futures 2012-2022 (Wilson et al., 2014) projections show that employment in manufacturing is expected to decline from 2.6 million in 2012 to 2.4 million in 2022, a fall of nine per cent. The manufacturing share of total UK employment is expected to drop from 8.2 per cent to 7.1 per cent over the same period. However, there will be 650,000 vacancies in the sector linked to replacement demand (the need to replace people who leave the sector workforce, for example through retirement or moving to another sector). Despite a decline in overall employment, GVA over the same period is expected to increase from £138 billion in 2012 to £160 billion in 2022. The manufacturing share of the UK GVA will remain relatively constant.

Although manufacturing employment as a whole is expected to decline up to 2022, recent forecasts have predicted that advanced manufacturing is expected to grow significantly in the coming years, particularly in Western Europe. The European Competitiveness Report (European Commission, 2013b) predicts the global advanced manufacturing market will double in size to £750 billion by 2020. This will be driven by growth in 3D printing (expected to grow globally by 13.5 per cent) and robotics and robot-related products (expected to grow by 36.4 per cent).

The number of high skilled jobs is also expected to increase up to 2022. This is reflected in the growth projections for the five key occupations (see Table 5.1).

Table 5.1 Employment projections for key occupations within manufacturing, 2012-2022

Occupation	Persons employed (2012)	Persons employed (2022)	Change persons employed	% change in persons employed	Replacement demand
Production managers and directors in manufacturing	284,800	349,000	64,200	23%	109,800
Biological scientists and biochemists	86,600	104,300	17,700	20%	28,000
Production and process engineers	52,800	63,600	10,800	20%	17,100
Metal working production and maintenance fitters	214,100	197,700	-16,400	-8%	66,900
Assemblers (electrical and electronic products)	30,500	22,600	-8,000	-26%	8,500
Total selected occupations	668,900	737,300	68,300	10%	230,300
Total manufacturing	2,646,000	2,417,000	-229,000	-9%	650,000

UKCES Working Futures 2012-2022 (Wilson et al., 2014)

There will be a significant increase in jobs for production managers and directors in manufacturing, biological scientists and production and process engineers. Each occupation will experience growth of over 20 per cent. In contrast, the level of employment for metal working production and maintenance fitters and assemblers is expected to fall. The number of metal working production and maintenance fitters is expected to fall by eight per cent (16,000 jobs) and assemblers jobs are expected to fall by 26 per cent (8,000). However, due to replacement demand there will still be job opportunities in these two occupations.

5.2 The future skills required for key occupations

5.2.1 Production managers and directors in manufacturing

There is anticipated to be a general shift towards production managers/directors requiring more business-related skills. Employers reported facing a significant challenge in ensuring staff that have both the business skills and technical production skills to perform their role effectively.

Some employers interviewed expected that in future they may have to split the occupation into two distinct roles. One role will focus on quality assurance and regulatory aspects of the job. The other role will involve overseeing the design process and management of the production line. These changes are likely to increase the number of production managers/directors in manufacturing in accordance with the Working Futures projections.

In large OEMs, the consensus among employers is that the role of production managers and directors in manufacturing will shift to becoming more focused on supply chain management, purchasing, contract negotiation and large scale project management. This is partly a consequence of the complexity of new product components (meaning that one individual is unlikely to understand how all the components in a product work) and the growing trend of outsourcing production to supply chain companies, which are better equipped to specialise in developing niche components.

> [In future] you will not just looking down within your organisation about your manufacturing capability…you will be looking outside your organisation where you have a different level of control and influence to make sure that the values of your company are being absorbed and represented in the supply chain…they have a direct impact on your brand and product' (Large employer, Aerospace industry).

Recent research (Foresight 2013; BIS 2010a) suggests that future growth opportunities in emerging markets are likely to require production managers and directors in manufacturing to have skills in creating trade partnerships.

In future, production managers/directors in manufacturing will also need to dedicate more time to continuous professional development to ensure they keep abreast of the latest sector developments. This may require a step change in how managers think about their role. New technologies such as composites and nanotechnology are increasing the pace of change in the sector. New materials that can be used in production are being created every year as a consequence of these technologies. These products will need to be tracked and appraised for their potential usefulness to the manufacturing process, as UK manufacturers face growing competition from China, the USA and emerging economies.

5.2.2 Biological scientists and biochemists

New digital technologies will make clinical trials less labour intensive, consequently freeing the time for biological scientists and biochemists to focus on other tasks. This will likely mean that workers in the future will be investing more time in R&D to develop new products. Employers will also benefit from new business opportunities, as large scale trials become more feasible as they will be less costly.

> In future, computer technology should make clinical trials far easier to do. We will be able to do things that at the moment we can only dream of. This means we can develop new products that would otherwise be unfeasible, and also means we will be able to put more resources into researching and designing new products (Small employer, pharmaceuticals sector).

Employers are expected to invest more in R&D in future, which will support new jobs in areas such as biological sciences and biochemistry. However, not all of these jobs will be created in the manufacturing sector. Some will be created in research facilities in universities, which are increasingly working in partnership with employers.

To develop new innovative products, employers will be aiming to recruit graduates with detailed knowledge of particular technologies. This is likely to result in an increasing need for specialist knowledge among new entrants, with a growing number of employers expecting students to gain a masters or doctorate degree before entering the sector. The search for high-performing students is likely to make the UK workforce even more international in nature.

In future, there is expected to be a growth in biological scientists and biochemists working within manufacturing industries. For example, the potential use of bioscience products in metal coating will lead to more biological scientists and biochemists working in the automotive industry. This brings a need for biological scientists to develop their knowledge of different industries, so they can apply their scientific skills effectively in different environments.

5.2.3 Production and process engineers

Production and process engineers will in future require a broader understanding of different production methods, as employers diversify their offer to meet increasing customer demand for tailored or bespoke products. This will increase demand for continuous professional development training and self-learning.

> Production engineers will in future need to be at the forefront of new developments. They should be able to take advantage of innovation in a way that is affordable, reliable and deliverable by your own manufacturing teams or the supply chain (Medium-sized employer, automotive).

The increasing complexity of production methods and growing use of sub-contracting may also require production and process engineers to require greater skills in project management, supply chain management and maintaining quality across multiple manufacturing sites.

The difficulties employers experience in recruiting production and process engineers is likely to become more acute in future, as 10,800 new jobs are predicted to be created by 2020. To address these issues, some employers may recruit more technicians on the production line to support the process for monitoring production and designing products. This is likely to result in new pathways into the sector and increasing demand for apprenticeship provision.

As with biological scientists, increasing future investment in R&D will likely increase demand for graduates with masters and doctorate degrees. Some employers, and particularly larger companies, will increasingly look to recruit high performing graduates from outside the UK to meet skills shortages.

Production engineers are also expected to play a key role in supporting the roll out of industrial biotechnology (SSC Advanced Manufacturing Cluster, 2009). This requires production engineers to have knowledge of biology, genetics and microbiology to manage more varied production methods.

5.2.4 Metal working production and maintenance fitters

In future, software development skills will become an increasingly important part of maintenance fitters' role. Some employers are likely to employ specialist software engineers in their maintenance teams to perform specific diagnostic assessments and repairs to machines.

> In ten years' time new technologies will require more complex programming skills to programme the PCUs (Programme Control Units). Maintenance fitters will need the computer skills to maintain these programmes. The job will be a lot less about working with your hands and more about what you can do with a keyboard (Small employer, manufacturer of machinery and equipment).

New types of maintenance fitting jobs are likely to be created in future following the growing automation of the production process. Technologies such as 3D printing and silicon technology are also likely to result in more complex machines being employed, which in turn will require regular maintenance and monitoring, boosting employment in certain areas even if the overall number of maintenance fitter jobs falls.

In future, the role of maintenance fitters is expected to become more service-focused, as manufacturers outsource more complex machine calibration and system setting to specialist machine maintenance companies. This will result in maintenance fitters requiring greater skills in customer service, relationship management and a broader understanding of the application of manufacturing equipment.

For metal workers, some jobs in future may be replaced by assembler or machine operator roles, following the increasing use of laser cutting and 3D printing. The level of skills required by metal workers are likely to increase however, as a larger proportion of jobs will be in developing more specialist, customised products.

5.2.5 Assemblers (electric and electronic products)

Although in future technologies such as 3D printing and plastic electronics will be commonly used in the sector, the skills required from assemblers are not expected to change significantly. New technologies largely result in fewer components requiring assemblers, but it is expected that components will joined through traditional methods such as soldering.

> I don't think the role of assemblers will change in the future. It will still be about putting together components to a plan. If anything, it should become easier as the components will be made using lasers and 3D printers so will be more accurate and need less preparation before they can be joined together (Small employer, electronics and electrical industry).

Demand for assembler roles is expected to decrease in future as the use of laser cutting tools and growing automation of production lines will mean that new products will require less preparation and can be more easily slotted together. However, this will be balanced by an increase in jobs for technicians to design and develop new products using machine tools. There will still be niche and specialist manufacturers that will continue to require assemblers to develop hand-crafted products. Assemblers will need to understand how components work and have high technical craft skills as these products will be more complex to assemble.

6 Current and future interest in occupational standards

Chapter summary

This chapter draws on employer interviews and the 2014 UK Commission's Employer Perspectives Survey. It sets out employers' current and future interest in occupational standards, including National Occupational Standards (NOS).

The 2014 UK Commission's Employer Perspectives Survey indicates that manufacturing employers have a slightly lower than average awareness of NOS. Most employers interviewed were also not aware of NOS, but, when pressed, employers generally understood that key sector training, such as apprenticeships, were based on a consistent set of national standards.

Employers report that as a performance management tool NOS were a useful starting point, but may require tailoring before they are applicable to specific work environments. This was largely because standards do not always refer to specific machines. NOS were, however, generally considered to be a crucial tool in ensuring consistency in training standards, particularly apprenticeships.

The research suggests high level NOS are widely considered important by employers for training, as they ensure the focus is on general skills that can be applied to different technologies. As some employers noted, the pace of technological advances in manufacturing means that specific machinery soon becomes obsolete and new technology takes its place.

As a consequence of these factors, relatively few of the employers interviewed used NOS to develop performance management tools. However, use of NOS may not always be visible to employers: for example, a large proportion of those offering Apprenticeships were not aware they were based on NOS. In addition, some recruitment companies and other specialists may be using NOS to develop their products but this is not necessarily apparent to employers.

6.1 Overview of National Occupational Standards in manufacturing

National Occupational Standards describe the knowledge, skills and understanding an individual needs to be competent at a job. They are UK-wide, demand-led, evidence-based benchmarks of competent performance which underpin vocational learning and development, apprenticeships and qualifications across all sectors, occupations and parts of the UK.

NOS can be used in many different ways. For example:

- awarding bodies can use NOS to create qualifications (including those used in Apprenticeships) to train individuals for a job;
- employers can use them create a job description to recruit new staff or a training plan to develop their skills;
- individuals can research and identify different types of jobs which match their skills and experience.

The vision for NOS is to ensure they are employer demand driven and based on informed analysis of current and future labour market need. UKCES is working with networks of employers (including through professional bodies, sector skills organisations and industrial partnerships) to ensure that NOS articulate the ambition and aspiration of their workforces clearly and effectively.

National Occupational Standards (NOS) for manufacturing cover a wide range of sub sectors. These sub sectors fall under the remit of a range of sector skills councils, including Cogent, Semta and Improve. They include sector-specific suites in industries such as:

- aeronautical engineering;
- automotive engineering;
- composite engineering;
- fabrication and welding engineering;
- performing manufacturing operations;
- life sciences;
- manufacture of textile products.

Overall, there are over 20 NOS suites that relate to different manufacturing sectors.

6.2 Overall awareness and use of National Occupational Standards

The 2014 UK Commission's Employer Perspectives Survey indicates that manufacturing employers have a slightly lower than average awareness of NOS. Two-thirds of manufacturing employers had not heard of NOS, the highest proportion of any major sector. One in 20 manufacturing employers (five per cent) have made use of NOS in some way, compared to one in ten (10 per cent) of all employers (UKCEPS, 2014).

However, employers may be using NOS or products based on NOS without necessarily being aware that they are linked to NOS. For example, the UK Commission's Employer Perspectives Survey shows that 82 per cent of UK employers offering formal Apprenticeships in 2014 stated that they did not use NOS, when elements of all of these Apprenticeships were based on NOS.

6.2.1 The use of standards in the sector

Most employers interviewed for this study acknowledged the importance of having clear standards in place for employees. This was understood to bring benefits in improving health and safety on site, increasing the efficiency of production processes and providing a 'kite mark' to help win contracts.

A broad range of standards are used by advanced manufacturing employers to inform their business processes and staff development practices. The diversity in standards is unsurprising, considering the range of industries that form the advanced manufacturing sector.

Common standards used by employers include:

- **Health and Safety standards.** Most employers use standards to determine how equipment should be used and what precautions employees are required to take. Employers typically use standards developed by the Health and Safety Executive, and International Organization for Standardization (ISO) on areas such as Manual Handling, Forklift truck driving and general health and safety in the workplace.
- **Industry specific standards.** A few employers reported using standards such as ISO 9011 (production line processes) and British Standards Institute (BSI) products for the use of manufacturing machines. In the electronics and electrical sector, employers also reported using Association Connecting Electronics Industries (IPC) standards on electronic circuit design and manufacture.
- **Sub-contracting standards.** Some employers reported having to comply with the Safe Contractor requirements. SMEs reported that many large employers require all their sub-contractors to conform to these standards. Even if it is not a mandatory

requirement, supply chain employers reported that achieving these standards enabled them to win more sub-contracting work.

Some employers, mostly SMEs, did not explicitly use standards to develop performance management tools (such as role profiles, performance matrices). These employers generally believed that the uniqueness of their business meant that standard occupational tools did not reflect the needs of their organisation. For these employers role profiles and performance frameworks were largely developed in house.

> We believe that it is the managers in the organisation that are best-placed to understand what is required from staff in the organisation (Small employer, chemicals industry).

There appeared to be greater demand for standards among employers that had made changes to their production processes in recent years. There was a sense that when performance management tools are considered ‘dynamic’, employers are more inclined to use standards to identify good and effective practice in performing certain job roles. In contrast, employers that reported they had not changed their role profiles in the last few years were less likely to use standards.

Time pressures also constrain the extent to which employers use standards. In smaller companies, when the owner/manager is largely responsible for HR, employers commonly reported that they had little time to identify effective standards or update their performance management tools. Companies that had dedicated HR functions were far more likely to use external standards in their organisation.

As a result of time pressures, there appears to be a growing trend of employers outsourcing the development of role profiles and performance management tools to recruitment agencies. A few employers stated they recently employed a recruitment company to develop role profiles required for new job adverts, and have consequently continued to use these role profiles for in-house performance management. Employers believed that the input and expertise of the recruitment company was useful in developing these tools. One large employer also reported outsourcing the development of standards to an ‘occupational psychologist’ who drew on national and professional body standards, as well as research on the nature of occupation to develop appropriate role profiles.

6.2.2 Employer awareness and use of NOS

Relatively few of the employers interviewed stated they were aware of NOS. However, when pressed employers generally understood that key sector training, such as NVQs and apprenticeships, were based on a consistent set of national training standards.

Awareness of NOS was higher among larger employers. There is a sense that occupational standards are more valuable to organisations that employ a high volume of staff working across multiple sites and with different managers, where ensuring consistency in work standards can be more difficult. In contrast, smaller employers largely reported that they felt occupational standards were less relevant because *"we are a small team and I so I can see if people are doing the job properly".*

Awareness was also higher among employers that contributed to area or sector-level initiatives, such as participating in Local Economic Partnerships (LEPs) or Trailblazer apprenticeships (in England) and working with sector skills councils. In these groups, NOS are considered one of many levers to help improve productivity and quality in the sector.

6.2.3 Perceptions of NOS

As a performance management tool, NOS were considered a potential starting point. However, employers were keen to stress that the limitation with 'off the shelf' products is that they can require tailoring before they are seen as applicable to employers' work environment.

The main limitations with NOS were reported to be:

- **The standards do not include reference to the specific machinery used by employers.** In manufacturing, the machinery that workers use largely dictates their responsibilities. For example, engineers will need to perform specific functions on a certain design software package, and machine operators will need to use specific equipment. This information needs to be included in a job role specification to ensure they are meaningful, but they are not included in NOS that are required to be 'technology independent'.
- **NOS do not always reflect the fluid nature of job roles in SMEs**. Companies with relatively few employees (less than 20) often have staff that conduct a broad range of functions. For example, we interviewed employers who reported that technicians play a key role in supporting the design process, which is commonly the responsibility of engineers. As a consequence, employers believed that many of their job roles were specific to their organisation.

NOS were, however, generally considered to be a crucial tool in ensuring consistency in the quality and relevance training standards, particularly apprenticeships. When recruiting new staff, employers want to be assured that an individual that completed an apprenticeship with another employer has the same core knowledge, skills and competencies as an apprentice trained in their organisation.

High level NOS are widely considered important by employers for training as they ensure the focus is on general skills that can be applied to different technologies. As some employers noted, the pace of technological advances in manufacturing means that specific machinery soon becomes obsolete and new technology takes its place. Employers acknowledge that for any new recruit, there will be a need for induction training so they learn about the specific technology and equipment used by any given company.

However, ensuring that NOS remain sufficiently generalisable to be an effective tool for informing training potentially limits their application as a performance management tool. Employers generally require these tools to have detailed information on specific technologies to be meaningful. This means that, while NOS can be used to develop performance management tools, doing so requires adjustments, which may discourage some employers from using them.

As a consequence of these factors, relatively few of the employers interviewed used NOS to develop performance management tools. Where NOS were used, it was as one of many sources used by HR staff to develop role profiles. However, it is possible that the use of NOS is not always visible to employers. For example some recruitment companies and other specialists that develop job descriptions may be using NOS to develop their products, but this would not necessarily be visible to employers.

7 Conclusions and recommendations

7.1 Conclusions

7.1.1 Sector outlook

Advanced manufacturing is a significant part of the manufacturing sector, comprising around 23 per cent of the total number of manufacturing enterprises. These enterprises generated over £72 billion of GVA in 2013. Although the manufacturing sector has decreased by 11 per cent over between 2008 and 2012, some industries have experienced significant growth over the same period, most notably pharmaceuticals, aerospace and scientific research and development (ABS, 2014).

The advanced manufacturing sector makes up four per cent of total employment in the UK, employing 1.3 million people in 2014, increasing by 68,000 since 2009. The sector is dominated by men, who comprise 74 per cent of the sector workforce. This is similar to the gender split in the manufacturing sector as a whole (LFS, September 2014).

The sector is very diverse, incorporating industries such as aerospace, automotive, pharmaceuticals, chemical manufacturing and electronics. As a consequence, there is significant variation in the occupations in the sector. No occupation comprises more than five per cent of the total number of jobs. Most occupations are only common in two or three advanced manufacturing industries.

Although the manufacturing sector is expected to decline in size up to 2022 (Wilson et al., 2014), EU projections (EU Commission, 2013) suggest the advanced manufacturing will grow significantly over the same period. This will be due to the increasing use of technology to generate efficiencies in the production process, and employers developing innovative new products that can be traded internationally.

However, to achieve this desired growth there are a range of challenges that UK advanced manufacturing employers must overcome, most notably:

- **Accessing funding to bring to market new products.** Although the UK performs well in patent applications, companies in the UK and Europe invest far less well brining these products to market.
- **Investing in R&D.** Advanced manufacturing is largely reliant on high quality R&D, which will require high-quality science and engineering graduates to enter and progress in the sector.

- **Maximising export opportunities.** Advanced manufacturing employers export a higher proportion of goods than the manufacturing sector as a whole. Taking advantage of new overseas market is seen as a key contributor to growth.
- **Taking advantage of potentially transformative enabling technologies.** There are a range of new technologies that are expected to provide significant stimulus to the advanced manufacturing sector as they enable new products to be created and improve the efficiency of production processes. These enabling technologies include additive manufacturing; composite manufacturing; nanotechnology; plastic electronics; silicon electronics and industrial biotechnology.

7.1.2 Current workforce and skills challenges

The employers interviewed suggest that there is a growing shift towards senior managers and professionals requiring more business-related skills in order to identify new business opportunities, meet regulatory requirements and to be able to critically appraise the benefits of different technologies and how they could impact on the production line.

The growing 'computerisation' of production processes and increasing reliance on design software and computer-led manufacturing machines is resulting in all workers having to develop additional IT skills (both general IT literacy and being able to use new software packages). Senior managers and professional staff need skills to use a broader range of software and equipment for designing production systems and interpret computer-collected information to monitor quality. Operational staff also have to be able to use new computer-led equipment and identify faults when they occur.

Design skills and CNC skills are also becoming more important due to the increasing use of computers on the production line. The growing complexity of new products is resulting in some employers experiencing skills challenges in these areas.

Advanced manufacturing techniques are starting to bring significant efficiency savings to the sector. In pharmaceuticals, there is evidence of new technologies making clinical trials less costly and less time consuming for biological scientists and biochemists. This both creates new business opportunities for employers and also allows biological scientists and biochemists to invest more time in high-value activities such as R&D. In other sectors, advanced manufacturing methods such as 3D printing, plastic electronics and laser cutting are increasing the ease with which products can be prefabricated, reducing the need for assemblers and factory floor workers.

Increasing customer demand for tailored or bespoke products is also resulting in shorter production runs and a more varied manufacturer offer. This is requiring professional and operational staff to have a wider knowledge and understanding of different technologies and production methods.

Over the last few years the sector has experienced significant difficulties in recruiting to some professional occupations, most notably biological scientists/biochemists and engineers. Some employers recruit from outside the UK. However, there is also a growing trend of employers taking on apprentices to train them to a position where they can progress to these roles, largely with positive results. In addition, many employers are already working with SSCs and relevant industrial partnerships to address skills issues.

7.1.3 Future workforce and skills challenges

Employers anticipate that new technologies are expected to make senior manager and professional roles more complex, which is likely to lead to growing demarcation of roles. Production managers/directors in manufacturing may split into jobs focusing on quality and regulation on one side, and on the design and development of products on the production line on the other. For production and process engineers, an increasing part of the design role is likely to be done by technicians, with engineers having more of an oversight role. The number of jobs in these occupations is also expected to increase overall up to 2020.

It is expected that, in future, there will be an increase in sub-contracting to develop new, more complex products. Consequently, some senior managers and professionals, particularly those in large employers, will require greater skills in project management, supply chain management and maintaining quality across multiple manufacturing sites. In order to keep pace with new developments, there will also be an increasing need for senior managers and professionals to undertake continuing professional development and self-learning.

Increasing investment in R&D is also likely to result in employers requiring increasingly specialist skills among new entrants. Consequently there is likely to be an increased demand for STEM graduates educated to masters or doctorate level.

The growing automation of the production process is also likely to result in the number of assembler jobs decreasing. However, this may be balanced by an increase in some technical occupations.

7.1.4 The role of NOS

The UK Commission's Employer Perspectives Survey 2014 shows relatively low awareness of NOS across the manufacturing sector, compared to the total economy. Although employers were not aware of NOS *per se*, the interviews found that most were aware that key vocational training such as apprenticeships and NVQs were developed around a common set of standards.

There are a wide range of standards used by the sector that generally apply to health and safety, sub-contracting and sector specific skills. NOS are less widely used because employers generally require job descriptions and performance tools to relate to specific technologies and software packages. However, some employers have employed recruitment agencies and occupational specialists to develop role profiles. It is likely that these organisations are using NOS alongside a range of information sources (including professional standards and ISO standards) to develop these role profiles.

NOS were generally considered to be a crucial tool in ensuring consistency in training standards, particularly apprenticeships. This was perceived to help ensure greater consistency in the quality and relevance in training, supporting the recruitment and professional development of staff.

The general nature of NOS, which makes them a useful tool for informing training, potentially limits their application as a performance management tool. This does not mean that NOS cannot be used to develop performance management tools, but that to do so may require adjustments, which could discourage some employers from using them.

7.2 Recommendations

The need for an increasingly IT-competent workforce at all levels may be a defining characteristic of the future advanced manufacturing skills base. **Employers need to invest in developing a workforce capable of taking advantage of new technologies by providing training and support on design/CNC software packages**.

Universities and vocational training providers need to liaise with employers to ensure that technology skills are embedded at the heart of a wide range of STEM-related programmes to give the future workforce the grounding and adaptability to transition to a range of manufacturing roles (as well as roles beyond manufacturing). Many courses already do this and, arguably, the greater challenge relates to the upskilling and continuous development of the existing workforce.

In this context, **other training priorities for employers should include leadership and management and supply chain management**. Collectively these training investments will help the sector respond to changes taking place as a consequence of new technologies. While supply chain management is already a core function, especially for OEMs, there is the potential that, in future, increased sub-contracting in new areas and the increased complexity of products will substantially increase the pressures on managers and senior staff. This is unlikely just to be an issue for large businesses.

Scientific professional roles associated with advanced manufacturing are already associated with a culture of professional development. In future there is likely to be greater onus on production managers, directors and similar professional roles adopting this kind of culture. **Managers in advanced manufacturing should explore ways to take ownership over their own continuing professional development and ensure that they have the space and learning opportunities in place to meet future demands.** There are likely to be benefits in considering new structured CPD programmes and the extent that these can made relevant to wide cross-section of managers/professionals. There is scope for this to be another route to cascading new ideas through the sector (from large to small businesses and vice versa; between industries and so on).

Some employers report that offering apprenticeships has enabled them to address skills and performance challenges, and helped in recruiting and progressing production and process engineers. **Other employers within advanced manufacturing could assess the benefits of offering apprenticeships, and ensure they have clear pathways in place to enable progression to higher-level technical and professional roles.**

For a long time it has been recognised that manufacturing – and advanced manufacturing in particular – benefits from collaboration and partnership with higher education. In the context of supply chain relationships these models are likely to continue to be important for generating and sharing innovations that will impact on advanced manufacturing jobs. Importantly, an infrastructure is in place that has skills and training at its heart (e.g. the Catapult Network, Industrial Partnerships and SSCs as well as the existing supply chain clusters around individual Original Equipment Manufacturers). **Continued investment by government in these models is likely to be worthwhile in the context of industries that need to mitigate risk in order to pursue business development / innovation.** In the context of future skills challenges, there are a set of measures that might inform the level, nature and targeting of future investment. These include:

- Whether training funded through or informed by networks/partnerships is accessible to a cross-section of advanced manufacturing jobs.

- How effectively networks/partnerships with an industry or specific technology-focus can reach out to support businesses and employees in related areas. **There may be a role for government to help foster these links and support the development of skills and knowledge beyond traditional industry silos**, partly in recognition that career paths may become more varied and permeable in future.
- The ultimate sustainability of these networks/partnerships in terms of the value they offer to businesses to continue engagement. **Universities, research centres and other training providers should share learning about 'what works' in terms of the industry role as a partner to and customer of these services** (for example, how training programmes in general are improved through collaboration between business and education for the purposes of solving a business problem).

In general, partnerships with universities are providing significant benefits to employers. SMEs in particular have found investing in universities to research new products far more cost-effective than conducting R&D in-house. There are opportunities for more SMEs to benefit from these relationships, and consequently the **industries and government should conduct more research to examine good practice in engaging SMEs in R&D and disseminate this widely across the sector.**

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Appendix A: Methodological note

Defining Advanced Manufacturing

The broad definition of advanced manufacturing is the ‘use of cutting edge skills or technologies to generate efficiencies and improvements to production processes’ (EU Skills Panorama, 2014). However, although advanced manufacturing techniques can be applied across all parts of the sector, they have tended to predominate in specific sub-sectors. In practice, advanced manufacturing technologies are far more likely to be used in technology intensive industries.

Eurostat publishes statistics on high-technology sectors[10]. This provides the most established method of relating general concepts of advanced manufacturing to statistical classifications of industries. It contains a degree of subtlety that allows for a relatively sophisticated classification based on a sector dimension, a product dimension and patents (Eurostat, 2013):

- The sector approach classifies industries by technological intensity measured in terms of R&D expenditure/value added and classifies manufacturing industries as ‘high’, ‘medium-high’, ‘medium-low’ and ‘low’ technology on this basis.
- The product approach is based on OECD concepts of the ‘R&D intensity of products’ as a function of total sales.
- The patent approach incorporates high-tech and biotechnology patents as defined by the International Patent Classification.

The sector approach provided the basis for the advanced manufacturing definition as it direct relates to SIC industries. This could then be cross-referenced to the high-technology product group, which enabled refinement to the sector classification to include ‘medium-high’ as well as ‘high’ technology industries, in order to ensure that all advanced manufacturing products were covered. The classification of patents does not directly relate to an industry-based definition of advanced manufacturing, but provides a further rationale for the inclusion of the scientific research and development industry.

[10] High-tech statistics comprise economic, employment and ‘science, technology and innovation’ (STI) data describing manufacturing and services industries, broken down by technological intensity.

Table A.1 summarises the rationale for including or excluding industries at the three-digit SIC Industry Group level.

Table A.1 Rationale for determining the advanced manufacturing industries

Industry Division- SIC number and title	Rationale for inclusion in advanced manufacturing scope
10 Manufacture of food products	Excluded: Low-technology industry
11 Manufacture of beverages	Excluded: Low-technology industry
12 Manufacture of tobacco products	Excluded: Low-technology industry
13 Manufacture of textiles	Excluded: Low-technology industry
14 Manufacture of wearing apparel	Excluded: Low-technology industry
15 Manufacture of leather/related products	Excluded: Low-technology industry
16 Manufacture of wood and of products of wood and cork, except furniture	Excluded: Low-technology industry
17 Manufacture of paper and paper products	Excluded: Low-technology industry
18 Printing/reproduction of recorded media	Excluded: Low- and medium-low tech industry
19 Manufacture of coke and refined petroleum products	Excluded: Medium-low technology industry
20 Manufacture of chemicals and chemical products	Included: Medium-high technology industry
21 Manufacture of basic pharmaceutical products and pharmaceutical preparations	Included: High-technology industry
22 Manufacture of rubber and plastic products	Excluded: Medium-low technology industry
23 Manufacture of other non-metallic mineral products	Excluded: Medium-low technology industry
24 Manufacture of basic metals	Excluded: Medium-low technology industry
25 Manufacture of fabricated metal products, except machinery and equipment	Partially included: Primarily medium-low tech, except 25.4 (manufacture of weapons and ammunition), which is medium-high tech
26 Manufacture of computer, electronic and optical products	Included: High-technology industry
27 Manufacture of electrical equipment	Included: Medium-high technology industry
28 Manufacture of machinery/equipment n.e.c	Included: Medium-high technology industry
29 Manufacture of motor vehicles and trailers	Included: Medium-high technology industry
30 Manufacture of other transport equipment	Partially included: Mix of high-tech (30.3: air, spacecraft/related machinery) and medium-high tech (30.2: locomotives etc; 30.4: military vehicles; 30.9: transport equipment n.e.c. – motorcycles etc). One medium-low tech group (30.1: building of ships and boats) is excluded
31 Manufacture of furniture	Excluded: Low-technology industry
32 Other manufacturing	Partially included: Primarily low-tech. One medium-high tech group (32.5: manufacture of medical/dental instruments) is included
33 Repair and installation of machinery/equipment	Excluded: Medium-low technology industry

72 Scientific research and development	Partially included: 72.1 Research and experimental development on natural sciences and engineering is included. 72.2 Research and experimental development on social sciences and humanities is excluded.

Source: ICF based on Eurostat, 2013 and ONS, 2009

Appendix B: Labour Force Survey occupation data

Table B.1 Distribution of production managers/directors in manufacturing by industry

Industry (selected)	Total number	Percentage (all industries
25 Manufacture fabricated metal products, excluding machinery	**22,444**	**7.9%**
71 Architectural and engineering	*18,248*	*6.4%*
10 Manufacture of food products	16,523	5.8%
28 Manufacture of machinery n.e.c.	**16,198**	**5.7%**
43 Specialised construction activities	*15,880*	*5.6%*
46 Wholesale trade, except vehicles	*11,502*	*4.1%*
22 Manufacture rubber plastic products	11,384	4.0%
18 Printing and recorded media	10,620	3.7%
26 Manufacture computer, electronic & optical	**9,773**	**3.5%**
42 Civil engineering	*9,669*	*3.4%*
30 Manufacture of other transport	8,546	3.0%
24 Manufacture of basic metals	7,718	2.7%
23 Manufacture non-metallic mineral products	7,411	2.6%
20 Manufacture of chemicals	6,754	2.4%
33 Repair and installation of machinery	*6,630*	*2.3%*
Total (manufacturing[11])	**167,552**	**59.2%**
Total (all industries)	**283,226**	**100%**

Source: LFS Four-quarter average (October 2013 to September 2014), Industry division in main job (2-digits), Person weight. Note: Advanced manufacturing industries in bold. Non-manufacturing industries in italics

[11] Manufacturing – Section C, Industries 10-33

Table B.2 Distribution of biological scientists and biochemists by industry

Industry (selected)	Total number	Percentage (all industries
86 Human health activities	*23,981*	*24.5%*
72 Scientific research and development	**23,416**	**23.9%**
85 Education	*11,321*	*11.6%*
21 Manufacture of pharmaceuticals	**8,633**	**8.8%**
71 Architectural and engineering	*5,224*	*5.3%*
84 Public admin, defence, social sec	*4,729*	*4.8%*
94 Activities membership organisations	*3,696*	*3.8%*
01 Crop, animal production, hunting	*3,638*	*3.7%*
46 Wholesale trade, except vehicles	*2,883*	*2.9%*
36 Water collection, treatment & supply	*1,991*	*2.0%*
74 Other prof, scientific and technical	*1,651*	*1.7%*
91 Libraries, archives, museums	*1,117*	*1.1%*
81 Services to buildings and landscape	*1,080*	*1.1%*
20 Manufacture of chemicals	**1,067**	**1.1%**
75 Veterinary activities	*451*	*0.5%*
Total (manufacturing[12])	**10,751**	**11.0%[13]**
Total (all industries)	**97,778**	**100%**

Source: LFS Four-quarter average (October 2013 to September 2014), Industry division in main job (2-digits), Person weight. Note: Advanced manufacturing industries in bold. Non-manufacturing industries in italics

[12] Manufacturing – Section C, Industries 10-33

[13] NB: excluding SIC72 – which is included in the advanced manufacturing definition

Table B.3 Distribution of production and process engineers by industry

Industry (selected)	Total number	Percentage (all industries
71 Architectural and engineering	*8,480*	*15.3%*
30 Manufacture of other transport	**4,737**	**8.6%**
28 Manufacture of machinery n.e.c.	**4,311**	**7.8%**
46 Wholesale trade, except vehicles	*4,183*	*7.6%*
29 Manufacture vehicles and trailers	**3,754**	**6.8%**
20 Manufacture of chemicals	**3,430**	**6.2%**
26 Manufacture computer, electronic & optical	**3,043**	**5.5%**
25 Manufacture fabricated metal products, excluding machinery	**2,997**	**5.4%**
09 Mining support service activities	*2,252*	*4.1%*
27 Manufacture of electrical equipment	**1,869**	**3.4%**
24 Manufacture of basic metals	1,626	2.9%
21 Manufacture of pharmaceuticals	**1,381**	**2.5%**
33 Repair and installation of machinery	1,349	2.4%
19 Manufacture of coke & refined petrol	1,321	2.4%
22 Manufacture rubber plastic products	927	1.7%
Total (manufacturing[14])	**32,503**	**58.8**
Total (all industries)	**55,321**	**100**

Source: LFS Four-quarter average (October 2013 to September 2014), Industry division in main job (2-digits), Person weight. Note: Advanced manufacturing industries in bold. Non-manufacturing industries in italics

[14] Manufacturing – Section C, Industries 10-33

Table B.4 Distribution of metal working production and maintenance fitters by industry

Industry (selected)	Total number	Percentage (all industries
33 Repair and installation of machinery	25,347	13.2%
28 Manufacture of machinery n.e.c.	**19,021**	**9.9%**
25 Manufacture fabricated metal products, excluding machinery	**18,279**	**9.5%**
43 Specialised construction activities	*10,483*	*5.5%*
30 Manufacture of other transport	**9,540**	**5.0%**
10 Manufacture of food products	9,208	4.8%
29 Manufacture of vehicles and trailers	**7,841**	**4.1%**
41 Construction of buildings	*6,388*	*3.3%*
46 Wholesale trade, except vehicles	*5,945*	*3.1%*
22 Manufacture rubber plastic products	5,192	2.7%
24 Manufacture of basic metals	4,540	2.4%
95 Repair of computers and other goods	*4,189*	*2.2%*
71 Architectural and engineering	*4,145*	*2.2%*
23 Manufacture of non-metallic mineral products	3,864	2.0%
09 Mining support service activities	*3,843*	*2.0%*
Total (manufacturing[15])	**117,078**	**61.0%**
Total (all industries)	**191,944**	**100**

Source: LFS Four-quarter average (October 2013 to September 2014), Industry division in main job (2-digits), Person weight. Note: Advanced manufacturing industries in bold. Non-manufacturing industries in italics

[15] Manufacturing – Section C, Industries 10-33

Table B.5 Distribution of assemblers (electric/electronic) by industry

Industry (selected)	Total number	Percentage (all industries
26 Manufacture of computers, electronic & optical	**11,010**	**36.2%**
27 Manufacture of electrical equipment	**5,934**	**19.5%**
28 Manufacture of machinery n.e.c.	**3,330**	**11.0%**
46 Wholesale trade, except vehicles	*1,403*	*4.6%*
33 Repair and installation of machinery	1,338	4.4%
43 Specialised construction activities	*1,063*	*3.5%*
61 Telecommunications	*762*	*2.5%*
23 Manufacture of non-metallic mineral products	749	2.5%
18 Printing and recorded media	749	2.5%
95 Repair of computers and other goods	*744*	*2.4%*
29 Manufacture of vehicles and trailers	**634**	**2.1%**
71 Architectural and engineering	*577*	*1.9%*
62 Computer programming and consultancy	*576*	*1.9%*
25 Manufacture fabricated metal products, excluding machinery	**367**	**1.2%**
86 Human health activities	*278*	*0.9%*
Total (manufacturing[16])	**24,426**	**80.3%**
Total (all industries)	**30,410**	**100%**

Source: LFS Four-quarter average (October 2013 to September 2014), Industry division in main job (2-digits), Person weight. Note: Advanced manufacturing industries in bold. Non-manufacturing industries in italics

[16] Manufacturing – Section C, Industries 10-33

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