The Sector Skills Council for Science, Engineering and Manufacturing Technologies

semta

Skills and the future of Advanced Manufacturing

A Summary Skills Assessment for the SSC Advanced Manufacturing Cluster

December 2009

Advanced Manufacturing Cluster Membership

semta — The Sector Skills Council for Science, Engineering and Manufacturing Technologies

cogent — Skills for Science Based Industries

Improve — food & drink sector skills council

proskills — MAKING SKILLS WORK

skillfast-uk — The Sector Skills Council for fashion and textiles

Contents

1 Advanced Manufacturing: the UK response to global realities

Britain has a long and distinguished tradition as a manufacturing economy. Having created the technical innovations that triggered the industrial revolution, British manufacturing has continued to adapt to the changing nature of industrial and commercial markets. However, the early lead that put our enterprises in a commanding world position in Victorian times has long gone, and a range of tough global forces have increasingly tested the competitive strength of our manufacturing enterprises. The most obvious relate to economies with labour costs so low that firms in England cannot expect to compete, but there are others. It is in this context that the Government has committed to the leadership of an active industrial policy to take the UK into post-recession recovery with a common sense of purpose.

The White Paper 'New Industry, New Jobs' (NINJ), published in April 2009, set out a number of specific technological opportunities for economic growth and renewal, marking a shift in Government strategy towards a more proactive approach to industrial policy. Advanced Manufacturing is one of the six priority areas where there is clearly a global growth potential and Britain is the world's 6th largest manufacturing economy.

In response to the commitment laid down in NINJ, in July 2009, the report 'Advanced Manufacturing – Building Britain's Future' announced a package of funding measures to help UK manufacturers of all sizes and sectors to fully benefit from innovation drawing on key emerging technologies and new market opportunities.

'Advanced Manufacturing' describes industries and businesses which use a high level of design or scientific skills to produce innovative and technologically complex products and processes. The specialist requirements involved in Advanced Manufacturing Technologies (AMT) are associated with goods and services of high value. High value added manufacturing skills will be needed to secure the country's economic future to be both progressive and competitive in the global marketplace. AMT will also aid the transition to a low carbon economy by enabling energy efficiency savings.

Government has already taken certain action to address the skills needs of Manufacturing. A range of public policy measures are in place to ensure that companies and individuals are getting skills support at all levels to enable the economy to grow faster when recovery begins and to improve the skills base to exploit potential markets for future economic success in the Advanced Manufacturing technologies and sectors. These measures include: *Apprenticeships* (more than 23,500 engineering apprentice starts in 2007/08 in Advanced Manufacturing sectors); *Train to Gain Sector Compacts* led by Semta and Cogent Sector Skills Councils (SSCs), which cover the Advanced Manufacturing sectors and technologies; *National Skills Academies* for Manufacturing and for Materials Production and Supply; and *Foundation Degrees* which are designed with businesses and often delivered in the workplace. However, the stakes are high and more needs to be done.

Background

This summary report is the product of collaboration between five Sector Skills Councils responsible for skills issues in the majority of manufacturing in the UK and seeks to advance understanding of:

- The strategic context and drivers behind the development of Advanced Manufacturing technologies;
- The range and scope of Advanced Manufacturing technologies and how they affect many areas of economic life;
- The current skills issues facing the development of Advanced Manufacturing technologies;
- Anticipated future skills demand and supply issues, including the identification of skills mismatches;
- Cross-cutting issues affecting a number of individual Advanced Manufacturing technologies and industries; and,
- Key messages for government and priorities for action to support the development of Advanced Manufacturing.

Partners involved in the Advanced Manufacturing 'cluster'

The diverse and cross-cutting nature of the Advanced Manufacturing agenda was addressed by a group of Sector Skills Councils knowledgeable about a wide range of manufacturing. The cluster was led by Semta, the Sector Skills Council for Science, Engineering and Manufacturing Technologies. The cluster partners who have collaborated in producing this report are shown below, with the sectoral scope they represent.

Partners	Industrial Coverage
COGENT SSC	Chemical and Pharmaceutical, Oil, Gas, Nuclear, Petroleum and Polymers
Improve SSC	Food and Drink
Proskills SSC	Building Products, Coatings, Extractive and Mineral Processing, Furniture, Furnishings and Interiors, Glass and Glazing, Glazed Ceramics, Paper and Pulp and Printing
Semta	Science, Engineering and Manufacturing Technologies
Skillfast UK	Fashion and Textiles

Advanced Manufacturing SIC specification

While categorising a set of emerging technologies is inevitably a challenge for industrial classifications based on the world as it currently is (in fact, generally, *how it recently looked*), the structure of the sectors of relevance to the technologies/applications in this report is summarised in terms of the UK's *Standard Industrial Classification* (SIC) in Annex A.

A framework for Advanced Manufacturing Technologies (AMT)

Advanced Manufacturing is already an area of strength in the UK economy exemplified in areas such as aerospace and bioscience, and the Government's Advanced Manufacturing Strategy, together with expertise from the application sectors, has identified six areas of technological innovations/applications, each of which is examined in some depth in this report, to assess the relevant skills challenge.

- Aerospace
- Plastic/printed electronics
- Silicon electronics
- Industrial Biotechnology
- Composites
- Nanotechnology

In addition, a final section summarises some key further technologies of growing importance in the *supply chain* to the main manufacturing sectors.

Summary of Conclusions

The approach:

This is the first serious analysis by UK sectoral skills bodies of the skill needs relating to *emerging technologies* as opposed to the needs of existing sectors. It arises from a clear commitment by Government to address strategic industrial needs in a more pro-active way, and confirms investment in support of a number of technological areas showing most promise for future opportunities for British enterprise. This represents a welcome more strategic approach at a time when a significant economic downturn has reduced 'normal' demand for skills. It is less a *gearing-up for the recovery*, and more a gearing-up for *what lies beyond the recovery*.

The task is therefore importantly different from the 'usual' labour market assessments carried out by Sector Skills Councils. The first difference is that many of the metrics that bring concrete (measurable) evidence to the analysis of employer needs are either not relevant or not available. This limits the analysis to broader, qualitative observations whose assessment sometimes varies between different commentators and experts. The second is that the emerging nature of the technologies involved brings with it greater uncertainty about how things will develop in practice, and how different technological and market developments will pan out into skill needs: this is the world of 'guesstimates' more than 'estimates'. Finally, since the emerging technologies examined are potentially usable in a wide range of sectors, the assessment must be performed by a number of Sector Skills Councils. While this collaboration brings with it considerable additional communication overheads, it has proved constructive and, Semta believes, effective, and this encouraging initial experience can be built on for the future.

While challenging in these ways, the exercise is nevertheless valuable in other respects. The first is that while knowledge of current skill needs (and their recent trends) is important, policy responses inevitably take time to be implemented, particularly in skills work. The learning 'pipelines' associated with the provision of new learning in response to labour market needs are often long in comparison with the dynamics of markets. Past attempts at 'manpower planning' have generally proved that the additional supply arising from well-intentioned specific investment boosts often arrives too late.

The reality of this *lag* means that policy responses are most effective when assessments of future demand are sound. However, given the uncertainties already noted, responses to analysis of likely future skills need are, of necessity, comparatively broad-brush, in particular in comparison with some of the usual outcomes of employer surveys, based on recruitment difficulty (*Hard-to-Fill Vacancy*) data, and often, in engineering manufacture, on very narrow technical skill requirements.

Finally, it is important to recognise that this more pro-active policy stance provides an opportunity for greater commitment than before to some of the generic findings that have come from labour market assessments over recent years (often beyond the realm of specific technical skills-raising), but on which progress has been limited. If such measures really would make a difference to the productivity of the workforce and the competitiveness of UK enterprises, then they must indeed form an integral part of a more serious industrial policy on skills.

It is in this context that the key findings of this initial analysis must be considered. Clearly each area of technology/application has certain needs of its own, and these will be explored in more detail as the initial analysis reported in this summary is elaborated and extended. However, given the existence of specialised agencies devoted to each area, with considerable expertise in the technologies, the greatest contribution of this *Summary Skills Assessment* probably lies in the distillation of common skills aspects of the needs in these different areas.

Specific Common Conclusions

Key common conclusions from the seven summary analyses:

1) There is considerable further Research and Development involved in the effective commercial exploitation of these Advanced Manufacturing technologies. Thus ***high-level technical skills represent the most important element of specific skills demand*** in relation to Advanced Manufacturing. It is not possible to conclude whether limits to learning provision capacity (in the availability of university courses) are posing any significant constraints, and there are likely to be both variations between technologies and variations over time. In general, available evidence suggests that a comparatively small proportion of Higher Education (HE) leavers enter employment in the relevant engineering sector. This would imply that the attractiveness of the work is probably more important than possible limits on numbers studying the relevant technologies in universities. However, flows of science, technology and engineering graduates, post-graduates and post-Doctoral researchers, with an understanding of the specific technology or of the underlying sciences[1], remain central and need to be reviewed in detail for each technology as markets develop.

2) The wide range of application areas for most of these technologies means that, for effective and creative exploitation, expertise in the technology itself needs to be augmented by knowledge and understanding of the various application areas, and this means the ***need for a range of disciplines to be applied*****.** This can take place through the creation of multi-disciplinary teams, but will inevitably benefit from inter-disciplinary expertise, in particular in smaller companies and teams, where the cost of bringing together a representative from all the relevant disciplines might be prohibitive. There are various approaches to this challenge, including certain enabling initiatives from the public sector, but Higher Education leavers with a broad set of interests and sufficient understanding of

[1] current flows through HE courses on Plastic Electronics, Industrial Biotechnology, Composites, and Nanotechnology are comparatively small; volumes through Aerospace and Electronic Engineering much larger. The underlying Bodies of Knowledge of importance to these technologies come from Physics, Chemistry, Biological sciences, and Materials (Science and Engineering).

the basic characteristics of certain application areas are of particular value. This emphasises the need for HE provision to have breadth as well as depth, and strengthens the value of inter-disciplinary elements of HE courses (e.g. teamwork experience through group projects).

3) While high-level technical skills are central, any serious national investment strategy to accelerate effective exploitation and commercialisation of emerging technologies should also include a commitment to ***assuring an accelerated supply of capable and competent technical support staff*****.** The commitment in the BIS White Paper[2] to a 'technician class' is encouraging, but, with a poor track record of respect for, and initial formation of, technicians in our country, as compared to most continental European countries, making this happen will require considerably greater commitment than in the past. This commitment will need to involve:

    a) substantial promotional investments to raise the image of technical support work,

    b) major public investment for learning provision through initial formation frameworks, in particular *apprenticeships*, probably at both *advanced* (NVQ Level 3) and *higher* (NVQ/QCF L4) levels, and

    c) a new attitude among employers (not just large employers) to the investment for the future involved in mentoring young people, both in relation to work placement for undergraduate students and formal apprenticeship programmes for the technicians.

   While such a radical commitment is challenging, it is needed if real improvement is to be achieved in this area.

4) Effective and fast commercialisation of applications of new technologies requires ***expertise beyond an adequate supply of technical skills***. Indeed, our country has in the past suffered a notorious weakness in its ability to bring creative inventions (the product of creative *technical* skills and ingenuity) to market. With the global competition now faced by indigenous companies, this weakness is no longer excusable if we are to prosper as a manufacturing and exporting nation. While government can do certain things, companies themselves (and their financial backers), must prepare/acquire adequate human resources in the other areas necessary for successful entry and growth in new markets. In particular, this must include skills in a) Intellectual Property (IP) management, b) New Product and Process Development and Implementation (NPPDI), c) Production and Manufacturing Engineering, and d) Marketing.

[2] BIS (2009) Skills For Growth

Marketing skills are necessary to validly assess market potential as part of the product design process and to prepare effectively for the early marketing and sales campaigns. There are real challenges to effective planning and management of the deployment of such skills. For example, it is natural for a company to hold back on recruiting marketing and sales skills until a product is 'ready'. On the other hand, once the product is ready, it needs bringing to market quickly to establish a sound position in relation to the competitive products that are to be expected. This cannot happen effectively without previous marketing investment, planning, preparation, and gearing-up.

In addition, assessing in advance the *speed of market growth of a successful product* is not easy: many new companies and products are challenged, in particular in assuring consistent quality, by the sheer magnitude of the scaling-up challenge. There are different ways in which these tasks can be carried out, but for greatest market impact each enterprise must recognise in good time that it needs this to be done, and public policy can contribute, for example through advice, guidance, and perhaps even consultancy, through the Business Link network.

While the lead on many of these functions will be taken by specialists, the more business and market understanding that graduate scientists and engineers have, the more effective their contribution will be.

5) The deployment of new technologies brings with it a number of risks. While many of these must be handled by each enterprise, there are also transcendent risks associated with (in particular) health and safety and environmental concerns about particular technologies. The obvious examples are public concern about genetically modified products, and about possible health risks associated with some elements of nanotechnology. Public policy has to draw a delicate balance in this area between trying to minimise possible risk to future consumers and minimising constraints to British enterprises of early entry into potential major world markets. Government is aware of this balance, but effective collaboration between the emerging industries and policy officials plays a key role in ***minimising the risk of unnecessary constraints*** to commercial opportunities, and adequate skills in this area are particularly important for these emerging industries.

6) Adoption and exploitation of new technologies will always be more of a challenge for smaller established companies than for larger ones. Competitive pressures inevitably mean that small companies have little spare time or capacity for absorbing or adopting new approaches, and even where they do, many struggle to procure the finance to cover additional investment for the longer term. Most areas of manufacturing depend crucially on effective (and often Just-in-Time) supply chains, generally composed of small businesses. In general it is Small/Medium-sized Enterprises (SMEs) that are in most need of enterprise support activity, since larger companies tend to have more capacity to handle innovation through a range of support functions. The innovation barriers within SMEs should therefore be viewed as genuine market failures: the market works to 'optimise' current arrangements, not to enable (or even allow) significant change. Thus a key element of skills policy needs to ***find ways to overcome barriers to innovation within SMEs***, in particular, through possible funding for the time they would need to devote to mentoring students or apprentices.

7) Probably the greatest specific implication for public learning provision in this area relates to the Knowledge Transfer (KT) process from HEIs to enterprises. Much skills policy focuses on the supply of people from universities as the key KT flow. However, in practice little knowledge transfer occurs through the recruitment of graduates, or even most postgraduates, since even MSc courses are rarely able to provide learners with sufficient depth and breadth of very specialist expertise. This confirms the conclusion of many studies that companies, in particular SMEs, could benefit particularly strongly from the ***provision by HEIs of short-courses, focused on specific technical areas, and timed for company convenience***. While many university staff would like to increase the amount of such provision, the funding realities of universities do not always make this easy, and improved mechanisms and funding arrangements for this would be welcomed by industry.

8) Where the adoption of new technologies by existing sectors is concerned (e.g. aerospace, electronics) the supply of R&D skills needs to be augmented with ***knowledge and understanding of how things work in existing industries***. Thus graduate and postgraduate flows in the enabling technologies need to be supplemented by graduates with more general engineering knowledge.

9) Finally, as with most skills issues, the element of ***the image of work in these areas*** cannot be ignored. Even without some of the risk factors flagged above, the appeal of work in this area will have to compete with the appeal of working in many other sectors and occupations perceived to be ‘sexy; or ‘cool’ for young people. The main difference here is that, because these areas have generally not yet matured into their own sector, there is no corresponding established sectoral institutional activity (trade associations, etc.) to respond to this need. In this situation, it is presumably appropriate for public policy to coordinate promotional activity for these strategically important areas.

These issues are picked up within the following sections.

2 What drives demand for Advanced Manufacturing skills?

The demand for skills is a ***derived*** demand: companies need people to perform functions and roles, some known in advance, others not. Thus the demand for skills for Advanced Manufacturing depends on the work to be done by the companies in this area. It is important with all enterprise support policy, including skills, to recognise that macro-economic perspectives are often not how issues are seen at the level of the company. However, at the macro level, the main drivers are reasonably well recognised, as follows:

- ***Globalisation***
  This results in markets being opened up, which provides both threats and opportunities for companies across England and the UK.

- ***Economic Growth***
  In broad terms, demand for skills, and so recruitment activity, will grow as the economy grows, although there will inevitably be certain variations between different sectors (and, for labour markets, different occupations).

- ***Technology development***
  Technological innovation both enables changes to the nature of products and services, as well as the way companies do business, and thus creates new markets with their own growth, for which new skills are needed. In many cases, new approaches result in the decline of related markets, and technology is the major driver for changing the types of skills needed in the labour market.

- ***Demographics***
  Workforces are dynamic: the flows into and out of work in particular occupations and sectors arise because people move on from their jobs, sometimes to other work, sometimes to non-paid activity. As well as occupational or sectoral mobility, there is also spatial mobility: people often move to where there are greater work opportunities, sometimes in other countries. Ultimately people move out of work for good – mostly to retire. An important relationship (arising largely from age demographic distributions) is that between flows out of work (retirement) and flows into work (mostly from those leaving full-time education). Demand for skills does not just depend on the growth (or otherwise) of a particular workforce ('expansion)' demand, but also on the numbers needed to replace those leaving ('replacement' demand).

- ***Multi-level governance and regulation***
  Markets (both product/service and labour) operate within societies, and there is always an element of constraint/intervention from the state. While this can vary considerably between countries, it involves both fiscal matters – lower tax levels can increase employment levels and demand for skills – and regulation of various kinds. As well as posing certain constraints to employment arrangements, regulation generally creates demand of its own, for work associated with its development, implementation and compliance requirements. As indicated, these factors can come from local, regional, national or (for European countries) EU-level governance.

- ***Environmental change***
  Environmental change stimulates demand for skills in various ways. The normal assumption is that environmental concerns result in regulation, to which companies have to respond as shown above. However, such change can also stimulate secondary skill demand through the need to respond to specific enterprise- or market- level disturbances, and through new opportunities arising from markets created in response to regulation (the low carbon economy is a prime example).

- ***Changing identities and values and consumer demand***
  Consumer preferences have always changed over time, and will continue to do so. However, changing social values can influence economic activity other than through changing consumption patterns. A relevant example of this would be the changing public attitudes to *in vivo* work in animal experimentation.

The relative importance of the different elements is shown in each section.

3 Aerospace

3.1 Background to the sector and main drivers

Aerospace supplies three main markets: civil, defence and space (civil and defence). Each product area is also at the centre of a set of service activities including Maintenance, Repair and Overhaul (MRO).

3.1 1 What drives demand for skills?

Political - Government has a central role as sponsor, customer, regulator and market gatekeeper. There is significant Government spend on defence capability due to national security issues, but budgets are under pressure.

Economic – The UK aerospace industry has a 25% share of the global market and is the second largest in the world behind the US.[3] The global downturn has impacted on the cost base of aerospace activities with some airlines deferring or cancelling orders and global defence budgets being cut. UK aerospace faces global competition from other EU countries for high value Research & Development (R&D) work and emerging economies for lower value assembly. Major manufacturers are now collaborating to lower risk and costs.

In 2008, there were 600 UK aerospace employers, employing 112,000 people and generating £22.3 billion in turnover.[4] Aerospace is a major customer of the wider manufacturing and service sectors that form the indirect supply chain.

Social - Consumer and business demand for air travel has grown globally while the relative cost of flying has decreased. Although customers expect competitive fares, irrespective of oil price increases, public awareness of the importance of reduced emissions has grown.

Technological - In 2007, £2.9bn was invested in aerospace R&D. Critical technologies for the present and future development of aerospace are: the information technologies to manage an autonomous and smart vehicle; the development of lightweight composite materials and structure configuration to optimise vehicle performance; the technologies associated with the systems issues of life-cycle-cost, operation, and maintenance, are a driving force in the design of new aerospace systems; the technologies relating to environmental factors, such as the control of pollution and reduction of noise, will play an important role in future aerospace vehicles and systems.

Legal and Environmental - The aerospace industry has high regulatory, quality, and safety requirements due to its safety critical nature. Strategic environmental initiatives in Europe include ACARE, Clean Sky, Single European Skies (SESAR) and the 7th Framework Programme. The Government is focusing on reducing emissions by investing funds in low carbon technology development within the aerospace sector.

[3] A/D/S The trade body advancing UK Aerospace, Defence and Security
[4] ABI 2008, ONS

3.2 Current skills

3.2.1 What is the current demand for skills?

In 2007, value-added per employee for UK aerospace was £71,200, an increase of 36% over ten years.[5] Productivity improvements have been achieved by investing heavily in R&D and cost reduction (process excellence, use of lean principles and supply chain rationalisation) and the management and technical skills necessary to implement these.

Management, professional and technician occupations now make up 54% of the workforce (41% ten years ago).[6] The proportion of professional and technician jobs in the workforce has grown significantly. The Space sector is very focused on graduates/postgraduates rather than vocationally trained occupations.

In 2007, 35% of aerospace companies in England recruited but there were still hard-to-fill vacancies (15% of establishments), which cost the aerospace sector £35 million in lost productivity. Aerospace is competing for highly skilled personnel and this is reflected in the median aerospace salary being 36% higher than for manufacturing.[7]

In aerospace, the A350 aircraft work is getting sign off, requiring systems design and stress engineers.[8] Multiple clients may need V5 design and stress engineers to support both systems and structures across the UK. The A330, A400M and A380 models are providing opportunities for engineers in the concessions, modifications and manufacturing arenas. It is expected that there will be sustained requirement for Concessions Design/Check Stress and Manufacturing Engineers.

Tight budgets mean interest is focused on talented future stars.

Demand remains consistently positive for engineers in the satellite, defence, UAV and consultancy sectors, specifically for knowledge of composites, due to demand for advanced materials within defence.

In terms of skilled trades, there is a steady requirement across aerospace for: electricians, Radio Frequency technicians and Surface Mount Technology operators (aerospace electronics), both on a permanent and sub contract basis.

Electronic systems on modern aircraft, from flight control to fuel consumption, are increasingly complex and IT skills are central to the development, build and maintenance of Eurofighter and the Airbus super-jumbo. Large-scale MoD projects, like the single communications platform for the UK armed forces, underlines the need for a range of electronic systems on aircraft to be able to ‘talk’ to ground-based and mobile systems. [9]

[5] ABI 2007, ONS
[6] LFS 1999, 2008, ONS
[7] ASHE 2008, ONS
[8] http://newsweaver.co.uk/matchtech/e_article001442502.cfm
[9] http://www.contractoruk.com/news/002594.html

3.2.2 What is the evidence of skills mismatch?

Semta's Skills Needs Assessments for Aerospace highlighted four main skills issues: Management and Leadership, Productivity and Competitiveness, Technical Workforce Development and Strategic Workforce Planning.

In 2007, aerospace employers felt that skills gaps for professionals and managers would have most impact on their business. A quarter of those with skills gaps had management skills gaps for leadership and team leader skills. Other management skills gaps include lean implementation, project management and supply chain management. Many SMEs are not investing in skills due to a lack of management capability in strategic workforce planning and development. In 2007, 64% of aerospace SMEs in England felt that their employees had not needed to acquire new skills or knowledge over the previous 2-3 years, which does not match up with the ambitions of a sector striving for innovation and improved productivity.

The 21st century supply chains (SC21) programme has been endorsed by the aerospace trade association A|D|S and employers to accelerate the competitiveness of the aerospace & defence industry by raising the performance of its supply chains, focusing on certification & quality improvement, development and performance.

Aerospace hard-to-fill vacancies in 2007 were due to a lack of required qualifications and skills, a lack of required work experience and a general lack of applicants. 10% of aerospace companies felt their employees had skills gaps (17% for engineering). Two-thirds of these companies had technical skills gaps which related to aircraft engineering, metalworking, welding and fabrication and CNC machine operations.[10] Over the last ten years, those qualified to NVQ level 3 (craft/skilled trades occupation) have decreased from 44% to 33% of the workforce. Investment in new technology and a focus on moving up the value chain has led to an 'offshoring' of lower value craft and operator level production activity. However, those technical jobs that remain at this level are increasingly more complex due to innovation, so there is a constant workforce development requirement for upskilling and multiskilling.

Aerospace supply chains extend across other advanced manufacturing sectors such as composites, nanotechnology and electronics, so there is a high level of competition for a decreasing pool of skilled workers and STEM graduates. 14% of aerospace companies in England had problems recruiting graduates in 2007. Numbers of new first degree students studying aerospace and other engineering and technology subjects are falling below the level of current achievements. Fewer than 20% of aerospace graduates go on to work directly in the aerospace sector. The pool of available UK aerospace graduates is actually lower as a quarter of these students are foreign nationals, not eligible to work in the UK or able to pass security clearance for defence work.

As some aerospace employers are having issues with supply of graduates and are also not happy with their level of practical skills, they have started to look at alternatives such as the technician level, Higher Apprenticeship in Engineering.

An ageing workforce (8% of the current aerospace workforce is aged 60 plus) will mean that significant numbers of skilled individuals will be leaving the industry in the near future, leading to further hard-to-fill vacancies and skills gaps.[11] A general lack of applicants will compound these demographic problems and have an effect on numbers of new entrants via the apprenticeship and graduate route.

[10] Research and Development in UK Businesses, ONS 2007
[11] LFS 2008, ONS

To ensure an adequate supply of skilled people throughout the workforce, aerospace employers are increasingly investing in training through a variety of routes, particularly: in-house (41%), commercial training providers (29%), equipment supplier/ vendor training (28%), Further Education (FE) (21%), employer associations/professional bodies (17%) and Higher Education (HE) (14%).[12]

3.3 Future skills

3.3.1 What will drive future demand for skills?

In 2007, aerospace employers felt that over the next 2-3 years employees would need to acquire new skills or knowledge due to: introduction of new technologies or equipment, development of new products and services, new legislative or regulatory requirements and introduction of new working practices.

Aerospace companies involved in Semta's Sector Compact felt the following drivers would most impact their business and hence their future skills requirements: Quality, Cost and Delivery (QCD), age profile of the workforce, ways of working/processes, technology, local/global competitive pressures, waste management, global quality standards/ISO 9000 and TS 16949, markets, economic conditions and legislation.[13]

The aerospace market is forecast to grow by 25% in real terms over the next 20 years to $250 billion per year worldwide. Increasing fuel prices will boost orders for new fuel-efficient aircraft. Those unable to invest in new aircraft will gain efficiencies through maintenance, repair and overhaul (MRO) processes.

The aerospace platform (commercial airliner, combat jet, helicopter, space launcher and satellite) is increasingly part of a wider system involving ground-based equipment, military command control and communication, 'smart weapons' and wider 'battlespace' management concepts, as well as the ground segments of space-based operations and launcher operations. There are still significant market opportunities in the airborne, fixed-wing and rotary sectors, including unmanned systems.

The UK Space sector currently employs 16,000 highly qualified staff. This fast growing global market is anticipated to be worth $1 trillion by 2020.[14] The UK has strengths in satellite applications (earth observation, communications, navigation and positioning) and in space science instrumentation and robotics. Satellite technology will be important for monitoring climate change and the market for space tourism is expected to grow.

MROs will grow in size as airlines outsource non-core functions. Green initiatives such as engine washes, winglets, painting, weight reduction, and bio fuel modifications will be provided by the MRO sector. There will be a focus on whole-life support (including installation, commissioning, diagnostics, repairs, overhauls and upgrades).

The UK Aerospace sector needs to have the skills to undertake research that will ensure a prominent position in aerodynamics and propulsion systems, advanced materials such as composites and advanced electric drives. Product innovation over the next 20 years will see developments in information management, data fusion, fluid dynamics modelling and applications, new materials, propulsion, systems engineering and autonomous operation, introducing a new range of products. In civil aerospace, demand for environmentally friendly, high efficiency aircraft

[12] Semta LMS 2007
[13] Analysis of Sector Compact data , Semta 2009
[14] Chas Bishop (2008) Space: The Skills Need

will require new aircraft design such as the Blended Wing Body, new materials and new propulsion technology. Innovations in space technology will rapidly diffuse into the wider aerospace market.

Growth of transnational aerospace companies and adoption of global procurement strategies will put pressure on small and medium-sized enterprises (SMEs) to become more innovative and competitive, as large companies try to reduce number of suppliers.

3.3.2 What will be the future demand for skills?

Overall, aerospace employment is likely to decrease in the future due to movement up the value chain, productivity improvements and supply chain rationalisation. Taking into account replacement demand, over the next five years there will be a net requirement for 8,000 new entrants (1,600 people per annum) in management and technical occupations into aerospace in England.[15] Expected demand is for 1,600 managers, 1,900 professionals, 1,300 technicians, 1,600 craft workers and 1,500 operators.

The aerospace sector will require 1,900 people (380 per annum) with Level 4+ skills; 500 managers, 700 professionals and scientists and 700 technicians over the next five years.

	Qualifications level required			
Higher level occupations	Postgraduate (Level 5)	Graduates (Level 4)	Total Level 4+ (5 years)	Total Level 4+ (per annum)
Managers	100	400	500	100
Professionals & scientists	200	500	700	140
Technicians	100	600	700	140
Total required (5 years)	400	1,500	1,900	380
Total required (per annum)	80	300	380	

There will be increased demand for skills in all occupations, particularly highly skilled managers, professionals and technicians to address innovation and emerging technologies.

Management - to operate successfully in complex global aerospace markets, a range of leadership and management skills at global standards will be required including: change management, business modelling, risk management, supply chain management, value chain management, knowledge management and strategic workforce development.

Professionals - will need a mix of technical and business skills to meet future requirements for developing and designing commercially viable technology and products while communicating and managing projects effectively across supply chains.

Technical skills - demand for high level general engineering skills, mechanical, electrical, electronics and specific aerospace skills due to new product development that cuts across different engineering disciplines. Systems skills (design, modelling and integration) for high integrity systems, software (systems, modelling and simulation), mathematics, advanced materials engineering (lightweight, smart, electric and magnetic), diagnostic and prognostic skills, skills to support emerging technologies, exploitation of new product development, process excellence, research skills.

[15] Semta Employment Forecasting Model, 2007

Technicians – will require a range of technical and management/business skills as they interface between design and production, optimising processes.

Technical skills - lean manufacturing, process excellence, whole product life cycle, design skills, composites, MRO licensed engineers (Part 66, Category B and above).

Business skills – costing, project management, teamworking, problem solving and communication skills to facilitate Integrated Product Teams, marketing.

3.4 Supply-side issues

3.4.1 What is the current supply of skills?

Current supply issues for the aerospace sector centre on low numbers of applicants, apprentice recruitment and the supply of graduates and technicians.

A good supply of young people educated in science, technology, engineering and mathematics (STEM) subjects is important as aerospace is competing for these skills with other sectors of the economy. Numbers sitting Maths 'A' level have increased between 2002 and 2009, however, Physics 'A' level declined between 2002 and 2006, with a slight upward trend to 2009.

Emphasis on full-time education has reduced the overall supply of young people to train as apprentices. 2% of the aerospace workforce is apprentices. Only 9% of aerospace sites in England employ apprentices, with Small and Medium Enterprises (SMEs) in the supply chain least likely to employ them. While many Tier 1s and Original Equipment Manufacturers (OEMs) have a good track record in training apprentices, in general Tier 2 and 3 aerospace companies are reluctant due to cost.

Over the last ten years, the percentage of the aerospace workforce in England qualified to NVQ level 4 plus has increased from 32% to 41%, to deliver higher value R&D activities. A highly qualified workforce with advanced degrees, particularly in science and engineering, is likely to be the greatest predictor of success for aerospace. 13,000 scientists and engineers and 3,000 technicians work in UK aerospace R&D activities

During 2007/8 there were 1,285 first degrees awarded in UK aerospace engineering and a total of 1,235 new entrants (first year full-time first degree students) studying aerospace engineering in the UK. In terms of other key subject areas, numbers studying core degree subjects such as Physics had levelled off and Mathematics students were 30% down on 2002/3.

Major aerospace employers have built strong relationships with their local F.E and H.E institutes to ensure an adequate supply of high quality apprentice and graduate recruits. They are generally happy with quality of training provided.

3.4.2 What will be the future supply of skills?

Many students are not achieving the required maths and science levels to enter aerospace engineering. Numbers of new first degree students studying aerospace and other engineering and technology subjects are generally decreasing. This will impact on the future supply available to the aerospace industry of those achieving a first degree in aerospace and other important engineering and technology subjects.

To just meet replacement demand requirements for highly skilled workers (NVQ L4+) aerospace will need an annual supply of at least 400 people (100 managers, 140 professionals/scientists and 140 technicians) for the next five years.

Graduates are currently entering aerospace with the following profile of subjects (in order of size of intake):

Postgraduates - business studies, aerospace engineering, management studies, general engineering, mechanical engineering, electronic and electrical, production and manufacturing, physics, computer science and materials technology

First degree - aerospace engineering, mechanical, business studies, general engineering, electronic and electrical, management studies, production and manufacturing engineering, computer science, mathematics and design.

There are generally low numbers of postgraduates studying the cutting edge/emerging technologies required by aerospace employers.

Graduates entering the industry lack employability skills: in some cases employers estimated that graduates would take up to two years to acquire the necessary skills to make a positive contribution to the business. Universities and businesses need to work together to ensure greater vocational relevance. This may help to get more graduates into the aerospace supply chain. Process Excellence and Project Management are particular skills gaps among engineering graduates that need to be addressed.

Engineering has a negative image among young people, so attracting apprentices into aerospace in the future could be an issue.

The Apprenticeship Framework can be used for upskilling of the workforce and is a good vehicle for adult skills development. It provides accelerated entry into the workplace, saving costs associated with providing Advanced Apprenticeship and Foundation Degree programmes back to back and allows higher education, project, and work-based learning to be integrated.

Maintenance, Repair and Overhaul (MROs), employers reported that in recent years both airlines and MROs have not been recruiting apprentices and this has led to a shortage of potential licensed engineers. MROs have responded by reinstituting apprenticeships, but many feel that this may be too little too late to compensate for the predicted shortages.

3.4.3 Can supply meet demand?

Demographic changes mean there will be fewer new entrants to engineering. New and innovative strategies will have to be adopted by aerospace companies such as entering into partnerships with schools, sponsoring students and marketing the sector to underrepresented groups to ensure a steady supply of workers.

Potentially, future supply could meet demand through a mix of recruitment, retention, training and Continuing Professional Development (CPD). Enabling the shift into higher value manufacturing requires increased ability to multi-skill or up-skill the existing workforce, particularly adults, to effectively utilise their skills.

The aerospace sector currently has 41% of the workforce qualified to NVQ level 4+ but the sector target of 50% by 2022 is not currently achievable by focusing on graduates alone. Although the total number of graduates available is enough to supply aerospace's requirements, many of these graduates are also in demand from a range of other sectors.

If numbers of technicians (associate professionals) within aerospace were to increase via the Higher Apprenticeship in Engineering, this could both offset the potential shortage of technical graduates to meet the 2020 target and meet concerns from some aerospace employers that graduates do not have sufficient practical skills. Employers are increasingly sponsoring those trained vocationally to study degrees as this gets round their issues with taking on graduates with poor technical skills.

SMEs in the supply chain will need to increase the number of technicians with skills in process excellence and lean to allow higher value work to be absorbed from OEMs and Tier 1s. If the supply of skills within SME supply chains is not adequate, work will be 'off-shored.'

The civil aviation industry is predicting a shortage of licensed mechanics, resulting from expected retirements and low supply of new entrants into the field. Recent layoffs have temporarily resolved this issue but a lack of new entrants will result in poaching of qualified workers.

SEMTA has developed a Higher Apprenticeship in Engineering Technology in England and Wales. The aim of the apprenticeship programme is to increase the number of high-level engineering technicians and incorporated engineers by 1,000 per year for the engineering, manufacturing and technology sector.

Multiskilling and upskilling will be increasingly important due to a convergence of technology and the requirement to operate in a complex supply chain. Professional registration of appropriate technical personnel could foster high standard, certified engineers. Once acquired, skills must be kept up to date through development and training which will help retain highly skilled staff. Semta has actively engaged with the aerospace sector to upskill the workforce by providing funding for vocational training via the Sector Compact initiative.

Some of aerospace's short-term skills needs could be met from those redundant from other engineering sectors, particularly automotive, where there are skills related to supply chain, design and composites. However, there would be an upskilling/re-training requirement.

Key barriers to training for aerospace companies include the cost of training locally, times of the day which courses are run, being too busy to train, not having experienced staff to deliver training and not having staff skilled at buying in training.

Although aerospace training provision networks are fairly well established, emerging technologies will require new centres of expertise and training in specific technologies highlighted by the work of the National Composites Network. Establishment and enhancement of Teaching Centres of Excellence would provide specialised post-graduate training and continuing professional development to industry personnel and could offset the fact that aerospace research facilities at universities are facing cutbacks and scaling down their aeronautical test equipment to cut costs, which could damage the industry.[16] Establishing SME clusters around HE/FE and training provider establishments might encourage new Foundation Degree programmes.

There are concerns about the capability of training providers, and FE colleges in particular, to respond to sophisticated high performance and lean techniques. Aerospace employers feel that it would be more appropriate that Tier 1s develop the training expertise in-house and are able to cascade it down the supply chain as the technology is not available from external training providers. A focus on QCD will require growth in the use of lean and continuous improvement techniques, making the greater uptake of the B-IT qualification more important. Additional development of the infrastructure to deliver B-IT will be implemented through the supply chain via the National Skills Academy for Manufacturing.

3.5 Geography

In England, aerospace activity is regionally concentrated in the North West, South West, East Midlands and South East and is a significant contributor in terms of employment, value added, clustering of research and development networks and foreign inward investment. Major employers in England include Airbus, Rolls Royce, BAE Systems, Astrium and Marshalls Aerospace.

[16] Professional Engineering 9 September 2009

4 Plastic Electronics

4.1 Background to the sector and main drivers

The term plastic electronics, also known as printed electronics, is used to describe electronics based on semi-conducting organic polymer materials.

The technology means that diodes and transistors can be printed on flexible plastic substrates using inks made up of semi-conductive organic polymers. These polymers can be solution-based, enabling them to be printed using inkjet or other printing techniques onto flexible or rigid surfaces. The different functioning layers that make up the electronic device or circuits can be added one by one to the substrate. The basic flexible substrates commonly used in plastic electronics are manufactured polymers such as polyethylene terephthalate (PET, used in plastic bottles) or polycarbonate (PC).

Plastic electronics is a nascent sector, very much at the start of its development, but with a recognised potential for growth in which the UK could play a leading part.

It is unlikely that plastic electronics will completely replace silicon electronics and the more mature semi-conductor industry, because of its technical and performance characteristics. Plastic electronics does have a number of advantages for certain types of products where a compliant surface or where thinness and weight are major design requirements. There are strong possibilities that a new range of products and markets will be developed and in this sense it is a disruptive technology, with products opening up new markets. There will be some competition in current electronics markets, for example in the electronic books market where a number of companies from across the world are entering the market, but based on rigid LED displays[17]

Estimates of the size of this market vary, since take-up is dependent on a number of factors, including the growth of products for the low-carbon economy:

[17] In addition to Sony, there is the Barnes and Noble ‘Nook’ and other devices from iRex technologies (a spin-off from Royal Philips Electronics) located at Eindhoven in the Netherlands, Asustek (Taiwan) and FirstPaper (New York), Bangkok Post, 22nd October 2009, World Business News, pB5

Examples of possible applications are:

Energy efficient lighting • Lighting, signage, displays • Organic/Polymer Light Emitting Diodes (OLEDs and P-OLEDs)	**Smart fabrics and intelligent textiles** • **Wearable displays** • **Illuminated safety clothing** • Novel fashion items and clothing that build on the UK's reputation for design
Flexible displays • Large format displays – public information, retail and advertising • Roll up displays • Posters and retail 'shelf edge' displays • Electronic paper • e-readers – light, flexible with less glare and more robust against accidental damage than rigid readers**.**	**Sensors** • Medical sensors can be embedded in dressings, bio-sensors • Intelligent packaging for the pharmaceutical and food industries – labels that change colour if food items go outside their recommended temperature range or shelf life • low cost electronic radio-frequency identification (RFID) tags • Sensors in laminates and coatings
Photovoltaic cells • Large scale to feed into grid • Off grid solutions including self-charging mobile phones and laptops. • transparent wafer-thin batteries	**Flexible electronic circuitry** • Disposable electronics, consumer throwaway • Hand held and mobile equipment

4.1.1 Contribution to the Low Carbon economy

Plastic electronics technology will not only contribute to the low carbon economy in terms of products, such as photovoltaics, but there are perhaps even more opportunities for small scale photovoltaic devices to recharge mobile telephones, MP3 players and other devices. With the responsibility for reducing carbon footprint being increasingly placed on individuals and businesses, the use of plastic electronics for developing low energy lighting for the home and emergency lighting systems can also be recognised as having a key role in reducing energy use. The Carbon Trust are already investing in research into larger scale photovoltaics.

Unlike traditional semi-conductors, which need to be made at high-temperatures in clean rooms, plastic electronics can be printed at low (room) temperature, so much less energy is used in production[18]. Xerox have recently announced that they have developed a new silver ink with a melting point of just 140 degrees[19].

Plastic electronics is less wasteful of resources because it is an additive manufacturing process with only those materials that are needed being printed, unlike silicon electronics, where sheets of chips are produced and the areas that are not needed are etched off[20].

Plastic electronics devices are lighter, because they are printed on a flexible film substrate, therefore in any applications where they are used, less energy will be consumed, either in terms of fuel for transport or in packaging requirements.

[18] BBC website, 3rd January 2007 http://news.bbc.co.uk/1/hi/technology/6227455.stm
[19] Xerox news website 27th October 2009 http://www.xerox.com
[20] University of Reading, Capturing value from research networks in emerging technologies http://www.printedelectronics.net/about-electronics.htm

Organic/Polymer Light Emitting Diodes (OLEDs and P-OLEDs) technology is very energy efficient and can be used in ultra-thin lighting displays that will operate at lower voltages than LCDs (liquid crystal displays). Furthermore, they emit light as a function of their electrical operation and the display does not require the manufacture of additional backlights or filters.

4.2 Current skills

Current skills used in the sector are mainly Research and Development skills at postgraduate and post-doctoral level that are involved in the early development of the technology.

The development and short term needs of the sector require teams of individuals with multidisciplinary awareness from a number of areas of expertise. This multidisciplinary awareness is needed to realise the products that the technology makes possible and which products might be successful.

The main skills needed for these multidisciplinary teams are:

- electronic engineering, optics and nanotechnology
- printing and ink technology
- materials science – thin films and coatings
- chemistry
- physics.

However, there are a number of other skills which are also needed to support the development of the industry:

- Designers to work across the sectors of electronics, printing, textiles and other materials - industrial and graphic design to generate attractive products to develop the markets. These can range from low carbon products, off-grid chargers for electronic items such as mobile phones and laptops to novel fashion items.
- Materials scientists to develop the substrates for printing on, including polymers, and to develop the inks for use in plastic electronics and the methods by which the inks can be applied.
- Skills within the current manufacturers of printers, particularly in the development of ink jet printers, to print the electronic components more effectively.

Also, it is important to realise that at this stage of the development of the technology, the design, testing and diagnostics software for plastic electronics has not yet been fully developed. Products need to be designed using basic electronics principles with a limited number of components, rather than using the building blocks of standard integrated circuits that can be put together and controlled and tested by software. Today's electronics engineers may have limited experience of designing circuits in this way and will need to have these skills developed. Additionally, when the circuit design software has been fully developed, software specialists will have to be trained in its use.

To summarise, in order to develop and fully utilise the plastic electronics technologies, the main skills that are needed are at postgraduate and doctoral level R&D skills with a multidisciplinary approach. The table below shows the main disciplines from which these skills are being used.

	Electronic engineering	Printing	Materials Science	Chemistry	Physics
Sector					
Plastic electronics	✓	✓	✓	✓	✓

4.3 Future skills

As products are developed in the laboratory and go into production, there will be a greater need for technicians who will be involved in testing, prototyping, design implementation and optimisation of products and manufacturing processes. As the markets develop, these will be needed in increasing numbers within the next 3-5 years.

There is, therefore, a need to develop technicians' skills, in particular in electronic engineering and printing, where they need to have multidisciplinary awareness, but do not need to be trained in plastic electronics specifically. These will be, for example, electronics technicians with an awareness of printing, materials science or chemistry, who will be able to apply their skills over a range of activities.

Although plastic electronics products can be produced on a small scale, once larger markets have been established and products go into mass production, the same multidisciplinary awareness will be needed for the skilled workforce within production plants. Inkjet and other techniques that can be used in the printing of electronics are reflected in the current National Occupational Standards (NOS) for the industry. However, as the industry grows and the demand for intermediate and lower-level industrial skills grows, there may be a need to update these to reflect advances in technology and products.

The favoured progression route within the sector appears to be for the development of staff at all levels with electronics or printing skills and an awareness of the other disciplines required. It is considered that any one individual with multi-disciplinary skills would not necessarily have the depth of knowledge to work in such a fast moving sector.

Quality is also going to be of overriding importance for the future of this technology, to an extent that has not existed previously in the electronics and printing sectors. For example, a 'printing error' might not just result in the wrong letter appearing on a page in an e-newspaper, but that page having nothing on it at all!

There are a number of supporting skill sets that are needed to ensure that markets grow to create a demand for the products that plastic electronics can create:

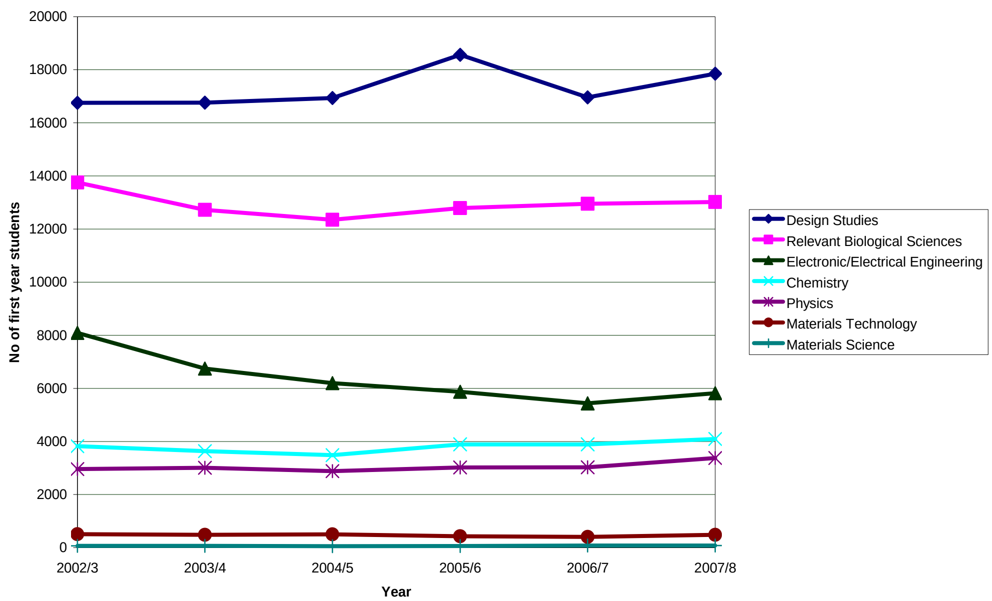
- New Product Development and Implementation (NPDI) skills - products and markets are still at the development stage, getting the products to market quickly will be very important and so NPDI skills will be important in increasing the rate of growth of the sector.
- Quality control skills
- Lean manufacturing techniques, particularly 6-Sigma and Quality, Cost and Delivery measurement.
- Development of printer technology and printer equipment manufacturing.

As is the case in the wider printing industry, it is likely that manufacturers of printed electronics will also need to offer a range of added-value services to remain competitive. This will require skills in areas such as customer service, flexible product design and consultation, and multimedia and other digital methods.

4.4 Supply-side issues

Figure 1 covers one area of the supply of skills to the sector: the numbers of first year first degree students in the main relevant subjects.

Figure 1: Number of first year first degree students studying subjects relevant to plastic electronics.



Source: Hesa first year degree students 2002 to 2008

While there has been a fall in student numbers taking some of the relevant subjects since 2002, electronic and electrical engineering has shown a major decline with first year students taking this subject decreasing from 8,090 in 2002-3 to 5,815 in 2007-8, a fall of over 28%.

Some subjects that had seen a decline in interest, such as chemistry and physics, have increased in number over the last 3-4 years. The numbers of first year students on courses in materials science and materials technology is fairly small and of those taking materials technology, between 10-15% are studying engineering materials specifically.

A further supply problem for the electronic engineering sector is that, in common with other science and engineering sectors, the industry takes in only a small fraction of the total number of graduates in the relevant subjects each year. Simply increasing the numbers of students in these subjects, although this is clearly needed, will not produce a substantial increase in supply of those people with the right skills for the sector. There is a need to make the sector far more attractive to undergraduates taking the relevant subjects and this is something that the sector itself will need to address.

The Sector Skills Agreement for electronics[21] highlights that in traditional electronics manufacture the main hard-to-fill vacancies for electronics were for technicians and machine operator roles. Hard-to-fill vacancies were mainly due to a lack of applicants with the required skills (including a lack of electrical/electronic and computer/machinery programming skills) and previous job experience. The main impacts of the hard-to-fill vacancies were: increased workload for other staff; increased running costs; difficulties meeting customer service objectives and loss of business orders.

In terms of the supply of technicians to the sector, traditionally most of these have undertaken HNC/Ds, which, in England, are being replaced by Foundation Degrees. The trend in HND achievement in electronic and electrical engineering shows a substantial decline of almost one third from 580 to 400 between 2002/3 and 2005/6. This decline has not been compensated for by the growth in Foundation Degree achievement. Over the same period the number achieving Foundation Degrees in electronic and electrical engineering grew by 45 from 65 to 110.[22]

4.5 Geography

The UK has been leading in the research, development and production of plastic electronics from the development of the substrates to the development of inkjet and printing processes to support the technology[23], but other countries are now catching up including Germany and the USA.

The plastic electronics sector is relatively easy to enter, because it does not require the large scale capital investment that the semi-conductor industry does. The relatively low cost of entry to the sector means that plastic electronics manufacturing facilities do not have to be based in a particular country or location.

At this early stage of the sector's evolution, the development of clusters that bring together universities and industry will be instrumental in taking forward the growth of the sector.

Innovative research and development work has taken place at a number of universities across England including Cambridge, Reading, Manchester and Durham. Work at Reading University by Dr Zella King has produced a Competence Matrix for Plastic Electronics in the UK highlighting the universities in which expertise, in electronics, printing and materials science. See Annex B.

[21] Semta (2004) Sector Skills Agreement Electronics, Automotive and Aerospace
[22] Source HESA 2007
[23] BERR, April 2008, Plastic electronics in the UK, A guide to UK capability 2008/9

Cambridge is one of the locations that has been at the forefront of *electronics* development in the sector for over a decade. The technology for plastic electronics on thin film and flexible plastic substrates was developed at Cambridge University's Cavendish Laboratory. The company Plastic Logic was a spin-out from the Cavendish Laboratory and its flexible e-reader, which has been in development some 10 years, is due to be launched early next year. However, the production plant for the e-reader has been located not near Cambridge but in Dresden, Germany. Its location was probably not linked to the supply of skills, but rather incentives to encourage inward investment into this area.

North West England is important in terms of chemicals input into the sector and this is where the only UK manufacturer of electronics grade film is located.

As methods are relatively similar to those used in 'normal' printing, it is likely that many existing printers will be able to adopt printed electronics techniques by using and building on their current skills and machinery. The printing industry is spread across the UK. Of some 162,400 employed in the sector, 31,500 (15%) are in the East of England, 25,900 (13%) in the South East and 18,900 (12%) in the North West.

There are five research centres in the UK that support plastic electronics R&D, four in England and one in Wales:

- CIKC (Cambridge Integrated Knowledge Centre) based in Cambridge
- OMIC (Organic Materials Innovation Centre) based in Manchester.
- PETeC (Printable Electronics Technology Centre) based in Sedgefield
- CPI (Centre for Process Innovation) based in the North East. This is part of the same organisation as PETeC and was formed from a merger of the Centre for Process Innovation (CPI) on Teesside and the Centre for Nanotechnology, Microtechnology and Photonics (Cenamps) in Newcastle upon Tyne.
- WCPC (Welsh Centre for Printing and Coating) based at Swansea University.

5 Silicon Electronics

5.1 Background to the sector and main drivers

Silicon electronics is another part of the electronics sector that has been identified in the Government's Advanced Manufacturing strategy[24] as a sector in which there are growth opportunities. Silicon electronics is the design, development and manufacture of extremely small electronic devices on wafers of single-crystal silicon that consume very little power'.

This specific definition of silicon electronics highlights the leading edge technologies that are being developed in the field of microelectronics, photonics and electrical systems. These technologies underpin all the sectors that manufacture consumer and industrial products, such as sensors, lasers, embedded systems, displays and photovoltaic cell technologies.

The global electronic products sector is estimated to be worth $2.0 trillion and the semiconductors sector alone accounts for some $260 billion of this.[25]

Semiconductors

Semiconductor devices are manufactured both as discrete devices and as integrated circuits which consist of a number (from a few to millions) of devices manufactured and interconnected on a single semiconductor substrate. Silicon is fabricated into boules (rods) that are large enough in diameter to allow the production of wafers, single crystal Silicon, multicrystalline Silicon, amorphous Silicon[26] and all have many uses. A wafer is a thin slice of semiconductor material, such as silicon crystal, used in the fabrication of integrated circuits and other micro devices. Several types of solar cells are made from wafers. Silicon carbide (SiC) has been used as the raw material for blue light emitting diodes (LEDs) and is being investigated further for use in devices that can stand high temperatures and environments that have significant levels of radiation.

Research and development in the area of silicon electronics has seen the recent development of normally fragile and brittle silicon chips into a stretchy and flexible product, thus paving the way for a new generation of devices and applications.[27] For example, they could be used in brain implants or in latex gloves used during surgery to measure and monitor vital signs. This research involves a different approach than plastic electronics, and the semiconductor still retains its performance characteristics.

There is the possibility of using this flexible semi-conductor technology in aircraft, for example building compact antennae or creating 360-degree surveillance applications by embedding chips across the surface of the fuselage.

[24] BIS (2009) Advanced Manufacturing – Building Britain's Future
[25] http://www.innovateuk.org/ourstrategy/technology-areas/electronicsphotonicsandelectricalsystems.ashx, accessed 30/11/09
[26] http://www.daviddarling.info/encyclopedia/S/AE_silicon.html
[27] http://news.bbc.co.uk/1/hi/technology/7313203.stm

Background to the electronics sector

Silicon electronics is part of the overall electronics industry, which includes a broad variety of activities including the manufacture of office machinery, computers, telecommunications equipment, medical devices, consumer electronics and components such as semiconductors. The electronics industry as a whole enjoyed strong output growth over the 1990s, driven by rapid technological change. Despite rapid productivity growth, output growth was fast enough to stem the fall in employment seen in the 1970s and 1980s. Over investment and the subsequent slump in global ICT spending at the end of the 1990s led to a sharp decline in both output and employment.

Electronics in the UK is dominated mainly by a few multinational companies, but there are also a large number of small and medium sized firms. One reason for the growth of a range of companies is that the UK has considerable strengths in design and software. There are also several small firms still involved in the manufacture of end user electronics items and components for end user items.

High input costs and falling margins have increased the tendency for manufacturing firms to relocate production to low cost economies. The savings made from this are reinvested into recruiting skilled labour in the UK to focus on product design and on hiring sales personnel to improve customer service. Given the UK's emerging strengths in design and software, an increasing number of electronics firms are following this trend, which was once the domain of large multinationals. The more routine production of end user electronics items is outsourced to locations with adequate skills but lower costs than in Western Europe. Eastern Europe (especially the new members of the EU) and Asia (increasingly China) are attracting much of the outsourced production as not only are transport and labour costs low in these countries, but they are also closer to the main markets.

Sections of the electronics, electrical engineering and instruments manufacturing industries are facing pressure on margins that makes industrial concentration, economies of scale and relocation to lower cost regions increasingly attractive. However, the demand for electronics products is less dependent on the economic cycle than other manufacturing sectors such as electrical goods.

Although the outlook for these export oriented industries will improve as the sector focuses on high specification, high value added areas, as the economy recovers the pressure on margins will perpetuate the drive for productivity gains and the trend to relocate.

The UK Government has played a key role in the advancement of silicon technologies[28], in relation to photonics, lighting, displays and optoelectronics. There has been public funding for R&D in electronics and collaborative work between industry and universities is being encouraged. However, there has been concern about a lack of support for the development of photovoltaics and the PV industry lags behind the USA, Japan and Germany.

Consumer and business demand for technologically efficient goods with reduced carbon emissions has grown globally. The global electronic products sector is estimated to be worth $2.0 trillion and the semiconductor sector alone accounts for some $260 billion of this.[29]

[28] TSB (2008) Electronics, Photonics and Electrical Systems, Key Technology Area 2008-2011
[29] http://www.innovateuk.org/ourstrategy/technology-areas/electronicsphotonicsandelectricalsystems.ashx, accessed 30/11/09

The UK has nearly a third of Europe's silicon design companies, which makes it a global centre for innovation, independent design and the development of new technologies.[30] Major industries and universities are collaborating on R&D activities.

Electronics employers were asked about whether they thought their skills requirements would change and why in the Semta LMS 2007. 61% of employers in the electronics/electrical sector said that they expect skills to change in the coming 2-3 years. The main drivers for this change in skill requirements mentioned were: new legislative or regulatory requirements (45% of employers in the sector), new technologies or equipment (43%), new products or services (34%) and new working practices (31%).

More recently, electronics companies involved in Semta's Sector Compact felt the following drivers would impact most on their business and hence their future skills requirements: the need for improvements in Quality, Cost and Delivery (QCD), changes in ways of working/processes, local/global competitive pressures. The age profile of the workforce, changing markets and changing technology were also mentioned.

The National Microelectronics Institute has summarised the current position of the electronics sector as follows:[31]

- The UK electronics industry is worth approximately £23 billion a year and is the fifth largest in the world in terms of production.
- The UK is a centre for global electronics development companies with major research and development or manufacturing bases - for semiconductors almost 80% of the activity comes from foreign direct investment.
- 40% of European semiconductor design revenue comes from the UK.
- The UK is home to 40% of Europe's semiconductor design houses.
- The UK has a high content of analogue, mixed signal and RF capability

5.1.2 Contribution to the Low Carbon Economy

The increased demand for alternative renewable energy sources has helped to drive demand for photovoltaic (PV) solutions, based on combinations of amorphous silicon, microcrystalline silicon and nanocrystalline and silicon nanowire, which have a zero carbon footprint.

The PV solar cell market has been dominated by silicon wafer technology, but one of the drawbacks until now, which has limited the growth in the market, has been cost. For PV to be taken up for large-scale energy conversion their efficiency needs to be improved and production costs reduced. There are a number of new approaches that are developing to overcome these issues, based around amorphous silicon. Thin-film PV solutions are the most rapidly growing portion of the PV landscape with approximately 23% of the overall PV market in 2008.

[30] TSB (2008) Electronics, Photonics and Electrical Systems, Key Technology Area 2008-2011
[31] National Microelectronics Institute http://www.nmi.org.uk/publications-and-downloads/sector-info?searched=survey&highlight=ajaxSearch_highlight+ajaxSearch_highlight1sdfsdfs Accessed 30/11/2009

5.3 Current skills

The growth of silicon technologies makes it difficult for the industry to match capacity with demand. Innovations in skills are likely to be related to those of R&D at postgraduate, doctoral and post doctoral level. It takes close to three years to bring a semi-conductor manufacturing plant to full capacity. Planning and foresight is required to anticipate a skill shortage which needs to be followed up with investment in appropriate skills training with employers working closely with the SSCs. It is necessary to refresh the skills of employees in this rapidly changing environment on a continuous basis so that they are in a position to introduce and operate the next generation of advanced processes. Therefore there is a need for technicians and craft level workers to be trained in fundamental electronics knowledge that they can then apply across a number of applications.[32]

Skills in circuit design, control systems, embedded software design, mathematical modelling and simulation, systems design and engineering skills for use in advanced manufacturing and quality control are most important. The largest skills shift is in the area of supply chain development, outsourcing, after market support, innovation management and lean as well as sales and marketing.

Comparing the level of qualifications prevalent in the electronics/electrical sector (see Annex Table C1), it would appear that the sector's workforce has a greater proportion of higher level qualifications than other sectors in engineering in England. 36% of the sector's workforce has qualifications at NVQ Level 4 or above, compared with 26% of the engineering manufacturing workforce as a whole[33].

Indeed, the Semta LMS 2007 found that electronic/electrical employers were more likely to have recruited recent graduates than other engineering sectors. 19% of employers in the sector had recruited recent graduates compared with 12% across the whole of engineering[34].

In terms of skills gaps, employers were most likely to report technical and engineering skills gaps. The main technical skills gaps identified across craft, operative, technician and professional engineering occupations for the electronics sector were in skills for: Computer Aided Design (CAD), assembly line or production robotics, CNC machine operation, Computer Aided Engineering (CAE).

5.4 Future skills

To meet the technological changes in silicon electronics, there are likely to be roles in the near future for people who are skilled at designing (particularly higher level technicians) and running manufacturing departments with in particular the design and manufacture of products and processes that minimise wastage.

The level of training undertaken by employers (in particular those 'at risk' through complacency or lack of understanding and funding) in the Semta sector will need to improve[35]. There is move towards higher value added activities such as system design, technical support, advanced materials selection and processing, which need specific training such as in the use of silicon electronics. These are not often locally available as standalone courses and often form part of a

[32] TSB (2008) Electronics, Photonics and Electrical Systems, Key Technology Area 2008-2011
[33] Source: Annual Population Survey 2006, ONS *in* Semta (Dec 2008), *Engineering Skills Balance Sheet: England*
[34] Semta (Dec 2008), *Engineering Skills Balance Sheet: England.*
[35] Semta (Dec 2008), *Engineering Skills Balance Sheet: England.*

larger qualification. Thus there is a need to make these courses more accessible for workforce development. Skills in oxidation and isolation technology, etching, lithography, statistics for semi-conductor manufacturing are just a few examples. Silicon electronic technologies present both the catalyst and the opportunity for the industry to continue to reinvent itself, reinvest in existing product design and secure long-term employment and technology capability.

The Semta/IER employment forecasting model provides projections of employers for each of Semta's engineering sectors. This shows that there will be a need for 16,400 employees in 2010-2014 in the electronics sector, simply to replace those who are leaving due to retirement. This equates to a net requirement of 3,280 people per annum coming into the sector.

The National Microelectronics Institute (NMI)[36] recognises the value of skills for this sector and has commended the Chair of Semta's Electronics Sector Strategy Group for his contribution as follows:

> "The group is clearly focused on shaping and articulating the skills and knowledge requirements demanded by the electronics industry both now and in the future. Since October 2008 more than £4.5m of public funding support has been delivered to electronics companies through the sector compact administered by Semta."

5.5 Supply-side issues

Silicon electronics manufacturing demands knowledge of electronics engineering, materials science, device physics, process chemistry, batch manufacturing, statistics, quality management and other disciplines.

Data from HESA show that there has been a decline in student numbers taking relevant STEM subjects since 2002. The numbers of first year students studying electronic or electrical engineering has decreased from 8,090 in 2002-3 to 5,815 in 2007-8, a fall of over 28%.[37] The same appears to be true of FE students. The trend in HND achievement in electronic and electrical engineering shows a substantial decline of almost one third from 580 to 400 between 2002/3 and 2005/6. This decline has not been compensated for by the growth in Foundation Degrees achievement. Over the same period the number achieving Foundation Degrees in electronic and electrical engineering grew from 65 to 110.[38]

Based on analysis of the numbers of first year electronic/electrical engineering undergraduate students from England that are studying across the UK and the numbers of UK domiciled first year undergraduate engineering students studying in England, it is possible to identify net flows of students into and out of England (Table 5.1). This does not take into account the numbers of overseas students that may be studying in England.

[36] http://www.nmi.org.uk/publications-and-downloads/press-releases/skills-take-centre-stage-as-national-microelectronics-institute-recognises-indro-mukerjee-for-contri?searched=Semta&highlight=ajaxSearch_highlight+ajaxSearch_highlight1sdfsdfs

[37] HESA first year degree students 2002 to 2008

[38] Source: HESA 2007

This provides one indication of the relative strengths and weaknesses of current HE provision by course area. The analysis[39] shows that while the most popular engineering courses (2005/6) for first year students in England were in Electrical & Electronic Engineering (5,855 first year students), there was a *net outflow* of students to other parts of the UK (of -180 students). This indicates that electronics/electrical engineering provision is not as well developed in England as in other part of the UK, relative to the population.

Table 5.1: Net flows of HE students into or out of England based on numbers of first year students by subject of study *

Course Area	Numbers of first year students domiciled in region 2005/2006	Numbers of first year students studying in region 2005/2006	Net inflow into Region (+) Net outflow leaving Region (-)
Electrical & Electronic Engineering	6,035	5,855	-180
Mechanical Engineering	4,140	4,170	30
General Engineering	4,515	4,020	-495
Production & Manufacturing Engineering	1,295	1,345	50
Aerospace Engineering	1,750	1,780	30
Naval Architecture	300	315	15
Metallurgy	95	100	5
Others in Engineering and Technology	4,150	3,325	-825
Total	22,280	20,920	-1,360

*Data cover all UK domiciled students working towards any HE qualifications
Source: HESA Student records

Simply increasing the numbers of students in the relevant STEM subjects, although clearly needed, will not produce a substantial increase in the supply of people with the right skills to the sector. There is a need to make the sector far more attractive to undergraduates taking the relevant subjects and this is something that the sector itself will need to address. To address some of these issues the University Network for the Silicon Industry was set up.

The 'University Network for the Silicon Industry'[40] is an umbrella organisation of ten universities that provide a programme of studies in Advanced Silicon processing and Manufacturing Technologies. The programme is available to graduate engineers employed in the silicon manufacturing sector and can act as a fast track for career development.

[39] Semta (Dec 2008), *Engineering Skills Balance Sheet: England.*

[40] University Network for the Silicon Industry http://www-icprocessing.ee.surrey.ac.uk/network.htm

5.6 Geography

While national data are not available for specific sub-sectors such as silicon electronics, Table 5.2 below gives an indication of the main concentrations of the sub-sector and shows the number of workplaces and employment in SIC 32.1, which covers the manufacture of electronic valves and tubes and other electronic components and includes the manufacture of semiconductors.

While Scotland has the greatest concentration of employment, with generally larger companies, employment is greatest in the East of England, the South West and the South East. They are concentrated in these areas for historical reasons and therefore command a regional advantage around which other companies (e.g. start-ups) can congregate.

Table 5.2: Distribution of workplaces and employment in SIC 32.1 - the manufacture of electronic valves and tubes and other electronic components

Location	Workplaces	Employees
Scotland	50	4,500
East of England	120	3,900
South West	100	3,700
South East	180	3,200
North West	60	2,200
East Midlands	50	1,600
Wales	30	1,200
North East	30	1,200
West Midlands	70	1,100
London	50	800
Yorkshire & the Humber	30	300

The National Microelectronics Institute membership reflects this regional distribution and is mainly concentrated in the South of England along the M3/M4 corridor and around Cambridge (Silicon Fen) and Bristol (Silicon Gorge).

An estimated 250 companies working in microelectronics design across the South West region are set to benefit from £500,000 funding from the Government's Department for Business, Innovation & Skills (BIS) for the development of a Centre of Excellence for Silicon Design in the South West. This investment is also seen as recognition of the microelectronics contribution to the low carbon economy.

Companies who make silicon electronic products and devices include Diodes Zetex Semiconductors Ltd, NEC Semiconductors UK Ltd, NXP Semiconductors Ltd, Zarlink Semiconductors, Honda Connections, Strient Plc, Avx Ltd, Advanced Communication Technology Centre, Plessey Semi Conductors Ltd, Hewlett Packcard, and Motorola Semi-Conductors to name but a few.

6 Industrial Biotechnology

6.1 Background to the sector and main drivers

Historically the development of the use of biotechnology has been in the food and drink, pharmaceutical and biological intermediary sectors, where the production of biologically based products (e.g. beer, vaccines and enzymes) has made full use of processes which have been researched and developed in the biological sciences.

The key market sector to date for the application of Industrial Biotechnology (IB) has been in the pharmaceuticals and other health care products (vaccines) sectors, having developed from their strong links with life science R&D. Advances in the use of molecular biology, genomics and microbiology made in the 70s, 80s and 90s have led to the increased use of biotechnology in large scale biological production of products such as synthetic insulin, human growth factor and clotting agents.

Leading on from this, it has been recognised that the technology lends itself to the manufacture of chemical products and in particular products which rely on the use of oil as their stock material.

In addition to the drive for higher efficiency and reduction in carbon emissions, IB offers a genuine viable alternative for the manufacture of such products. Key candidates include the manufacture of biofuels from arable feedstocks, bio-pesticides and industrial cleaning chemicals. This is not a disruptive technology, the markets remain the same as those that are traditionally produced for the use of the chemicals and fuels process industries.

Therefore, the focus for the research and development of IB has moved from the bioscience based industries, such as pharmaceuticals, to chemical manufacturing. While the end uses of the products will remain the same, the processes used to manufacture them are still being developed, hence the need for further R&D in this sector.

Globally, the technology has received significant attention and investment and yet its full potential has yet to be fully realised. The barriers to IB's adoption by the chemical sector remain significant and lessons, particularly related to Genetically Modified (GM) crops, must be learnt to avoid any such public rejection of the use of the technology by consumers.

Estimates of the global IB market to 2025 vary from £150bn to £350bn with the UK potential being in the order of £4bn to £12bn. The latter corresponds to up to 20% of the UK sales value of chemicals today.

In summary, whilst the potential for the expansion of biotechnology R&D into the chemicals sector is evolving, the take up of the technology in the chemicals sector so far is at best limited. In fact, in recent decades the chemicals industry has become much less R&D intensive, with the exception of the Pharmaceuticals sub-sector. Even so, R&D investment in the chemicals manufacturing sector still totals more than £21bn each year in the UK.

The European Technology Platform for Sustainable Chemistry (SusChem), through the development of a Strategic Research Agenda, has identified the major areas of research that need to be developed to ensure that IB becomes a significant contributor to successful future bio-based economies. The research needs to focus on three main areas: biomass, bioprocesses and bioproducts, including bio-energy[41].

[41] Industrial biotechnology - A Strategic Research Agenda for Europe, 2006

6.1.1 Contribution to the low carbon economy

The chemical industry is one of the largest manufacturing industries in the UK and has had one of the highest growth rates. There are over 2,600 chemical industry establishments in Great Britain employing about 200,000 people[42]. Turnover has shown substantial growth since 2005. Over the last decade the industry grew more than five times faster than the average for all industry driven by productivity increases. The Gross Value Added per employee is £77,017 compared to the national average of £34,810[43].

The chemical industry is one of the highest industrial users of energy and is reliant on security of supply of its main feed-stocks – oil and gas - and the stability of that market. IB has the potential to lower the carbon footprint of the industry through biocatalytical processes and to reduce environmental impact by using aqueous (water-based) chemistries. In short, IB offers a route to sustainable development for the sector. But IB requires the chemicals sector to innovate through new technology based on bioscience.

The key drivers associated with the development of a low carbon economy has put IB right at the centre of the strategy with the promise of providing a renewable low carbon alternative to the current petrochemical approach used to produce today's chemicals. So with uncertainties increasing over the continuing supply of raw materials and regulatory pressure to reduce CO_2 emissions and energy consumption, R&D is being rapidly targeted to realise the potential of this technology.

Within the food industry, biotechnology is being applied to food crops with various aims - to improve productivity, reduce waste in transit and provide health benefits for consumers. For example, this will reduce fat absorption during frying and reduce damage from fungal pathogens. Further advances in science and technology are likely to impact on food production, potentially increasing yields and making food healthier and more environmentally sustainable.

6.1.2 Adoption of IB in the chemicals industry

IB is relevant to all the main subsectors of chemicals – Commodity Chemicals, Speciality Chemicals, Fine Chemicals – but especially to Speciality and Fine Chemicals. In these sub-sectors not only is the impact already visible but the pace of penetration is predicted to accelerate.

A number of examples of IB in chemical manufacturing are already apparent in the UK:

- Manufacture of S-Chloropropionic Acid (Avecia)
- Enzymatic Synthesis of Acrylic Acid (Ciba/BASF)
- Enzymatic Catalysed Synthesis of Polyesters (Baxenden Chemicals)

The Chemical Innovation Knowledge Transfer Network recently surveyed the sector on the awareness of IB.[44] Key findings were that at least 33% of the sample were already using IB with a further 13% considering its use. Larger companies tended to be the main users but there was evidence of IB in all sizes of company in the sample. The main areas perceived for application of IB in the near future were:

---

[42] Cogent Chemistry Industry Factsheet, 2007
[43] ABI ONS 2007
[44] *Survey to Assess the Use and Awareness of Industrial Biotechnology in the Chemicals and Chemistry-using Industries in the UK, Chemical* Innovation Knowledge Transfer Network, 2008

Chemicals manufacture	Enzyme production (detergents)
Polymer manufacture	Bioremediation
Biofuels manufacture	Fermentation processes
Algae oil production	Oil extraction (food and cosmetics)
Anaerobic digestion	

The results of the survey provide clear evidence of the growing take-up of IB. The early users are in renewable energies (biofuels, fermentation and effluent treatment). The main barriers to IB uptake were quoted as: lack of awareness, knowledge, expertise and experience. In addition, high risk and investment costs were cited. It was concluded that IB is a targeted activity for chemicals, relevant to up to half the sector.

Commercialisation of the technology is key to its widespread adoption and this is one of the fundamental challenges faced in the UK, as whilst the R&D of such technologies has always been a strength, the subsequent commercialisation has generally taken place elsewhere.

As with the use of biotechnology in other areas, R&D has to play a more *applied* role to ensure that the discoveries made are successfully transferred into the process environment with the aim of new products being manufactured.

6.2 Current skills

With the priority that Government is now assigning to IB and the traditional strength that the UK has in this area, the successful development of this technology will depend on the skills pipeline and HE, public and private sectors working together closely to ensure that skills do not become a critical roadblock to the adoption of the technology across a wider range of industrial sectors.

As with other advanced technology areas, the focus is on higher level skills to meet the requirement of this area (PhDs and MScs with a specialism in industrial biotechnology). While the technology has become well established within both the pharmaceutical and biotechnology sectors, the use of the technology is still in its infancy in the chemicals sector and as such there is a requirement for R&D personnel in these areas to develop new skill sets.

With the global recession and climate change featuring at the top of political agendas, the drive for IB to become a reality is becoming intense and so the demand for higher skilled employees, conversant with the technology and the R&D of the technology, will continue to increase significantly in the coming years.

A 2008 survey by the Department for Business, Innovation and Skills) BIS (IB – GT, November, 2008) suggested that the numbers of people in the chemicals industries with the required *biological* sciences training was very small, with the result that IB R&D in the sector was extremely limited.

The response to this has been seen in research funding from the Biology and Bioscience Research Council (BBSRC) in areas of significance to biotechnology for industry (REF BBSRC report – Oct 2009).

These include targeted priority studentships in bioprocessing, Masters Training Grants (MTGs) in IB and bioprocessing and Industrial CASE Studentships, which allow greater involvement from the private sector in PhD research programmes.

The adoption of industrial biotechnology by the chemical manufacturing environment will lead to an increase in demand for skills related to the technology as businesses across the sector seek to make greater use of IB to replace existing chemistry based products and develop new bio-based ones. There has been a degree of reticence in the sector to accept the technology and if this continues there will be a reduction in its ability to compete in global markets.

The BIS survey (IB – GT, November, 2008) cited a lack of expertise as the most important barrier to companies looking to use and develop IB but also among existing IB users who stated they had problems recruiting people with the right skill sets.

So clearly the availability of people with the appropriate R&D skills mix is a barrier to success, although it is not the only one.

In 2007, Cogent carried out its Sector Skills Agreement (SSA) research into the Chemicals industry[10]. This highlighted, in particular, the age profile and skills shortages and gaps in the large technical workforce of process operators, technicians and skilled trades that account for over 70% of the overall workforce.

The SSA process also revealed, among other things:

- A lack of skills and knowledge required for process improvements.
- The need for more Technical Apprentices

To enable IB to take hold requires a new skills set for the chemicals sector. The skills shortages and gaps will depend on the state of the industry today, the diffusion and translation of innovation, and the success of skills supply to make the science happen. The following section reviews this position.

6.3 Future skills

Within the food industry, the skills requirements in terms of biotechnology will be focused on the need for NVQ Level 4 food scientists and technologists, and higher skilled operatives (from NVQ Level 2 to Level 3) to control more efficient production operations.

For the chemicals industry, Cogent has undertaken some scenario planning work, using an analysis building on the Working Futures forecasts to 2017.

This analysis uses a working scenario in line with Working Futures. It forecasts a substantial net replacement demand of up to one-third of the 2007 workforce due to age and market change driven by IB. Taking account of all factors, it is estimated that by 2017 the chemicals workforce (excluding petrochemicals, paints and pharmaceuticals) may employ 100,000 people, of which 33,000 will be new employees sourced from the supply in education and training. These new jobs will be in technical and process operations (42% or 14,000 apprentices etc) and professional grades (39% or 13,000 graduates etc). It is estimated that approximately 50% of these jobs will require knowledge of industrial biotechnology.

The complexion of the technical and professional occupations will change towards greater interdisciplinarity. To some extent the trends will follow what is now established in the Bio-pharmaceuticals sector, with growth in discovery companies followed by mergers and acquisitions. This will be particularly relevant to the chemicals industry to prime the innovation pipeline with knowledge, skills and Intellectual Property Rights (IPR) in an industry in which R&D has lapsed relative to other high-technology sectors.

The change in manufacturing processes will induce increased skills gaps and stimulate a requirement for significant workforce development, especially in the large technical and process operator workforces. There is a strong need to develop and retain highly skilled individuals who work at the chemistry-biology-engineering interface to lead the next generation of innovation as well as to act as industry leaders in the future.

The section below summarises the main issues that have been highlighted in discussions around the industry:[45]

- With the focus on the R&D of IB products in the chemical sector, the need will be for higher level skills, namely first degrees, MScs and PhDs in the relevant subject areas
- Graduates and post graduates will also need to have multidisciplinary experience wherever possible as industrial biotechnology crosses the boundaries between such areas as biology, genetics, microbiology, chemistry and chemical engineering.
- With the emphasis on applied research, work experience will provide practical working skills for graduates and post graduates alike.
- Technicians capable of running equipment associated with the development of the technology e.g. Biofermentation pilot plants
- New Product Development (NPD) and project management skills to provide the ability to generate products from the research being done in IB.
- Team working skills to ensure that researchers can work effectively with bioprocess engineers in the scaling up of bench top products to commercial scales
- Researchers with the skills to move seamlessly backwards and forwards across the interface between chemistry and the biosciences to enable them to develop biochemical/chemical products using biological feedstock and processes.

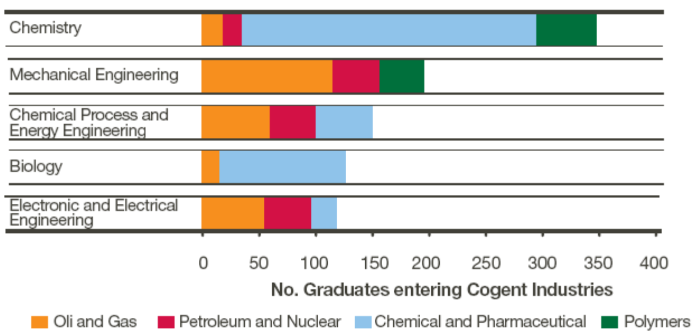
6.4 Supply-side issues

For the graduate intake as a whole in the chemicals sector, 75% are employed (at least initially) in the technical/associated professional levels or higher. It is noted in passing that the science and engineering intake by the industry is a very small fraction of the total produced annually by HE, thereby indicating that simply increasing the numbers of students in these subjects is a weak lever to effect supply to the industry.

Across the Cogent sectors the flow of science graduates is dominated by chemistry graduates, with almost 350 entering from this discipline alone in 2006, mainly into the chemicals and pharmaceuticals sectors. Of note, is the fact that these industries also recruited a further 100 biologists in 2006. These industries were also the largest recruiters of graduates across the sector (70%), see figure 6.1 below.

[45] The Science cluster is a group of 12 SSCs all of whom have employers who have an interest in science based skills.

Figure 6.1: Number of graduates entering Cogent sectors[46]



The Cogent estimates of employment stock and flow across the sectors, based on Working Futures projections, suggests that intake to the chemicals sector is likely to be about 1,800 graduates per year. However, this estimate probably exaggerates the actual requirement of higher level skills, since 25% of graduates are initially employed in occupations below NVQ Level 4[47].

The aforementioned recruitment levels suggest a 25% shortfall in graduate intake to the sector to achieve the 13,000 higher level skills demand by 2017. This needs to be confirmed by further consultation, testing scenarios with the industry. Cogent and Semta plan to work with experts in the sector through the SSC Science Cluster. This is in response to the recommendations of the IB-IGT, which highlighted the need for more work in this area.

Analysis of the remaining workforce is equally important in this field due to the high proportion of *technical occupations* supporting the business. It is estimated that 14,000 replacement posts in technical and process operations are required. In this area, large skills gaps are apparent, with supply being insufficient to meet replacement demand. It is also predicted that this deficit will increase substantially in the period to 2017.

The following table 6.1 shows the trend number of first year undergraduates in the subjects relevant to IB, and is taken as an indication of the number of graduates that are likely to be available for employment. The numbers of students taking relevant biological science and chemistry degrees had been declining, but in recent years the number has recovered. Only a limited number of students are enrolled on courses specifically on Industrial Biotechnology. One of the factors that the industry has to tackle is how to attract graduates in the science subjects that are needed into the sector.

[46] Source HESA, in *Higher Education and the Cogent Workforce,* Cogent SSC, 2008, http://www.cogent-ssc.com/research/Publications/factsheets/HE_Factsheet.pdf
[47] Cogent

Table 6.1: First year full-time first degree students by subject of study in 2002/03 – 2007/8

	2002/3	2003/4	2004/5	2005/6	2006/7	2007/8
Relevant Biological Sciences[1]	13750	12725	12350	12785	12955	13015
Chemistry	3825	3640	3485	3895	3890	4095
Industrial Biotechnology	50	35	20	20	25	0

Source HESA 2009
[1]Biological sciences excluding psychology and sports science

In the case of technicians, many of them have previously been trained through HNC/D programmes and more recently through Foundation Degrees. Between 2002/3 to 2005/6 the number of students undertaking HNDs in Chemistry almost halved (starting at just under 100). Cogent is working on creating a flexible, work-based Technical Foundation Degree Framework of which chemicals and bioscience are key sectoral strands. The chemicals strand is aimed at laboratory technicians and is being led by Manchester Metropolitan University and the University of Kent is leading in the bioscience strand. These workforce frameworks are aimed at upskilling existing staff in technical roles. This project is an important test of employer demand for HE provision in workforce development and the co-funding model for learning *through* work.

IPR and global competition for skills

Global competition will remain intense and it has been noted that there exists the possibility that the R&D associated with IB will in itself become a marketable asset for the UK economy (pp35, BERR IB2025 report, May, 2009).

It has been suggested that these global pressures have the potential to result in “a war for talent” as global players scour the world for key personnel with the right skills and experience sets resulting in intense competition for R&D scientists[48].

6.5 Geography

UK Strengths in IB

As a location, the UK has a number of potential advantages for an IB future: a large domestic demand for sustainable materials; a sophisticated and mature consumer market; good global trading links; strong regional clusters; a strong science and engineering base in the HE community; and, one of the strongest global R&D capabilities in biotechnology.

Current R&D centres of excellence in industrial biotechnology largely reside in key universities throughout UK (IB-IGT report Feb 2009) and will remain so for the foreseeable future as chemical sector companies develop collaborative partnerships with them and their own R&D capability to embrace the new technology.

Chemical production is distributed throughout the UK but there are three principal, long-established chemicals clusters in England, in the North West, the North East, and the Yorkshire and Humber regions of England. Grangemouth in Scotland is a further important cluster.

[48] Ernst & Young: Strategic Business Risk, Biotechnology 2008

7 Composites

7.1 Background to the sector and main drivers

Composites comprise a mixture of two or more discrete materials which, when physically combined, give a material with superior mechanical properties. Advanced composites, including Polymer Matrix Composites, Metal-Matrix Composites and Fibre Reinforced Polymers offer numerous applications, primarily because an extensive range of fibres, resins and metals can be developed to bespoke design and mechanical demand. In particular, carbon fibre, with its low density and high strength can be combined with a polymer/resin to yield a composite that can be moulded. Key features of such composites are:

- low density
- high mechanical strength
- moulding versatility
- low maintenance
- corrosion resistance

It is through these features that composites offer potential in replacing metals for many applications. This can: reduce production times and costs (moulding rather than forging and machining), increase lifetimes (reduced susceptibility to corrosion), increase performance (lower inertia due to low density). The significant energy savings both in production and operation means composites find application in many manufacturing sectors such as

- Automotive
- Aerospace
- Marine
- Construction
- Domestic Appliances
- Medical Devices
- Turbines

The UK polymer industry is therefore a major part of the supply chain network supporting UK capacity in these sectors. It is often found in clustered in regions with such manufacturing capacity, such as the East and West Midlands.

Engineered composite materials must be formed to shape. The textile matrix material can be introduced to the reinforcement before or after the reinforcement material is placed in the mould cavity or onto the mould surface. The matrix material experiences a melding event, after which the part shape is, essentially, set. Depending upon the nature of the matrix material, this melding event can occur in various ways such as chemical polymerization or solidification from the melted state. Thus composites can be used for many cross-sector purposes. Composite textiles, for example, can be used for:

- Aerospace components (tails, wings, fuselages propellers)
- Boat and scull hulls
- Bicycle frames and racing car bodies.
- Fishing rods, storage tanks, and baseball bats.
- Aircraft wings and fuselage, for example the new Boeing 787 structure is composed largely of composites.

According to BIS[49], estimates of the future value of the UK composite market in the construction and automotive sectors, is at least £20bn, while the UK market for composite wind turbine blades will be worth in excess of £5bn. Composites is also a fast-growing export sector.

The polymer and plastics industry is highly diverse and comprises many enterprises in the supply chain to end-product manufacturers, especially those in the front line of economic activity e.g. automotive, aerospace and construction. Over 7,500 companies operate within the sector employing some 286,000 people.

The industry has an annual turnover of £19.76bn, with a GVA of £7.31bn. These nationally derived measures are spread across the many process industries in the sector which operate at various levels. Within this large population, the composites sector is the highest value-adding part of the sector.

As stated, the key manufacturing markets for composites are currently aerospace, automotive, and marine sectors. The sections below detail the importance of composite materials to each of these sectors.

7.1.1 Aerospace

Aerospace is probably the leading sector for the use of composites, with future estimates stating that by 2020 90% of the world's aircraft will be comprised of 80% composite materials[50]. Cost and performance are key to this sector and in particular the benefits incurred from the use of lighter weight materials. Key usage in this sector focuses on the use of composites for the manufacture of wings and fuselage of aircraft, internal ducting and the manufacture of landing gear and brakes. Major aerospace companies (Airbus, British Aerospace, etc), rely on a supply chain where the adoption of composites technology is not as advanced as in the leading companies.

In addition to the manufacture of composites, the services related to aerospace will be changed by the increased use of these advanced materials, namely those companies involved in the maintenance, repair and overhaul (MRO), which will also be impacted by the use of the new materials.

R&D continues to drive innovation in the development and usage of composites in aerospace and whilst a significant level of R&D expertise resides with HEIs, the level of collaboration with industry is increasing even though it is mainly with the larger companies.

Global competition is intense, with the major players being multinational companies who might well consider the availability of skills amongst workforces when making decisions about manufacturing locations.

7.1.2 Automotive

Within the automotive sector the most rapid development and uptake of the usage of composites has been in the niche areas of the sector, namely in motorsport and manufacture of high performance vehicles. This is in part due to performance improvements outweighing the need to keep costs in check.

---

[49] Department for Business Innovation and Skills, http://interactive.bis.gov.uk/advancedmanufacturing/annex-case-studies/composite-materials/

[50] Composite Skills Study 2008 – BIC Innovation

However, this picture is changing as costs are coming down and manufacturing processes are improving and becoming more efficient. As a result the use of composites is increasing in mass produced passenger vehicles, trucks and buses.

But with the ownership of the large volume car manufacturers resting outside the UK, decisions on the use of composites could take place elsewhere. The National Composites Network Automotive Roadmap[51] suggested that the part of the UK automotive sector that would benefit most from further support would be the niche and specialist vehicle areas. The SME supply chain for these companies is important and as a result the need for composite related skills in these companies will become more important.

With the drive towards the development and introduction of low carbon vehicles to help meet targets for CO_2 emissions reduction, composites will be integral in reducing vehicle weight, so as to improve overall performance and reduce fuel consumption.

7.1.3 Marine

The types of composites and their uses are similar in marine to other sectors. However, the low volumes of finished product preclude the use of mass production processes. It is also recognised that the sector as a whole is characterised by a resistance to change which could lead to its demise within the UK[52].

The sector is made up of a variety of segments which include leisure craft, work boats, military craft, ships, speed boats and large yachts.

Composite usage is established in the traditional marine industries whilst other parts of the sectors (ship building) use traditional materials.

The drivers for composite usage in marine companies include performance criteria (weight, durability) with a move towards higher modulus materials, cost reduction and design.

Marine employers see themselves at a distinct disadvantage to the aerospace and automotive sector when competing for skilled resource and in fact have seen those with composite skills in marine companies being lured to companies in those sectors.

7.1.4 Contribution to the low carbon economy

The low carbon based economy agenda that has been set by governments throughout the world will continue to accelerate the demand for composites which are seen as having a key role to play in meeting the ambitious carbon reduction targets that have been set. Start up costs, skills availability, health and safety, handling requirements, and disposal requirements are also playing a role in employers' approaches to the use of composites.

With the weight reduction benefits offered by composites, manufacturers see them as making a significant contribution to improving the performance of their vehicles in the area of fuel consumption which in turn will reduce the levels of CO_2 emissions.

[51] NCN Foresight Report 2007
[52] NCN Foresight Report 2007

In aerospace. composites have also enabled the production of large aircraft (Airbus A380), so reducing the number of flights which will also reduce carbon emissions.

While focusing on polymer composites, other composites, such as metal-matrix composites and inorganic composites are finding specialist application as well.

7.2 Current skills

National data swamp the polymer composites sector within what is a large and diverse UK industry. The occupational distribution of the polymers and plastics workforce illustrates that the sector in general is a mature one relying on process technology rather than new science. Accordingly, the dominant occupations are managers (20%) and process operators (35%). Furthermore, only 1,000 (0.3%) of employees are employed in an R&D capacity.[53] Composites are an exception to this trend.

The composites industries require researchers, innovators, technologists, designers and highly-skilled processing technicians with skills in the areas of manufacture, assembly, disposal and maintenance, repair and overhaul (MRO) to ensure adoption of the technology and remain at the forefront of developments and world demand for more versatile, lightweight, low-cost and energy-saving products. This, combined with the UK's premiere international reputation for engineering and design, offers the potential for it to become a global leader in the sector. This will require innovation in process technology, materials technology, technology transfer and accelerated diffusion and translation to manufacturing capacity in the polymers industry and the manufacturing sectors.

Composites are receiving significant Government R&D funding (circa £64 million over an 8-year period going to composites R&D[54]). However, public sector R&D is increasingly under pressure due to the recession, which could lead to cuts. As composites are still reliant on R&D to drive the development of the technology these cuts would slow the evolution of the technology and subsequent adoption by the private sector. In addition, there will be increasing pressure from Government and private sector funders for R&D to become more widely applied to generate a return on investment.

The investment required to develop new and emerging technologies and upskill/re-skill the workforce is substantial, but with global competitors ramping up their use and development of composites there is a real risk that companies in England could lose out and large multinational companies could relocate their businesses overseas where the required skills are more readily available.

In Europe there has been major investment in the development of composite technology centres and clusters for the provision of composites skills training both for employees and graduates[55] so the need for the UK plc and government to up its game in meeting the skills gaps and shortages is essential.

Composites are a rapidly growing technology and there is a critical need for upskilling the workforce, both within the polymer industry and metals industries which produce the composites and the manufacturing industries making use of the composites. Within the manufacturing sectors, the current skills needs identified are as follows[56];

---

[53] *Skills for Science Industries,* Cogent 2008; R&D in UK Business, 2006
[54] UKTI website http://www.entrepreneurs.gov.uk/gep/6101/en-GB.html
[55] NCN Polymer Composites Sector – UK Skills paper 2009
[56] Aerospace, Automotive and Marine Technology roadmaps 2005-2006

Automotive: Greater competence in CAD engineering, 'crash' durability and cost modelling skills, prototype development, project management skills and tooling and jigging skills.

Aerospace: Materials and process structures design, materials and process engineers, design and stress engineers for composite structures and people with large scale processing experience.

Marine: Carbon fibre specialists, laminators and knowledge of product and process techniques (problem solving, troubleshooting etc.)

The supply chain to these industries is critical and it is here where the biggest challenges are faced in increasing SMEs' commitment and involvement to training

In addition, the requirement for management and commercialisation skills needs further investigation, to identify the business skills that HE individuals moving into the private sector will need to successfully develop markets and sell new products in the future.

More multidisciplinary graduates and postgraduates with practical experience are needed, along with more technicians, if the UK is to compete internationally and ensure that global manufacturers both remain and are attracted to UK.

7.3 Future skills

Clearly there is a significant increase in demand for a workforce with a range of skills relating to composite manufacture and usage. However, there are real concerns that industries will struggle to meet their existing business requirements, let alone future growth as a result of the skills shortages and gaps that exist in composites.[57]

This will negatively impact not only on the competitiveness of UK based companies but also on the future attractiveness of inward investors as other countries offer more skilled workforces.

In response to this, the Government is in the process of developing a cross sector UK composite strategy to be published in Autumn 2010, which will explore in detail the key challenges for sectors involved in the exploitation of composites and the most appropriate Government intervention. Issues to be explored include: ways to increase the availability of skilled composite engineers, ways to raise the awareness of the capabilities of composite materials, and what steps are necessary to help improve the UK's capacity to produce composite structures cost effectively at the speed and volume required by key markets crucial to the UK's economic future.[58]

[57] NCN 2009, Polymer Composites Sector – UK Skills report
[58] BIS Advanced Manufacturing website 2009

Future skills requirements have been identified by the National Composites Network as:[59]

> **Short term:** Processing techniques of hand laminating, infusion (vacuum forming) and prepreg lay up, need training support.
>
> **Medium term:** The more advanced industries will have to be trained for automation whereas the lower tech companies will adopt infusion/pre-preg.
>
> **Long term:** All industries will have to adopt automation processes and the skills associated with them.

In addition, a greater understanding of composite physical properties is needed along with NPD and project management skills to provide the ability to generate products from the technologies being researched when working in collaboration with HEI and technical research organisations.

Graduates are needed whose degrees have a bigger element of composites studies and have industrial experience. If this is to happen it assumes commitment from companies to provide sandwich placements.

Qualified technicians who understand composites and the associated design and manufacturing processes are needed.

It should be noted that whilst there is a universal call for more composites skills training among employers, when training is offered the take up is insufficient to justify the establishment of ongoing courses[60]. Some of the perceived reasons for this were cited as:

- No established career pathways.
- No culture of formal training (SMEs).
- Composite content of qualifications not sufficient
- Lack of interest in funding linked to qualifications
- A preference amongst SMEs for in-house and job specific training.

A new, high level, strategic employers' group to lead on a national Skills Strategy for the Composites Industry is being set up to look at both current and future skills requirements in the UK. The Composites Employers Skills Group will be jointly managed by Semta and Cogent SSCs in accordance with their new Partnership Agreement and supported by NCN and BIS. Key workstreams will include workforce development, 14-19 and higher education.

7.4 Supply-side issues

Composites provision naturally sits with Materials in Higher Education. Much undergraduate provision in this area, especially in polymer technology has disappeared. Indeed, the formerly strong part-time provision, e.g. in HNC, has declined rapidly over the last decade thereby limiting access to training for workforce development purposes. In contrast, the UK has a strong postgraduate focus on Composite materials. Such departments draw in graduate chemists, physicists and biologists with appropriate skills, to work closely with and alongside engineers and mathematicians to provide the range of interdisciplinary skills required for innovation and technological progress required. A brief, but not comprehensive, review identifies the HEIs listed in Annex C as key players in this postgraduate area.

[59] NCN 2009, Polymer Composites Sector – UK Skills report
[60] NCN 2009, Polymer Composites Sector – UK Skills report

A prime focus for many of these institutions is collaboration between academia and industry and knowledge transfer partnerships. But there is still a gap in strategic manufacturing research, to support the supply chain for materials processing.

As demand for composites rises, the supply of postgraduate specialist skills will be at a high premium in the emerging industry. To support this activity a highly qualified technical support workforce will be essential. In the case of the latter, there is a gap in provision. 'Working Higher' a Cogent-Higher Education Funding Council for England (HEFCE) Foundation Degree initiative is addressing this[61]. It is designed to be a solution to workforce development needs by creating a flexible, work-based Technical Foundation Degree Framework of which Polymers/Composites is a key sectoral strand being led by London Metropolitan University. The workforce framework is aimed at the upskilling of existing staff in technical roles. The flexible provision for learning through work, provided by *Working Higher*, will allow employers to better manage workforce development, will widen access for those in employment without prior HE experience and enhance employability for the future workforce. A list of those HEIs engaged in research related to composites is given in Annex D, Table D1.

In terms of available developing composite training at the technician, craft and operative level, Semta has worked closely with employers to develop an extensive range of National Occupational Standards (NOS) and National Vocational Qualifications (NVQs)[62] (See Annex D, Tables D1 and D2) to address the requirements for composite training across the aeronautical, automotive, marine engineering and mechanical equipment manufacturing sectors.

7.5 Geography[63]

As previously mentioned, the polymer sector is a major part of the supply chain supporting composites capacity for the manufacturing industries. It is found clustered in regions with manufacturing capacity, such as the West and East Midlands, as well as in the traditional chemicals industry concentrations of North West England (see Table 7.1).

Table 7.1: Employment in the polymer sector in England

English Region	Employees	% of Workforce In England
North West	26,500	17%
Yorks & the Humber	18,800	12%
North East	10,500	7%
East Midlands	21,800	14%
West Midlands	21,000	13%
East of England	19,200	12%
South East	19,200	12%
London	6,500	4%
South West	13,800	9%
Total England	157,300	

[61] *Working Higher* is a £3m Higher Education Funding Council for England (HEFCE) funded collaboration between Cogent, the University of Hull and the Higher Education Academy Physical Science Centre.
[62] Polymer Composites Sector UK Skills September 2009
[63] Cogent Regional Factsheets, 2007 - http://www.cogent-ssc.com/research/regionsindustry.php

Indeed, to date, tackling the shortage of trained employees has taken place regionally, driven by the Regional Development Agencies (RDAs), has resulted in a disjointed, uncoordinated approach. Examples of these initiatives include the development of a Composite Technician award (SEEDA), development of South West Composite Gateway (SWDA), proposal for a regional Composite Centre (EEDA), creation of a dedicated MSc in Composites Materials at Bolton University (NWDA). In Wales there are also developments which will impact on skills provision in the UK as a whole, the Welsh Composites Centre (Welsh Assembly) and the proposal for an applied knowledge hub for advanced materials and manufacturing systems in North Wales.

8 Nanotechnology

8.1 Background to the sector and main drivers

The global nanotechnology market has been projected to be worth anything from $1-3 trillion by 2015[64]. This kind of estimate is generally over optimistic but a more conservative one puts the figure at closer to $81bn[65]. Such figures enable benchmarking to take place with respect to England's position in the global market for products incorporating nanotechnology.

Investment in R&D for nanotechnology has been substantial and its commercial use is increasing at a significant rate. However, there are some concerns that could reduce the momentum. The pressures that employers are facing in using nanotechnology which could detrimentally affect the growth of the sector include health and safety, handling requirements and consumer scepticism to the technology. The recession and the subsequent global downturn in demand have had the expected negative impact on investment both in terms of new equipment required and the related operator training.

In addition, a major new global player has emerged. China is investing heavily in R&D ($12bn)[66] and sees nanotechnology as an area for significant growth.

Nanotechnology is an “enabling technology” and as with all new technologies the risks are high. But global competitors will be looking to it to increase their competitive advantage, so UK companies may well find themselves forced down this route.

Nanotechnology has been targeted for Government funding in recent years including a £90 million six-year programme for nanotechnology R&D. However, the public sector research institutes are increasingly under pressure due to the recession and any cut in public spending could negatively impact on R&D spending in this area. As nanotechnology is still reliant on R&D to drive the development of the technology, these expected cuts could slow the evolution of the technology and its subsequent adoption by the private sector.

However, the current Government focus on growth in emerging high technology sectors outlined in ‘New Industries, New Jobs’, could mean that levels of R&D in nanotechnology can be maintained.

Key markets for nanotechnology include the electronics, life sciences/medical R&D, automotive, aerospace, chemicals, polymers and pharmaceuticals sectors.

Nanotechnology does, and will, continue to play a key role in the ICT products supply chain where electronic component manufacturers are prevalent. For example, nanotechnology is seen as an enabler for the development and manufacture of more energy efficient lightweight displays (LEDs).

Further investigation into the environmental and H&S effects of using nanotechnology will be important and will influence the speed of adoption and uptake, particularly given the widespread use of electronic devices.

Global competition is intense, particularly from Japan, South Korea and the US, and while the hype surrounding the technology remains high, new products incorporating the technology could still be some way down the line (e.g. 5-10 years for carbon nano-tube transistors).

[64] Third International Dialogue on Responsible Research and Development of Nanotechnology 2008
[65] Nanoposts 2008 report, Nanomaterials and Markets 2008-2015
[66] Guardian Newspaper article March 2009 www.guardian.co.uk/technology/2009/mar/26/nanotechnology-china/print

The life sciences/medical R&D sector was one of the first to be involved in nanotechnology. A new branch of biotechnology, nanobiotechnology, has evolved and is looking at the ways in which nanotechnology will impact on areas such as drug delivery, therapeutics, implants, medical devices, tissue engineering and diagnostics.

The risk of a “brain drain” to countries such as the US remains, but the strong R&D infrastructure and healthcare industries that are based in England help limit this.

The automotive sector, as a leader in the adoption and use of cutting edge technologies, will be a key area for the use of nanotechnology as manufacturers seek to gain competitive advantage in the areas of cost reduction, reduced air pollution, recyclability, safety, and longer service life, and meet the increasing levels of environmental and safety legislation. However, the key to a wider acceptance of the use of this technology and its products will be the price-performance ratio and environmental sustainability of the products, when compared with traditional automotive material technologies.

In aerospace, the opportunities for using nanotechnology fall into five potential areas of the supply chain and include coatings, structural materials, sensors, electronics and energy/emission reduction. Of these, the first two are likely to benefit the most from nanotechnology in the medium term, to 2015. Stringent testing and quality control procedures, coupled with long product cycles, could slow down the introduction of nanotechnologies as a potential solution, but competitors such as Boeing in the US are committing resource to the development of the technology.

In the chemicals, polymers and pharmaceuticals sectors, examples of the use of nanotechnology include the manufacture of nano-sized particulates, the synthesis of smart molecules for specific purposes, the controlled growth of nano-sized structures and ‘machines’ (e.g. carbon nano-tubes, and nano-rotors etc) for widespread use as materials in devices.

Commercialisation of the technology is key to its widespread adoption and this is one of the major challenges faced, as while the R&D of such technologies has always been a strength, subsequent commercialisation has quite often taken place overseas.

Globally, the technology has received significant attention and investment but has still to fulfil its potential. Concerns have recently been raised regarding the health and environmental impacts of nanotechnology and this will result in a greater requirement for research prior to its wider adoption by industrial sectors.

8.1.1 Contribution to the low carbon economy

A study for Defra[67] identified five key areas where the use of nanotechnology would be beneficial to the environment. These consist of fuel additives, solar cells, the hydrogen economy, batteries and insulation.

[67] Environmentally Beneficial Nanotechnologies: Barriers and Opportunities, 2007

The potential benefits of nanotechnology include an increase in the fuel efficiency of engines through the use of nanoparticle additives, a significant reduction in the production costs of solar cells, the use of nanotechnology to develop efficient hydrogen storage and improve the efficiency of hydrogen fuel cells in hydrogen powered vehicles to enable electric vehicles to recharge much more quickly and to provide aerogel insulation for solid walled buildings and nano-coatings for windows.

So it can be seen that nanotechnology has significant potential for reducing greenhouse gas emissions, with estimates of reductions between 2% and 20% by 2050.

Table 8.1: Summary of environmentally beneficial nanotechnologies

Application	Application Impact of Nanotechnology in area[1]	Infrastructural Changes[2]	Benefit (Mte CO_2 per annum)[3]	Timescale for Implementation (yrs)[4]
Fuel efficiency	Critical	Low	<3	<5
Insulation	Moderate	Low	<3	3-8
Photovoltaics	High	Moderate	c.6	>5
Electrical storage	High	High	10 - 42	10 - 40
Hydrogen Economy	Critical	Very high	29 - 120	20 - 40

Source - Environmentally Beneficial Nanotechnologies: Barriers and Opportunities, 2007

[1] Impact of nanotechnology describes the effect nanotechnology is likely to have in the area compared to other technologies.
[2] Infrastructural changes indicates the effort bring the nanotechnology to market.
[3] Benefit is the estimate of the maximum potential CO_2 saving by implementing the technology.
[4] Timescale for implementation is the projected distance (in years) before the technology will be fully implemented.

Nanotechnology is already being used in the food industry. It has the potential to reduce food borne disease, pesticides use on crops, antibiotics use in livestock and the improvement of supply-chain efficiency and security. Nanoproducts in food could improve health, through facilitating the uptake of nutrients for example[68]. Regarding the implications of sustainability and low carbon, researchers have demonstrated that nanotechnology could cut residual food waste by half. For example, a nanoparticle-based coating stops food sticking to the sides of a container.

With increasing importance attached to the development of low carbon solutions and the ongoing drive to reduce costs and relentless demands for heightened functionality, advanced manufacturing sectors are well placed to take advantage of the potential that exists within the technology.

[68] Cabinet Office, 2008, Food – an analysis of the issues.

8.2 Current skills

At present the technology is still largely R&D based so the focus has been on higher level skills to meet the requirement of this area (PhDs, MScs with a specialism in nanotechnology).

However, it is clear that multidisciplinary experience is highly beneficial as nanotechnology crosses the boundaries between such areas as natural sciences and engineering and has lead to the establishment of a number of Doctoral Training Centres (DTCs) around the country, where interdisciplinary research activities form the basis of four-year research doctorates undertaken.

For example, the Life Sciences Interface Doctoral Training Centre (LSI DTC) is an interdisciplinary programme at the University of Oxford. It aims to train graduates from both physical and mathematical backgrounds, as well as those from the life sciences, interested in the more theoretical aspects of their disciplines, to interface with biological sciences. Its main application areas are bioinformatics, bionanotechnology, medical imaging, and computational biology.

While the industrial potential of the technology is still to fully emerge the current skills required focus on research and development of the technology, together with an understanding of intellectual property (IP) and new product development (NPD).

At the same time the manufacture of nanomaterials is increasing. Therefore highly skilled technicians are required who are capable of running complex equipment (such as scanning tunnelling microscopes and electron microscopes).

8.3 Future skills

The introduction of nanotechnology into the manufacturing environment will undoubtedly lead to an increase in demand for skills related to nanotechnology as businesses across the sectors seek to make greater use of nanomaterials in their products. Failure to address such skills needs will reduce their competitiveness within the global markets in which they operate.

In the food industry, skills requirements for nanotechnology will be focused on the need for higher skilled food scientists to develop anti-microbial activity to ensure food safety and security, resulting in an extension of product life.

As the technology becomes more embedded in industry and cost effective, the need for high level skilled technicians/operators will increase with a subsequent increase in the need for materials handling, fabrication and health and safety training. The timing for this is difficult to predict as the barriers to incorporating the technology into manufacturing remain significant and go beyond skills shortages/gaps, cost and environmental health and safety impact.

In addition to broaden multidisciplinary skills, scientists and engineers will require management skills in areas such as finance, technology management and technology strategy, high tech marketing, IP strategy and in science and technology policy if they are to successfully commercialise their research findings and establish high performing companies.

8.4 Supply-side issues

FE colleges provide a range of STEM courses but there are no specific modules on nanotechnology. A number of graduate degrees courses[69] in engineering, physics, electronics, and chemistry are offered as modules within a variety of BEng and BSc courses throughout the UK with Queen Mary University of London, Swansea and Leeds offering degrees that are nanotechnology focused in terms of content.

At postgraduate level a range of MSc courses are offered at HEIs across the UK[70] that cover a range of areas relating to nanotechnology. At doctorate level, HEIs across the country are offering PhDs in nanotechnology research[71]. Universities are also starting to offer a number of nanotechnology short courses (1- 2 days) which they are marketing as CPD courses.

8.5 Geography

As the technology will be used in a significant number of Semta's sectors, the need for nanotechnology training provision will be seen throughout the country and with the creation of the 24 Micro and Nano Technology Centres[72] with expertise in areas that include Fabrication, Metrology, Medicine and Materials, there now exists a network of centres of excellence to provide specialist support and training for companies in the area of nanotechnology.

[69] UCAS course search, Nanotechnology http://search.ucas.com accessed 26/11/2009
[70] Nanotechnology Knowledge Transfer Network http://mnt.globalwatchonline.com/epicentric_portal/site/MNT/menuitem.c4c8c53d9cf4c7609ccece35ebd001a0/
[71] Nanotechnology Knowledge Transfer Network
[72] Appendix 3 - TSB Report Nanoscale Technologies Strategy 2009-12

9 Advanced Manufacturing's lifeblood: the Supply Chain

There are small but important clusters of companies across the UK who form a vital part of the supply chain to several of the downstream advanced manufacturing industries detailed in this report. These include the following categories of products:

9.1 Coatings

Advanced coatings contribute towards the improved performance, protection and appearance of many products, ranging from cars to houses to specific industrial applications. Coatings contain a wide range of materials including ceramics, plastics, and metals as well as more traditional pigments, and are usually applied as liquids or powders. Uses directly relevant to the industries in this report include adding protective and anti-corrosive properties to metals used in aerospace and space technologies, manufacturing printing inks for plastic electronics, and a growing recognition of the benefits that nanotechnology can bring to a huge variety of end products. There is a notable cluster of coatings companies the North West and a significant presence in the South East. The continuing need for higher level chemistry knowledge and skills in research and development for the industry means that knowledge transfer between industry and universities will continue to be important, as will support from other research and trade associations such as the British Coatings Federation and the Paint Research Association. At a lower level, the industry has a comprehensive technical certificate including content up to level–5 and an Apprenticeship framework, for which continuing support will be welcome.

9.2 Technical Ceramics and Refractories

Ceramics can provide a range of properties including great strength for relatively little weight, and can be manufactured to variety of specifications including protective casings for aircraft, engine components, synthetic bones and teeth, and capacitors in electric circuits. The specific insulating properties of refractory ceramics mean they are able to maintain their strength and structure at very high temperatures, and are often used as insulating materials in reactors, furnaces, and engines. Specialised skills are needed in the design and engineering of the materials, as well as in forming and moulding processes. The heart of the ceramics industry is in the West Midlands, and there are a number of specialised refractory manufacturers in the UK, notably in Yorkshire and Derbyshire. Continuing engagement with materials engineers and scientists will prove important to stimulating innovation and product design and lower level skills for the industry can be supplied through the existing Apprenticeship framework.

9.3 Glass

Similar to ceramics, glass has a range of properties that can be exploited in advanced products from fibre-optic cables to aircraft windows, from lenses to glass fibre. The technical glass industry has a significant presence in the Midlands and Yorkshire.

9.4 Textiles and 'Technical' Textiles

9.4.1 Background to the technical textiles sector and main drivers

The textiles sector has its roots in the innovative use of fibres, which continue to underpin the fabric of industrial society today. Whilst not seen as an obvious component of Advanced Materials and Products to the layman, textile fibres, whether natural or man made, contribute to the success of new technology in at least four of six areas of Advanced Manufacturing identified in this report.

1. Aerospace and automotive textile manufacturing

Automotive and aerospace textile employers include all the supply chain companies involved in the manufacture of textile components for cars, commercial vehicles and aircraft. This sub-sector represents the most valuable market for textile and technical textiles.

The key components supplied by the sector include:

- Airbags and seat belts
- Upholstery yarns and fabrics
- Needle punched headliners, carpets, boot liners, sound-proofing and insulation
- Lightweight nonwovens used in filters
- Tyre cord fabrics

2. Industrial Biotechnology

Textile and technical textile products in this field are diverse, providing innovative solutions within the fields of medicine and ranging from tissue engineering to wound dressings and implants. Within fixed structures textiles are employed to replace and complement traditional materials and perform a variety of functions including reinforcement, sealing, insulation and fire protection.

Typical applications include:

- Medical textiles including all those textile materials used in health and hygiene applications such as dressings, artificial veins and prostheses.
- Breathable, temperature-regulating materials
- Lightweight, shock-proof materials
- Water and dirt repellent materials

3. Composite Textiles

The flexible nature of a textile product means it can be easily preformed into a shape and then fixed in that shape using complex polymer structures. In this way, engineered composite components can be produced that combine light weight with strength. Along with the medical use of textiles, this is a growth area of UK specialism recognised across the world.

Examples of composite textiles include:

- Aerospace components (tails, wings, fuselages, propellers).
- Boat and scull hulls.
- Lightweight bicycle frames and racing car bodies.
- Fishing rods, storage tanks, and baseball bats.

4. Nanotechnology

Nanotechnology is enabling a new generation of textile products to be developed known as ‘smart’ textiles. These are able to monitor personal health through wearable and aesthetic products and the ability to weave or knit nano-fibres into garments is revolutionising the monitoring of health. Similarly, this technology is revolutionising everyday clothing from heavy industry to fashion through products that include:

- Materials that cope with spillages through super absorbency.
- Provide antimicrobial and anti-mosquito protection into a vast array of products.
- Change the natural characteristics of a ‘natural product’ to enhance its positive elements or cap its negative elements e.g. improved wind and water resistance in clothing worn by sailors
- Textile pressure and strain sensors, used in clothing that can measure heart rate and respiratory rates, and to detect movement in buildings and structures
- Electrically conductive textile materials, used in health monitoring garments, utilised by the military for inconspicuous communication tools, and for fashion items e.g. Ipod jackets or mp3 players integrated into snowboarding equipment
- Water and dirt repellent materials

What drives demand for skills?

Political: As a traditional UK sector, textiles and technical textiles have their roots in the industrial power base of the 19th Century. In the 21st century the sector, whilst significantly reduced in size still has a strong hold in the Midlands and the North where it has embraced new technology and innovation to become a major supply of components to the emerging advanced manufacturing sectors. This includes the manufacture of textiles-based components that prolong the life of patients in the health service and protective clothing for the Police and Armed Forces.

Economic: Technical textiles are a sector that encompasses a very wide sub-sector spread that is set to face rapid growth levels. Advances in production technology sees manufacturers evolving textile manufacturing techniques to develop new products to meet a range of what could be seen as non traditional textiles markets. Textiles companies now cater for a wide range of high performance end-users, including construction, civil engineering, industrial applications, automotive aerospace, medical applications and technical and high performance garments sectors.

According to a DTI sponsored report, output from the UK Technical Textiles industry is estimated at £1.2 billion. Latest Skillfast-UK research data suggests that that there may be up to 1,000 technical textile enterprises, employing up to 40,000 people, concentrated in the English regions East Midlands, North West, Yorkshire and the Humber, South West and Scotland.

Social: Lightweight components used in aerospace and transport are contributing to cost reductions brought about by fuel efficiency driven by low weights and reduced rolling resistance. New generation aircraft, buses, cars and trains have a significant element of their construction that includes textile-based or textile composite-based product. The ability of textile companies to diversify enables the social fabric of many communities to be maintained.

Technological: Woven, knitted and extruded fibres play a large part in the development of products across a range of applications that impact on products developed from the field of sport to environmental control. Such technological advances are only possible by the development and manipulation of fibres that can produce the desired component or accessory. The University of Manchester leads this field of R&D making significant advances in the use of smart textiles and their application to nanotechnology

Environmental: Textile and technical textile products contribute to the management and control of emissions and spillage. Super absorbency new generation textile products help to control hazardous waste and provide protection to individuals whose role is to monitor and manage such events.

9.4.2 Current skills

What is the current demand for skills?

Research by Skillfast-UK in 2008 indicated that the textiles sector could expect to need to replace 30% of its workforce by 2020. This took into account the age demographic of the existing workforce and the continuing trend towards specialised manufacturing units offering niche and specialised services. This shift reveals an increasing need for professional and higher level technical staff, including nano and fibre technologists, supported by sales and marketing specialists.

The requirement is typically for a degree in a technical discipline such as engineering, chemistry or textiles technology and this is often extended to sales and marketing roles. The profile of recruitment needs is very different to that observed for the other textiles manufacturing sub-sectors. Technical textile employers are around twice as likely to identify a requirement for professional and high level technical staff and only half as likely to identify a need for operative level staff.

9.4.3 Future skills

What will be future demand for skills?

The following are identified as the key skills-related issues for the textile and technical textiles industry. It is likely that the technical textiles workforce has a qualification profile that is weighted more towards the higher levels; however, the preponderance of operative staff suggests that the pattern is broadly similar to that of textiles as a whole. There is a need to address:

- A shortfall in graduate technologists with the knowledge and experience of textile technology needed to drive the process of technical innovation that is critical to the future performance of the industry.
- The lack of a NOS framework of technical textile competencies to assist graduate recruitment and skills development targeted on science (chemistry, biology, physics and far reaching scientific bias) graduates/postgraduates to introduce them to the textiles sector.
- The lack of a specific technical textiles Apprenticeship to replace the traditional HNC/D routes and provide 21st century technicians.
- The lack of guidance for employers to enable them to take advantage of, for example KTPs and STEM placement opportunities.
- Ongoing demographic issues that will impact on continued access to skilled workers in the areas of:
  - Research and technology development.
  - Technical yarn spinners.
  - Technical fabric weavers.
  - Technical fabric knitters.
  - Manufacturers of ‘non-wovens’.
  - Coaters and finishers.

9.4.4 Supply-side issues

What is the current supply of skills?

The industry is supported by three key universities in the north of England that focus on the application of textiles within the context of advanced manufacturing. These institutions provide able graduates who are able to contribute to the development of company products.

However, the critical area of skills resides at technician level where other university programmes tend to have a strong ‘fashion’ focus, with the type of scientific expertise required not emerging until students progress to Masters level. Similarly, technical programmes at HNC/D level are declining due to lack of interest from students and negative image. This will have a major impact in future years as demographics see the current skilled workforce approach retirement.

What are the barriers to the supply of skills?

Most textile and technical textiles employers report that they are satisfied with the access and quality of support offered by providers (colleges and universities), although some complain about the lack of accessible provision due to their location outside traditional textiles areas. This provides a significant barrier to these companies who respond by developing their own 'in-house' programmes to maintain their craft/technical skills base

However, overriding the sector's approach to skills development are the following key factors which, in descending order, are:

- Cost in terms of production downtime, often complicated by continental shift patterns/continuous working and a 'lean' workforce
- Lack of specialised and advanced courses at a regional and even national level
- Out of pocket cost of courses
- Lack of in-house infrastructure to organise effective training
- Reluctance of employees to participate in training in their own time
- A lack of knowledge of intellectual property issues inhibits collaboration between universities, researchers and sector businesses.

To counter this, the industry makes a significant investment in the recruitment of young people, both in terms of graduates and school leavers. No data are currently available specifically for the qualifications profile of the technical textiles workforce. However, it is estimated that across textiles manufacturing as a whole, 51 per cent have no qualifications or are qualified at below NVQ Level 2 equivalent; this contrasts with the average for the UK workforce as a whole, which stands at less than one third. This in itself constitutes a barrier to future skills development.

9.4.5 Sector Summary

The textiles and technical textiles industry is reliant for its future success on continuous technical innovation and product development. This creates a need for a combination of scientific, textile and commercial skills.

Aerospace/space, composites, industrial biotechnology and nanotechnology are growth industries and textiles have a major role to play in their development. In order for the industry to take advantage of these developments it must understand the dynamics of these sub-sectors and the skills that textiles companies need to ensure a sustainable future.

On that basis the key recruitment needs of the textiles industry centres on professional and higher level technical staff, including technologists supported by sales and marketing specialists. Demographics are also driving the need to develop the next generation of skilled trades such as loom technicians, knitters and weavers.

In response to these identified and potential skill deficiencies, employers are making significant investment in the recruitment of young people, both in terms of graduates and school leavers. However, many employers indicate that they have encountered problems in recruiting the right young people because of the negative image that people have of textiles manufacturing processes and further development of science, technology, engineering and mathematics activities are crucial here.

It is clear that across the whole supply chain, higher level skills focused mainly on STEM subjects such as materials engineering, chemistry, and other physical sciences will be the driving force behind product development and innovation. Good links with universities and industry and research associations will continue to be important to continue the tradition of knowledge transfer between academic and industrial environments, and to stimulate innovation and new products. To support this, ongoing support for business development and lower-level manufacturing qualifications will aid companies who have identified market opportunities and want to grow their business. Ensuring flexibility will be the key to skills supply, and modular qualifications that can be tailored to individual company needs will help smaller companies to specialise and larger companies to develop their workforce in an efficient and business-focused manner. Whilst the mature and well established companies will require continuing support to help maintain their business, it will also be important to support new developments to ensure the industries remain relevant and competitive.

.

Abbreviations

ACARE	Advisory Council for Aeronautics Research in Europe
A|D|S	(Aerospace, Defence and Security industry body)
AMT	Advanced Manufacturing Technologies
ASHE	(ONS) Annual Survey of Hours and Earnings
ATM	Automatic Traffic Management (Air Traffic)
BBSRC	Biotechnology and Biological Sciences Research Council (BBSRC)
BERD	Business Enterprise Research and Development
B-IT	Business Improvement Techniques
BOP	Balance of Payments (basis for international trade statistics)
CAD	Computer Aided Design
CASE	Collaborative Award in Science and Engineering (Studentships)
CBI	Confederation of British Industry
CIKC	Cambridge Integrated Knowledge Centre
CNC	Computer Numerical Control
CPD	Continuing Professional Development
CPI	Centre for Process Innovation
DBIS	Department for Business, Innovation and Skills
DLHE	Destinations of Leavers from Higher Education' (HESA datasets)
DIUS	(former) Department for Industry, Universities and Skills
DTC	Doctoral Training Centres
DTI	(former) Department for Trade and Industry
EEA	European Economic Area
EEDA	East of England Development Agency
EEF	Engineering Employers' Federation
EQF	European Qualifications Framework
EU	European Union
FE	Further Education
GHG	Green House Gas
GM	Genetically Modified
HE	Higher Education
HEFCE	Higher Education Funding Council for England
HEI	Higher Education Institution
HESA	Higher Education Statistics Agency
HMG	Her Majesty's Government
HR	Human Resources
HtFVs	Hard-to-fill Vacancies
IER	Institute for Employment Research
IES	Institute for Employment Studies
IGT	Industry Growth Team (DBIS)
IPR	Intellectual Property Rights
IB	Industrial Biotechnology
ISO	International Standards Organisation
IT	Information Technology
L&M	Leadership and Management
LCD	Liquid Crystal Diode
LED	Light Emitting Diode
LFS	(ONS) Labour Force Survey
LMI	Labour Market Intelligence
LMS	Labour Market Survey
LSI	Life Sciences Interface
MAC	Migration Advisory Committee
MRO	Maintenance, Repair and Overhaul (Aerospace industry)

MSc	Master of Science
NESS	National Employer Skills Survey (for England)
NINJ	'New Industry, New Jobs'
NPD	New Product Development
NPDI	New Product Development and Implementation
NPPDI	New Product and Process Development Implementation
NSAM	National Skills Academy for Manufacturing
NVQ	National Vocational Qualification
NWDA	North West Development Agency
OECD	Organisation for Economic Co-operation and Development
OEM	Original Equipment Manufacturer
OMIC	Organic Materials Innovation Centre (Manchester)
ONS	Office for National Statistics
OLED	Organic Light Emitting Diode
QCD	Quality, Cost & Delivery
PC	Poly Carbonate
PET	polyethylene terephthalate
PETeC	Printable Electronics Technology Centre
PhD	Doctor of Philosophy
P-OLED	Polymer Organic Light Emitting Diodes
R&D	Research and Development
RDA	Regional Development Agency
RF	Radio Frequency
SEEDA	South East England Development Agency
SESAR	Single European Sky ATM Research
SIC	Standard Industry Classification
SiC	Silicon Carbide
SME	Small/Medium-sized Enterprise
SMT	Surface Mount Technology (electronics)
SOC	Standard Occupational Classification
SSA	Sector Skills Agreement
SSC	Sector Skills Council
SSDA	(former) Sector Skills Development Agency
SSVs	'Skill-Shortage Vacancies'
STEM	Science, Technology, Engineering and Mathematics
SusChem	The European Technology Platform for Sustainable Chemistry
SVQ	Scotttish Vocational Qualification
SW	South West
SWCG	South West Composite Gateway
TS	Technical Specification
UAV	Unmanned Aerial Vehicle
UCAS	Universities and Colleges Admissions Service
UK	United Kingdom
UKCES	UK Commission for Employment and Skills
USA	United States of America
VET	Vocational Education and Training
WBL	Work-based Learning
WCPC	Welsh Centre for Printing and Coating

Annexes

Annex A

Advanced Manufacturing Cluster Related SIC codes

proskills
MAKING SKILLS WORK

Proskills					
Aerospace/Space	**Plastic/printed Electronics and Silicon electronics**	**Composites**	**Industrial Biotechnology**	**Nanotechnology**	**Others e.g. cross-cutting**
Ceramics, Tiles and coatings in the supply chain 24.301 Manufacture of paints, varnishes and similar coatings 26.23 Manufacture of ceramic insulators and insulating fittings 26.24 Manufacture of other technical ceramic products 26.25 Manufacture of other ceramic products 26.26 Manufacture of refractory ceramic products	**Printed electronics** 22.22 Printing not elsewhere classified 22.25 Ancillary activities related to printing 24.302 Manufacture of printing ink			**Advanced coatings** 24.301 Manufacture of paints, varnishes and similar coatings 24.302 Manufacture of printing ink	**Supply chain issues**

skillfast-uk
The Sector Skills Council for fashion and textiles

Skillsfast UK					
Aerospace/Space	**Plastic/printed Electronics and Silicon electronics**	**Composites**	**Industrial Biotechnology**	**Nanotechnology**	**Others e.g. cross-cutting**
13.99 Manufacture of other textiles n.e.c 18.22 Manufacture of other outerwear 17.4 Manufacture of made-up textile articles, except apparel		17.17 Preparation and spinning of other textile fibres Advanced textiles	13.96 Manufacture of other technical and industrial textiles n.e.c	13.99 Manufacture of other textiles n.e.c	13.10 Preparation and spinning of textile fibres

Cogent					
Aerospace/Space	**Plastic/printed Electronics and Silicon electronics**	**Composites**	**Industrial Biotechnology**	**Nanotechnology**	**Others e.g. cross-cutting**
Reinforced plastics, resins and composite materials manufacture 24.16 Manufacture of Plastics in primary forms 25.21 Manufacture of plastic tubes, sheets, plates and profiles 25.24 Manufacture of other plastic products	Manufacture of functional plastics and polymeric materials 24.16 Manufacture of Plastics in primary forms 25.21 Manufacture of plastic tubes, sheets, plates and profiles 25.24 Manufacture of other plastic products	Manufacture of advanced and reinforced plastics, resins and polymeric materials; blending with functional materials Supply chain to automotive, aerospace and construction industries 24.16 Manufacture of plastics in primary forms 25.21 Manufacture of plastic tubes, sheets, plates and profiles 25.23 Manufacture of builders ware plastic	New biotechnology processes for future chemicals industry; h Highly specific molecular modifications in chemicals industry Biofuels and biorefineries 23.20 Manufacture of refined petroleum products 24.11 Manufacture of Industrial Gases 24.12 Manufacture of dyes and pigments 24.14 Manufacture of other organic basic chemicals 24.15 Manufacture of fertilisers and nitrogen compounds	Smart molecule synthesis 24.12 Manufacture of Dyes & Pigments 24.13 Manufacture of inorganic basic chemicals 24.52 Manufacture of perfumes and toilet preparations 24.65 Manufacture of Prepared Unrecorded Media 24.66 Manufacture of chemicals not elsewhere specified.	Advanced component manufacturer supply chain to nuclear industry This nuclear sector not explicitly covered by SIC codes. 24.16 Manufacture of Plastics in primary forms

Cogent (Continued)					
Aerospace/Space	**Plastic/printed Electronics and Silicon electronics**	**Composites**	**Industrial Biotechnology**	**Nanotechnology**	**Others e.g. cross-cutting**
		25.24 Manufacture of other plastic products	24.20 Manufacture of Pesticides 24.41 Manufacture of basic pharmaceutical products 24.42 Manufacture of pharmaceutical preparations 24.51 Manufacture of soap and detergents, cleaning and polishing preparations 24.52 Manufacture of Cosmetics & Detergents 24.62 Manufacture of glues and gelatine 24.63 Manufacture of essential oils 24.66 Manufacture of chemicals not elsewhere specified		

Semta					
Aerospace/Space	**Plastic/printed Electronics and Silicon electronics**	**Composites**	**Industrial Biotechnology**	**Nanotechnology**	**Others e.g. cross-cutting**
Advanced fuels – engine design, Composites, Wing design, Satellites, Space IGT, Rocket science, Missiles and Defence sector 35.3 Manufacture of aircraft and spacecraft	Applications in electronics, displays, lighting, semi-conductors. Possible uses in aerospace, automotive, marine at later stages, 32.1 manufacture of electronic valves and tubes and other electronic components	Applications in aerospace, marine, automotive sectors 35.3 Manufacture of aircraft and spacecraft 35.1 Building and repairing of ships and boats 34 Manufacture of Motor Vehicles, Trailers and Semi-trailers	Applications in biosciences, aerospace, automotive and electronics 24.41 Manufacture of basic pharmaceuticals 24.42 Manufacture of pharmaceutical preparations 73.10 Research and experimental development on natural sciences and engineering	Applications in electronics (semi-conductors), automotive and aerospace. Bioscience research and development 32.1 manufacture of electronic valves and tubes and other electronic components 34 Manufacture of Motor Vehicles, Trailers and Semi-trailers 35.3 Manufacture of aircraft and spacecraft 73.1 Research and experimental development on natural sciences and engineering	New Product & Process Development & Introduction (NPPDI)

Improve					
Aerospace/Space	**Plastic/printed Electronics and Silicon electronics**	**Composites**	**Industrial Biotechnology**	**Nanotechnology**	**Others e.g. cross-cutting**
			IB in food production Probiotics, Nutriceuticals, Enzyme cropping, Microbial replication and breeding 15 manufacture of food products and beverages 51.38 Wholesale of other food including fish, crustaceans and molluscs		Robotics, Low carbon, Waste management systems, including Biowaste and Technology for Sustainability

Annex B

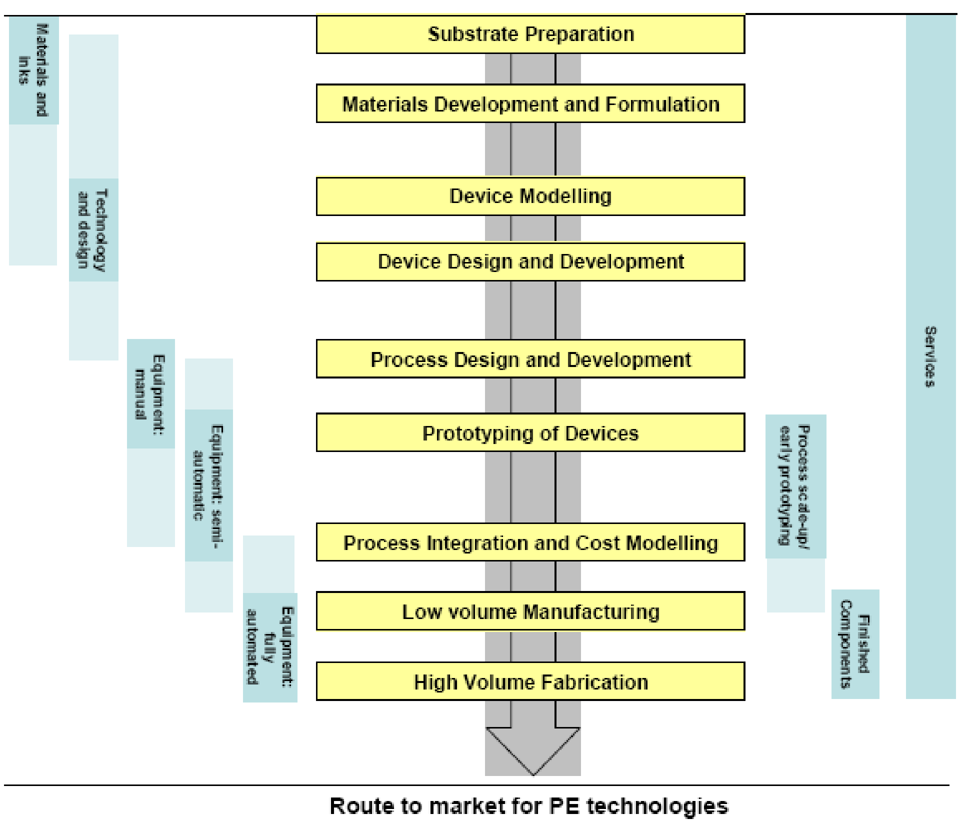
Plastic Electronics

The Welsh Centre for Printing and Coating (WCPC)

The Welsh Centre for Printing and Coating (WCPC) at Swansea University is one of the main centres for advanced printing research and industry support in the UK. It has just received approval for funding to help facilitate knowledge transfer in printed electronics and functional materials, and to explore their use they can have in a wide range of industrial contexts including smart packaging and clothing, large area electronic circuits, lighting and photovoltaics. Since the technology and skills required for the printing process are very similar to those used in more traditional printing, there are a number of companies already in existence in Wales who will be working with the university to develop effective manufacturing and roll out processes. As well as working with printing companies and Proskills, the Sector Skills Council for the industry, the university will be working with companies in the supply chain and end users to fully explore the value added process and implications for the wider economy. Use of a similar model in other areas of the UK would help to establish this new technology, driving innovation and industrialisation among existing printing clusters and stimulating new growth.

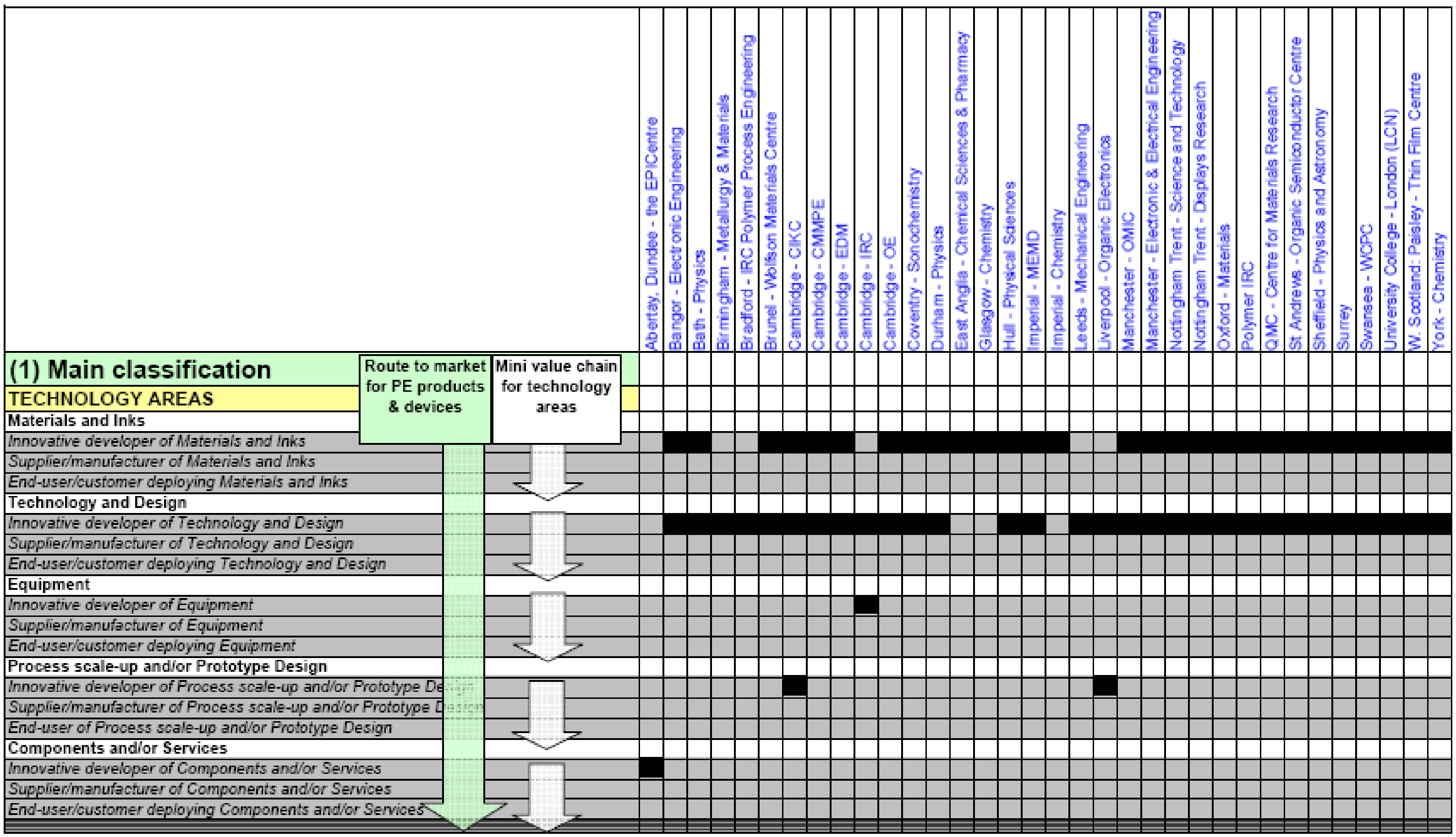
Cambridge University Cavendish Laboratory

Figure 3: Process flow chain for the development of new plastic electronics technologies



Source: Dr Zella King of the University of Reading Mapping Technological Competence in Plastics Electronics in the UK

Competence Matrix for Plastic Electronics in the UK. Section 1: Universities



Source: Cathy J Curling, Dr Zella King of the University of Reading. Competence Matrix http://www.printedelectronics.net/documents/CompetenceMatrix

Annex C

Silicon Electronics

BioMEMS, Organic and Silicon Electronics Group[73]

Laboratories based at the University of Liverpool host micro- and nano-manufacturing facilities, test and operation equipment for microfluidics (lab-on-chip) and sensors, biomedical, organic and silicon devices and circuits.

The group focuses on the design, fabrication, testing, measurement, analysis and modelling of micro/nano structures and devices that integrate silicon and related materials, polymers and biomolecules.

Significant activity on electrical and optical materials characterisation underpins the device related work. Design and modelling is conducted using Silvaco, Cadence and Coventor tools. Some highlights of the capabilities include: spectro-ellipsometry, atomic force microscopy and nanofabrication, laser ablation micro/nano-fabrication and a pilot line for the production of polymer thin film transistors.

[73] http://www.liv.ac.uk/info/research/biomems_electronics/

Table C1: Highest qualification held by the workforce within Engineering sectors in England compared with all sectors (%)

Qualification level	NVQ Level	Metals	Mechanical Equipment	Electrical Equipment & Electronics	Automotive	Other Transport Equipment	All Engineering	All sectors (England)	All sectors (England)
Degree or equivalent	Level 4 or above	8%	13%	23%	13%	21%	15%	22%	22%
Higher education	Level 4 or above	9%	11%	13%	10%	14%	11%	9%	9%
GCE A Level or equivalent	Level 3	33%	32%	25%	30%	37%	31%	23%	23%
GCSE grades A-C or equivalent	Level 2	19%	19%	18%	22%	14%	19%	23%	23%
Other qualifications		15%	11%	11%	12%	7%	11%	12%	12%
No qualification	None	15%	12%	8%	13%	7%	11%	10%	10%
Don't know		1%	1%	1%	0%	1%	1%	1%	1%
Total		100%	100%	100%	100%	100%	100%	100%	100%

Source: Office for National Statistics, Source: Annual Population Survey 2006

Annex D

Composites

Table D1: Examples of HEIs engaged in Research and Development related to composites

- University of Nottingham – Polymer Composites Group
- University of Newcastle upon Tyne - Centre for Composite Materials Engineering
- University of Plymouth – Advanced Composites Manufacturing Centre
- University of Manchester - Manchester Materials Science Centre
- Cambridge University Materials Science and Metallurgy
- Southampton University - Ship Science
- Loughborough University - Institute of Polymer Technology and Materials
- University of Wales, Swansea - Department of Materials Engineering
- University of Reading – Department of Engineering
- Imperial College :London - Imperial College Centre for Composite Materials
- University of Sheffield – Ceramics and Composites Laboratory
- The National Physical Laboratory
- The Leeds/Bradford/Durham Polymers IRC
- Cranfield University – Composites Centre.
- The North West Composites Centre – Universities of Bolton, Manchester, Liverpool, Lancaster
- University of Bristol – Advanced Composites Centre for Innovation in Science.

Table D2 Semta National Occupational Standards: Composites-related

Occupational Standard	Suite
Applying Finishes to Composite Mouldings	Materials Processing and Finishing
Applying Finishes to Composite Mouldings	Mechanical Manufacturing Engineering
Applying Finishes to Motorsport Composite Mouldings	Automotive Engineering
Applying Finishes to Vehicle Composite Mouldings	Automotive Engineering
Applying Surface Finishes to Composite Mouldings	Fabrication and Welding Engineering
Applying Surface Finishes to Composite Mouldings	Mechanical Manufacturing Engineering
Assembling Aircraft Composite Components	Aeronautical Engineering
Assembling Composite Components	Performing Engineering Operations
Assembling Composite Vehicle Components	Automotive Engineering
Assembling Engineering Woodwork	Engineering Woodworking, Pattern and Model Making
Assembling Marine Composite Components	Marine Engineering
Assembling Wood/Composite Pattern, Corebox or Model Components	Engineering Woodworking, Pattern and Model Making
Bonding Composite Mouldings	Fabrication and Welding Engineering
Bonding Composite Mouldings	Fabrication and Welding Engineering
Bonding Composite Mouldings	Mechanical Manufacturing Engineering
Bonding Composite Mouldings	Mechanical Manufacturing Engineering
Bonding Composite Mouldings	Materials Processing and Finishing
Bonding Marine Composite Components	Marine Engineering
Bonding Motorsport Composite Mouldings	Automotive Engineering
Bonding Vehicle Composite Components	Automotive Engineering
Carrying Out Bonding Activities on Composite Mouldings	Materials Processing and Finishing
Carrying Out Bonding Operations on Aircraft Composite Components	Aeronautical Engineering
Carrying Out Bonding Operations on Marine Composite Components	Marine Engineering
Carrying Out Composite Assembly Activities	Materials Processing and Finishing
Carrying Out Composite Moulding Activities	Performing Engineering Operations
Carrying Out Pre-Preg Laminating Techniques	Materials Processing and Finishing
Carrying Out Repairs to Aircraft Composite Mouldings	Aeronautical Engineering
Carrying Out Repairs to Composite Mouldings	Materials Processing and Finishing
Carrying Out Repairs to Composite Mouldings	Mechanical Manufacturing Engineering
Carrying Out Repairs to Marine Composite Mouldings	Marine Engineering

Occupational Standard (Continued)	Suite
Carrying out repairs to Yacht and Boat Composite Components	Marine Engineering
Carrying Out Surface Finishing Activities on Composite Mouldings	Materials Processing and Finishing
Carrying Out Trimming of Composite Mouldings using Hand Tools	Materials Processing and Finishing
Carrying Out Trimming Operations on Aircraft Composite Components	Aeronautical Engineering
Carrying Out Trimming Operations on Marine Composite Mouldings	Marine Engineering
Carrying Out Vacuum Forming of Composite Materials	Materials Processing and Finishing
Checking Aircraft Composite Mouldings for Defects	Aeronautical Engineering
Checking Composite Mouldings for Defects	Materials Processing and Finishing
Checking Marine Composite Components/Mouldings for Defects	Marine Engineering
Cutting and Shaping Wooden Components for Yachts and Boats using Machines	Marine Engineering
Fitting Marine Composite Components to the Vessel, Craft or Structure	Marine Engineering
Identifying Defects in Composite Mouldings	Fabrication and Welding Engineering
Identifying Defects in Composite Mouldings	Mechanical Manufacturing Engineering
Identifying Defects in Composite Mouldings	Mechanical Manufacturing Engineering
Identifying Defects in Composite Mouldings.	Materials Processing and Finishing
Identifying Defects in Marine Composite Components and Assemblies	Marine Engineering
Identifying Defects in Motorsport Composite Mouldings	Automotive Engineering
Installing Composite Components in Yachts and Boats	Marine Engineering
Installing Marine Composite Components	Marine Engineering
Installing Woodwork Structures, Furniture and Fittings	Engineering Woodworking, Pattern and Model Making
Making components from composite materials	Performing Engineering Operations
Making Composite Mouldings using Wet Lay-up Techniques	Materials Processing and Finishing
Manufacturing Vehicle Composite Mouldings using Pre-Preg Laminating Techniques	Automotive Engineering
Manufacturing Vehicle Composite Mouldings using Wet Lay-Up Techniques	Automotive Engineering
Marking out for engineering activities	Performing Engineering Operations
Marking Out Wood and Composite Materials	Engineering Woodworking, Pattern and Model Making

Occupational Standard (Continued)	Suite
Preparing Aircraft Components for Surface Finishing/Coating	Aeronautical Engineering
Preparing Yacht and Boat Surfaces for Painting/Finishing	Marine Engineering
Producing Aircraft Components using Pre-Preg Laminating Techniques	Aeronautical Engineering
Producing Aircraft Components using Resin Infusion Techniques	Aeronautical Engineering
Producing Aircraft Components using Wet Lay-up Techniques	Aeronautical Engineering
Producing and Assembling Substrates for Vehicle Components	Automotive Engineering
Producing and Finishing Components using Woodworking Hand Tools	Engineering Woodworking, Pattern and Model Making
Producing Components by Vacuum Forming	Materials Processing and Finishing
Producing Components using Woodworking Machines	Engineering Woodworking, Pattern and Model Making
Producing Composite Assemblies	Mechanical Manufacturing Engineering
Producing Composite Assemblies	Mechanical Manufacturing Engineering
Producing Composite Assemblies	Materials Processing and Finishing
Producing Composite Assemblies	Fabrication and Welding Engineering
Producing Composite Assemblies	Fabrication and Welding Engineering
Producing Composite Assemblies	Performing Engineering Operations
Producing Composite Mouldings using Pre-Preg Laminating Techniques	Performing Engineering Operations
Producing Composite Mouldings using Pre-Preg Laminating Techniques	Fabrication and Welding Engineering
Producing Composite Mouldings using Pre-Preg Laminating Techniques	Materials Processing and Finishing
Producing Composite Mouldings using Pre-Preg Laminating Techniques	Mechanical Manufacturing Engineering
Producing Composite Mouldings using Pre-Preg Laminating Techniques	Mechanical Manufacturing Engineering
Producing Composite Mouldings using Resin Infusion Techniques	Performing Engineering Operations
Producing Composite Mouldings using Wet Lay-Up Techniques	Performing Engineering Operations
Producing Composite Mouldings using Wet Lay-up Techniques	Mechanical Manufacturing Engineering
Producing Composite Mouldings using Wet Lay-up Techniques	Materials Processing and Finishing
Producing Composite Mouldings using Wet Lay-Up Techniques	Mechanical Manufacturing Engineering

Occupational Standard (Continued)	Suite
Producing Composite Mouldings using Wet Lay-up Techniques	Fabrication and Welding Engineering
Producing Marine Composite Assemblies	Marine Engineering
Producing Marine Composite Components using Pre-Preg Laminating Techniques	Marine Engineering
Producing Marine Composite Components using Wet Lay-Up Techniques	Marine Engineering
Producing Marine Wooden Components using Machines	Marine Engineering
Producing Motorsport Composite Assemblies	Automotive Engineering
Producing Motorsport Composite Mouldings using Pre-Preg Laminating	Automotive Engineering
Producing Motorsport Composite Mouldings using Resin Infusion Laminating	Automotive Engineering
Producing Motorsport Composite Mouldings using Wet Lay-up Techniques	Automotive Engineering
Producing Pattern, Corebox or Model Components using Flexible Composite Materials	Engineering Woodworking, Pattern and Model Making
Producing Pattern, Corebox or Model Components using Woodworking Hand Tools	Engineering Woodworking, Pattern and Model Making
Producing Pattern, Corebox or Model Components using Woodworking Machines	Engineering Woodworking, Pattern and Model Making
Producing Platework Assemblies	Fabrication and Welding Engineering
Producing Platework Assemblies	Fabrication and Welding Engineering
Producing Structural Components for Yachts and Boats using Machines	Marine Engineering
Producing Wooden Furniture/Outfitting Components for Yachts and Boats using Machines	Marine Engineering
Repairing Composite Mouldings	Materials Processing and Finishing
Repairing Composite Mouldings	Mechanical Manufacturing Engineering
Repairing Defects in Vehicle Composite Mouldings	Automotive Engineering
Repairing Marine Composite Components and Assemblies	Marine Engineering
Repairing Motorsport Composite Mouldings	Automotive Engineering
Repairing Yacht and Boat Composite Components	Marine Engineering
Restoring Motorsport Mechanical Components to Usable Condition by Repair	Automotive Engineering
Shaping Marine Wooden Components using Machines	Marine Engineering
Trimming Composite Mouldings using Hand Tools	Fabrication and Welding Engineering
Trimming Composite Mouldings using Hand Tools	Fabrication and Welding Engineering
Trimming Composite Mouldings using hand Tools	Mechanical Manufacturing Engineering

Occupational Standard (Continued)	Suite
Trimming Composite Mouldings using Hand Tools	Mechanical Manufacturing Engineering
Trimming Composite Mouldings using Hand Tools	Materials Processing and Finishing
Trimming Marine Composite Mouldings	Marine Engineering
Trimming Motorsport Composite Mouldings using Hand Tools	Automotive Engineering
Trimming Vehicle Composite Mouldings using Hand Tools	Automotive Engineering
Using Pre-Preg Laminating Techniques to Produce Marine Composite Components	Marine Engineering
Using Wet Lay-Up Techniques to Produce Marine Composite Components	Marine Engineering
Vacuum Forming Composite Materials	Fabrication and Welding Engineering
Vacuum Forming Composite Materials	Mechanical Manufacturing Engineering
Vacuum Forming Marine Composite Materials	Marine Engineering
Source NCN Website	

http://www.ncn-uk.co.uk/DesktopDefault.aspx?tabindex=21&tabid=390

Table D3: Composite-related National Vocational Qualifications

Title	Level	Awarding Body
City & Guilds Level 3 NVQ in Fabrication and Welding Engineering	3	City & Guilds
EAL Level 3 NVQ in Fabrication and Welding	3	EAL
EAL Level 3 NVQ in Mechanical Manufacturing Engineering	3	EAL
EAL Level 3 NVQ in Aeronautical Engineering	3	EAL
City & Guilds Level 3 NVQ in Mechanical Manufacturing Engineering	3	City & Guilds
EAL Level 2 NVQ in Mechanical Manufacturing Engineering	2	EAL
EAL Level 3 NVQ in Automotive Engineering	3	EAL
EAL Level 3 NVQ in Engineering Woodworking, Pattern and Model Making	3	EAL
EAL Level 2 NVQ in Fabrication and Welding Engineering	2	EAL
ETCAL Level 3 NVQ in Mechanical Manufacturing Engineering	3	ETCAL
City & Guilds Level 3 NVQ in Engineering Woodworking, Pattern and Model Making	3	City & Guilds
City & Guilds Level 2 NVQ in Fabrication and Welding Engineering	2	City & Guilds
EAL Level 2 NVQ in Aeronautical Engineering	2	EAL
City & Guilds Level 2 NVQ in Aeronautical Engineering	2	City & Guilds
ETCAL Level 3 NVQ in Fabrication and Welding Engineering	3	ETCAL
ETCAL Level 2 NVQ in Fabrication and Welding Engineering	2	ETCAL
City & Guilds Level 2 NVQ in Mechanical Manufacturing Engineering	2	City & Guilds
City & Guilds Level 3 NVQ in Materials Processing and Finishing	3	City & Guilds
ETCAL Level 3 NVQ in Aeronautical Engineering	3	ETCAL
ETCAL Level 2 NVQ in Mechanical Manufacturing Engineering	2	ETCAL
EAL Level 3 NVQ in Materials Processing and Finishing	3	EAL
EAL Level 3 NVQ in Marine Engineering	3	EAL
EAL Level 2 NVQ in Marine Engineering	2	EAL
SASL Level 2 Certificate in Polymer Composite Wet Lay up	2	SASL
ETCAL Level 3 NVQ in Materials Processing and Finishing	3	ETCAL
City & Guilds Level 1 NVQ in Performing Engineering Operations	1	City & Guilds
EAL Level 1 NVQ in Performing Engineering Operations	1	EAL
ETCAL Level 1 NVQ in Performing Engineering Operations	1	ETCAL

Source NCN Website
http://www.ncn-uk.co.uk/DesktopDefault.aspx?tabindex=20&tabid=397

The Sector Skills Council for Science, Engineering and Manufacturing Technologies

For further information please contact Semta Customer Services:
T: 0845 643 9001 E: customerservices@semta.org.uk
W: www.semta.org.uk