Technology Strategy Board
Driving Innovation

A landscape for the future of high value manufacturing in the UK

A study conducted for the Technology Strategy Board

February 2012

Foreword

The UK is a major competitor in the £6.5 trillion global manufacturing economy. High value manufacturing (HVM) – the application of leading edge technical knowledge and expertise to the creation of products, production processes and associated services – has the potential to bring sustainable growth and major economic benefits to the UK. This study sets out to understand the global manufacturing context in which UK companies must compete and how that context is expected to evolve over the next 15-20 years.

This report draws upon a wide consultation with industry, academe and institutions, to identify competencies that can allow companies to successfully deliver innovation in manufacturing across a broad range of industry sectors.
It provides a landscape against which industrial companies, government agencies and other key stakeholders can develop a shared view of emerging opportunities that can create long-term value within the UK economy.

Technology Strategy Board
Driving Innovation

EPSRC
Pioneering research and skills

BIS | Department for Business Innovation & Skills

IfM | MANAGEMENT TECHNOLOGY POLICY

'By commissioning this study and sponsoring the extensive consultations it has involved, we sought to provide a future focus for our new HVM strategy and the recently established HVM Catapult. This report provides a robust platform for future developments so that we can move forward in high value manufacturing aligned more than ever with EPSRC, BBSRC and our mutual sponsors, BIS.'
Will Barton, Head of Manufacturing, Technology Strategy Board

'The UK has a well-deserved international reputation for the quality of its science and engineering research. However, the pathway to impact from excellent research can be convoluted. This report highlights a number of areas of clear national advantage, where the prospects for successful innovative outcomes are strong. There is already good alignment between EPSRC Centres for Innovative Manufacturing, Doctoral Training Centres and the Technology Strategy Board – but we see opportunity for greater engagement with other Centres, programmes and projects. The strategic focus described within this report, provides an opportunity to build and sustain manufacturing competitiveness over the long-term.'
Mark Claydon-Smith, EPSRC Lead, Manufacturing the Future

'Using tried and tested roadmapping techniques, coupled with a highly structured consultation process, this report reflects the views of a broad cross-section of senior industrialists, academics and institutions. Their collective expertise provides an excellent foundation on which to build robust and focussed policies to support our vital manufacturing industries.'
Professor Sir Mike Gregory,
Head of the University of Cambridge Institute for Manufacturing

'The manufacturing sectors in the UK are reservoirs of technology capability and expertise. As such, they are a national asset and vital to our future competitiveness. Manufacturing accounts for a disproportionately large proportion of R&D investment and activity, and manufacturing innovation drives our economy and benefits other sectors. Our objective of returning the UK to a path of sustainable economic growth, driven by business investment, can only be achieved through strengthening and expanding our manufacturing sectors. BIS welcomes this report, which identifies the challenges we face, the opportunities that present themselves and sets a clear direction not only for future public sector research and innovation activities across Technology Strategy Board, EPSRC and BBSRC, but also for a wider range of policies that are essential to the competitiveness of this sector and the UK'.
Fergus Harradence, Deputy Director, Innovation Policy, BIS

Executive summary

This report summarises the main findings of a study of the UK manufacturing environment conducted on behalf of the Technology Strategy Board. A major part of the study was a broad consultation exercise with industry, academia and government. This included the Technology Strategy Board high value manufacturing (HVM) Catapult and knowledge transfer networks.

The study maps out the environment that will shape the UK's HVM and innovation base over the next 15-20 years.

The consultation exercise identified a number of areas where there was broad consensus on trends, drivers, challenges and opportunities for UK manufacturing. This has led to the identification of a group of first pass key 'national competencies' in which the UK should consider developing industrial capability so it can meet the future challenges identified in the study.

A national competency is an attribute of the national manufacturing industry that enables businesses to respond to the changing global trends and drivers in a way that captures value for the UK in the future.

Five cross-cutting strategic themes have been identified and the findings are consolidated against these. Strategic themes are shown below; national competencies are summarised under these themes in the diagram on the following page.

1. Resource efficiency:	Securing UK manufacturing technologies against scarcity of energy and other resources
2. Manufacturing systems:	Increasing the global competitiveness of UK manufacturing technologies by creating more efficient and effective manufacturing systems
3. Materials integration:	Creating innovative products, through the integration of new materials, coatings and electronics with new manufacturing technologies
4. Manufacturing processes:	Developing new, agile, more cost-effective manufacturing processes
5. Business models:	Building new business models to realise superior value systems.

There is strong overlap between these themes. Global competitiveness underpins all the themes and new business models are essential for the realisation of value.

The study outputs will be used to inform public policies and investment programmes, particularly in the HVM Catapult, across a wide range of industrial sectors. The study also provides a context for the development of national research strategies designed to support industrial growth. Its findings enable the creation of a consistent and informed framework – a high value manufacturing 'landscape'. This should be further developed so that government and industry can review their policies and strategies in the future. Indeed, the output of the study has been extensively employed to inform the Technology Strategy Board's HVM Strategy and the part the HVM Catapult plays in the delivery of that strategy, in a consistent and linked way. Industrial systems are dynamic in their nature and the structure of the study allows individual sectors and organisations to explore the opportunities within their areas in more depth. The material has been collected in a structured and systematic way that allows the analysis to be refreshed to reflect changing circumstances.

Strategic themes and associated national competencies

Contents

1 Introduction

This report sets out the key findings of a study commissioned by the Technology Strategy Board to map the environment that will shape the UK's high value manufacturing (HVM) and innovation base over the next 15-20 years.

The study identifies:

- the most important trends influencing the changing nature of manufacturing globally
- the greatest challenges and opportunities related to the on-going economic competitiveness of UK manufacturing enterprise
- the most promising UK emerging science, engineering and management innovations, that could help meet these challenges and opportunities and capture the value for the UK.

The study design took account of previous work in leading manufacturing nations, ensuring that findings could be compared with those of international competitors. Data gathering centred on a structured consultation. Participants came from a wide range of organisations and included senior industrialists and academics together with representatives from the Technology Strategy Board High Value Manufacturing Catapult (formerly known as Technology and Innovation Centre), knowledge transfer networks (KTN), the Engineering and Physical Sciences Research Council (EPSRC), Biotechnology and Biological Sciences Research Council (BBSRC), government departments and institutions.

The findings have been consolidated to provide a high level view of key 'national competencies' in which the UK should develop industrial capability to meet the challenges identified in the study.

2 Outline of study process

The study identifies key elements of the high value manufacturing environment, based on consultations with industry, academia and government, adopting a 15-20 year time frame. The study was developed over a six-month period in summer and autumn 2011. A key element of the process was to consult widely with those involved in manufacturing and in supporting the sector.

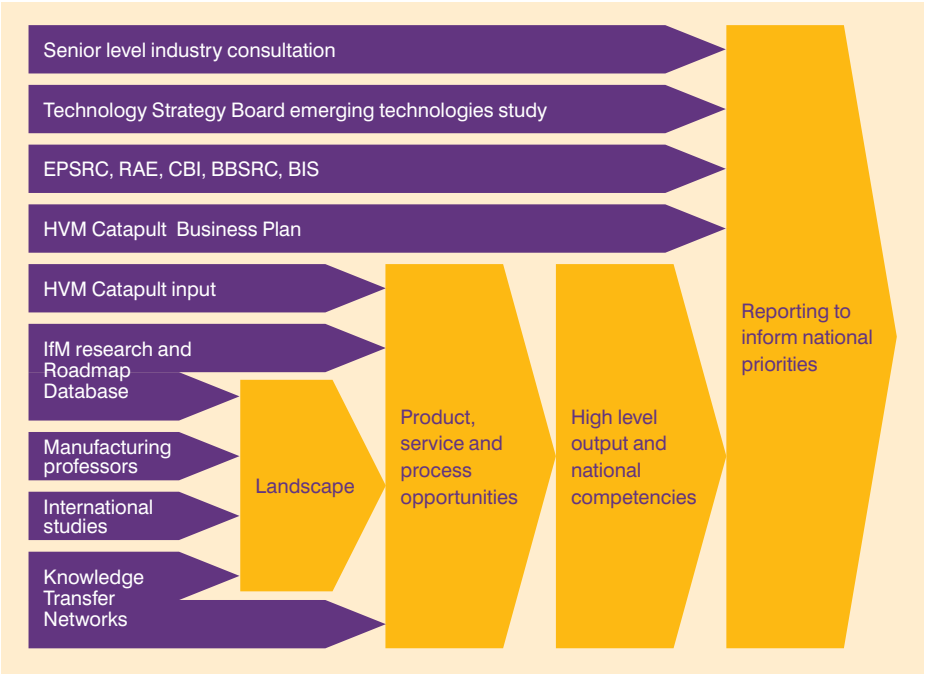
Consultation approach

The study involved three streams of work:

- an industry-based consultation with a cross-section of leaders of UK manufacturing industry
- an expert-group based consultation with representatives of: the research community (including EPSRC Centres for Innovative Manufacturing and BBSRC); the public sector, including the Department for Business, Innovation and Skills (BIS); and professional and trade organisations such as the Confederation of British Industry (CBI) and Royal Academy of Engineering (RAE)
- an examination of current and potential opportunities identified by the HVM Catapult and the knowledge transfer networks.

Figure 1 illustrates the project's inputs and the flow of the main results. Contributors generated ideas, provided information and verified emerging findings. These inputs are the foundation of the results.

Figure 1: Study approach and key contributors



The study approach and data structure have been established to facilitate traceability and comparison both across sectors and internationally:

- The approach has built on the strong alignment in the views of the contributors by enabling the development of a broad consensus on emerging opportunities
- Industrial systems that make up and surround manufacturing are dynamic in their nature and the structure of this study provides a basis for market sectors and organisations to explore the opportunities within their areas further in a way that allows comparison with other sectors
- The material has been collected in a structured and systematic way which allows the source of input to be traced and the analysis to be refreshed in the context of changing circumstances
- The data is presented in a format that facilitates comparison with similar initiatives undertaken by other countries and organisations.

This report provides the context for the development of the medium to long-term strategy of the Technology Strategy Board high value manufacturing team and the HVM Catapult. It will also be used to inform public research in this area and strategic interventions by government.

The approach provides a framework for deeper exploration of opportunities, challenges and capabilities. Importantly, it offers the opportunity to develop a consistent and informed framework for manufacturing that government and industry can use to review their policies and strategies in support of industrial growth.

3 The manufacturing environment

High value manufacturing is the application of leading-edge technical knowledge and expertise for the creation of products, production processes and associated services, which have strong potential to bring sustainable growth and high economic value to the UK. Activities may stretch from R&D at one end to recycling at the other.

The manufacturing environment can be thought of as a landscape consisting of seven interlinked strands:

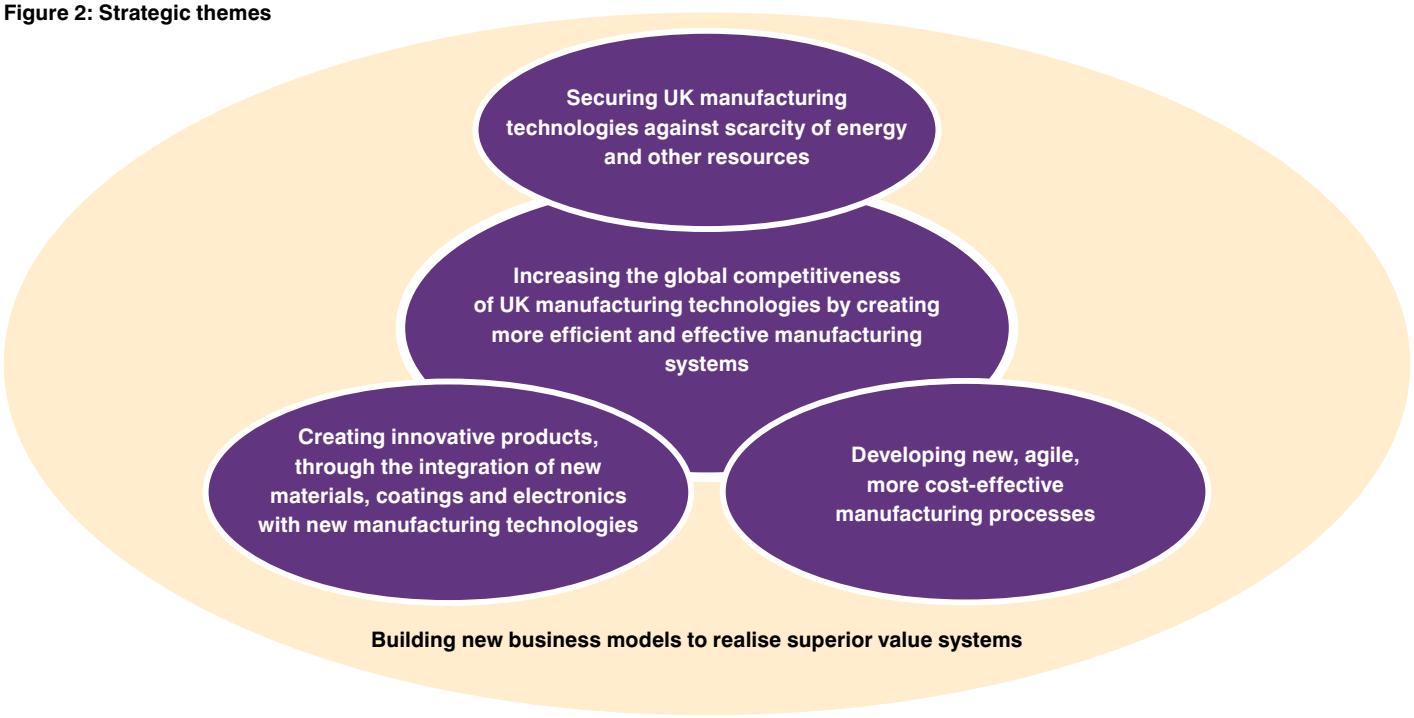
- trends and drivers: events or patterns that will influence manufacturing industries in the future
- challenges: overcoming obstacles in creating and/or providing value for the UK
- market needs and opportunities: products, processes or services that can capture market share to 2025
- high value manufacturing needs: products, processes or services that the manufacturing industry will have to provide to meet the perceived market needs if it is to be competitive in the future
- national competency: an attribute of the national manufacturing industry that enables businesses to respond to the key global trends and drivers, to be competitive and to capture value in global markets for the UK in the future
- research and development: emerging science and technologies that have the potential to have a positive impact on HVM products, processes, services and activities to underpin the development of competencies
- enablers: actions required to overcome the non-technical obstacles to HVM value creation and capture.

Five cross-cutting strategic themes have emerged from the consultation.

1. Resource efficiency:	Securing UK manufacturing technologies against scarcity of energy and other resources
2. Manufacturing systems:	Increasing the global competitiveness of UK manufacturing technologies by creating more efficient and effective manufacturing systems
3. Materials integration:	Creating innovative products, through the integration of new materials, coatings and electronics with new manufacturing technologies
4. Manufacturing processes:	Developing new, agile, more cost-effective manufacturing processes
5. Business models:	Building new business models to realise superior value systems.

The relationships between themes are illustrated in Figure 2:

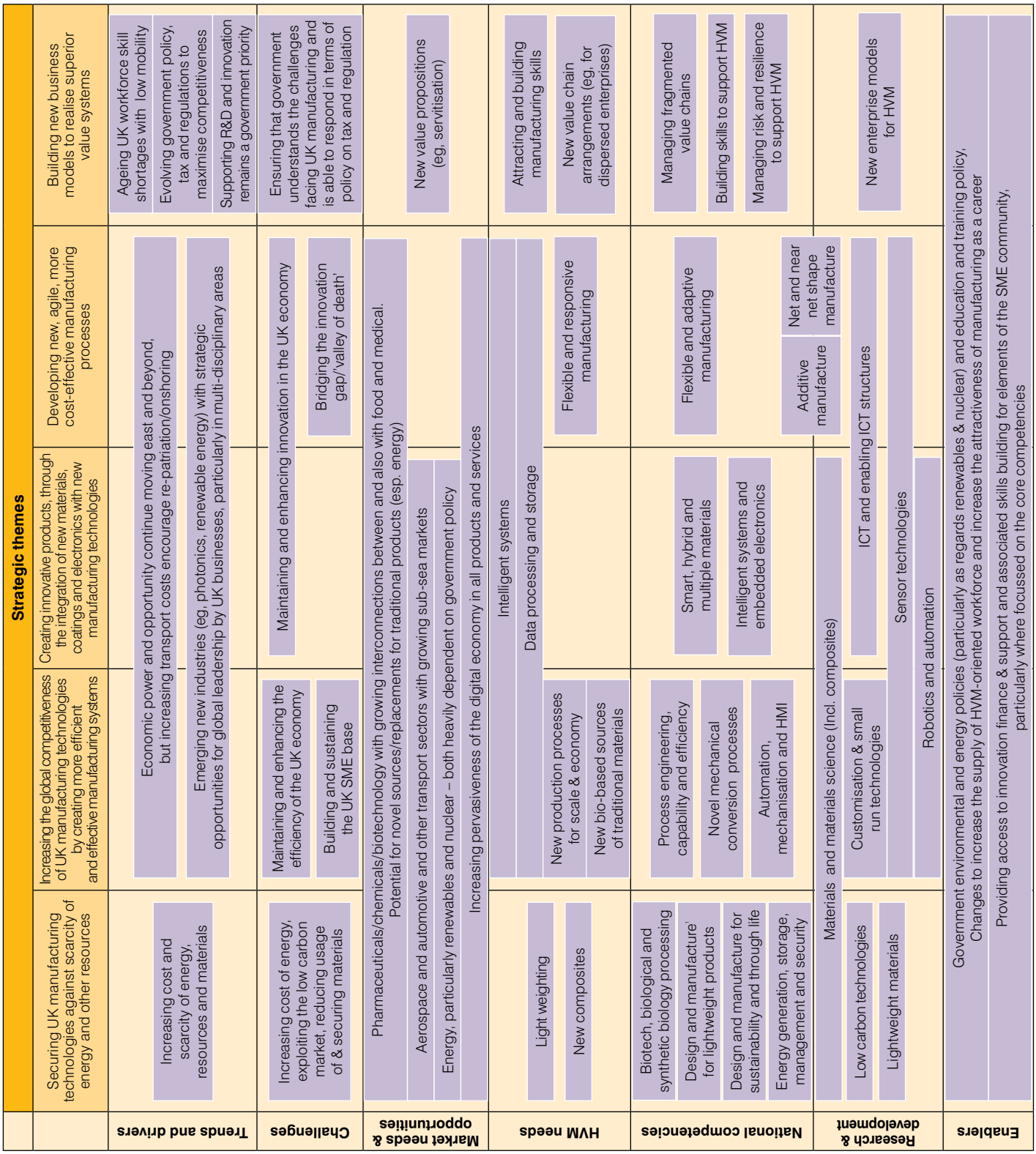
Figure 2: Strategic themes



There is strong overlap between these themes. Global competitiveness underpins all the themes and new business models are essential for the realisation of value.

Figure 3:
Landscape overview

Figure 3 illustrates the structure of the landscape in the form of a manufacturing roadmap as it has emerged from the study, by giving examples of the elements appropriate to each level. Sections 4-10 describe these elements in more detail.



4 Trends and drivers – future influences on manufacturing

Leading trends and drivers

The consultation repeatedly highlighted the need to reduce material and energy use in production. This is partly related to environmental concerns, but also reflected an expectation of increasing scarcity of energy and materials and industry's resulting inability to guarantee security of supply. One outcome of this is likely to be greater reliance on renewable resources.

UK skills shortages emerge as a major issue. Reasons for this included: 'baby boomers' retiring, along with loss of their accumulated expertise; an increase in overseas competition for highly qualified staff; lack of mobility in the skills base and a perception that the UK education system is not best aligned with industry needs.

Economic and environmental developments will result in changes in legislation, notably around emissions and sustainability. British industry will need to adapt to this, and ideally influence its creation, in order to remain competitive.

The rise of the BRIC (Brazil, Russia, India and China) economies and others will ensure that economic power and opportunity continue to move away from North America and Europe. At the same time, the increasing costs of fuel and transport will encourage repatriation of production and 'on shoring'. On shoring of production to the UK brings a number of challenges, not least in terms of the need to restore knowledge and skills, which may be partly or wholly lost.

Other important trends and drivers

Continued government support for R&D and innovation remains very important if the UK is to realise its potential in high value manufacturing. New industries such as photonics and renewable energy have been identified as both globally important and areas in which the UK is well placed to develop strategic global leadership. Many of these industries require multi-disciplinary skills in which the UK excels.

Global original equipment manufacturer (OEM) procurement policies attracted much comment. There was widespread concern that the UK-based supply chain is declining as a result of 'disaggregation' of OEM procurement, whereby multiple lines of procurement feeding through Tier One suppliers disfavour UK SMEs. Increased demand for higher level manufacturing skills (and reduced demand for lower level skills), together with SMEs' reduced ability to access finance, were factors seen to compound the risk of value-add activity moving overseas and threatening SMEs' role in the value chain.

Other significant views included the points below:

UK businesses will require continued access to both credit and funding, including venture capital (VC) funding, if competitiveness is to be achieved. However, the current global financial crisis makes funding especially problematic.

The rise of the digital economy and an associated increase in customised products will have an impact on traditional products. Integration is expected to have more of an influence on innovation than will new R&D; smart vehicles and other products will successfully integrate existing technologies and processes alongside new technology to meet increasing consumer demands.

The costs associated with production in the UK are still high compared with some competitor nations. Strategies will be required to address this, either through cost reduction or competitive advantage.

The growing, ageing population places additional burdens on the state sector (such as retirement and healthcare provision) but also offers significant opportunities for new markets, particularly medical and pharmaceutical.

Importance and linkages with cross-cutting themes

The importance of a trend or driver was judged by how frequently it occurred in documented submissions and meetings/ workshops. Note that these priorities reflect total feedback across sectors. Sector-specific views are discussed in section 6.

Table 1 shows how the prioritised trends and drivers in order of importance are linked to the five strategic themes running through the study.

Table 1: Prioritised trends and drivers linked to the five strategic themes

Trends and drivers	Strategic theme				
	Securing UK manufacturing technologies against scarcity of energy and other resources	Increasing the global competitiveness of UK manufacturing technologies by creating more efficient and effective manfacturing systems	Creating innovative products, through the integration of new materials, coatings and electronics with new manufacturing technologies	Developing new, agile, more cost-effective manufacturing processes	Building new business models to realise superior value systems
Increasing cost and scarcity driving importance of security of supply, use of fewer materials, including water, and less energy including water for all outputs as well as more reliance on renewable resources	strongly linked	lightly linked	lightly linked	lightly linked	
Ageing UK workforce, skill shortages (and into 2015+) with low mobility					strongly linked
Influencing and adapting to evolving government policy, tax and regulations to maximise competitiveness (including those related to emissions and sustainability)	moderately linked				strongly linked
Economic power and opportunity continue moving east and beyond, but increasing transport costs encourage repatriation/on shoring		strongly linked	moderately linked	moderately linked	
Supporting R&D and innovation remains a government priority				moderately linked	moderately linked
Emerging new industries (eg, photonics, renewable energy) with strategic opportunities for global leadership by UK businesses, particularly in multi-disciplinary areas		moderately linked	strongly linked	moderately linked	
Affluence increasing the pace of change				moderately linked	
Declining UK-based supply chain and increasing threats to SME from combination of skills and finance shortage, together with global OEM procurement policies		moderately linked			moderately linked
Accessing credit and funding (including VC) and political impact on policy timeframes					moderately linked
Rising 'digital economy' and impact on 'traditional' products, processes and services as well as creation of 'new' demands		moderately linked	moderately linked		
Producing in UK incurs high cost of factors of production		strongly linked			
Growing, ageing population increases demand, waste and imposes challenges for health, social care and food	lightly linked		strongly linked		

Key: strongly linked moderately linked lightly linked

5 Challenges – overcoming obstacles to value creation

The challenges identified by consultation participants were, in many cases, directly linked to the trends and drivers described.

The principal challenges identified included:

- responding to the increasing cost of energy, particularly: exploiting the low carbon market; reducing usage of and securing materials
- building necessary skills and attracting them to manufacturing
- constructively influencing the evolution of government economic, taxation and regulatory policies and ensuring ability to adapt, exploit and conform as these policies evolve
- bridging the innovation gap/'valley of death'
- creating new business models to exploit innovation and capture value.

In some cases, however, the relative importance accorded to trends/drivers and challenges was different. For example, whereas the driver of cost and scarcity of materials was a very prominent theme, the challenge of responding to this development received only moderate comment. Similarly, the challenge of 'maintaining and enhancing the innovation capacity of the UK economy' was seen as moderately important – yet the shift of power and wealth to which it responds was viewed as a very important trend. This disconnect is one sided: no challenges were identified by the consultation as being more important than the trends and drivers they address.

Table 2 summarises the challenges associated with the future of high value manufacturing identified by the consultation and compares them with the priority accorded to associated trends and drivers.

Table 2: Comparison of perceived importance of trends and drivers and challenges

Challenge	Importance	Trend or driver	Importance
Responding to the increasing cost of energy, particularly exploiting the low carbon market, and reducing usage of and securing materials	High	Increasing cost and scarcity; driving importance of security of supply; use of fewer materials – including water and less energy for all outputs as well as more reliance on renewable resources	Very high
Building necessary skills and attracting them to manufacturing	Very high	Ageing UK workforce, skill shortages (and into 2015+) with low mobility	Very high
Constructively influencing the evolution of government economic, taxation and regulatory policies and ensuring ability to adapt, exploit and conform as these policies evolve	Very high	Influencing and adapting to evolving government policy, tax and regulations to maximise competitiveness (including those related to emissions and sustainability)	Very high
Maintaining and enhancing the innovation capability of the UK economy	Moderate	Economic power and opportunity continue moving east and beyond – but increasing transport costs encourage repatriation/on shoring	Very high
Bridging the innovation gap/'valley of death'	High	Supporting R&D and innovation remains a government priority	High
Creating new business models to exploit innovation and capture value	High	Emerging industries (eg. photonics, renewable energy) with strategic opportunities for global leadership by UK businesses particularly in multi-disciplinary areas	High
		Affluence increasing the pace of change	Moderate
Building and sustaining the UK SME base and its role in the value chain	Moderate	Declining UK-based supply chain and increasing threats to SME from combination of skills and finance shortage together with global OEM procurement policies	High
Attracting investment to manufacturing in the prevailing economic and cultural climate	Moderate	Accessing credit and funding (including VC) and political impact on policy timeframes	Moderate
Exploiting new product, process and services opportunities available in the digital economy	Moderate	Rising 'digital economy' and impact on 'traditional' products, processes and service as well as creation of 'new' demands	Moderate
Maintaining and enhancing the efficiency of the UK economy	Moderate	Producing in UK incurs high cost of factors of production	Moderate
Exploiting growing markets associated with ageing population – particularly health care	Moderate	Growing, ageing population increases demand, waste and imposes challenges for health, social care and food	Moderate

6 Market needs and opportunities – market sector focus

The study focused on an initial set of HVM sectors based on consideration of the potential for high value product and service opportunities that might be viable in or around the 2025 timescale. The sectors identified, shown in Table 3, are end-customer facing, fast growing, R&D-intensive and are seen to have potential technological advantage for the UK.

The key sectors emerging from this initial study were, in no particular order, as follows:

- food
- biotechnology
- chemicals
- pharmaceuticals
- medical
- aerospace, defence and space
- automotive
- rail
- marine (including under-sea)
- nuclear
- energy
- oil and gas
- mining
- built environment
- electronics
- retail, entertainment and consumer goods
- digital economy (including infrastructure), communications and security.

A database has been developed of products, processes or services that can generate revenue – fulfilling markets to 2025. This will underpin the longer-term strategy development of the HVM Catapult.

This study explored the impact of different trends and drivers, and their associated challenges, for each of the sectors. These results are summarised in Table 3.

Note that the darker the intersection, the stronger the importance, as rated by the KTN for the sector, or cross-sector KTNs where no sector-specific KTN exists.

As part of the analysis, the needs of each market sector were also assessed in terms of potential HVM requirements. These are discussed in the next section.

Table 3: Sector impact of trends and drivers: views of knowledge transfer networks

Trends and drivers	Importance	Food	Biotechnology	Chemicals	Pharmaceuticals	Medical	Aerospace, defence and space	Automotive	Rail	Marine (inc. under sea)	Nuclear	Energy	Oil and gas	Mining	Built environment	Electronics	Retail, entertainment and consumer goods	Digital economy (incl infrastructure, communications) and security
Increasing cost and scarcity driving importance of security of supply, use of fewer materials and less energy including water for all outputs as well as more reliance on renewable resources	Very high																	
Ageing UK workforce, skill shortages (and into 2015+) with low mobility	Very high																	
Influencing and adapting to evolving government policy, tax and regulations to maximise competitiveness including sustainability	Very high																	
Economic power and opportunity continue moving east and beyond – but increasing transport costs encourage re-patriation/on shoring	Very high																	
Supporting R&D and innovation remains a government priority	High																	
Emerging new industries (eg, photonics, renewable energy) with strategic opportunities for global leadership by UK businesses particularly in multi-disciplinary areas	High	Not tested with KTNs																
Affluence increasing the pace of change	Moderate																	
Declining UK-based supply chain and increasing threats to SME from combination of skills and finance shortage together with global OEM procurement policies	High																	
Accessing credit and funding (including VC) and political impact on policy timeframes	Moderate																	
Rising 'digital economy' and impact on 'traditional' products, services and processes as well as creation of 'new' demands	Moderate																	
Producing in UK incurs high cost of factors of production	Moderate	Not tested with KTNs																
Growing, ageing population increases demand, waste and imposes challenges for health, social care and food	Moderate																	
Repatriating manufacturing to the UK due to increased costs	Moderate																	
Benefiting from inward as well as outward investment	Moderate																	

Key: Low importance — Very high importance

7 High value manufacturing needs – creating a competitive offering

High value manufacturing needs were defined as deliverables that UK manufacturing industry must be able to meet to compete in the future. As opposed to market needs, which are or can be specific to certain sectors, these advances were shown to have applications in a wide variety of sectors and can be common to manufacturing industry as a whole.

The study examined these needs across all the sectors to identify commonalities and shared technology requirements. For example, many of the different transport sectors have identified manufacturing needs in light-weighting (making structural components lighter), which requires new design, technology and materials. Although not all of the issues concerned with light-weighting are common across all of these sectors, their prevalence across several sectors suggests that this is a general need for HVM.

The wider consultation process indicated that identification and adoption of new business models, such as creating value from dispersed enterprises, distributed manufacturing and the servitisation of manufacturing, will be important.

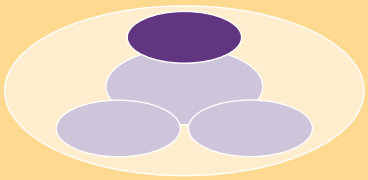
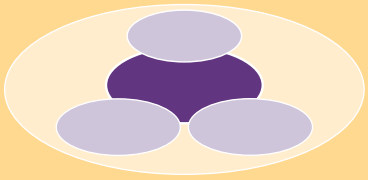
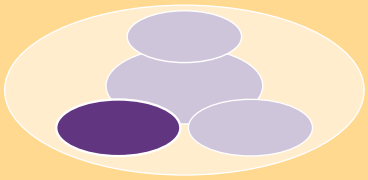
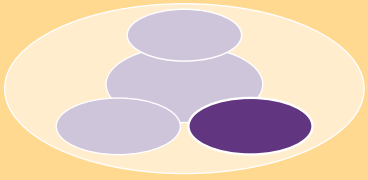
The most significant high value manufacturing needs identified include:

- new production processes for scale and economy
- design and manufacture for light-weighting
- flexible and responsive manufacturing
- intelligent systems
- data processing and storage
- new composites
- alternative, bio-based sources for existing products and process materials
- systems modelling and simulation (including prototyping)
- new power sources
- organic materials for electronics applications
- new high performance materials
- improved, integrated system design
- characteristics and modelling of new materials
- products from waste and virgin biomass
- through-life engineering.

8 National competencies – capturing value in 2025

The key national competencies identified by the study have been clustered into the five strategic themes. Figure 4 shows national competencies mapped to the themes.

Figure 4: National competencies mapped to strategic themes

Symbol	Strategic theme	National competency
	**Securing UK manufacturing technologies against scarcity of energy and other resources**	■ Energy generation, storage, management and security ■ Design and manufacture for sustainability and through life ■ Biotech, biological and synthetic biology processing ■ Design and manufacture for lightweight vehicles, structures and devices
	**Increasing the global competitiveness of UK manufacturing technologies by creating more efficient and effective manufacturing systems**	■ Understanding designing and manufacturing formulated products ■ 'Plug and play' manufacturing ■ Design & manufacture for small-scale & miniaturisation ■ Process engineering capability and efficiency across food, pharmaceuticals & chemicals ■ Novel mechanical conversion processes for scale economy and efficiency ■ Systems modelling & integrated design/simulation ■ Automation, mechanisation and human/machine interface
	**Creating innovative products, through the integration of new materials, coatings and electronics with new manufacturing technologies**	■ Smart, hybrid and multiple materials ■ Intelligent systems and embedded electronics ■ Development and application of advanced coatings
	**Developing new, agile, more cost-effective manufacturing processes**	■ Flexible and adaptive manufacturing ■ Combining product development steps in parallel/ concurrent engineering ■ Additive manufacture ■ Net and near net shape manufacture
	Building new business models to realise superior value systems	■ Managing fragmented value chains including distributed manufacturing to support HVM ■ Building new business models to support HVM ■ Developing and retaining skills to support HVM ■ Managing risk and resilience to support HVM

These competencies are more fully defined in Annex 1.

9 Research and development – emerging science and technology

A major focus of the consultation was the identification of research, development and innovation opportunities – particularly through dialogue with industry and the academic science base as well as written submissions. Stakeholders were asked:

- Which manufacturing **processes and systems** are going to be the most important for the UK in the period, and why?
- What are the most promising emerging **science, engineering and technology innovations** which would address these trends and challenges for the UK manufacturing base, and why?

The feedback emphasised a) process and b) product and service technologies towards which emerging science, engineering and technology innovations can contribute.

The most significant process and service technologies identified included:

- additive manufacturing
- net shape manufacturing
- robotics and automation
- customisation
- small run technologies (including distributed manufacture and 'batch size of one')
- micro and nano-manufacturing processes
- end of life activities: recycling, re-use, renewing and re-lifing
- surface engineering (finishing and coating processes)
- link design and manufacturing more closely
- integrating technologies and processes
- bioprocessing for new/replacement materials/fuels
- ICT and enabling ICT structures.

The most significant product and service technologies identified included:

- materials and materials science (excluding composites)
- low carbon technologies
- lightweight materials
- ICT and enabling ICT structures
- biomaterials
- sensor technologies
- integrated technologies
- nanotechnologies
- energy storage
- hydrogen fuel cells
- robots
- integrated products and services
- new composites
- nanomaterials.

Annex 2 illustrates the nature and significance of these process, service and product technologies, through a selection of comments received during the consultation process.

10 Barriers and enablers – supporting HVM

Potential barriers to successful adoption can be usefully separated into technical and non-technical aspects. The study also captured the non-technical barriers to successful adoption, and sought to identify enablers – the policies and practices required to overcome these.

During consultation sessions, participants were asked to identify and locate in the HVM landscape those interventions they believed would act as enablers for HVM value realisation. Suggestions were organised under the following headings: skills and culture (including entrepreneurship); funding (public and private); intellectual property (IP) and protection; infrastructure; supply networks and value chains; policy, regulation and standards; as well as strategic and operational manufacturing management.

It should be noted that participants were not asked to give their views as to the most important enablers. In this way the consultation took steps to avoid positive advocacy by contributors.

The results were compared with findings from other areas of the HVM landscape analysis. A cross-cutting analysis using these non-technology enablers allowed programmes and action to be identified and prioritised to yield impact across the entire HVM landscape.

The three most important enablers identified by this process were: public policy and funding; HVM Catapult; strategic and operational manufacturing management.

1. Public policy and funding

The policy and financial context against which HVM value realisation will take place will form a central part of its success, in particular:

- government environmental and energy policies (particularly renewable energy sources and nuclear)
- education and training policy to improve skills and increase the attractiveness of manufacturing as a career
- access to innovation support and associated investment, including SMEs, especially where focused on key national competencies
- access to well informed and targeted private finance.

2. HVM Catapult

The HVM Catapult has a key role to play in moving the UK's HVM agenda forward:

- establishing a coherent set of priorities for HVM in the national context which supports industrial and public investment in key competencies and associated innovation realisation
- maintaining current focus on competencies in novel manufacturing processes
- building national competency related to the digital economy sector and consider exploitation in the built environment and security sectors (subject to potential overlap with other bodies)
- focusing on key process industry competencies and investigating how and whether they may be effectively translated to benefit the food sector.

3. Strategic and operational manufacturing management

Building national competency in value realisation is needed to support:

- optimisation of the UK manufacturing value chain to reflect the changing nature of manufacturing and so enable greater value to be generated by existing assets
- enterprise resilience in highly dispersed value chains.

11 Next steps

Project outputs, although interim given the study timescales, will be used to inform Technology Strategy Board and the HVM Catapult policies and programmes and are highly relevant to a wide range of industrial sectors. The findings also provide a context for the development of national research strategies.

This report forms a significant platform upon which the Technology Strategy Board High Value Manufacturing Strategy, issued in early 2012, has been developed. As the Strategy rolls out, there will be an on-going need to return to this study to mine and to build on the extensive database it has created. The Strategy and the associated implementation plan represent a set of recommendations derived in part from the landscape developed in this report.

It is also suggested that companies and industry bodies make use of the findings of this study in the development of their future R&D plans and business road maps.

The latter stages of the study are also of value to the new manufacturing *Foresight* programme initiated in 2011 by the Department for Business, Innovation and Skills. This initiative shares many objectives with this study together with a remit enabling in-depth analysis of various aspects of manufacturing futures.

Annex 1: Competency definitions

1. Resource efficiency: Securing UK manufacturing technologies against scarcity of energy and other resources

Energy generation, storage, management and security
Energy storage, energy management and transport focusing on energy cost, security and novel generation technology. New energy sources including next generation nuclear and energy transmission with low loss and low visual impact.

Design and manufacture for sustainability and through-life
Design and manufacture of sustainable and innovative products including cleaner processes, low carbon outcomes and less waste. Robust design for disassembly (recycling) and through life engineering.

Biotech, biological and synthetic biology processing
Alternative bio-and synthetic bio-based sources for new and existing products and processes. Processing of biologics for pharmaceutical and medical applications.

Design and manufacture for lightweight vehicles, structures and devices
Light weighting to reduce energy consumption and emissions, reduce costs and increase efficiency. Composite, new and hybrid structures design, fabrication, joining and assembly. Multifunction component design and manufacture.

2. Manufacturing systems: Increasing the global competitiveness of UK manufacturing technologies by creating more efficient and effective manufacturing systems

Process engineering capability across food, pharmaceuticals and chemicals
Development and application of common capability across food processing, pharmaceuticals and chemicals. Redesigning processes to increase their yields and increase operational efficiency.

Design and manufacture for small-scale and miniaturisation
Miniaturisation, design and manufacturing of smaller products such as specialised drugs, batteries and electronics. High precision and micro/nano-engineered products and processes and integration with macro-scale.

Systems modelling and integrated design/simulation
Systems modelling and simulation tools, integrated system design, simulation and validation. Virtual prototyping, materials models, functionality and design. System integration of high complexity products.

Automation, mechanisation and human/machine interface
Process automation and human machine interface. Autonomy applications, particularly in production and servicing.

'Plug and play' manufacturing
Application of modularity to develop a high volume production environment, where the production units can be combined in a flexible manner and serviced more effectively.

Novel mechanical conversion processes for scale, economy and efficiency
The application of new primary and secondary mechanical conversion technologies and processes e.g. low energy forming/forging, tool-less and one-shot manufacturing, new machine tool technologies and welding processes/applications including e.g. welding to titanium and magnesium.

Understanding, designing and manufacturing formulated products
Understanding design and manufacture of formulated products for relevant sectors across the supply chain.

3. Materials integration: Creating innovative products, through the integration of new materials, coatings and electronics with new manufacturing technologies

Smart, hybrid and multiple materials
Design, modelling and manufacturing processes of multi-metallic components and high performance materials. Structures and components with integrated functions and tailored material properties and location-specific properties. Enhanced, faster joining capability with a range of materials.

Intelligent systems and embedded electronics
Robust 'live' data capture and comprehensive capture and use of product/process information. New sensor/NDT devices and smart and multi-functional components which are embedded and/or intelligent. Large area, printable, cheap electronics, integrated with other manufacturing processes for energy management, security, packaging and light weighting. Integration of electronics into product and materials design.

Development and application of advanced coatings
Development and application of advanced coatings across multiple sectors.

4. Manufacturing processes: Developing new, agile, more cost-effective manufacturing processes

Flexible, adaptive manufacture
Flexibility of production and manufacturing supporting customised and rapidly reconfigurable manufacturing. Adaptive manufacturing including single step, flexible reconfiguration and process technology that can adapt to feedstock of different types and compositions and mass customisation techniques.

Combining product development steps in parallel/concurrent engineering
Real-time market analysis and response and systems to reduce development time. Combining marketing, design, manufacturing, standards, regulations and procurement and early user engagement.

Additive manufacture
Application of additive layer manufacturing techniques or other freeform techniques of joining materials to fabricate intermediate and end use products including direct digital manufacturing methods.

Net and near net shape manufacture
Initial production of items very close to the final net shape, reducing the need for surface finishing. Tool-less manufacturing with single actions to produce final parts or one toolset for full production system with one pass production.

5. Business models: Building new business models to realise superior value systems

Managing fragmented value chains to support HVM
Managing complex value delivery across the value chain in multiple locations and exploiting 'economies of small scale' to develop and produce close to the customer.

Building new business models to support HVM
New business models, with flexible arrangements to create new value.

Developing and retaining skills to support HVM
Associated training and skills in HVM, provision of employees with cross-disciplinary skills and the ability to combine knowledge.

Managing risk and resilience to support HVM
Mechanisms to ensure HVM strategy and associated product strategies are inherently compliant to necessary standards across the value chain. Governance to ensure HVM product, service and process outcomes meet strategic intent.

Annex 2: Priority product, process and service technologies: supporting comments

Table A1: Priority process technologies – quotes from the consultation

Process technologies	Example comments received in consultation process
Additive manufacturing	'Additive manufacturing will change everything, but needs to be coupled with additive systems – structure, processing, display all as one – structural electronics.'
Net shape manufacturing	'[These] technologies will reduce wastage to near nothing and minimise manufacturing steps.'
Robotics and automation	'Robotics designs, in particular to increase accuracy and allow 6-sigma, particularly in low volume and to support quality. They address all of the key challenges (the environmental lobby, the need to reduce waste, skilled labour shortages, high cost overheads, ROI, health and safety, quality, regulation, etc).'
Customisation	'Processes will increasingly need to serve small sub-populations all the way to a personalised level of provision.'
Small run technologies (including distributed manufacture and 'batch size of one')	'Processes improvement through low capital, low volume processing (to do with cars what we do with phones.'
Micro and nano-manufacturing processes	'Physics and morphology of micro and nanomanufacturing processes; advances in scale-down and eventually microfluidic mimics hold significant promise; novel methods for nanopatterning and nanostructuring applicable to different materials.'
End of life activities: recycling, re-use, renewing and re-lifing	'Recycling and re-use of materials: recovery and re-use is not just refreshing but re-lifing. Replacement of existing manufacturing processes and systems is not an option so life extension and asset management is essential.'
Surface engineering (finishing and coating processes)	'A far greater range [of processes] are now available Surface engineering, electroplating, plasma spraying, physical vapour deposition (PVD), chemical vapour deposition (CVD), chemical conversion method, welding, cladding, laser surfacing, etc.'
Link design and manufacturing more closely	'Getting it right first time through good design for speed to market.'
Integrating technologies and processes	'We do not do enough or are good enough at optimisation and integrating multiple resources and systems to get a new and innovative deliverable. Certain innovative manufacturing processes will also be important to the UK as they increasingly contain new IP from the interfaces of manufacturing with physics, chemistry and materials science domains that cannot be easily decoded and copied by competitors overseas. For example, new materials and process combinations in the plastic electronics industry and new casting methods for producing high precision turbine parts.'
Bioprocessing for new/ replacement materials/fuels	'Biofuels and bio manufacturing as alternative to oil; use of biology and genetics to drive processes for materials synthesis; manufacturing of high volume biopharmaceuticals and chemical intermediates.'
ICT and enabling ICT structures	'Ability to integrate new and existing processes and systems in a customisable manner (including ICT)'; 'Intelligent use of ICT will differentiate us from our competitors and it is a key enabler in most technological developments.'

Table A2: Priority product technologies – quotes from the consultation

Product technologies	Example comments received in consultation process
Materials and materials science (excl. composites)	'There is a resurgence in the materials sector in new products (composites but also steels, etc.): high/super strength; low weight; coatings and structures; biomass.'
Low carbon technologies	'Innovations will, as with food, become exponentially more important. We need to nurse these innovations along to maturity – anything with CO_2 reduction technologies and systems to create low energy manufacturing – the next generation will include: lithium batteries, hydrogen, etc.'
Lightweight materials	'Everything and anything involved in light-weighting is key in automotive: battery tech. development; electrification; light – weighting and composites; intelligent transport systems and process development (simulation, manufacturing systems, advanced manufacturing systems – manufacturing technology development).'
ICT and enabling ICT structures	'Ability to integrate new and existing processes and systems in a customisable manner (including ICT)'; 'Intelligent use of ICT will differentiate us from our competitors and it is a key enabler in most technological developments.'
Biomaterials	'Bioengineering [of] food and other materials'; 'Novel biomaterials'; 'Bio-medicine'; 'Bio-medicine and biology.'
Sensor technologies	'Greater sensor, control device and actuator integration with increased embedded intelligence leading to reduced costs, greater reliability, ease of deployment, and greater performance.'
Integrated technologies	'Hybrid technologies in vehicles: reduce battery size and weight combined with fly-wheel technology for recuperating braking energy.'
Nanotechnologies	'Nanotechnologies, particularly the use of catalysts to reduce energy consumption and in water desalination'; 'Integration and translation of micro/nano-manufacturing processes into platforms for healthcare applications'; 'Novel methods for nano-patterning and nano-structuring.'
Energy storage	'Reduced energy consumption technologies'; 'Waste to energy processes (anaerobic processes)'; 'Renewable energy technologies.'
Hydrogen fuel cells	'Hydrogen fuel cells and hydrogen storage' (repeated references).
Robots	'Robots and assembly processes' (repeated references); '[There is] more and more sophistication in robotics here in the UK.'
Integrated products and services	'Integrating products and services [to realise] more value rather than a very divided portfolio of revenue-generating products'; 'Intelligent combination in through-life manufacturing and service.'
New composites	'Novel and advanced composites' (repeated references).
Nanomaterials	'Nanomaterials' (repeated references); 'Need to tailor nanomaterials better and scale them up.'

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