High Level Group on Key Enabling Technologies

Thematic Report by the Working Team on Advanced Manufacturing Systems

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INTRODUCTION

Europe, the cradle of the Industrial Revolution, hosts a manufacturing base that builds its strength on a long-established engineering tradition, a strong R&D capacity and universities, the ability of industry to adapt to technological progress and to produce high quality products that find customers all around the globe. Europe is homeland to major manufacturing industries (engineering, energy, chemical, transport and communication industries, metalworking, electronics, construction, plastic, food and beverage) which enjoy these advantages offered to maintain a competitive and profitable business in European territories. Factories have been a focal point of value creation for society for centuries. Manufacturing industries contributed to some 17.1% of GDP and accounted for some 22 million jobs in the EU in 2007[1].

Moreover, the same manufacturing industry provides technologies and solutions, which are needed to respond to major challenges of the 21st century, namely, climate change, resource and energy efficiency, security, ageing society and sustainable mobility in order to ensure a better future for society. Europe remains a top-class manufacturing base and is a world leader in a good number of high-end technologies. Meanwhile, the existence of manufacturing facilities in Europe offers innumerable economic and social benefits to society.

The European Commission therefore, identifies **Advanced Manufacturing Systems (AMS)** as the sixth and crosscutting KET besides five Key Enabling Technologies (KET) of current critical relevance (photonics, nanotechnology, advanced materials, micro/nanoelectronics and biotechnology)[2]. The Commission's Communication states that KETs will be the driving force behind the development of new products, which will be available on the market by 2020. Significant investments in science and R&D will be required to master these technologies some of which are not yet fully exploitable.

However, a world-class science in KETs that would be cultivated in Europe which does not result in goods and services with economic value added is of little use to society. Advanced manufacturing systems are required to produce high value marketable knowledge-based goods and the related services based on KETs. Therefore, equal efforts will need to be invested in the development and deployment of AMS to create economic value from KETs. AMS are central to the supply and value chains of KETs. KETs will enable the development of new products, and at the same time, **Europe needs to work on factory concepts to manufacture these products and generate economic value.**

In today's globalised world, European manufacturing faces significant challenges. Over the last decades, thanks to the progress in communication and transport technologies and the globalisation of supply chains, the most modern manufacturing technologies have simultaneously reached territories in remote corners of the world. Modern manufacturing

[1] Data provided by the European Commission

[2] "Preparing for our future: Developing a common strategy for key enabling technologies in the EU", Communication of the European Commission, (COM(2009)512), September 2009

technologies have been implemented by emerging countries, which has facilitated a rapid industrialization process. Meanwhile, some of the industrial activity has become too costly to be maintained in Europe on the one hand, some new generation sectors have blossomed, on the other. In high-end technologies as well, Europe's competitiveness is put to test by manufacturers in emerging economies, which are building up a sound R&D base, and state-of-the-art manufacturing facilities in their homeland.

The progression of growth in overseas countries at rates well above that seen in the EU, only reinforces their technological potential. If maintained, the current momentum of R&D investments in emerging economies seems likely to level the differences in technological development between different regions of the world in the near future. In other words, **most products will be produced everywhere in the world and geographical advantages will erode**. Therefore, Europe, which is seen its manufacturing base, due to the increasing investment in growth areas of the world, is facing the challenge of ensuring that it maintains its export-led growth, if it is to compete in a global environment.

In a natural resource lacking, but highly educated Europe there are many obvious reasons why **focus needs to be put on high-end technologies with high R&D and knowledge intensity** and that require a minimum of (scarce) materials as indicated by the selected KETs.

A key for success in all industries in an increasingly competitive global environment will be to have a foresight for developing the goods and services, which do not exist in the market yet and which will be on demand tomorrow. These products and services will be resource and energy-efficient so as to allow for responding to the pressure from depleting natural resources and high energy and commodity prices. Nevertheless, **those who design the products of tomorrow will have to think about how to produce them as well**. This applies especially to European industry, once it starts to create increasing added value by using micro and nano technologies to manufacture the products of tomorrow. The production technologies used in advanced manufacturing tools of tomorrow will have to offer the capacity to add materials at nano and micro precision, something seen today in microelectronics only.

In conditions depicted above, those who innovate the most rapidly to energy and resource saving products and who respond to customer needs for quality, customization, delivery time, environmental performance, security, safety and services can win in markets. This competitive advantage can only be built on manufacturing strength, which is best achieved **through the acquisition of the highest technology and equipment in time.** In other words, advanced manufacturing systems will have an ever-increasing role in determining industrial competitiveness in a highly competitive international environment. Those who master advanced manufacturing systems will be endowed with the right tools to respond to needs related to cost, quality and cycle time.

Further, there are some structural challenges that hamper the competitiveness of manufacturing in Europe compared to emerging economies. Energy prices in Europe, which have a significant impact on cost-competitiveness, are twice as high as competitor countries and regions. Moreover, Europe has an ageing population and a declining number of engineering graduates and is likely to face a lack of skilled workforce needed in the manufacturing industry. China currently graduates much more engineering students than Europe or US.[3] Although, the value of this educated work force is likely to rise so long as professional engineers gain experience. Therefore, **public policy will play an increasingly important role** to address these challenges and set the right frame for the deployment for the future development of manufacturing and AMS in Europe.

This report prepared by the Working Team on Advanced Manufacturing Systems presents a vision on Advanced Manufacturing Systems. It contains policy recommendations that aim **to link innovation policies for Key Enabling Technologies to an industrial policy,** which will underpin the deployment and further development of available and not-yet-available advanced manufacturing technologies in Europe.

Innovation should lead to (new) industrial activities. Advanced manufacturing technologies in this document are necessary to **turn Key Enabling Technologies into value for our society.** This includes creating jobs and contributing to GDP growth.

1. Scope of the thematic area

Definition of Advanced Manufacturing: Advanced Manufacturing Systems (AMS) comprise production systems and associated services, processes, plants and equipment, including automation, robotics, measurement systems, cognitive information processing, signal processing and production control by high-speed information and communication systems.

AMS are essential for productivity gains across sectors such as the aerospace, automotive, consumer products, electronics, engineering, energy-intensive, food and agricultural as well as optical industries. They also can make an effective response to societal challenges including health, climate change, resource efficiency and job creation."

1.1. Description of Advanced Manufacturing Systems

AMS involve manufacturing operations that create **high-tech products**, use innovative techniques in manufacturing and invent **new processes and technologies for future manufacturing**[4]. The AMS definition used in this document covers both manufacturing of high-tech product, processes and solutions for future manufacturing, as well as services associated to them.

[3] "China is producing 300,000 graduates in the sciences every year - three times the number that EU universities are producing. and India is having similar success: 450,000 engineering graduates every year are filing out of Indian universities." *Bring young people back to science*, Cordis, European Comission 03/12/2008 http://cordis.europa.eu/search/index.cfm?fuseaction=news.document&N_RCN=30205

[4] Caroline M. Sallee , Erin Agemy, Alex L. Rosaen "The University Research Corridor Support for Advanced Manufacturing in Michigan Michigan State University", University of Michigan, Wayne State University July 2010

Some significant features can be identified to help distinguish AMS from traditional manufacturing technologies. AMS significantly increase **speed**, decrease **costs** or **materials consumption**, and improve operating precision, as well as **environmental aspects**, such as waste and pollution of manufacturing processes. AMS include the use of different materials composed of traditional structures, as well as, of new elements and compounds. They entail the integration of new technology (such as ICT) and processes to help improve the conception, design, production, testing, handling, distribution and recycling of a product.

Moreover, AMS have a strong potential for a **multi-sectoral application**, are key to industrial **productivity gains**, and can make an effective response **to societal challenges** like energy efficiency, climate change and resource scarcity.

Advanced Manufacturing Systems are **capital intensive**, **knowledge intensive** and demand high levels of **intellectual capital**. Advanced manufacturing strength is built on strong human skills and a **multi-disciplinary** legacy in sciences including materials technology, ICT, mechatronics, physics, nanotechnology among others.

AMS are often characterized by a high level of numerical control and automation, customisation, scalability and high skill-intensity. AMS integrate information technologies and knowledge into manufacturing process (eg. digital production modeling, real time modeling of the factory, online non-destructive-testing) which help optimize the production and factories. Unlike other KETs, AMS comprise not a single technology but **a combination of different technologies** which include, among others, material engineering technologies (e.g. cutting, knitting, turning; forming, pressing, chipping), electronic and computing technologies, and their combination, measuring technologies (including optical and chemical technologies), transportation technologies and other logistic technologies. New avenues in AMS are additive manufacturing at the nano-micro level scale such as the 22 nm lithography, atomic layer deposition, nano/microliter droplets, micro precision placements, micro flows, process intensification, etc. At these scales, other physical phenomena, even within a few years down to control material behaviour with quantum effects, are reached.

Manufacturing industries used to create added value by removing, reshaping, mixing and/or adding materials and assembling components into more valuable (sub) products. In advanced manufacturing systems, these **processes act on smaller and smaller scales**. From swords and steam vessels via radio tubes to integrated circuits and micro droplets, value is now created at micro-nano scale where electrons and photons are controlled or where material is added with as in the case of atomic layer depositions.

For the **process industries**, AMS aim at processes designed from the start to incorporate highly efficient, inherently safe and environmentally benign technologies and tailor-made products with designed properties making efficient use of (e.g. renewable) resources. They help achieve smaller size facilities based on process intensification technologies with maximized re-use of materials; equipment that is geared for multiple usage and purpose -thus increasing flexibility and decreasing cost - and plants that are equipped with appropriate control systems for the physical, chemical or biochemical transformation they process.

1.2. Coverage of the KET on AMS

The focus of this report will be on advanced manufacturing systems linked to five KETs and the situation of AMS within the **value chain of KETs** will be analyzed. In a snapshot, a value chain from left to right on a horizontal line comprises materials, processes, sub assemblies or base chemicals, then final products. Then, per item vertically it includes a chain of suppliers (sometimes first-tier and second-tier). High-tech equipment/systems/tool suppliers is an example (for Europe an important one) of a supplier to the processes in the value chain.

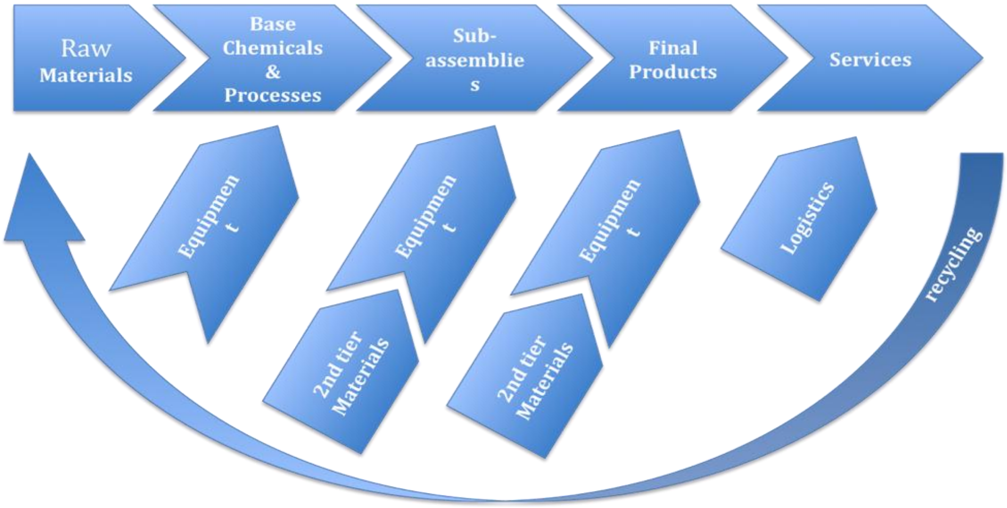

Figure 1 Value chain of the AMS KET

During the Open Day on Advanced Manufacturing Systems[5], the participants agreed that one should consider in the value chain of advanced manufacturing every processes **from the first handling of raw material (**fossil based feedstock, biomass, metals, recycled materials, CO_2, critical raw materials etc**) to the production of final goods**. In general, participants agreed that in the current state the scope of the definition should be as wide as possible in order to include every kind of advanced industry (Pharmaceuticals, Automotive, Biotechnology, ICT, micro- and nano-electronics & food sector) and every process in the value chain from the conversion of raw materials (by process industries) to the conversion of materials to products (by discrete manufacturing).

Process Industries encompass primary manufacturing of materials and chemicals, via physical, chemical and biochemical transformation and formulation of raw materials, basic feedstocks and other chemicals using continuous or batch processes. Examples are chemical, pharmaceutical, biotechnology and steel industry. These industries deliver materials which are the basis of discrete manufacturing and are thus essential part of manufacturing value chains. The challenge is the resource efficient (process) factory of the future that will utilize

[5] Open Day on Advanced Manufacturing Systems, 15 November 2010, Brussels

knowledge on KET as biotechnology and advanced materials. The KET photonics, electronics and nano tech are key for factory of the future that will use the output of the process industries. See figure 2.

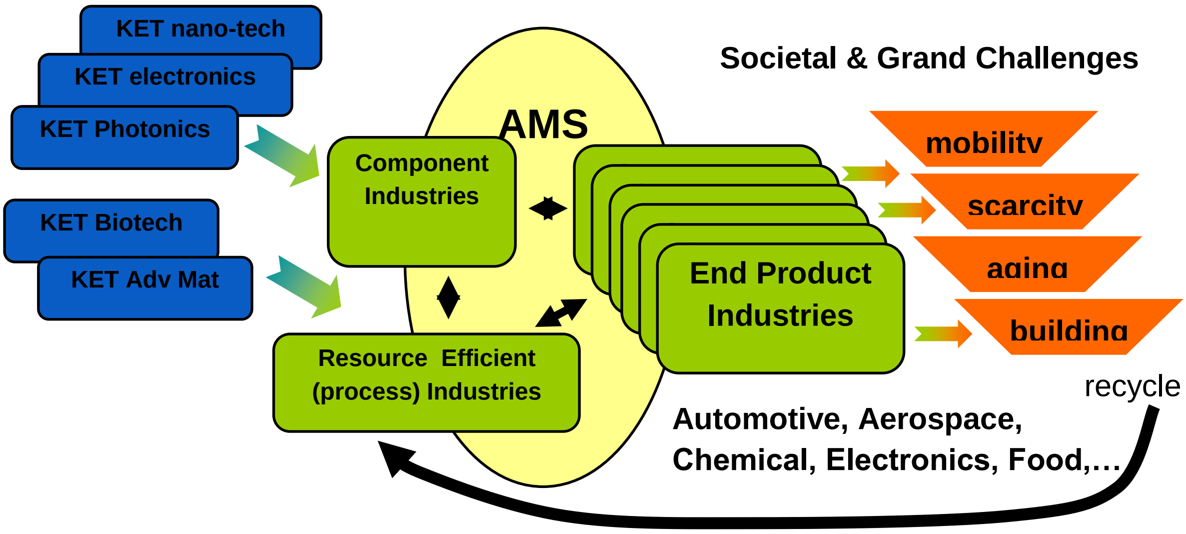

Figure 2 Contribution of KETs to the factory of the future for component and process industries

Today, one cannot think of valuable manufactured goods isolated from the **associated services** (eg. after sales support, maintenance, repair). The more the industry approaches the limits of technological improvement and the more nations worldwide evolve into a convergence in technological development level, the more the value of products is built on services provided to customers. Services have a direct impact on the competitiveness of manufacturing and are therefore included in AMS presented in this document.

In a broader perspective, **business/management models** (eg. lean production, supply-chain integration etc.) can be included in AMS given their impact on the efficiency of production, productivity and environmental performance.

Further, there is a deep and multi-disciplinary engineering background (mechanical, electric and electronic, physics, chemical, software engineering etc[6]) behind AMS, which is cultivated in top class technical schools and within enterprises. Therefore, the **human factor (skills)** is also included in the KET on AMS and policy recommendations included in this document.

[6] Multidisciplinary disciplines sometimes described by combined names as mechatronics, optronics, flowtronics, embedded software, telematics, etc.

2. Contribution of AMS in tackling grand societal challenges

2.1. Grand challenges

The Europe 2020 Strategy[7] highlights the short and long-term challenges Europe has to tackle. The immediate challenge is putting the European economy back on an upward path of growth and job creation, whilst long-term global challenges comprise *inter alia* globalisation, pressure on resources and ageing population. The 2020 Strategy underlines the role of 'technology' as the ultimate solution-provider for tackling these challenges. It shows the way forward as investing in key technologies, which will help innovative ideas be turned into new products and services that create growth, quality jobs and help address European and global societal challenges.

Innovation is, thus placed at the heart of the Europe 2020 strategy and technological innovation makes up large share of it. The 2020 Strategy recognizes notably the need for the development of new production methods to reduce natural resource use; investing in carbon-capture technologies and electric vehicles to help to reduce carbon emissions; and the deployment of key technologies to allow older people to live independently and active in society.

Five KETs (nanotech, biotech, micro/nanoelectronics, advanced materials, photonics), which are leading-edge technologies of the 21st century underpin innovation in many of these strategic sectors and play a key role in making new products and services **affordable** for the population at large. They contribute to the development of disruptive technologies across sectors such as energy (e.g. renewable energies; bio-fuel, solar energy etc), transport (e.g. lighter, safer and energy efficient transport vehicles), manufacturing (e.g. reduced material and process rates, energy saving), chemistry and environment (e.g. fuel cell, sensors for environmental monitoring), information and communication (e.g. micro-controllers for secure communication, banking and commerce), medicine (e.g. gene therapy and genetic testing), consumer goods (e.g. cell phones, LED, LCDs) etc. They help build up a more productive, energy- and resource-efficient economy. Products with enhanced features have the potential to bear high economic value as well as they ensure a more comfortable, healthy and safe life for consumers in a clean environment.

Nevertheless, one should keep in mind that today, every high value product or service which relies on key technologies has a manufacturing process behind it. Manufacturing enables technological innovations to be applied in goods and services, which are marketable in the marketplace. Products of high value and with superior features, enabled by KETs, cannot generate any value for society and economy if they are not affordable or if they are not put into the market in time. **Advanced manufacturing not only allows turning technological achievements into products and services, but it also enables a cost-effective, resource efficient and timely production and commercialization.**

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[7] European Commission Communication, *A Strategy for Smart and Sustainable Growth {COM(2010) 2020}*, Brussels, 3 March 2010

If Europe is to measure the exact value of KETs for society, one should look at the situation from a **'life-cycle' point of view**. The amount of energy and resource used to manufacture new products based on KETs, the waste generated, their lifespan and recyclability are the criteria that should be taken into account while assessing their economic and environmental benefits. This depends very much on the manufacturing systems employed in KETs applications.

For example, composites, an example of advanced materials, which are high performing and durable, require more energy and other inputs to produce, create more waste in their manufacturing and are difficult to recycle[8]. The need for further advances in manufacturing methods used to produce composites to reduce energy and resource consumption.

If we take the example of solar cells, solar photovoltaic (PV) active layers as well as coating and barrier layers require too many rare metals. Industry will face 'supply' problems in a near future. Current thin film solar cells include toxic elements such as arsenic and cadmium. A shift towards organic PV, which are significantly less toxic and recyclable, will be required in a resource-scarce Europe. Roll-to-roll (R2R) manufacturing, which is cheaper than thin-film deposition, will be key to organic PV cell manufacturing and at a large scale to meet an increasing demand for renewable energy at affordable costs.

The micro/nanoelectronics Working Group reports that for their sector, AMS is a pre-condition for zero defect in production. The reduction of production waste can reduce the normalized electricity, water and waste dramatically (depending on product and product line, 2-10%).

As for process industries, they enable the use of alternative materials such as biomass, metals, recycled materials and CO_2 in industrial processes and products. They ensure the efficient use of critical raw materials which are rare in Europe. Advanced manufacturing have a potential to boost the contribution of process industries to **sustainability** by improving energy efficiency and water efficient management.

In addition, 'productivity' is another important criterion to maximize benefits of KETs. A study by Deutsche Bank Research shows that the share of production equipment (machinery) may account for as much as two-thirds of costs in organic PV R2R technologies in which materials play a minor role. Thus, giving a boost to production machinery in order to lower material usage, higher efficiency and simpler manufacturing methods will lead to lower processing costs, more rapid throughput times and higher quality and output[9]. This will be very much in line with the EU's resources strategy.

In short then, **AMS are the key to make KETs and new products affordable and accessible so as to multiply their societal and economic benefits.** AMS are central to the

[8] OECD, "Environmental Outlook" 2001, Paris

[9] Josef Auer, Philipp Ehmer, Eric Heymann, Tobias Just, Uwe Perlitz."Deutsche Bank Research – German Mechanical Engineering", Deutsche Bank, 2008, Frankfurt am Main

sustainability of the value chain of KETs insofar as they provide for productivity gains, economization in energy and resource use and they reduce waste creation.

It is the flexibility of the European infrastructure and of actors in AMS that will enable the creation of an economy that can live up to grand challenges. Where previously dominant technologies were, for example military, space or even classic automotive driven, today's grand challenges require **energy, healthcare,** and **electric-mobility** solutions enabled by KETs.

2.2 Impact of AMS on new products

Micro/nanoelectronics provide cars with engine-control sensors and tire-pressure sensors that help economize on fuel consumption and reduce emissions. Semiconductors offer solutions for healthcare such as automatic blood-pressure monitors, pain-management devices implanted in the human body. Moreover, they help ensure security in society by generating solutions against cybercrime and advanced security in banking and commerce smartcard, as well as personal computers. LED lighting, made affordable by advances in **photonics technologies**, have a much longer life span than incandescent bulbs and offer more energy efficient lighting solutions for buildings. Photovoltaic solar panels that capture solar radiation and convert sunlight into electricity thereby providing renewable and viable energy generation solutions in an energy scarce world. **Nanotechnology** has a broad range of applications across sectors, such as improved manufacturing methods and systems, environment (e.g. water purification systems,) energy (e.g. enhanced renewable energy sources), medicine (e.g. use of nano-particles for cancer treatment) and better food production methods (e.g. increased safety in processing and packaging).

Another KET, **advanced materials,** can yield products that are less toxic, less expensive and more efficient than existing materials. These materials can make products lighter, stronger (such as composites) and cheaper, with significant benefits for the environment. For example, they help reduce the weight of transport vehicles, which leads to reduced fuel consumption and emissions, and help improve the bottom line for enterprises. Further, advances in **biotechnology** such as new types of diagnostic toolkits that allow analyzing proteins faster -and even at home- help diagnose diseases by individuals and at reduced costs. The use of biomass made from agricultural waste provides for a substitute to oil in everything from fuels to chemicals, plastics, packaging and pharmaceuticals. Biotechnology thus, can help decouple economic growth from the use of natural resources.

KET as electronics, photonics and nano are key for the manufacturing of components, but KET as advanced materials and biotechnology are in particular more important for a resource efficient (process) industry.

Finally, KETs have a direct impact on advanced manufacturing systems: for example, actuators and sensors powered by micro and nano-electronics or laser material processing systems, metrology and information processing powered by photonics. These are a few examples of societal and economic benefits of KETs.

Many of KETs are developing technologies and there are more efficient and less costly ways to exploit them. A commonality for all KETs is that they deal with adding and shaping materials at micro-nano meter scale; nanoelectronics deal with manipulating electrons, photonics deal with photons, nanotechnology with atoms etc. To be able to control the manufacturing of layers of material at atomic level is an advance manufacturing challenge on its own and requires costly production facilities, if it is to be done on a large scale. There is a lot of room for improvement in the manufacture of KETs with a view to costs, quality and output. **Advanced Manufacturing Systems and equipment can foster innovation and disruptive new processes** such as extreme ultraviolet lithography (EUV) and R2R production of organic thin film photovoltaics, so as to bring down costs and maximize benefits of KETs on new products.

Once production costs for KETs are lowered thanks to advanced manufacturing, further manufacturing is needed to enable the application of KETs of market products. For example, the micro-size medical devices (blood pressure monitors etc) enhanced by semiconductors need to be endowed with high precision features which rely on advanced micro-machining methods. Moreover, advanced production equipment and machinery ensure the continuous improvement of solar products through automation and more rapid throughput times, which help reduce costs for solar energy generation. **AMS help improve cost, quality, energy use and safety aspects of products enabled by KETs** alongside the value chain, by streamlining the design, manufacture, testing, handling, packaging, storage, distribution and recycling processes.

In conclusion, AMS underpin the competitiveness of all KETs and products by providing them with high **productivity gains and making them affordable for society,** and help make the most of KETs in tackling global challenges.

2.3 Importance of mastering AMS in Europe

In a resource-scarce and knowledge rich Europe, new products have to have a high knowledge content and a low material/energy resource need. The Europe 2020 Strategy advises, "to promote technologies and production methods that reduce natural resource use, and increase investment in the EU's existing natural assets"[10] for obvious reasons of environmental protection, but also economic security.

The European continent is lacking natural resource and it has limited land area. Therefore, its primary focus must be on manufacturing (including the creation of services) and in particular, on manufacturing of knowledge intensive goods that require low amount of materials, i.e. much smaller versions of products. Examples of smaller goods are the transition from HiFi set towards MP3 players into integration in a single mobile device (telephone, music/video player, agenda, email reader) of today and the expected very thin electronic sheets of tomorrow (Generation n+1 thin e-books or G n+2 flexible foil e-books).

[10] Ibid, European Commission Communication, 2010

Europe needs, thus, a strong innovation strategy to take up the global leadership in producing new products. However, scientific innovations allow for value creation 'once'. We need factories (manufacturing) for repetitive value creation. It is a great improvement to make a 10nm transistor at the university, but it still requires decades of engineering to develop a lithography wafer stepper capable of manufacturing billions of such transistors every minute. In other words, KETs can have a great scientific value, but one needs advanced manufacturing systems to generate economic value and thereby growth and jobs.

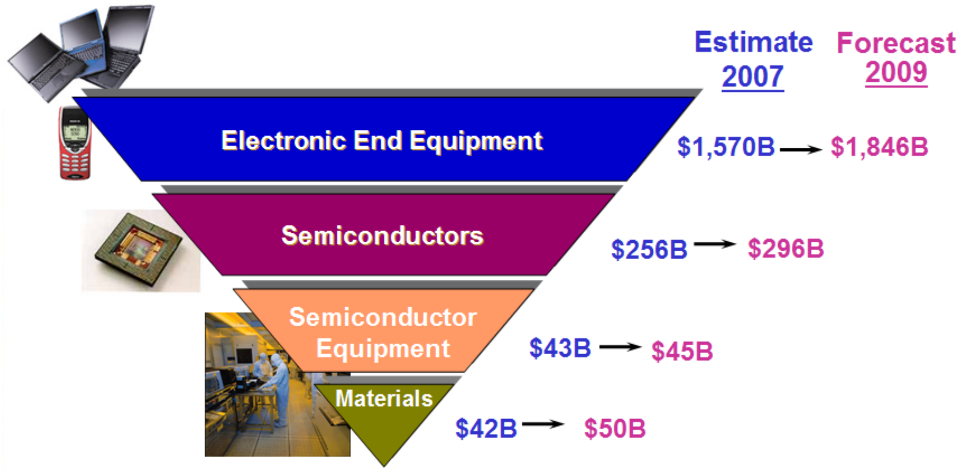


Figure 2 The reverse pyramide of enabling factor of manufacturing equipment

Moreover, to be the first to apply innovations and to put products on the market, Europe needs to **have factories to make new equipment to manufacture these new products on time**. Europe must maintain its leadership in the area of designing and producing the equipment and systems that later on will be used in all factories around the world. This must be done here in the EU. If Europe does not have its own factories, after several decades, it will be too late to catch up with the latest generations of equipment and ultimately Europe will lose its market share. KETs will lead to new products, and at the same time, the European industry should be working on the factory concepts to manufacture these products.

One has to bear in mind that manufacturing currently makes a large part of the added value and the employment in the EU. It is illustrative that in 2007 the manufacturing sector generated 30% of value added, 25,8% of employment and 22% of investments in EU 27(see figures 2 and 3). In some countries such as Hungary, Slovenia and Finland, it contributed more than two fifths of the non-financial business economy value added. Europe has therefore, a strong stake in maintaining leadership in AMS, which **underpins the productivity and competitiveness of all manufacturing industries.**

A leadership in AMS leads to **employment creation** by driving Europe's competitiveness in new industries (e.g. renewable, energy efficient products etc) and boosting productivity in major manufacturing sectors (automotive, aerospace, engineering, electronics etc). In addition, AMS, as the central driver of productivity, has a great potential to help tackle negative impacts of an ageing society in Europe.

Figure 3 Value added and employment in manufacturing, Member States and Norway, 2006 (1). Share in the non-financial business economy (%), Source: Eurostat

Indicator	Units	Value
Number of enterprises	thousands	2 323
Persons employed	thousands	34 541
Turnover	EUR million	7 273 512
Value added	EUR million	1 812 963
Gross operating surplus	EUR million	694 282
Investment	EUR million	262 448
Share of non-financial business economy:		
Employment	%	*25.8*
Value added (1)	%	30.0
Investment	%	*22.2*

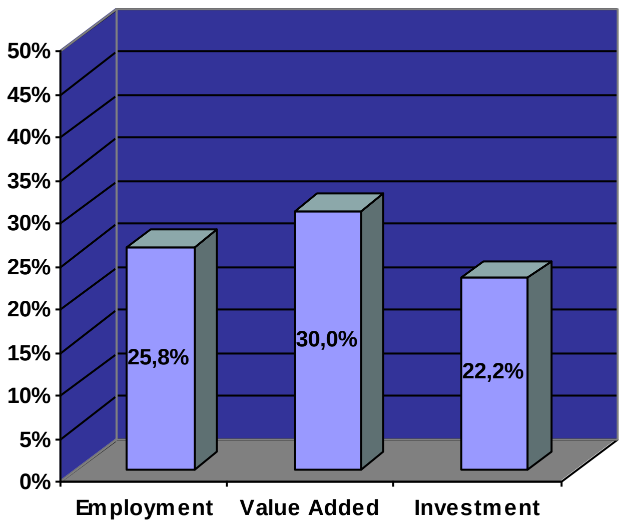


Figure 4 3 key indicators manufacturing, EU 27, 2007 (Eurostat)

The machinery sector which includes production machinery equipment (the basis of advanced manufacturing systems) is the only sector in which Europe recorded a trade surplus in 2007 together with the transport equipment sector. Europe can maintain a sustainable export led growth on highly competitive markets thanks to the export of high value production equipment and technology to the rest of the world. Advanced manufacturing and the European manufacturing base is **the engine of European exports and generator of wealth**.

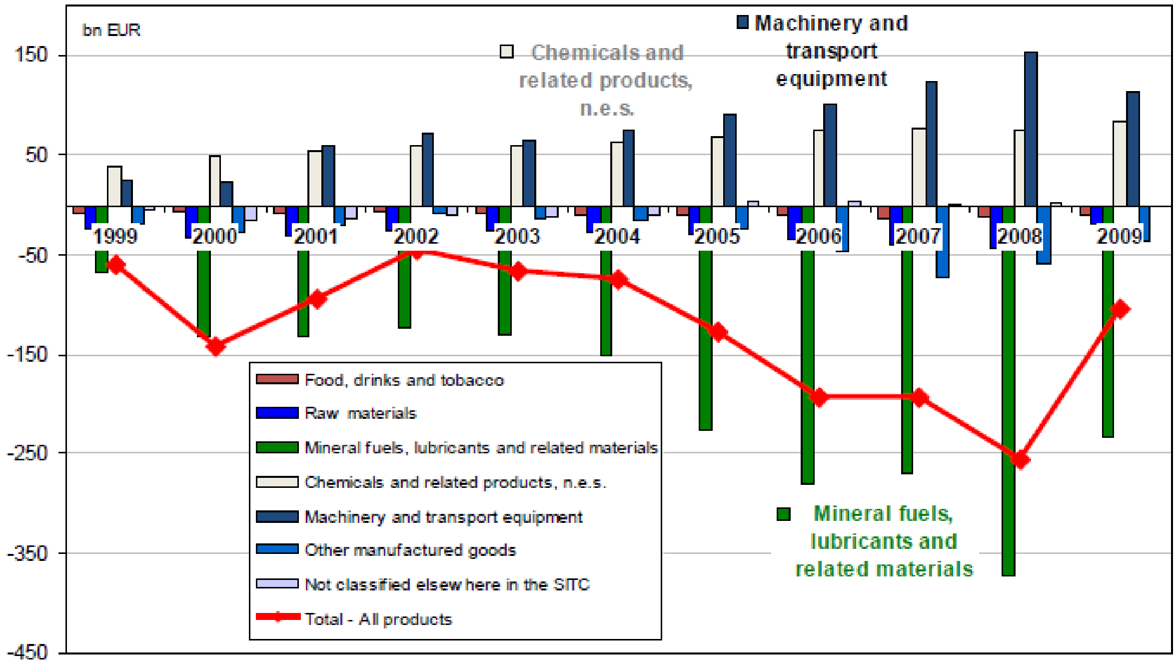


Figure 5 EU27 – trade balance in major products (Eurostat)

3. Analysis of the situation world-wide and in the EU

This section provides a detailed analysis of AMS within advanced materials, biotechnology, micro/nanoelectronics, nanotechnology and photonics. The analysis covers an of AMS within the value chain of each KET.

3.1. Advanced materials

During the Advanced Materials KET analysis, specific value chains relating to the grand challenges of concern were highlighted in order to provide a focus to what is an otherwise extremely broad subject.

The value chains considered by the Advanced Materials working group are as follows (each listed alongside a grand challenge theme):

Photovoltaics	Addressing energy and climate challenges
Advanced batteries	Addressing climate and more generally environmental challenges
Solid state lighting	Addressing energy and climate challenges
Gas Turbine/Aerospace	Addressing climate and energy generation
Health care	Addressing ageing population

To ensure that the most appropriate value chains were selected, it was desirable that each provided a suitable representation within a select range of advanced materials. The selection of representative advanced materials includes

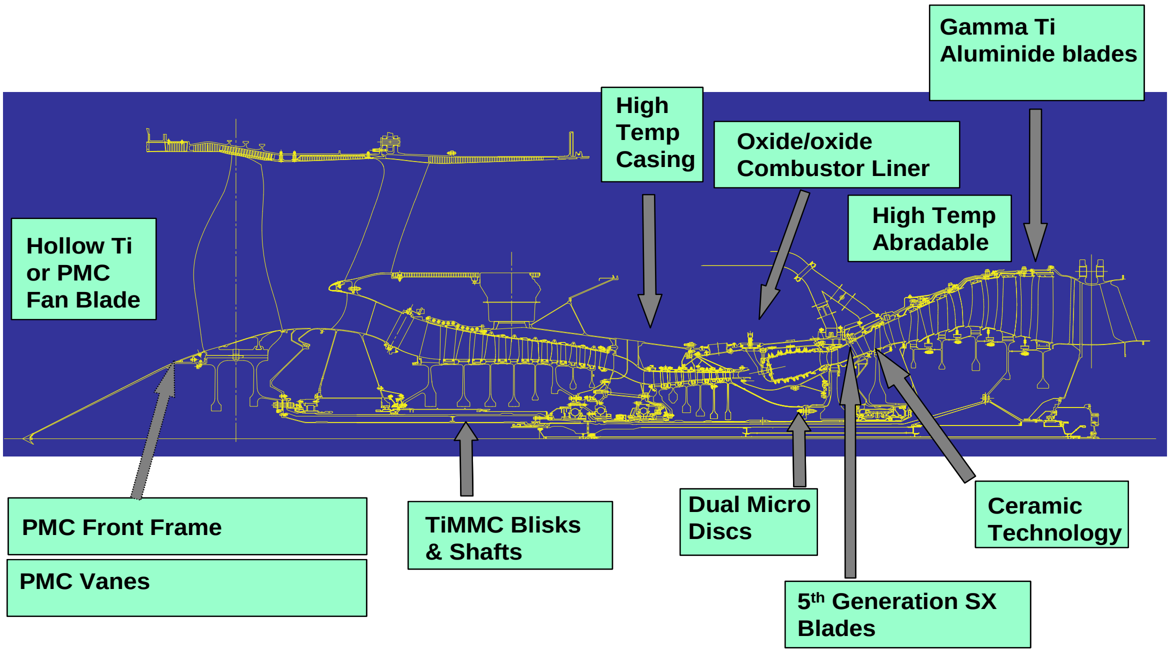
- **Advanced Metals** e.g. advanced stainless steel, super-alloys, intermetallics, etc,
- **Advanced Polymers** synthetic engineering-nonconducting polymers, engineered plastics, conducting polymers or organic-electronic materials OPEs, advanced coatings, advanced/nanofibbers, etc,
- **Advanced Ceramics and Superconductors** e.g. nanoceramics, piezoelectric ceramics, nanocrystals,
- **Novel Composites** e.g. polymer composites, continuous fibber ceramic composites, metal matrix composites, nanocomposites, nanopowders, metal fullerenes and nanotubes,
- **Advanced Biomaterials** e.g. bioengineered materials, biosynthetics, nanofibbers, catalyst

AMS for the advanced materials listed above does not start with processing or engineering of the materials, but essentially has to include the earlier value chain of manufacturing the new materials itself, which is the role of the process industries.

It has been detailed by the Advanced Materials Working Group that due to the vastness of the industries impacted by advanced materials technologies it is practically impossible to perform a SWOT analysis for each particular case, and certainly to accomplish it within the constraints of the HLG KETs assignment. A SWOT would have to be done for advanced materials technologies as they are implemented in each value chain. For reasons of space restriction in this report, the examination of only one of these value chains, the **gas turbine / aerospace** is provided below.

3.1.1. Vision – Current and potential contribution to addressing grand societal challenges

In the context of advanced materials, the aerospace value chain encompasses lightweight and high temperature materials. Examples of these are given in figure 6 with reference to a future aero-engine. It should be noted that gas turbines are reported to be the most important energy conversion technology for the future, not just for aerospace (International Energy Agency, 2009). Whilst both types of materials are important for running efficient gas turbine engines, lightweight hybrid materials are of particular importance for the airframer.



Advanced material examples:

Advanced single crystal Nickel based superalloys

Dual microstructure alloys

Titanium Aluminide superalloys

Intermetallic/ceramic turbine blades

Refractory metal turbine blades (silicides or aluminides)

Smart materials (e.g. shape memory alloys)

Ceramic Matrix Composites (SiC reinforced SiC CMC's or oxide-oxide matrix)

Figure 6 Schematic representation of advanced materials and their location on a future aero-engine.

Advanced manufacturing processes play an important role in ensuring the aerospace industry continues to look to address the grand challenges. The aerospace industry has a strong desire to ensure that its products are as fuel efficient as possible in line with the demands set by airline and military customers around the world with regard to more environmentally friendly aircraft.

Furthermore, the aviation sector is working towards achieving performance improvement targets by 2020, set by the Advisory Council for Aeronautics Research in Europe (ACARE). CO_2 emissions are to be reduced by 50% per passenger kilometre, noise by 50% and NOx by 80%, all from a 2000 baseline. The reduction in carbon-dioxide emissions will require a 15-20% improvement from the engine, 15-20% from the airframe and 5-10% from improved air traffic management and operational efficiency.

As well as fundamental advanced manufacturing processes required to realise new advanced materials the advanced manufacturing KET also covers “green manufacturing”. This is based on the complete product lifecycle from concept to end of life disposal, with decisions focusing on consuming the smallest amount of the world’s natural resources and ensuring a minimal impact on the environment.

Contribution of Advanced Materials in Aerospace in addressing the climate challenge :
Up to a limit, the efficiency of a gas turbine is very heavily dependent on the temperature that the engine core can tolerate. Materials’ research and development aimed at delivering turbine blade materials with higher and higher temperature capabilities have continued throughout the history of the gas turbine. Creep strength is a crucial factor, due to the continuous high axial loading from the rotation of the turbine. Other important attributes are fatigue strength and corrosion and oxidation resistance.

Improvements in temperature capability have been achieved through a combination of alloy development and manufacturing process technology, culminating in the advanced single crystal nickel based superalloys in use today. Figure 7 presents a schematic representation of this.

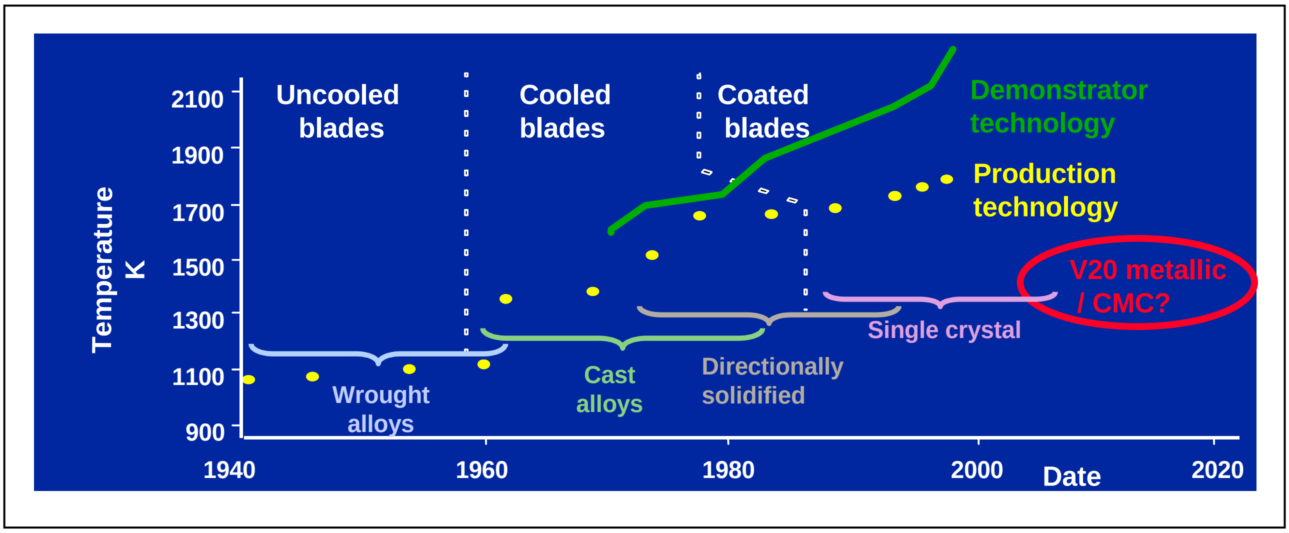


Figure 7 Temperature tolerance of a turbine blade as a function of materials and manufacturing technology development

3.1.2. Manufacturing Systems for Advanced Materials

It can be said that Advanced Materials in aerospace are driven by Advanced Manufacturing processes. These processes are generally related to machining, forming or joining but there are more advanced technologies being conceived. A current example would be the drive to powder manufacturing routes whether it is via near-net shape hot isostatically pressed (HIP) or some sort of powder deposition. Here the material that results is in a different microstructural condition from that in a cast or forged product and hence is a 'new' material but the drive is essentially through manufacturing.

Advances in materials technology and manufacturing processes will ensure the continued development of more environmentally friendly aero-engines and aero-engine derived power generation systems. The plot below displays the recent advances made by a leading gas turbine manufacturer in reducing CO_2 emissions.

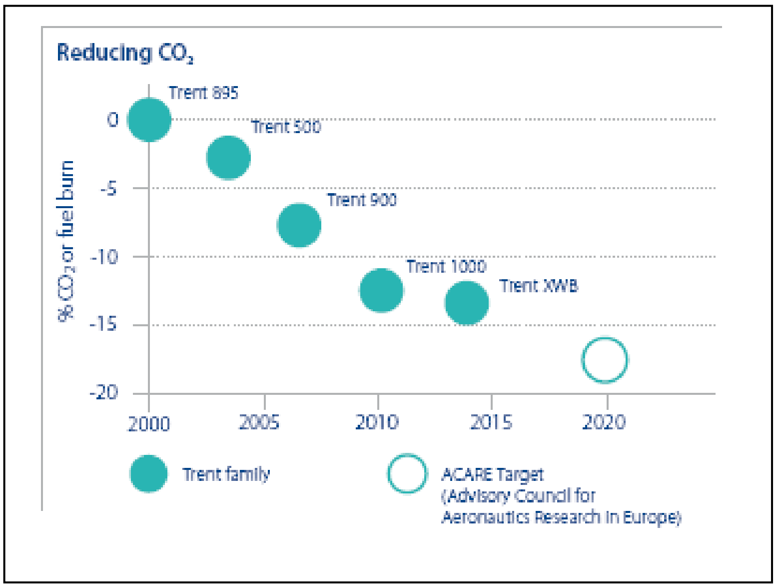


Figure 8 CO_2 emission reduction courtesy of Rolls-Royce plc

The aerospace industry has a clear vision on what is required from advanced manufacturing to secure the future of the aerospace industry in Europe and how it can address the grand challenges. The following core themes have been highlighted following a recent analysis conducted by the Aerospace and Defence KTN and the Advanced Design and Manufacturing National Technical Committee in the UK. The results of this research are still to be formerly released but it is expected to be published by the end of 201[11]. Some of these themes are also echoed in the "Factories for the future PPP" strategic roadmap.

- Near net shape processes
- Surface engineering
- Ultra low cost tooling
- Advanced material processing
- Through life digital engineering
- Virtual processes

The Factories of the Future initiative should therefore continue to be supported over the longer term as it plays a key role in the AMS and in the uptake of the other KETs by their client industries.

[11] "Strategic role of aerospace manufacturing research in relation to the A&D KTN roadmap", An advanced design and manufacturing national technical committee paper (to be published 2010).

3.1.3. Analysis of the current situation worldwide and in the EU

The advanced materials aspect of the gas turbine value chain is not easy to assess. As discussed already, developments are often driven by advanced manufacturing processes. The materials divisions within gas turbine OEM's are in general the developers of advanced materials. They initiate, co-fund and deliver the advanced materials and its associated process technology to an internal customer (the supply chain unit). This is often due to very clear OEM requirements to the material functionality and a strong impetus on capturing IP. Whenever available, OEMs are quite happy to adopt commercially available solutions, but this is a very rare occurrence and is often more associated to external suppliers of advanced polymers, ceramics and biofuels. A more common scenario has the materials developer placed as a strategic supply chain partner or a partner research institute or university. In this sense, the aerospace industry is a model example of how to deploy successfully novel and innovative technology. Stringent certification requirements and the high risk of implementing new materials technologies impose an approach where the aerospace companies are in control.

3.1.4. Industry Vital Statistics

Internationally, the civil air transport market has grown in terms of passenger miles since its inception and although the rate of growth has reduced from the heady 15% per year of the 1950's it now appears, a steady growth rate of 4-5% per year might be anticipated over the next two decades[12]. In the short term, hiatus excess new aircraft are being produced to be "parked" and aircraft retirements are at record levels but taking a longer view it would seem that somewhere in the region of 65,000 new aircraft will be produced over the next twenty years requiring in the region of 140,000 engines, the latter worth perhaps £500B.

In terms of land based power generation, the current predictions are that there is a worldwide market opportunity for gas turbine power generation of $137 bn out to 2017.

In 2000, the European aerospace industry employed 429000 persons directly and many more indirectly, with a consolidated turnover of €72300 million. Almost 15%of turnover was spent on research and development. Exporting more than half its output, the industry provided a positive trade balance of about €1900 million for the EU as a whole. Aerospace depends on an extended supply chain, including many small and medium-sized companies located in all 15 countries of the Union. However, as discussed previously the Advanced Materials aspect of the aerospace value chain (in particular the aero-engine) is not easy to assess. This complex industrial structure makes aerospace a leading contributor to wealth and employment all across the EU[13].

[12] Market Outlook, Forecast 2009 - 2028, Rolls Royce

[13] "Strategic Aerospace Review for the 21st Century" Star21, European Commission and DG Research (2002).

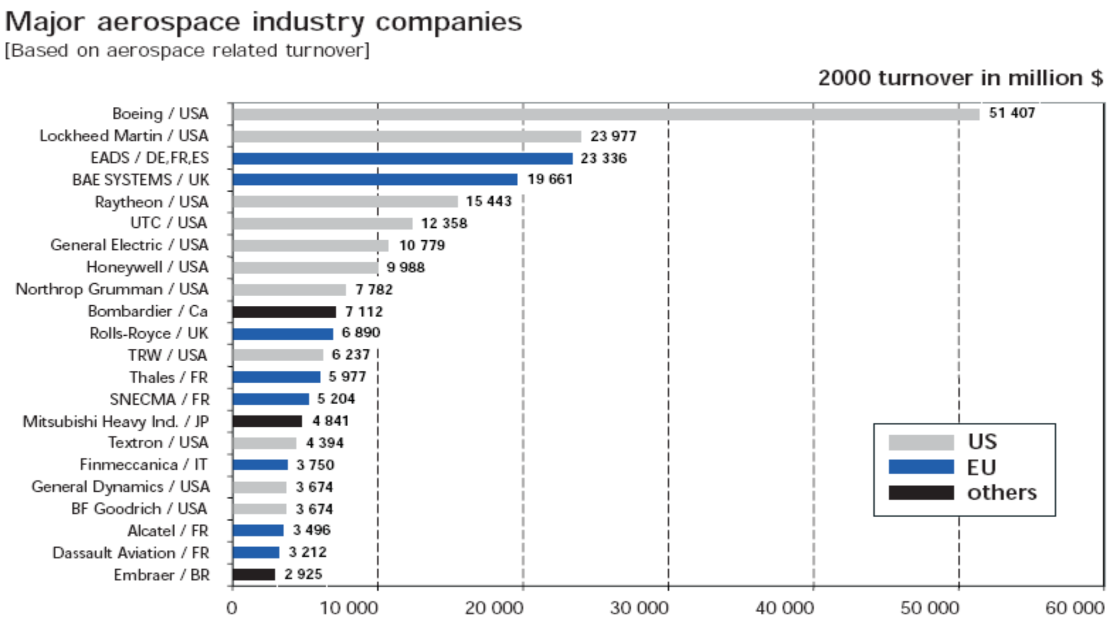


Figure 9 Star21 Strategic Aerospace Review for the 21st Century

3.1.5 . Drivers and obstacles

A few examples for deployment efforts in aerospace industry are presented below as they provide for best practices, which could be replicated across Europe. The aerospace industry is in a unique position in that it requires very little incentive to take up advanced manufacturing processes since it already has a remit to address the environmental grand challenge from both a customer cost effective point of view and following official regulation guidelines on emissions (ACARE).

Partnerships

Advanced Manufacturing Research Centres - The creation of Advanced Manufacturing Research Centres in UK serves as example of how to ensure the successful deployment of AMT KET to industry. This is a new model of collaborative partnership between industry, universities and RTOs (research and technology organisation) that should be expanded across the EU not just within the aerospace sector. The AMRC is a £60 million collaboration between world-leaders in the aerospace supply chain, key government offices and international academic institutions. This network is generally referred to as AXRC where X denotes a type of manufacturing technology for instance, machining, forming or joining. The AXRCs enable manufacturers and their supply chains to collaborate with academic institutions to prove concepts and demonstrate new technologies that can be exploited in novel products that are internationally competitive. In this fashion a robust and reliable supply chain for advanced materials for the aerospace industry can emerge that becomes more independent from the aerospace OEM's. The network[14] is growing rapidly, driven by the renewed interest from the UK's leading global aerospace manufacturers and the launch funding provided by the regional development agencies.

Process Modelling

The implementation of new materials is a major disruptive risk to the aerospace industry, but it is vital so that engine efficiencies can be improved. It typically takes 12-15 years to achieve a completely reliable, validated material. Timescales for the implementation of novel process cycles may be even longer.

The key is therefore better process modelling and physics-based computational analysis of materials manufacturing and performance to ensure increased confidence. This clearly includes lifetime predictions. The creation of centres of excellence on this topic is a potential route to validating and showcasing new advanced materials and their manufacturing processes. In this fashion, the introduction of new advanced materials and new system solutions can occur much faster. However, it is not clear at this stage how this would translate to policy.

Large Scale Demonstrator Programmes

The aerospace industry has a growing reputation for bringing through innovation on the topic of advanced materials and advanced manufacturing. Large-scale demonstrator programmes are excellent examples of how to deploy successfully technology. The Environmentally Friendly Engine (EFE) project[15] is a case example of this, and it is one that highlights the need for continued support from the EU on initiating such industrial partnerships. The programme links the basic research stage to a higher validation level via a series of tests on UK demonstrator vehicles. It is a collaborative venture led by Rolls-Royce with four key UK partners: Bombardier, Goodrich, GE Aviation UK (formerly Smiths) and HS Marston. The UK supply base will develop components for the programme within their area of expertise. Various funding sources have been established – Technology Strategy Board, MoD and the RDAs – but at least 50% of the cost is borne by industry.

[14] These centres include the Advanced Manufacturing Research Centre in Sheffield, the Advanced Forming Research Centre in Glasgow, the National Composites Centre in Bristol and the Manufacturing Technology Centre in Coventry. The EPSRC-also plans to renew University funding for a number of Innovative Manufacturing Research Centres.

[15] EFE is a 4 year, £95m programme started in January 2006. It is aimed at enhancing UK competitiveness in the fields of high temperature materials, high efficiency turbines, low emissions combustion, manufacturing technologies, engine controls, and nacelle aerodynamics. The work is an agreed part of the AeIGT National Aerospace Strategy leading to the achievement of the Advisory Council for Aeronautics Research in Europe (ACARE) goals.

3.2. Biotechnology

Increasing numbers of chemicals and materials are produced using biotechnology in one or more processing steps. AMS in this area comprise biotechnological processes to produce chemicals and materials not accessible by conventional means or in a more efficient way, and the eco-efficient use of renewable resources as raw material for industry. Industrial biotechnology will enable a range of industries to manufacture products in an economically and environmentally sustainable way.

Section in preparation focussed on the resource efficient process industry.

3.3. Micro/nano-electronics

Advanced manufacturing systems have an overlap with microelectronics technology in terms of supply side access to manufacturing processes, but also s/c involved in specific development of manufacturing processes. Micro/Nanoelectronics needs advanced manufacturing systems.

3.3.1. Description of Microelectronics Eco-systems

The More Moore Ecosystem: More Moore products are ICs for computing, consumer goods and communication. The most important products are microprocessors and memories. All More Moore products are digitally designed. The pace of innovation in this industry drives the constant shrinking of the IC enabling the same functionalities to be produced with smaller structures at a regular cadence.

Any company in the More Moore market has five important levers to outperform the other competitors:

- Shrinking: with new lithographic tools and photo resists the physical structures of the ICs can be reduced. The same functionality needs less silicon. Production costs decrease. There are technical and economical limits for this strategy, yet leaders in the sector have been so far able to overcome these obstacles time and again over the last decades and kept "Moore's Law" alive.

- Larger Wafer: The bigger the wafer, the more die that can be processed in parallel at a much reduced cost per die (= cost per chip).

- Production Volume: Size matters. Production costs decrease with production volume, as fixed cost are predominant.

- Financing: Leading edge More Moore fabs cost more than € 4 billion. Financing conditions have a strong impact on return of invest.

- Patents: It is easy to copy digital designs; patents are the only protection.

Most MM companies are IDMs (Intel, Samsung, Micron, Infineon, Hynix, STM etc) but there is a growing number of foundries (TSMC, Globalfoundries etc) and fabless companies (Qualcomm, Broadcom, Arm, AMD etc). The centers of gravity are USA, Korea, Taiwan and Japan. Europe has frontend production facilities in Ireland, Germany, France, Netherlands and Italy. The backend production is almost completely in Asia. This may change medium term because of new production methodologies (Through Silicon Via), where Frontend and Backend is combined.

These companies rely on equipment and material providers (like ASML, Zeiss, Wacker, Soitec etc), clean room providers (M&W Zander) etc. Moreover they co-operate with research institutes (IMEC, LETI). In this respect, Europe is well positioned both in terms of equipment and supplier industry and research institutes that both are integral part of the advanced manufacturing ecosystem of semiconductor industry.

The More than Moore ecosystem: More than Moore products are ICs and multichip components for automotive, industry, energy, security, healthcare, public transport etc. MtM products often rely on mixed signal or analog design. The ICs are not easily shrinkable. New designs are needed for cheaper ICs with smaller structures. MtM products often combine different features on one chip; for that reason different materials are used sometimes on the same chip, sometimes in the multichip component. Depending on the applications these additional materials may be GaAs, GaN, SiC, SiGe etc). MtM products are frequently custom tailored, not commodities.

More than Moore companies have four levers to outperform competitors:

- Larger wafer: The bigger the wafer, the more dyes can be processed in parallel. This strategy pays off only for big product lots.
- Big customers: Size of customers matters. Big product lots generate better profits than small ones.
- But also special niches may pay off. MtM production technology enables niche production with high profit.
- Expertise in materials and analog design. MtM is knowledge intensive. Customer tailored products rely on experience (and mutual trust).
- Deep knowledge about the system where the chip is to be integrated. The chip is an integral and differentiating part of the system.
- Quality: Zero defect production of customer tailored ICs is challenging.

The above description indicates that MtM companies have two ecosystems: one with the downstream industry (for chip design and chip integration into the downstream system) and one with the upstream industry for special materials and equipment.

Most MtM companies are IDMs (TI, STM, IFX, NXP), especially in Europe foundries are emerging (X-Fab, L-Foundry, Altis, Telefunken), they use former IDM fabs.

In contradiction to the MM case, MtM backend facilities are spread all over the world. Backend technology is often a differentiating factor of MtM products. Expertise is here more requested than cost cutting.

3.3.2. Industry Vital Statistics

The size of the **semiconductor** market globally was USD 226 billion in 2009 and is estimated to be about USD 300 billion in 2010. It is a capital intensive industry where the average ratio capex/turnover amounts to 21%. Moreover, it is a knowledge intensive industry where the average ratio R&D/turnover equals to 18%. The semiconductor industry has the second strongest R&D intensity (after pharmaceuticals)

Moreover, with a ratio of 18.1% of annual R&D expenditure over annual sales in 2008, the semiconductor industry is Europe’s second most R&D intensive sector. Its R&D intensity is over six times that of the EU industry average. Semiconductors rank alongside other sectors such as biotechnology or pharmaceuticals as a *High R&D intensity* sector Also at the worldwide level semiconductors rank third with an overall R&D intensity of 15%, again behind biotechnology and also pharmaceuticals and almost five times above the 3.3% world average, which grew 7% in 2008.[16] In Europe, around 110.000 people are employed in the sector.

In the **equipment and material supplier** industry: Europe is a market leader in lithography, SOI, bonding technology, ALD (Atomic Layer Deposition), etc. The sector employs 105 000 people (this figure includes to some degree employees for all 5 KETs). The sector has a strong interdependancy with other KETs as illustrated in the case of microelectronics suppliers entering the PV market. The sector generates manufacturing knowledge for PV and photonics and relies on advanced materials.

AMS well involved in the M&N ecosystem (benefits from Clusters ecosystems)

3.3.3. Manufacturing Systems for Micro/nanelectronics

AMS are key for product innovation and cost reduction. AMS is precondition for the Semiconductor industry. AMS copes with:

- Structure size of 40-300 nm.
- Zero defect strategy.
- Cost reduction of 20% p.a. since 40 years (shrinking and manufacturing science learning curve)
- Clean room quality like in space.

[16] Source:The 2009 EU Industrial R&D Investment Scoreboard European Commission, JRC/DG RTD

Advanced manufacturing systems & equipment foster innovation and disruptive new processes, for example :

- miniaturization : EUV lithography
- large scale wafer : strong evolution of equipment to 300mm (handling, FOUP,…); huge amount of R&D schedulede on 450mm
- bonding technology for advanced substrate or 3D integration
- wafer thinning (thickness of wafer about 10000 atomic layers)
- advanced metrology for zero defect

In practice, process R&D and manufacturing use the same lines to save time and costs. This link between process R&D and production has led to the concept of the 'lab-fab'. (The lab is the fab.)

AMS help reduce the Environmental Safety and Health impact in micro/nanoelectronics industry. The reduction of production trash, through zero defect strategy, can reduce the normalized electricity, water and waste dramatically. Moreover improved equipment and process technology reduces the environmental footprint.

World Semiconductor Council: The information collected from the 2008 data, shows that industry expectation levels are being implemented. The normalized reduction of electricity was 37% (NER) , water used in manufacturing 46%, and waste generated 46%, from the baseline of year 2001.

From an economic point of view, the relationship between AMS and micro and nano electronics industry is as follows. Manufacturing centres need heavy investment; their cost grows with every new generation of technology. Nowadays, a new world class manufacturing unit (More Moore) costs more than four billion dollars. Every € investment generates about one € yearly turnover. This ratio holds true for about five years; thereafter the investment is depreciated. Investments quickly become obsolete in sectors which require new machinery on a regular basis, and they must frequently adapt to the needs of new technologies.

3.3.4. Drivers and obstacles

AMS are a precondition to keep production capacities in Europe, since AMS saves labour and energy cost and improves the efficiency of the value chain.

Europe has strong capabilities in advanced semiconductor manufacturing systems but lacks **lead customers** (leading edge production sites), since the new big productions sites are mainly in Asia and US.

In terms of **energy costs**, in Italy, Germany and other member states, energy costs are double as high as in Malaysia.

The **capital** availability in Europe is another major obstacle compared to other parts of the world. In Asia investors frequently enjoy finance packages (tax holidays, grants), which ensure faster return on investment than in Europe (see Deloitte open day).

As regards **Research and Development**, original WTO rules allow a by far more aggressive funding scheme than the European R&D&I framework. This leads to a situation where up to 70% (and in Europe possibly more) of the annual revenue spent on R&D in in the micro/nanoelectronics is not eligible for adequate and comparative funding. The paradox here is that EU rules hit precisely those domains which guarantee European added value, European competitiveness and which could bridge the gap between R&D and commercialization and accelerate the time-to-market.[17] The rules are quite different in Asia.

Concerning investment in large production sites, the EU **state aid regime** laws which are intended to ensure a level playing field only within Europe are restrictive compared to outside Europe. This places global industries in Europe at a disadvantage. For larger investments the *decalage* mechanism - meaning that the more is invested the less intensive is the support - acts as an incentive to invest outside Europe. This affects also AMS.

3.4. Nanotechnology

Countless new nanomaterials have been synthesized in laboratories worldwide, opening up a wide variety of new applications. All too often, however, new exciting materials never leave the laboratory stage, because the road from the fundamentals of science through to end-systems production was too long and complicated.

It is a major challenge, therefore, to implement the use of nanomaterials and nanotechnologies in real world products. In order to create these high-value products, academia, materials producers and final system integrators have to work together in close collaborations along their value chains. The much stressed European paradox of being better in science than in reaping the economic benefits of the research can only be overcome if this type of collaboration along and among value chains becomes the standard procedure in Europe.

3.4.1. Current and potential contribution to addressing grand societal challenges

Nanotechnologies offer an opportunity for Europe to strengthen its manufacturing capacities while addressing societal challenges, through a rejuvenation of manufacturing technologies, processes and products as well as through creation of new business.

Increasing society's demands, while dwindling natural resources combined with increasing prices, decreasing availability of fresh water as well as adverse climate change underline the necessity to improve the overall efficiency of resource consumption for industrial production in the future. Continuous enhancement of the resource efficiency of

[17] **ESIA** European R&D Funding Support for Micro/nanoelectronics. ESIA position paper, Oct. 2010

processes via product as well as process technology innovations will become a key factor of success. Solutions can be provided by the development of integrated resource efficiency strategies within production units i.e. optimizing products and processes so that all input materials (incl. raw materials, renewable feedstock, energy, water, solvents, catalysts, packaging), all processes, output materials (including products, side products, waste streams), adaptation to environment, and all recycle options are optimized. Standardised, modular multipurpose plant concepts for rapidly adjustable production and corresponding supply chain concepts should also be optimized to reach sustainability objectives. Occupational safety has to be considered in the design of any process.

3.4.2. AMS for the manufacturing of new nanomaterials

Currently manufacturing processes for nanomaterials are relatively crude and dependent on processes not developed for nanomaterials but adapted to produce nanomaterials. Corresponding approaches to manufacturing processes often involve unit operations. Nanostructured and nanocontaining materials / intermediates, however, offer the possibility to combine or integrate multi-operational systems into fewer or single steps. In both cases nanomaterials provide new challenges for manufacturing processes including online monitoring . Development of new nanomaterials will require new unit operations and the clever combination of new and existing process steps.

Conventional technologies include:

- Synthesis;
  - Novel gas phase processes, e.g. plasma- or microwave assisted processes;
  - Novel wet processes, e.g. sol-gel processes;
- Dispersion and stabilisation;
- In-situ functionalisation and formulation;
- Integration in patterned and final system;

Advanced manufacturing technologies include:

- Self-assembly;
- Self-organisation (with long range order);
- In-situ generation of nanostructured materials.
- Scale-up by transferring patterning techniques from small scale lab processes to reel-to-reel manufacturing technologies.

3.4.3 Analysis of the situation worldwide and in the EU

Economic impact: Total worldwide sales revenues for nanotechnology were $ 11,671.3 million in 2009. They are expected to increase to more than $ 26000 Mio in 2015, a compound annual growth rate (CAGR) of 11.1 %. The largest nanotechnology segment in 2009 were nanomaterials. All nanomaterials will increase from nearly $ 10 bio to nearly $ 19,6 bio in 2015, a compound annual growth (CAGR) of 14,7 %. Sales of Nanotools will experience high growth. This market segment was worth $2,613.1 million in 2009 and will increase at a 3.3% compound annual growth rate (CAGR) to reach a value of $6,812.5 million in 2015[18].

Employment: estimates are that in 2008 there were 160.000 workers in nanotechnology, representing a 25% increase between 2000 and 2008. Assuming this trend is increasing by 2015 2.000.000 new jobs will be created by this technology, of which 40% reside in the US[19]. So far new jobs arise from the penetration of nanotechnology into industries like processing, manufacturing, ICT and consumers, where Europe has a strong industrial position in the global competition.[20] . The deployment of nanotechnologies is also a significant factor to strengthen the existing workforce.

3.4.4 Drivers and obstacles

Nanotechnologies require involvement of different industries before they become useful for society. Cross border cooperation along the value chains and cross industry partnerships will be necessary to enable the deployment of nanotechnologies. Traditionally, societal challenges were tackled by the public sector by working up along the value chain starting from the end-user sector, i.e. providers of the final consumer product, visible as leaders and innovators. Such a linear approach, although being safe and conventional, has proven not to deliver on its expectations in the past. Therefore, in order to speed up innovation in Europe, it should be complemented by an approach that allows innovation to start at key stages of the value chains simultaneously and involving multiple sectors (such as advanced material producers). This can create real competitive advantage and inspire breakthrough to comprehensive solutions. This approach would bring the implementation of innovation through public policies and “real life” business models[21] much nearer together.

Nanomaterials, like any innovative material can have high impact on the processing and manufacturing technologies of downstream industries. Process integration down in the value chains is a challenge, which has to be overcome to ensure the deployment of nanotechnologies. Heavy investments with longer pay-back times which are required for the uptake of nanotechnologies should be supported along the value chains.

Up-scaling is critical in the development of any new process In order to achieve mass production of nanomaterials , multipurpose plants will have to be developed. Demonstration at industrial scale should therefore be supported in order to promote the deployment of nanotechnologies. First industrial units are subsidized in some non European countries (ex. China, US).

These are key factors in accessing markets and important tools for accelerating the transfer of technology between science and industry. Nanostructures are analysed by very sophisticated instruments, which can be applied industrially only for low volume, high value

18 Andrew McWilliams, “Nanotechnology: A Realistic Market Assessment”, bcc Research, July 2010

19 NSF Report

20 Chemical Engineering News, Vol 88, No. 29

21 KET Open day on Nanotechnologies conclusion, 27 October 2010

production. Currently there are no applicable standards to reliably measure nanotechnology on-line during volume production. Therefore there is a danger that every value chain, or chain segment, will develop their own heterogeneous standards based on secondary properties.[22]

One of the major strength of the European economy is the network of small and large companies. In order to effectively contribute smaller enterprises need to be able to easily understand the precise allocation of responsibilities at EU and country level. Existing support structures are, in general, too complex despite efforts to simplify and make them SME-friendly.

Nanotechnology is by definition a technology that requires integrated approaches involving a variety of scientific, technical and engineering disciplines. Furthermore the development of resource efficient processes require efficient interlink between natural sciences and engineering. For the development of converging technologies, such as nano-bio , nano electronics , the multi-diciplinary skills will be critical.

3.5. Photonics

3.5.1 Photonics products

Photonic products can be grouped into:

- Light-out products (Displays, Solid State Lighting – SSL LED, Organic LED
- Light-in products (Solar PV)
- Light-manipulation (Photonic devices and components such as fibers, photonic chips & lasers for datacom, sensors,etc

Zooming in on the manufacturing of the different group of photonic products one can focus on two different manufacturing situations:

- Large Area as in Solar PV, OLED and Displays evolving from sheet-2-sheet (S2S) to roll-2-roll (R2R)
- Chip sized LED and photonic devices with a front-end (wafers) and a back-end (packaging)

For Advanced Manufacturing Systems we will propose for Photonics:

1. LED: Highly integrated, reliable and still recyclable LED assembly & disassembly
2. Solar PV: very high output (square km) production on R2R or S2S
3. Silicon Photonics chips foundry fab and (heterogeneous) packaging back-end factory
4. Laser component, datacom & sensor device & instruments manufacturing

Firstly, the different photonics products will be discussed, followed by the requirements and developments of the AMS needed to create these products.

[22] Leppänen, KET Open Day Nano 27 October 2010

Photonic Products are listed below. Advanced manufacturing needs to be developed at the same time for the take-up of these products.

i. **Display**: Displays are the largest market of photonic products. Europe lost its CRT

(Cathode Ray Tube) production to Japan, and then Japan lost its LCD production to Korea. Europe is not significantly involved in large size display products and the question that arises is who will do flexible displays as Organic Light Emitting Display (OLED) and Quantum LED (QLED)). It might be that some one in Europe comes with a breakthrough, but already within Photonics21 the decision was made not to focus on display products, It is not expected that in this field we get our factories back. .

ii. **LED:** Light Emitting Diode (LED) are known since the 1980. Initially LED appeared in electronics products, but the real development this decade is the replacement of light bulb. This market is heading for a growth explosion around 2015, when low cost in combination with reliability and quality of light are surpassing the light bulb. This will require improved process control in front-end LED wafer production and in packaging & reliability (thermo cooling) in back-end. At high brightness the main problem is to control droop (reduction of efficiency in lumen/W at high currents). This will require advanced process control during manufacturing. But next to these technological question, one could add here, that the Chinese strategy is to become world leader in LED manufacturing as China already has 3000 manufacturers active in producing LED and a target of 1 Million jobs and $ 30 billion export turnover by 2015. The only chance for Europe are the intelligent and due to scarcity issues, the recyclable LED where the application will be offices and public usage and were complete light management systems communicate with the sensors and intelligence in the LEDs. .

iii. **OLED:** Compared to the expected growth in LED, Organic Light Emitting Diodes is a niche market. LED price levels will become so fast so cheap that the initial costs for OLED remain relatively high. It will pick up once Solar Organic Photo voltaics (OPV) scales up to large quantities. OPV, on its turn leveraging on thin film PV, will create large R2R equipment after which a change in the active layer from PV (light-on) to LED (light-out) becomes a incremental step to get on a price level of LED.

iv. **Solar PV**

a. Silicon family PV - Here, (today very thin) crystalline silicon wafers one sheet-to-sheet production on glass is common, although on larger and larger panel sizes, similar to LCD displays. AMS needs included Plasma enhanced and Atomic Layer Depositions on very large areas, better (less silver) contacts.

b. Thin-film family (silicon alternatives) - Here Roll-2-Roll systems become possible and replace the S2S type of production, while using less costly, but sometimes in the future scarce rare earth materials.

c. Organic (electronic) PV family - Once efficiency is improved, it offers the future R-2-R, AMS including better barrier coatings and TCO (Transparent Conductive Oxides) using less rare earth metals compared to the other families.
d. Organic (bio-inspired) solar families - Other families that will appear on the market are bio-inspired technologies (algae's and long term) and mimic the photosynthesis process to produced electrons and hydrocarbons out of sunlight, water and C1 (CO_2 or CH_4) carbon chains.

Solar PV AMS need to scale up from low volume sheet-to-sheet to high volume sheet –to-sheet (Crystalline Silicon) as well as for the thin film and organic PV families realized R2R production for very high-volume (and still affordable amounts of critical materials) in the order beyond thousands of square kilometer per year with a very low price per square meter (or Watt peak per Euro). (Ps. OLED will then use same R2R AMS as OPV, the only difference is the active layer).

In the current situation most large scale solar PV factories are built in China with mainly European manufacturing equipment. (Europe leads with 60% equipment production) Once solar PV become competitive without subsidy at today's electricity pricing, the market and therefore the production capacities will explode. All research is concentrated on cheaper to manufacture solar panels as well as higher efficiencies.

v. **Photonics Integrated Circuits** (PIC) or devices (Datacom, Sensors, micro lasers):

During the seventies the manipulation of electrons was possible and then during the 80-ties and 90-ties first, micro-, and later nano-electronics business of electronics chips (integrated circuits ICs) have emerged. Today, it is possible to manipulate photons and during the last decade the first optical building blocks (Photonic ICs) have become available. During the next decades a similar evolution as Moore's Law for transistors and microprocessors will evolve for photonic chips with the holy grail of an all-optic computer still behind our planning horizon. The most interesting development of the last years is the increase in Silicon Photonic chips manufacturing (CMOS) compared to the already older, but very costly GaAs and other 3-5 technology. At this moment Photonics chips requires costly fiber interconnections. Active building blocks at chip level are surface mounted micro lasers, still GaX based. Combining these building block with much cheaper Silicon Photonics building blocks leads to heterogeneous packaging. To ultimate goal is to expand the silicon photonics building block and simplify the costly packages of today.

Optical datacom chips and (erbium doped) optical amplifiers for fiber are already available, but more functions are needed in data-communication chips and several new functions are needed for other applications as e.g. medical instrumentation, safety-security-industrial control sensors etc. These integrated nano photonics sensors consume hardly any power (3mW versu 100mW) and become very small. Optical datacom chip are entering the computer domain too with Intel's LightPeak as USB 3 replacement by optical connections. In other words, ICs (silicon electronics) are now, but PICs (Silicon Photonics) are coming as new products.

vi. **Photonics components** (Laser sources, fibers, mirrors etc.): Europe has a strong position in lasers, but also in certain optical components as for example the stack of 8 atomic precise layers for EUV mirrors. These components as e.g. lasers are used intensify in more and more manufacturing as well as in medical instrumentation.

vii. **Optic Instrumentation** (industrial, medical, scientific): Existing industries will continue to grow due to smaller and more powerful optic devices and components.

viii. New Photonics devices still to come.: New photonic products are expected to be enhanced with nano technologies as quantum dots (Q or QD), photonics crystals, plasmonics, carbon nano tubes (CNT) and maybe grapheme.. These products are in the research and sometimes already starting in the development phase. However, we do know that in several years we need AMS that can handle materials at nano level at an industrial level. The question is not if that is before or after 2020, but how to intensify research as a basis for the innovation ahead and the ultimate manufacturing of these material systems latter on.

3.5.2. Manufacturing systems for photonics

Equipment for photonic advanced manufacturing systems:

In micro-electrons, the notion front- and back-end semicon industries are used. This notion can also be used for photonics. In general from substrate and carrier to the barrier layers is front-end, from singulation to distribution is back-end. LED front-end is 2-4” wafer production, followed by the backend where the LED devices or lamps are manufactured.

In photonic devices, manufacturing back-end is more expensive then in electronic chips due to the heating problems or the cost of interconnection fibers and active lasers. Photonic front-end resembles front-end electronics with CMOS and GaX (where X can be many other elemens as Arsenicum, Nitride, Indium, etc).

In the solar PV, the notion front- and back end is less common. As solar PV production moves to larger and larger glass sheets and in the future on R2R resulting in the same economies of scale as front-end CMOS foundries. After the large glass sheets of R2R a back-end step follows to create a solar panel that can be sold.

The reason for this separation is the fact that manufacturing equipment for front and back-end are very different. In front-end AMS are needed that control material depositions on nano-scale as dimension from nano to sub-micro are key, in back-end dimensions from micro-millimeter to centimeters are encountered. In front-end is it about process technologies as deposition, litho, coating, printing, etching, etc and the corresponding material knowledge are key. In back-end handling (mechatronics) equipment able to precisely by very rapidly position is needed with requirements of 1 micrometer within 1 second.

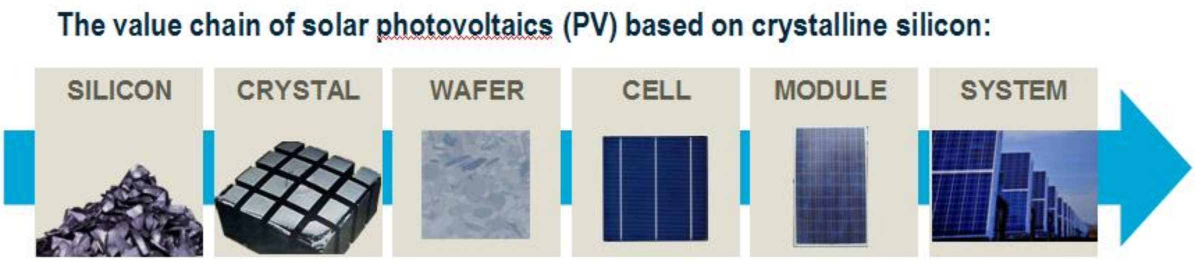


Figure 10 The value chain of solar photovoltaics (PV) based on crystalline silicon

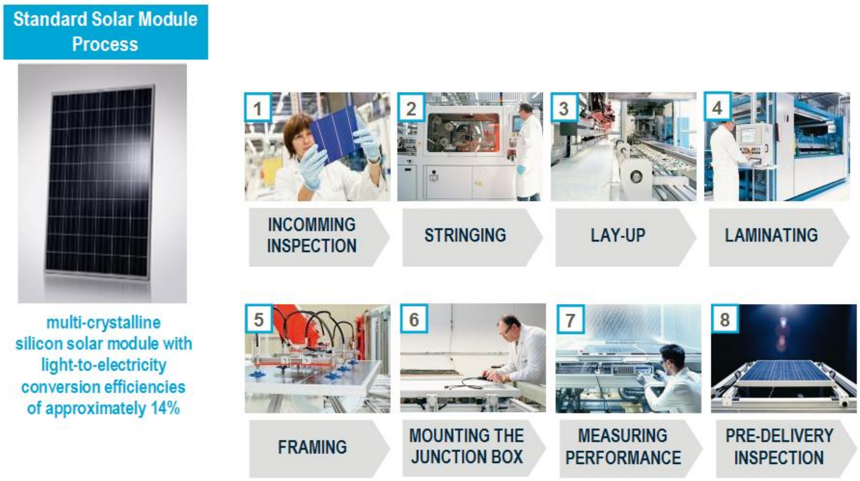


Figure 11 Standard crystalline-si module process (Reference: Q-Cells SE)

Materials for Photonic Products:

More than in any other area, all kind of nano-structured materials in the scientific pipeline are included in photonics products such as Quantum Dot (QD) LED, OLED, PV etc. The production of these materials in sufficient quantities and stability (before being embedded in the bulk product) is, similar to photonic equipment, a key technology to become successful.

Also in the photonic area, industry faces scarcity problems with rare-earth materials. This is in particular the case for the large area products (solar PV/OLED/Displays). The only alternative in the long run is organic, as in OLED and OPV, with enough efficiency.

Specific requirements for solar PV/OLED/Displays:

In Large Area Front-end Solar/OLED/Display, there is one new requirement for AMS; the surface has an extremely high flatness requirement and during production, any dust particle on that large surface must be avoided.

For display, a different manufacturing need exists. It is expected that small flexible displays as needed in all kind of mobile devices, eBooks, user interfaces in cars, but ultimately in all intelligent products that will be around us. Here Large Area is not so much an issues as with Solar PV panel and large size TV's. Such large size displays are an Asian led market. But for flexible display new factories are needed that better fit Europe's manufacturing conditions: low resource and much innovation needed.

Specific requirements for SSL LED and optical/nano-photonics chips:

This value chain is very similar to nano-electronic front-end CMOS wafer and then back-end packaging. Albeit similar to GaAs IC production in silicon/CMOS production, the different materials used in photonics are in majority GaX or 3/5 based and not welcome (read forbidden) in a CMOS front-end wafer fab. Also the front-end processes for GaX are still more difficult to control due to much higher processing temperatures. Where in Silicon 300 mm wafers are dealt with, in e.g. GaN growing MOCVD processes of 2 or 4 inches wafers are seen as large. Even at that small size a large amount of dies have such a variance in quality that binning it the only option to get enough die's within specs.

Another challenge is the back-end as packaging LED and PIC is still extreme costly compared to the front-end part. HB (high-brightness) LED cannot become too warm/hot and need a large heat sink. And Photonics ICs still need either a fiber coupling or hetereogeneous packaging with a surface mounted laser on the die.

A proposal for four characteristic Factories of the Future:

1. Highly integrated, reliable and still recyclable LED
2. Very high output (Square km) R2R solar PV production
3. Silicon Photonic fab + hetereogenous back-end (on board laser & functional component in one package) + integrated nano-photonics design houses
4. Photonics instrumentation manufacturing for lasers, optic data-com, photonic sensors,

3.5.2. Analysis of the current situation worldwide and in the EU

The world market grew in 2008 to 270 billion Euros, with e.g. lighting (lamps, components, materials, equipment) 80 Billion Euro creating beyond the photonic market itself a 180 Billion Euro market in luminaires and lighting systems & services. The photonics industry in Europe consists of more the 5000 companies and around 290.000 jobs. With most attention in Europe focused today on solar, one should not forget the importance of the lighting market for Europe with companies such as Philips and OSRAM, as well as the unique strength of Europe in photonic devices in health, industrial lasers, and optical datacom and sensor chips. Upon these last two products, a leading telecom industry has been built and/or is now used in security and automotive safety[23].

[23] Photonics.21

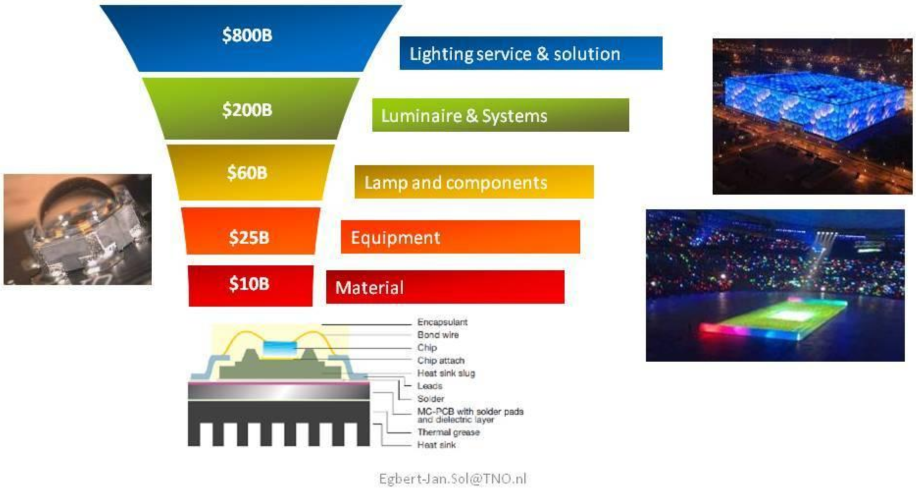


Figure 12 Value fountain for LED

4. Deploying AMS in the EU: scope for policy interventions

Europe has, since the industrial revolution, successfully concentrated on value creation in factories. Nevertheless, instead of job creators factories were seen as environment polluters. Over the last decades, governments in Europe have also learned some bad lessons from supporting some losing industry sectors at the taxpayers' expense, which gave a negative image to industrial policies.

Meanwhile, the European Internal Market was created and European rules banned specific countries from adopting policies aimed at protecting national companies (state aid). As a result, the EU has become the most open and competitive market in which only pre-competitive research for product innovation is funded by governments. Europe has concentrated on innovation policies, but has not developed industrial policies. European countries cannot develop an industrial policy on their own. **Therefore there is a need to define an industrial policy answer at European level for creating a level playing field for European manufacturers to compete at a global level.** The recent European Commission Communication "An industrial policy for the globalisation era", which proposes a comprehensive pan-European strategy and policy is a right step forward to address industry needs to this end.[24]

Other developed or developing nations and regions in the world developed their own models for industrial policies whilst Europe built up the Internal Market regime. Today, we observe in Asia and Americas highly protectionist and state-supported industrial development models against a European Internal Market which is open to competition internally and externally. Industry policies in USA are heavily defence oriented and everything but open if

[24] European Commission Communication, *An integrated Industrial Policy for the Globalisation Era - Putting Competitiveness and Sustainability at Front Stage* {COM(2010) 614}

it is labelled national security. Moreover, the state capitalism of China with its explicit industrial 5-year plans does not allow for a real open market. **The global playing field is not an equal level playing field for European manufacturers.** Especially, in high-tech sectors (ie. KETs) in which high volumes of investment is needed to build factories and to finance costly R&D research, European manufacturers find themselves in a disadvantaged position. They have to compete with state-supported companies in unequal conditions in world markets as well as in the Internal Market in the absence of strong market surveillance.

The Internal Market has played an essential role for the development of an innovative and competitiveness European industry. It has to be maintained and further integrated. In the meanwhile, the current global economic conditions requires a European industrial policy response to developments outside Europe which impact on the European manufacturing base.

Then, Europe needs to combine **innovation policy with industrial policies.** In Europe, innovation is paid for creating value 'once' whereas Asia creates repetitive value by implementing policies which support industrial activity. In Europe, the selection of an innovation policy for (new) photonic products, for example, should be extended to an industrial policy. In other words, combining a photonics innovation policy with industrial policy should lead to creation of the Solar R-2-R Photonics Factory of the Future, or similar an Electronics Factory of the Future or a Resource Efficient Process Factory of the Future.

This section provides recommendations for policy-makers with a view to streamline framework conditions in the EU to enable the take-up of key manufacturing technologies.

4.1. SWOT analysis for AMS in the EU

Basing on the conclusions of the analysis of the position of Advanced Manufacturing Systems in the value chain of each KET, the SWOT analysis of AMS in Europe is provided below. As per this analysis, the following section provides policy recommendations to facilitate and improve the deployment of AMS in Europe.

Strengths	**Opportunities**
Top class engineering tradition, expertise and know-how Broad technology basis Availability of a sound structure Technological and manufacturing clusters Cultural diversity in Europe	To enhance technological leadership To tap the potential of new (e.g. green industries) for growth and jobs creation To provide top class education To pioneer development for all industry

Weaknesses	Threats
Costly research Complex and bureaucratic R&D support structures Investment risks for individual private partners high Growing deficit of skilled staff Costly up-scaling of processes Public innovation policies focused on end of the value chains Barriers to commercialization Access to finance in capital markets Fragmented European markets Low labour mobility	Globalisation Application of precautionary principle when faced with new technologies State-supported rise of new industries Asymmetric conditions for trade in spite of WTO framework Ageing society, lack of skilled workforce Non-smart regulation Investment in R&D in other regions brings leading edge of manufacturing to other regions e.g. 450mm

4.2. Priorities for policy intervention

Europe is a strong global actor in technology development, but it has a historical weakness in developing technologies to market maturity. Many achievements fail to reach the market and disappear in the "valley of death". In some cases, research results benefits to industrial actors outside Europe which reap the economic benefits by commercializing them.

The reasons for this vary; research partnerships may fail to bring together all the strategic partners in the value chain in the case of which research results cannot go beyond the pre-competitive stage to reach the market. Funding for technology may not be sufficient and large-scale pilot projects may be required to support the take-up of young and emerging technologies. Sometimes, a lack of capital, the absence of entrepreneurial individuals or the inexistence of favorable framework conditions for business prevent companies from commercializing new innovative technologies. The **Valley of Death** imagery depicted by US Congressman Ehler[25] (see figure 13) refers to the difficulties in transition from basic research to applied research in the absence of sufficient public financing and/or private capital. It also refers to the difficulty of attracting private capital to support promising technologies which are at the development stage and, thus, cannot validate their commercial potential. It is possible to extend the right side of the gap to product development and firm creation. Europe should aim to seek to **bridge the gap between research and the markets**. Several conditions need to be met for making this happen.

[25] Vermon J.Ehlers, *Unlocking Our Future: Toward a New National Science Policy* - A Report to Congress by the House Committee on Science, Washington, D.C.: Government Printing Office, 1998. http://www.access.gpo.gov/congress/house/science/cp105-b/science105b.pdf

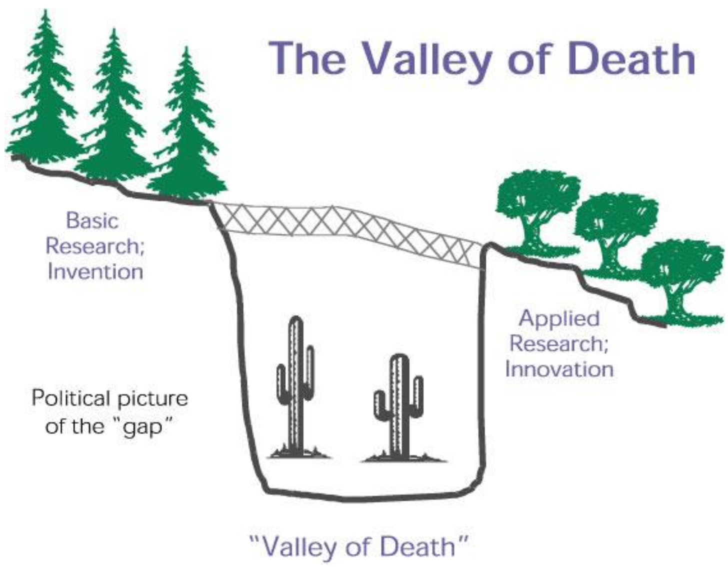


Figure 13 The Valley of Death image[26]

One of the main findings of the Advanced Manufacturing Systems Working Team (AMS WT) is that R&D follows the manufacturing location. Europe needs to **maintain a manufacturing base** if it is to support the deployment of AMS in Europe. The discussions in the AMS WT and the Open Day on AMS clearly show that innovation happens simultaneously at key stages of the **value chain** and with the involvement of multiple sectors. Networking and partnerships are key words for new technology development in advanced manufacturing systems.

In Europe, industry is negatively influenced by a lack of political commitment and vagueness about the support manufacturing will receive in the future. The predictability of regulatory regimes influences companies manufacturing companies' decisions whether to invest or not in Europe. Europe should develop **political foresight** and a long term **vision** for manufacturing. Governments should send strong positive signals to manufacturers to ensure the stability and confidence industry requires before making decisions for large-scale investments. Policies should aim at retaining manufacturing activity in Europe and establish the right framework conditions for **attracting European and non-European investments (factories).** Innovation will go happen where manufacturing is, that's why attracting foreign manufacturing investments is equally important.

The availability of a favourable business environment (ie. tax regime, access to finance etc), a sound **infrastructure** and competitive **energy** prices will play an important role in attracting manufacturing investments. Moreover, Europe should ensure the access of manufacturing companies to **raw material** at competitive prices.

[26] Branscomb M. Lewis and Auerswald Philip, *Between Invention and Innovation: An Analysis of Funding for Early-Stage Technology Development*, Report, National Institute of Standards and Technology- NIST GCR 02-841, November 2002. http://www.atp.nist.gov/eao/gcr02-841/gcr02-841.pdf

Strategic key enabling sectors require special attention. The return of support key enabling technologies for economy and society is very high. The high costs involved for start-up and R&D efforts may require sector-specific measures.

A significant challenge for advanced manufacturing in Europe is the rising price of RD investments due to an increased competition over high-end technologies and short product life-cycles. The **continuity of research funding** is essential to help European companies keep pace with international developments. No individual actor is able to handle the amount of costs required to develop leading-edge technologies, **cooperation between public and private actors** (ie. PPPs) and the **government-industry-academia triangle** should be further developed and supported. Industrial guidance of public policy and investments is essential for the efficient use of resources. **Research programmes need to be re-thought and re-designed** to aim at stimulating innovation along the value chain rather than generating individual technology or product development. The availability of **access to funding** at all levels (national, regional, European) should be ensured and manufacturers should be enabled to chose between different sources or combine them for financing innovation.

Innovation comes from people. Europe needs to bring up skilled engineers and technicians and ensure that they upgrade their skills throughout their carrier. AMS are knowledge-intensive.

New technologies which cross over the 'valley of death' and reach the market may not necessarily reach a critical mass and become self-sustained immediately. High investments in new technology do not often pay off in the short term. The existence of **market pull forces** may be crucial for creating economies of scale. Smart regulation, smart public procurement, standardization and effective market access to third countries are important factors which facilitate the take-up of new technologies, products and services on the market. Tools to support first industrial units should be developed.

European innovation and industrial policies are designed to stimulate competition for innovation in the Internal Market. However, today the biggest challenge for Europe is to tackle **external competitive pressures** and compete with emerging powers in Asia and Americas. Europe should identify the industrial policies implemented in other parts of the world which distort the global playing field and the competitiveness of European manufacturers. And then, Europe should formulate an effective response. European **trade policy** should complement European industrial policies so as to help put an end to unfair government practices and even the global playing field.

HIGHLIGHTS – Priorities for policy intervention

Maintain a sound manufacturing base in Europe

- *Industry needs political leadership and a strong clear support for manufacturing*
- *Attract European and non-European investment (factories) to Europe*
- *Guarantee a sound infrastructure, competitive energy prices and the security of raw material supply in Europe*
- *Mobilize and re-organize resources at all levels to support strategic and competitive key sectors which have a future in Europe*

Focus on tackling historical weaknesses of Europe (valley of death)

- *Rethink and redesign research and innovation programmes to enable innovation along the value chain from technology providers down to end-users*
- *Provide public support for scaling-up new technologies and large-scale pilot projects to help bring research results closer to markets*
- *Develop tools to support the first industrial units until they become self-sustained*
- *Ensure the availability of capital to cover the gap in the valley of death*
- *Promote entrepreneurship to encourage innovative companies to commercialize research results*
- *Deploy market pull forces for the creation of critical mass*
- *The availability and continuity of funding is crucial for high technologies*
- *AMS are knowledge-intensive and the availability of skills is vital*

Ensure a global level playing field

- *Complement industrial policies with a sound, pro-active trade policy which push for open markets and global rules for trade and competition*
- *Focus on tackling unfair competition coming from non-European economies*

4.3. Individual Policy Areas

Research and Innovation

Innovation Partnerships:

Europe's strength in AMS lies, to a large extent, in the existence of **strong, competitive and well-connected networks** composed of equipments manufacturers, technology providers, engineers, academic and research institutions in Europe. The existence of such networks enables innovation in advanced manufacturing technologies and help create real benefits for industrial actors across sectors.

Today, innovation starts **at key stages of the value chains simultaneously** and involve multiple sectors (from material producers to equipment manufacturers and end-users**). Cross border cooperation** along the value chains and cross industry partnerships are crucial to enable the deployment of advanced manufacturing technologies. For some KETs, the communication and networking between actors along the value chain is strong (ie. semiconductors). However, in relatively new industries such as the biotechnology industry, finding innovation partners may prove to be difficult.

There should be an **external dimension** of innovation partnerships. For some KETs, the majority of end-users or customers are outside Europe. Technology development is realised today through the early engagement of end-users in joint R&D activities with manufacturers. In the prospect of high growth and increasing number of customers in non-European countries, especially European SMEs need a reliable framework to develop such partnerships with their value chain which reaches out of Europe.

- Establish collaborative partnerships between industry, universities and research and technology organizations
- Bring world-leaders in the value chain with key government offices and international academic institutions (eg. British AMRC model)
- Implement innovation through public policies much nearer to “real life” business models by an approach that allows innovation to start at key stages of the value chains simultaneously and involving multiple sectors.
- At European level, leverage on the positive results obtained from PPPs. Adopt an entrepreneurial-minded approach to industrial policy in which industry cooperated with academia and government and guides public policy investments.
- Create the framework which would enable European SMEs to enter into partnerships for technology development from Europe with partners/customers in non-European countries. Reduce IPR risks and costs for creating such partnerships.

Research funding:

The establishment of production plants in KET areas require **high investments** at the **start-up** stage. Moreover, maintaining competitiveness in high-tech industries require **continuous investment** in R&D&I given the short product life-cycles and intensive global competition.

Europe has a significant strength in the design and development of advanced manufacturing technologies, however many achievements fail to reach the markets and/or end up being exploited by external actors outside Europe (ie. PV technology invented in Europe, but China makes and sells solar panels to Europe today**). Research and development funding programmes** need to be re-designed so as to allow technology developers to overcome the ‘valley of death’ and transfer the new technologies to markets. Europe should **prioritize strategic technologies** and use limited public resources wisely to support the development of technologies which address **societal challenges and contribute to sustainable development.**

- Shift the focus of research programmes from single technology or product development to the creation of innovation along the supply chain and real benefits for all partners.
- Up-scaling is critical in the development of any new process. Provide support for the demonstration of proof of concept at industrial scale in order to promote the deployment new technologies. Enable critical mass creation.
- Implement large-scale pilot projects which link the basic research stage to a higher validation level via a series of tests on demonstrators.
- Invest in centers of excellence focusing on KET topics for validating and showcasing new manufacturing processes
- Improve credit lines and funding by combining various sources (regional development, national, European, private)
- Create one-stop shops which enables manufacturers to choose or combine different sources of funding instead of being
- Design better exploitation, IPR and risk management schemes for public funded projects.

Intellectual Property Rights Protection

- Make the single European patent a reality to reduce costs of translation and paperwork for SMEs active in cross-border business
- Improve the European capacity to tackle the counterfeiting in global markets and the entry of non-European counterfeited manufacturing equipment to Europe.

SMEs and entrepreneurship

SMEs are important actors in technology development. However, unpredictable and costly regulations sometimes hamper their innovation potential. Access to capital is essential to bridge the gap between basic research and markets. Additionally, SMEs may have difficulties in reaching potential innovation partners in other countries and miss out important business opportunities (ie. technology transfer, technology partnerships). Even if they find these partners, red-tape and disparities between rules in countries across the Internal Market may hamper cross-border innovation. Awareness increasing and support for SMEs (simplification, better regulation , technology-transfer etc) can help reduce these costs and remove obstacles to cross-border innovation.

- Ensure the availability of credit guarantee instruments for innovative SMEs
- Diversify sources of finance for SMEs: develop alternatives to bank lending and help SMEs access to capital markets
- Encourage entrepreneurship by cutting red tape and facilitating cross-border investments.
- Facilitate the access of SMEs to European research funding through the simplification of rules and paperwork.
- Create the long-awaited European Private Company Statute to help facilitate the cross-border activities of SMEs and improve market access
- A shift to advanced manufacturing may require radical production and organization change. Provide support and consultancy for SMEs to manage risks and costs.
- Facilitate the access of innovative technology provider SMEs to business support for assistance against risks.
- Support SMEs for acquiring better capability to manage patenting, licensing or to expand their businesses (ie. by joint ventures) and benefit from economies of scale. (Few SMEs turn to big companies. They may have difficulties in managing high demands for their technology from big customers. Being bought or selling the technology to others is often an inevitable consequence.)

Education and training

- Combine the education of world class scientists with the education of highly skilled engineers to manufacture and handle new materials and technologies at industrial scale.
- Ensure continuous skills development through life-long learning. Training should also address skills required for exploitation and cooperation along the value chain.
- Promote math and science studies, lifelong learning, opening up our education system, mobility between industry and academia and facilitate the re-skilling of personnel.

- Send strong positive political signals about the future of European manufacturing to attract people to carriers in engineering and sciences.

- Review visa policies to Europe which is currently subsidizing studies of foreign students who take the knowledge they acquire in Europe back to their home country as they cannot get visa. Rethink the EU Blue Card)

Standardisation

- Use standards to facilitate the adoption of advanced manufacturing systems by end-user sectors

- Stimulate the expansion of green technologies through standards

- Increase Europe's clout in global standard-making. Improve the presence and influence of Europe in global standards-setting structures such as ISO. Europe is not leading the world in standards development.

Cluster policy

- Review the cluster policy. Establish clusters not only in poor regions but spread them all over Europe.

- Focus on establishing world-wide leading clusters which lead to critical mass.

- Aim at innovative clusters. Clusters fostering innovation should be prioritized.

- Promote not only physical, but also virtual clusters

Market pull (through public procurement, smart regulation, standards)

- Use smart public procurement for infrastructure investments (lighting, energy, transport etc) and help new technologies flourish in Europe.

- Use investment tax credits at national level to stimulate the modernization of the industrial base and the pursuit of investments in the area of energy efficient technologies.

- Stimulate, through investment tax credits and loss offsetting mechanisms, investment whether in research or in investment in capital assets.

- Use standards to prepare the ground for the acceptance and the expansion of new technologies in markets.

- Ensure the early engagement of public (industry, markets and consumers) for public acceptance of new technologies. Provide for risk management.

State Aid policy

In order to turn advances in KETs to industrial activity and enterprises costly research is followed by costly investments for plant construction. There is a long time-lag between the start up and the time heavy investment in new facilities starts paying back. First production units need to be supported until they reach a critical mass.

- Develop instruments to provide support for first industrial units

Regional policy

- Use European regional policy instruments to support scaling-up of new technologies

Energy

The security of supply and energy prices will affect future investment decisions in Europe, In terms of energy costs, in Italy, Germany and other member states, energy costs are double as high as in Malaysia.

- Ensure the security and the sustainability of energy supply (ie. step up investments in renewables)

- Liberalise and integrate European energy markets to ensure competitive energy prices for manufacturing companies.

Trade

Free and fair trade is essential for a global level playing field and facilitated market access. We have to fight protectionism in the internal market and on world markets to help innovative manufacturing companies reap the economic benefits of their innovations by exporting. Barriers to trade prevent companies from exploiting the full market potential of their products and services.

- Promote identical international regulations/standards

- Ensure access to raw materials at competitive market conditions is essential.

- Imports: Improve market surveillance to protect the competitive power of European manufacturing inside the Internal Market against machinery/equipment imported from non-EU countries which do not comply with EU regulation and standards.

- Push on a global level for the enforcement of IPR protection, which is key for the protection of the innovative power of European manufacturers outside Europe. Developing the WTO framework without reaching damaging compromises should be the focus.

- Improve market access for green products through a global consensus at WTO level and in bilateral agreements.

- Prevent key suppliers from restricting the export of raw material through taxes and licenses. Ensure the security of supply for manufacturing companies which plan to invest in Europe.

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