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DRAFT

Factories of the Future PPP

Strategic Multi-annual Roadmap

Prepared by:
Ad-hoc Industrial Advisory Group
Factories of the Future PPP

Note: This document is a first DRAFT resulting from the work of the Ad-Hoc Industrial Advisory Group of the Factories of the Future Public Private Partnership. A revised version of this document after consultation to the wide stakeholders community is expected in the coming months. For any information or to provide comments, please contact: rbueno@fatronik.com.

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1. Introduction and Background

Introduction

The Factories of the Future Public Private Partnership (FoF PPP) addresses the development of the next generation of production technologies that will be applied from 2015 onwards. The overall budget contribution to the initiative amounts to €1,200 million between 2010 and 2013, to be equally shared by the private sector represented by the European Association for the Factories of the Future (EFFRA), an initiative of the Manufuture European Technology Platform, and the the European Commission.

This Draft Strategic Multi-annual Roadmap has been prepared by the industrial representatives in the Ad-Hoc Industrial Advisory Group for the Factories of the Future Public-Private Partnership (AIAG FoF PPP), which was created in March 2009 with the mandate to help defining the research content of this initiative. The present document lays out industrial research priority areas for the implementation of the Factories of the Future Public-Private Partnership covering the period 2010 to 2013.

The prepration of this Draft is based on an initial stakeholders consultation process, including the European Technology Platforms on Advanced Engineering Materials and Technologies (‘EuMat’), European Steel Technology Platform (‘ESTEP’), Future Textiles and Clothing (‘FTC’), Photonics21 (‘Photonics’), Robotics (‘EUROP’), Networked European Software and services Initiative (NESSI), European Platform on smart systems Integration (‘EPoSS’), European Nanoelectronics Initiative Advisory council (‘ENIAC’) and Advanced Research and Technology for Embedded Intelligence and Systems (‘ARTEMIS’) and Future Manufacturing Technologies (‘MANUFUTURE’) with its working groups and sub-platforms namely, Agriculture Engineering Technologies (‘AET’), Clean Environment Technologies (‘CET’), European Concept, Foot Wear including Sports, Micro Nano Manufacturing (‘MINAM’), Rapid Manufacturing (‘RM’) and European Tooling. Therefore, it followed a cross-sectoral and cross-discipline approach.

The present document will be put on open consultation among public and private stakholders around Europe in July 2009. The final Strategic Multi-annual Roadmap for the FoF PPP is expected to be presented by the AIAG FoF PPP to the European Commission in December 2009.

The Draft Strategic Multi-annual Roadmap considers four sub-domains devoted to Sustainable manufacturing, ICT enabled intelligent manufacturing, High performance manufacturing, and Exploiting new materials through manufacturing.

The focus is on supporting collaborative research projects oriented towards industrial application. Therefore, priority areas should have industrially relevant demonstration elements, specially for the benefit of SMEs. Increased demonstration activities are foreseen towards the end of the period in 2012-2013. Project findings are expected to be implemented in production improvements within two years after the conclusion of the project.

Background

This Draft Strategic Multi-annual Roadmap for research and technological development in the field of manufacturing has been developed taking into consideration the main social, technological, environmental, economical and political drivers and the main market drivers for the manufacturing sector. On this basis, the main R&D needs have been derived, so that the achievement of the proposed goals will allow the European industry to face its main challenges in the next years.

In today's economic situation any research in technology in Europe would need to comply, as this initiative will do, with two requirements: the results of the research should start to pay back tax payers' money after four years and should make a significant contribution to the sustainability of society in Europe

A sustainable business in Europe not only has to be sustaining in terms of energy and resource efficiency but it also has to stress the fact that its role is to sustain its workers and employees. For instance, there are many family type businesses in Europe that have functioned very successfully according to these rules over decades.

In addition, a factory with a European footprint has to be based on European ethics. This will be its strength. The influence of these ethics on business success has to be researched and understood. Technology development has to be placed into such a context if it wants to achieve the goal of really making a contribution to the European society. This requires rethinking of internal strategies as well as of mechanisms on how to operate, evaluate and use the PPP projects.

The "Factories of the Future" initiative arises as the European response to the current economical crisis. This crisis shows that sustainability as a strategic goal not only focuses on maintaining an adequate workforce but also on rewarding the investors, as opposite to other strategies. Energy and resource efficiency as well as environmentally friendly operations are logical consequences of the proposed way forward. This has led to formulate "The Factory made in Europe" as the product of the future, under the auspices of the Factories of the Future Public Private Partnership (FoF PPP), addressing simultaneously competitiveness and sustainability challenges.

There are consequences if one adopts this view regarding social sustainability. A factory is not any longer a smart conglomeration of autonomic machines and processes that can be shifted to any other location in the world easily but it is an entity which focuses on person – machine cooperation in an intelligent way in which advanced technology is as important as a sound ethical basis for stabilizing the local and global human system called enterprise. All this will directly impact on the sustainability of the European manufacturing industry and its most important social impact will be keeping manufacturing (and hence wealth creation) related jobs in Europe.

As an outcome of the strategic reflections it is agreed that the European manufacturing industry needs a paradigm shift , from cost cutting to knowledge-based value adding, in order to achieve a sustainable and competitive system. Any future technology cannot be regarded as a standalone entity.

As a result of many workshops and many strategic discussions within European stakeholders of manufacturing industries and researchers, a successful strategic development of high added value technology should consider the following strategic sub-domains:

- Sustainable Manufacturing
- ICT enabled intelligent manufacturing
- High performance manufacturing
- Exploiting new materials through manufacturing

Technology, even though it plays an important role, is only one term in the equation that leads to economic success. Human skills, the form of organization, the mid and long term strategic focuses and the rules for financial decisions are at least as important. Knowledge based Innovation is the key concept: innovation carried through to a new service, a new applied method or a new product offered and sold to customers.

The use of the PPP projects results and the successful implementation of new technologies in European companies should be supported. Therefore, for the success of the Factories of the Future initiative at this stage of development in European industrial history, it is important to apply any mechanism available to make industrial enterprises in Europe successful.

By developing a public-private-partnership (PPP), there is commitment from both government and business to invest in new technologies and innovation that have a sustaining effect on business for the long term. For that reason, it is the aim of this roadmap to inspire industries to develop and demonstrate knowledge based innovation leading to its sustained competitiveness.

2. Vision and strategic objectives

Europe is one of the main players in the global economy and manufacturing industries contribute to a large extent to this situation. In the globalised world of the third millenium the following social, technological, environmental, economical and political (STEEP) factors are the main drivers for the current and future economy: Globalisation of the economy, Climate change, Ageing population, Public health for all, Poverty and social exclusion, Loss of bio-diversity, Increasing waste volumes, Soil lost and Transport congestion.

In this context, many enterprises are struggling to survive in the currently turbulent markets, and some are leaders and effectiveness. Others seek the future in services and emerging technologies. Many companies in the manufacturing area are leaders in the world market or have a high market share. Their base is technical innovation and strong customer-orientation. They are known worldwide as high performing manufacturers and deliverers of high-quality technical products. They all need to be orientated to the future vision and strategic development of factories in general as well as to the concrete plans for the specific changes to the particular factory system. This makes it necessary to implement the "Factories of the Future" initiative and secure and share experiences of the structural changes required to transition from the factory system of the past to more competitive and sustainable factories.

A holistic approach encompassing economy, society, environment and technology related actions is needed to face the situation. From the manufacturing R&D perspective, these global drivers lead to a key challenge, a new paradigm and proactive response: Competitive and Sustainable Manufacturing.

Competitive Sustainable Manufacturing (CSM),

- interacts with the Social, Technological, Economical, Environmental and Political (STEEP) context
- generates wealth, sustains jobs, manages human and physical resources: i.e from materials to energy, from food to intermediate and consumer products.
- concerns High Added Value products/services, processes sustaining their life cycles, business models, stakeholders involved
- relies on stakeholders ranging from: Industry, to Research Institutes, Universities, European, National, Regional Public Authorities and intermediate Organizations
- sustains the Knowledge generation, diffusion, use process
- implements the Research Innovation Market Value Chain
- encompasses from macro to field level

CSM requires the transformation of the European Manufacturing Industry into a High Adding Value (HAV) and Knowledge-based Industry, aiming at global leadership, through HAV Knowledge-based products / services, processes and business models.

As previously stated, many enterprises are struggling to survive in the currently turbulent markets, some are leaders in markets and effectiveness. Others seek the future in services and emerging technologies. They all need to be orientated to the future vision and strategic development.

The strategies envisaged aim at:

- increasing the efficiency of survival and transformation of enterprises to the requirements of customisation and sustainability,
- boosting the level of technologies of products and production towards global leadership,

- globalizing Europe as producer of factories and factory equipment (lead markets) with intelligent products and new business models,
- activating the potential of emerging technologies and developing solutions for emerging markets.

In the current turmoil, the pursuit of CSM is fundamental for relaunching the “real economy”, as the new frontier. The USA and European Union are already addressing it. To pursue CSM, the Manufuture European Technology Platform has developed the necessary Strategic Intelligence: i.e. Vision 2020, the Manufuture Porto Manifesto with its action lines (Stimulate private R&D investment, foster collaboration within a research network, prepare appropriate standards and regulations, overcome fragmentation in EU R&D and leverage EU’s science and research potential), the Strategic Research Agenda and Roadmaps and related implementation framework.

The recent launch of the European Economic Recovery Plan calledfor a “Factories of the Future Initiative”, based on the Manufuture European Technology Platform and related Sub-Platforms, including European Technology Platforms in the field of manufacturing.The development and implemention of the “FoF PPP”, requires:

- a Strategic Intelligence: Vision, SRAs, Roadmaps, as provided by Manufuture and related Platforms,
- a Reference Model for action, conceiving Social, Technological, Economical, Environmental and Political (STEEP) context evolution scenarios, deriving potential “Factory System” concepts, at given time horizons and, finally, defining Enabling Technologies necessary to implement them,
- human, infrastructural and financial resources.
- a constant revision of the above, following a “rolling approach”, to account for STEEP context and European Policy changes.

In particular, the general reference model, devised and adopted at this stage, links industrial and research priorities and actions through the roadmap developed and reported in this document. To account for the complexity and use, at its best, the work done by Manufuture and other platforms, the roadmap has been structured on 4 domains:

- Sustainable Manufacturing
- ICT enabled intelligent manufacturing
- High performance manufacturing
- Exploiting new materials through manufacturing

The development and implementation of the Factories of the Future Public-Private Partnership (FoF PPP) leads to the preparation of the current Factories of the Future PPP Strategic Multi-annual Roadmap (2010-2013) which will have the objective to help EU manufacturers across sectors, in particular SMEs, to adapt to global competitive pressures by increasing the technological base of EU manufacturing through the development and integration of the knowledge based enabling technologies of the future, such as engineering technologies for adaptable machines and industrial processes, ICT, and advanced materials, covering the production value-chain from raw materials to semi-finished and to final products.

3. Main industrial needs and related R&D challenges

Introduction

In order to survive the challenge of global competition, the European manufacturing industry will be increasingly forced to concentrate on specific key factors enhancing a wide competitive advantage through long-term innovation at the factory level.

A key factor in strengthening the European leadership in Product Engineering and Manufacturing Systems Development will be the ability to achieve cost efficiency, performance and robustness of manufacturing systems, within the increasing <u>product variability</u> and the continuously <u>changing production volumes</u>, both discrete and continuous.

Sustainable Manufacturing Systems - Evolution Drivers

Drivers	**Factory Cost**	**Flexibility Convertibility**	**Optimized Shop Floor Mgmt**	**Maintainability**	**Environment & Safety**
Production System	• Standard & lean • Low cost solutions • Modular and re-usable (“agile”) • Plug & Play modules • Industrial wireless applications • Life-cycle approach	• Flexible/Agile Systems • Re-programmable • Convertible solutions • Intelligent and rational use of automation vs. operators	• Integration of shop-floor automation at plant level • Intuitive HMI & field data collection and analysis • Virtual engineering • Digital Manufacturing (modeling & simulation)	• Local sensors for process monitoring • Remote diagnostics • Tele-service (WEB network)	• Design for safety and ergonomics • Energy saving applications • Innovative process (new joining technologies, MQL machining, …) • Innovative materials • Dismantling

In the actual scenario of global market competition the main industrial needs and R&D challenges to achieve a higher competitiveness of the manufacturing systems may be described in terms of general evolution drivers, as follows:

a) <u>cost efficiency</u> as pre-requisite, with extensive adoption of standards in production machinery, equipment and controls and massive use of lean, low cost solutions;
b) <u>low Time To Market</u>, from concept to market of new products thanks to ICT applications, which will more and more expand their reach in manufacturing industries;
c) increased focus on high-end components/goods through the implementation of enabling <u>processing technologies and materials</u> (nanotechnologies, engineered materials, <u>embedded intelligence</u>, etc);
d) quick and easy <u>convertibility/re-configurability</u> through a modular approach in factories archetypes, in order to maximize model independency of machinery and continuous re-use of existing infrastructures (<u>brown-field approach</u>);
e) higher and stable <u>product quality</u> through increased process robustness and easy maintainability (adaptive controls, remote diagnostics, etc), thus impacting directly manufacturing key performance indicators (KPI);
f) <u>higher productivity</u> under <u>better safety and ergonomics conditions</u>, through an upstream integration of workplace optimization for human well-being;

g) optimised consumption of resources through the use of energy efficient machinery, renewable power sources and extensive recovery of heat and dissipated energy.
h) Better reusability of systems and applications towards global interoperable factories, able to provide services and develop products, anytime, anywhere, independently of the systems, applications, culture or language in use in the different sites.
i) Global knowledge merging for a "seamless knowledgeable factory of the future". Increased global knowledge, will result in better production, less costs, less time to market, and enlarged opportunities for manufacturing business.

Manufacturing related R&D shall focus on incremental transformation of the main characteristics of the competitive scenario, towards "sustainable life-cycle cost": re-usable, flexible, modular, intelligent, digital, virtual, affordable, easy-to-use, easy-to-maintain and highly reliable "Factories of the Future".

Sustainable Manufacturing

Sustainability (balance in economic growth, social well-being and environmental protection) will be assured through enhanced environmental awareness in systems design and sustainable manufacturing processes and supply chain. The new Eco-Factory models and green product manufacturing would allow to design and produce sustainable products with drastically reduced energy consumption, enhanced advanced manufacturing processes based on renewable resources and safety and ergonomics for operators, addressing:

- Specific factors would allow to minimize the environmental impact and the resources consumption: new tools; dry minimum quantity lubrication (MQL) machining; new control strategies aimed at energy efficiency; and weight reduction for movable parts.
- The safety/ergonomy of manufacturing facilities will be ensured through advanced sensor applications, volumetric protection on machinery, intrinsic safety of systems, vision systems, and machinery intelligence for operator protection.
- The cost efficiency for enhanced competitiveness will be a pre-requisite for all sustainable manufacturing solutions, by means of modularity, agility and re-configurability and enhanced "Plug & Play" interoperability, allowing integration of new capabilities, as well as extensive adoption of standards.

ICT enabled intelligent manufacturing

The contribution of ICT aims to improve the efficiency, adaptability and sustainability of production systems and their integration within business processes in an increasingly globalized industry, requiring continuous change of products and production volumes.

Advanced manufacturing systems shall incorporate a series of innovative technological solutions related to:

- high-speed to market;
- manufacturing systems complexity reduction;
- fast re-configuration and wide re-tooling capacity of production systems;
- ease-to-use systems;
- advanced shop-floor management;
- Production network and Integrated Enterprise Management.

High performance manufacturing

The research activities under this area aim at enhancing European leadership in product engineering and manufacturing systems development. A key factor of competitive advantage will be the capacity to achieve cost efficiency, performance and robustness of manufacturing systems, with the constraint of increasing product variants and highly variable production volumes. To achieve a higher level of productivity and better reaction time at affordable costs, the solutions should be related to:

- higher and stable product quality through process robustness;
- High quality through consistent or self-correcting process parameters;
- Zero defect manufacture or immediate detection of flaws and feedback for predictive correction and maintenance;
- easy to install control systems;
- equipment which can autonomously adapt its configuration automatically to react to the external conditions through logic and modulated approach;
- new factory oriented frameworks for automation and robotics.

Exploiting new materials through manufacturing

The focus is on creating manufacturing processes that have the capability of cost-efficiently shaping, handling and assembling products composed of complex and novel materials and of new product concepts providing reduced environmental impact. It addresses both processes for customised production as well as new applications of existing processes for high added value (including multi-functional) products. These processes give cost-effective components with required service performance characteristics and should be energy efficient to help minimize life cycle CO_2 emissions from the component's use.

To achieve a higher level of productivity with the novel materials, the following topics should be considered and developed in the future:

- processing methods for "Carbon neutral" materials and manufacturing of new 'green' products;
- rapid and customised manufacturing of new materials, incorporating new functionalities
- processing production and integration of advanced materials for improved product quality, weight saving, improved behaviour at high temperature and functionality;
- ensuring principles of sustainable manufacturing are employed taking into account the needs of new materials.

3.1 Sustainable manufacturing

The competitiveness of European industry is promoted by generating step changes in a wide range of sectors and implementing decisive knowledge for new applications at the crossroads between different technologies and disciplines. A key objective for the manufacturing industry is not only to design green products, but also produce goods using a sustainable approach. Sustainable production is defined as the creation of goods and services using processes and systems which are not pollutant and reducing energy consumption while respecting the constraints of economic sustainability, security and health to workers. To close the loop on sustainable manufacturing, a clear focus and support for “de-manufacturing” or advanced recycling of products/process materials is equally required.

For European industry sustainability is today a key strategy. Manufacturers have taken up the challenge of designing a sustainable production system that has less environmental and social impact. The sustainability concern resides at the centre of any industrial RTD development. Environmental challenges such as climate change and resources scarcity are the sources of both constraints and opportunities for technological developments. Research will be focused on generating high added-value products and related processes and technologies to meet customer requirements as well as growth, public health, occupational safety, environmental protection, and societal values and expectations.

The following topics should be considered and developed:

- ***New Eco-Factory model*** (short term impact): optimised utilisation of energy streams, the environmental impact reduction and the improvement of resource efficiency will be the basis of the new advanced green manufacturing.
- ***Green Products Manufacturing*** (medium term impact): application of an integrated preventive environmental strategy to processes and products to increase the overall efficiency by the conservation of resources and energy, the elimination of emissions and wastes by point source treatment and recycling.

New Eco-Factory model

The objective will be to overcome existing process limitations by developing new production processes, which integrate innovative energy efficient technologies. Energy efficiency, resource efficiency and reduction of environmental impact will be addressed.

Energy efficiency: Up to 20% of energy costs can be cut by monitoring production equipment resource usage and health, new maintenance strategies, replacing out of date equipment, configuring systems according to differentiated processing needs, buying multi-functional devices and by simply ensuring equipment is turned off after use. The main objectives are the following:

- new control systems of production equipment/machines, based on optimised and self-adaptive strategies and fault tolerant, which lead to higher productivity and reduced energy consumption; control-intensive applications with high effectiveness and usability of the integrated automation and control systems (dynamic risk assessment, dynamic control planning, easy-to-use scheduling, industrial monitoring, control and field networking
- advanced manufacturing processes enabling low resource input, process intensification, low emission and tailored for product for different activities like surface treatments/functionalisation, coating and joining ensuring high process productivity while reducing environmental impact;
- design new machine tools and equipment, components, tooling and processes with low inertia moving parts and energy recovery and scavenging capabilities(ex. Flexible self-

optimising drive concepts, conversion of kinetic energy, storage and re-use of thermal energy, ..) and use of renewable energy technologies.

Resource efficiency: The aim is to ensure the efficient use of resources and the yield management and minimisation of waste (material, energy, etc) as well as to improve the sustainability of industry. The objectives are the following:

- optimise material and resource use across industries and minimise waste production and disposal by identifying synergies and evaluating the implementation of enabling technologies like Rapid Manufacturing and Roll to roll manufacturing;
- safe alternative material production process (use of renewable materials, heavy metals control,..), coherent management of hazardous materials (measurement methods, treatment standards, …) and increased use of bio-materials (bio-polymers, natural fibre composites…);
- life-cycle engineering and system simulation enabling economic and environmental sustainability of manufacturing systems, considering sustainable supply chains and recycling and reuse of new products/process materials/residuals and end-of-life material.
- development of new tools (based on new substrate materials and coatings) and production systems, enabling dry and Minimum Quantity Lubrication machining along with usage of environmentally-compatible lubricants;
- new maintenance strategies and reduction of maintenance cost in production equipment (increasing lifetime of critical components, increased resistance against failure, minimizing wear or corrosion, including on line monitoring, sensors,..);

Reduction of environmental impact:
Green products and green processes are achievable only if there are competitive manufacturers and service providers that offer reduction of environmental impact at an affordable cost. Challenges for the manufacturing industry, that R&D should address, are:

- Elimination or reduction of emissions (dust, air, water, noise, etc) with self-cleaning production systems
- Eco-efficient planning and energy-management systems of factories;
- Eco-design: Methods for integrating environmental criteria in the design and development of a product, service or process, considering the whole lifecycle in order to reduce environmental impacts by means of the implementation of the Life Cycle Assessment (LCA) tool.
- Lifecycle management and sustainable supply chains (holistic lifecycle assessment based on a consistent set of information on products, components and energy; LCA aggregated and availability to product designers to effectively feed them back to future products);

Green Products Manufacturing

In order to deliver breakthrough progress with major impacts on competitive and sustainable manufacturing, developing 'greener' products, putting the factory worker first and economic sustainability will be addressed. The advanced greener products request to develop the following items:

Developing 'greener' products: Improve the sustainability of the product portfolios through new processes, technology or procurement changes, incorporating at the same time the needs and requirements of the users of the products. Besides, for the consumer products industry, the challenge of defining robust solutions that line up with the environmental agenda requires creative use, both of sustainable product and process technologies. The research topics will be:

- develop new or improved technologies for recycling and recovery of materials and energy from waste, producing secondary materials with a high degree of purity and re-workability at lowest energy consumption; e.g. highly efficient sensors for the recognition, selection and sorting of components and materials
- develop procedures to identify best practices for de-manufacturing, dismantlig and recycling and best management practices in conjunction with eco-design and integration of information related to the recovery of the product and the integration of environmental policies at product design;
- methods for measuring and evaluating sustainability of products, processes & materials and industrial practices (such a Life Cycle Assessment (LCA), Life Cycle Cost (LCC), Environmental Risks Assessment (ERA),...) in order to assess manufacturing sustainability from the environmental standpoint within global networks, considering the entire product lifecycle.

Putting the factory worker first: Future production sites will be characterized by a large variety of sophisticated products with short cycle time and variability controlled manufacturing capability. In these novel manufacturing environment cost effective production will be assured by a mix between advanced production systems and workers capabilities. Research topics in the area of workers capabilities are mainly focused on:

- methodologies and technologies for advanced ergonomics solutions facilitating operations and improving workers well-being;
- new machine-operator interfaces
- manufacturing environment that encourages skills development.

Economic sustainability: the development of innovative products and equipment requires the definition of new business models which establish the best trade-off between increased complexity and benefits related to productivity, quality, flexibility and variable cost savings, including, for example:

- re-use of existing equipment and infrastructure by means of higher cross sector standardisation and modular approach;
- value chain extension to recycling and re-using of materials, components and products;
- introduction of the business opportunities offered by renewable energies.

3.2 ICT enabled intelligent manufacturing

The ICT contribution to the Factories of the Future aims at improving the efficiency, adaptability and sustainability of manufacturing systems as well as their better integration within business processes in an increasingly globalised industrial context. "Manufacturing" in this context is meant to include related product and process design and engineering and all process activities from small batch to continuous operations.

ICT is a key enabler for improving manufacturing at three levels:

a) ICT for agile manufacturing and customisation including process automation control, simulation and optimisation technologies, robotics, and tools for sustainable manufacturing (smart factories).

b) ICT to support value creation from global networked operations including global supply chain management, product-service linkage and management of distributed manufacturing assets (virtual factories).

c) ICT for better understanding and design of manufacturing systems and for better product life cycle management including simulation, modelling and knowledge management from product conception level down to manufacturing, operations, maintenance and disassembly/recycling (digital factories).

The expected impact would be:

- On 'Smart Factories': (a) A higher level of intelligence on the shop floor through context-aware, fault-tolerant, adaptable, reconfigurable interoperable, wireless and robust ICT. (b) Opening up new market areas for next-generation automation equipment and advanced industrial robots providing a boost to both the European industrial automation and robot suppliers as well as the end user industry. (c) Development of an early European market for advanced technologies such as electronic and photonic devices, automation equipment, and robot systems. (d) The penetration of advanced automation into small-scale manufacturing and crafts, especially through the introduction of new assistive automation and robot systems. (e) Increased productivity in labour intensive industries through a scalable automation approach, thus providing competitive solutions for new manufacturing paradigms, new products and innovative business models.

- On 'Virtual Factories': (a) Enabling advanced product-centric services (e.g. product authentication, IPR security, ICT-facilitated diagnosis and repair, remote performance/energy monitoring and logistics) through leveraging the improved efficiency of (embedded) product intelligence; (b) New business models and capabilities for improved management of global networked manufacturing and logistics (e.g. Software-as-a-Service (SaaS), service marketplaces, contract manufacturing, and fourth party logistics (4PL)); (c) Improved sustainability of product value for customers by offering solutions instead of single products and new product support services.

- On 'Digital Factories': Maintaining Europe's leadership in providing knowledge-driven platforms, tools, methodologies and lifecycle orientation to product development and manufacturing (e.g. planning, optimisation and monitoring of processes, plant configurations and assets in real time, as well as web-based engineering).

a) ICT for agile manufacturing and customisation:

Future production sites with a large variety of sophisticated products will offer flexible, short cycle time and variability controlled manufacturing capability. These manufacturing approaches ensure energy efficient, reliable and cost effective production ('smart factories') as well as production set-up/ramp-up with reduced cost and time through lean and simpler ICT. Related industry driven R&D activities include:

- Advanced[1] process automation, control and optimisation technologies and tools. These are essential for sustainable and reconfigurable manufacturing in all the sectors. They help, for example, achieve operational targets, increase yield versus material variability and consumption, ensure energy efficiency and reduce waste. They should support decentralised, distributed structures incorporating local intelligence. This is achieved through better systems modelling, global factory/plant simulations, highly integrated platforms and systems[2] and their seamless integration across process layers including with enterprise systems (e.g. MIS, ERP, MES) while also addressing the timeliness requirements of each layer. Integration efforts need also to address mass customisation applications and the timely and efficient delivery of customisation data. Research will be accompanied by training measures.

- Large scale testing and validation of robotics-based manufacturing and production processes in real-world environments. Pilot projects involving manufacturing industries and system integrators with the help of robotics industries will address challenging tasks in applications which have been resistant to traditional automation methods. The main involvement is expected with European manufacturing and production industries, such as food processing and packaging, service supply industries (logistics, transport and warehousing), lightweight goods manufacturing plants, as well as with system integrators.

- Novel methods of interaction with, and tasking of, intelligent automation and robotic systems that support flexible, small batch and craft manufacturing and new programming paradigms such as manual skill learning/transfer and process knowledge acquisition together with the use of such embedded process models/knowledge for task-based programming and control. Activities will aim at providing automation systems with more intuitive interfaces, and methods that allow for shorter changeover times and the faster introduction of novel products.

- Consistent middleware and /or integration framework for automation modules supporting the introduction of hyper-flexible manufacturing systems by allowing a “plug-and-produce” connection of automation equipment, robots and other intelligent machines, peripheral devices, smart sensors and industrial IT systems, thus providing scalable factory solutions.

- Novel large-scale control-intensive applications for high yield performance and energy efficiency to validate and benchmark the effectiveness and usability of the integrated automation and control systems. Activities will aim at improving solutions for dynamic risk assessment and dynamic control planning and easy-to-use scheduling, industrial monitoring, control, field networking and plant wide decision support: Work will be European-led and in conjunction with international initiatives involving industry groups and standardisation bodies[3].

- New metrology tools and methods for large-scale and real-time handling of manufacturing information: Intelligent devices and systems, embedded in high-tech machines and equipment (including process plants), for reliable, remote, efficient and precise in-situ measurement of complex process parameters, simultaneous characterisation of dimensions, shapes and compositions down to the atomic scale, with

[1] Advanced means adaptive, fault tolerant, optimising, reconfigurable, self-, etc.
[2] e.g. MCS, SCADA, DCS, PLC
[3] e.g. IEC/CENELEC, NAMUR, IEEE, ISA, NIST

wireless communication capabilities where necessary. Activities will include virtual-metrology-based equipment and process control. Standardisation efforts will be encouraged.

- Laser applications: (i) Novel lasers and laser systems for efficient, agile, flexible manufacturing of the future - both development and new manufacturing processes and techniques for low energy and efficient processing of new materials, and (ii) further development of mass customisation applications moving away from centralised to distributed laser-based and ICT assisted production of high-quality parts (using, for example, powders or liquids and including curing processes).

- Assessment of manufacturing, automation, handling and metrology equipment using standardised methodologies and metrics. User driven assessments offer fast feedback loops from the equipment users to the suppliers and help these to faster meet manufacturing requirements such as reliability, productivity and cost-of-ownership.

- Intelligent production machines supporting scalable advanced automation. These machines should include advanced functions such as automatic and guided programming, automated knowledge acquisition, dynamic and cooperative scheduling, intuitive diagnostics and explanations, and on demand functionality (internet delivered services).

b) ICT to support value creation from global networked manufacturing and logistics:

ICT if integrated end-to-end can provide clear insight and exact knowledge from data thereby supporting decision making and creating value from global networked operations ('virtual factories'). R&D activities include:

- Increasing management efficiency of global networked manufacturing: Enabling technologies under the emergent Internet of Things (IoT), such as RFID, wireless sensor networks, and machine-to-machine communication, significantly contributing to increased logistics efficiency, real-time monitoring of material flows and resource use. Integrating the IoT with the Internet of Services (IoS) in order to enable new real-world-aware services and business models for manufacturing and logistics. New technologies improving the collaboration and interoperability within supply and production networks (e.g. collaborative analytics, semantic technologies, automated data mapping). New ICT concepts, tools and methods for managing the increasing complexity of IT infrastructures in global supply and production networks (e.g. Service-Oriented Architectures (SOA) and device management tools).

- ICT for sustaining the value of products: ICT tools supporting the production of smart industrial goods, allowing advanced maintenance technologies and services (e.g. predictive and remote equipment maintenance simultaneously and across different sites), addressing challenges such as product quality and reliability, reducing waste and energy demand, enhancing safety and supporting fully automated lifecycle management, including product upgrades, re-manufacturing, recycling or disposal.

- Product/service systems: Supporting the manufacturing industry in undergoing the transition towards providing customer value via product-linked services or solutions based on integrated product/service systems. Novel ICT-based methods, tools and platforms shall aim to reduce the environmental footprint of traditional business models and facilitate the transition to new value-adding offers through a smart integration of products and associated services. Providing manufacturers and logistics providers with

ICT methods and tools (e.g. service marketplaces and web services technology), enabling them to offer easy-to-consume product-centric services and solutions.

- Managing volatile manufacturing assets: Manufacturing knowledge is essential to the survival of Europe's industrial competence. A migration to virtual manufacturing environments requires robust methods to manage intangible assets such as knowledge (e.g. bill-of-material, recipes, routings, inventories) and IPR (distributed across production sites, stakeholders and machinery). The focus will be on ICT-based solutions for the prevention of counterfeiting of physical systems (e.g. embedded chips and software checking compatibility of parts etc.) as well as the active protection of digital product representations.

c) ICT for better understanding and design of manufacturing systems and for better product life cycle management

Address the front-end stages of manufacturing ('digital factories'): in particular early concept modelling, simulation and evaluation, as well as the transformation of the knowledge-time curve, thus ensuring greater acquisition of knowledge earlier so that better informed manufacturing decisions can be taken. The handling of uncertainty is also a crucial area. The focus will be on:

- Knowledge and analysis: Comprehensive engineering platforms that enable cross-disciplinary information sharing and the capture and transfer of industrial design knowledge across stakeholders and the lifecycle, for example from use to design. Implementation should include extraction and inter-linking of knowledge from different simulation results and domains, for example new insights into complex product behaviour, i.e. implicit knowledge, as well as knowledge sharing and decision-making between experts and customers. Simulation frameworks should evolve into analysis frameworks that also encompass simulation in a comprehensive way, e.g. closing the loop from modelling, to evaluation and optimisation. They should cover areas such as cost analysis, energy efficiency, scheduling and feasibility.

- Enhanced, interoperable models: Models should be better, more intelligent and provide details of design intent. They should provide more predictive capabilities to help reduce the need for physical prototyping. Modelling should better encompass material and component properties and variations of these, and help to identify hidden impacts of gradients in stress, temperature, etc. The fragmentation associated with today's models and tools should be overcome. Interoperability, and consistency of data, information and knowledge, across the different stages of design, need to be addressed within design environments. Different types of models in use for different purposes, including process automation and control models, should become inter-linked at meta-level and support multidisciplinary simulation.

- Design environments: Collaborative design environments should be self-organising and able to adapt to the needs of different sectors and industries besides facilities for modelling, decision-making, and client-oriented simulation. Design environments should also be location and context aware with filters that direct selected information to different groups depending upon their needs and activities. It should be possible to add new tools and devices in a simple plug-and-play manner. New tools are needed to manage both the product architecture and the process architecture, and to manage the interaction between the different teams involved in the design process. Tools for multiple views of single representations should be available along with models to support management of the different teams.

- <u>Lifecycle management:</u> In addition to the technical data management perspective, product lifecycle management for all design information and analysis results requires synthesis methods and tools to adequately design products. As sustainability assessment includes environmental as well as economic and social issues, classical lifecycle assessment (LCA) methods and tools may prove inadequate for a holistic lifecycle assessment which is based on a consistent set of information on products, components and energy. The results of LCA analyses need to be analysed, aggregated and made available to product designers to effectively feed them back to future products. Decision makers should be able to weigh environmental and economic impacts against each other along the complete product lifecycle.

3.3 High performance manufacturing

The research activities under this area aim at enhancing European leadership in product engineering and manufacturing systems development. A key factor of competitive advantage will be the capacity to achieve cost efficiency, performance and robustness of manufacturing systems, with the constraint of increasing product variants and highly variable production volumes, both discrete and continuous.

The context of the economic crisis is modifying deeply the conditions for the decision of production equipment investment in the industry and particularly for SMEs
As an example, it is obvious that it is far more difficult to borrow money from the banks. Therefore:

- The return of investment must be explained in such a manner that the risk of loss is presented as being under control during the whole duration of the investment project,
- The project must have a break-even point in a short period of time as there is no good assessment of the medium term (more than three years).

It seems that this induces, more than before, an increase of technical solutions, which would have:

- To be less based on complex systems entirely composed of heavy machines and spreaded out automation, but, on the contrary, based on light and adaptive systems, with a increased role of the human workers, with more human/machine interactions.
- To plan progressive production investments
- To be easily reconfigurable from small small to large production series, using flexible technologies.
- To integrate adequately the necessary support of the modern IC technologies: that means simplification and real user friendliness.

The economic crisis shows the very basic needs versus the protection of the environment, as it has a great influence on the cultures of many developed countries, which are less consuming oriented and more addressing the long term.
For the production industry, this could have an influence on the design and the manufacturing of consuming products and maybe of industrial goods:

- The final products must be easy to dismantle (very important as it modifies the way to make the components and to assemble them), as they must all be recycled,
- The components must be composed of materials "easy to find in the nature", "easy to produce", "easy to recycle",
- For the daily use of the products, the amount of consumed energy must decrease and the new EuP Directive enforces this trend.

This could and even will induce the necessary redesign of numerous products, which are essential consumer goods (like as an example the household equipments).
This would deeply modify the way to produce and this question must be tackled in the future research projects, even if most of the main trends are already expressed in this multi-annual plan.

This shows three issues:

- For the industry in general, how to cope with a large variety of products in a context of crisis and of more humanist consuming culture,
- For the production itself, how to cope with these constraints,
- For the marketing, how to cope with the trend of the consumers, now more interested by the long life of the equipments to avoid waste and garbage.

As most of the products have mechanical and electronic parts, how to cope with the need of increased reliability together with a simplified design.

On top of that, there is a transversal trend which has to be taken into account: the cost of transportation and the capacity of the international logistics flows will need to cope with the variation of the orders, what means that more production would have to be considered "locally" (in Europe for the European manufacturing); that could change the investments for high performance manufacturing.

The main topics relevant to high-performance manufacturing are:

- Flexible machines and systems for rapid (re)configuration
- High precision manufacturing by plug and play, components based on adaptive smart material
- Planning tools for open reconfigurable and adaptive manufacturing systems
- In-situ process simulation
- Adaptiveness of production systems for optimal energy consumption

A further three topics have been selected as high performance manufacturing priorities by Factories of the Future work groups :

- New high performance manufacturing technologies
- Zero defect manufacturing
- Sustainable production technologies and systems

These topics would preserve their long term priorities but we can consider that the first set of topics are more practical, for such a plan. Let's insist on the importance of zero defect manufacturing for enhancing the high performance manufacturing.

As there is no mechanics without electronics, now in the most of the industrial or the consuming products, there is no advance in manufacturing equipments without the merging of the two technology fields, mechanics and ICT.
This explains why there is an overlap between the § 3.2 and 3.3. As the focus is not the same it seems better to accept this for a better understanding.

Flexible machines and systems for rapid (re)configurations
The mechatronic components are widely used in end-products, for example in the automotive and aerospace industries. With increased autonomy they will offer a very effective way to configure robotics and handling units. With increased precision and reliability (including fail-safe hard- and software-interfaces) they will become promising objects for the construction of rapidly reconfigurable manufacturing equipment, suitable to be used in a flexible production environment. The main objective is then to create radically new, self-adaptive machine structures with online self-optimisation, based on mechatronic modules. The new systems can feature multi-layer control, sensing and actuator structures with a high level of redundancy, which guarantees a high level of reliability and allows optimal performance of a production system under different conditions.
Innovation lies in moving from current 'assembled' sensor, actuator, and control system architectures to truly integrated mechatronic systems.
To cope with the necessary increased role of human workers and their integration, including safety aspects, the self adaptive robots and machines will share the work with human workers.
The main development issues expected in this area are:

1. development of tools for integrated optimised system configurations based on a mechatronic simulation with respect of the resulting performance (including damping characteristics, working envelope, etc.),
2. development of "adaptronic" modules and their integration into intelligent manufacturing equipment

a. active intelligent components (integrating sensors, actuators, control, mechanical structures), adaptronic modules and interfaces, MEMS, MOEMS).

b. enabling the production of micro-systems, micro-technologies (e.g. human machine interfaces dedicated to micro-systems manufacturing, miniaturised manufacturing equipment…).

c. enabling progressive, step by step production layout.

3. enable knowledge-based, self-learning systems through the development of multi-layer controls and model based real-time compensation routines, embedding machining process knowledge
4. development of flexible signal processing methods, and wireless communication mechanisms and flexible system busses with integrated power supply,
5. standardisation of mechanical, electrical and software interfaces.
6. using the above, break the limits of conventional/existing manufacturing processes (machining, tooling, technologies), realising breakthrough of manufacturing methods and processes.

Expected results are (i) tools and methods for mechatronic manufacturing systems and components modelling, set-up and use; (ii) demonstrating applications for mechatronic modules and their usage in machines and production systems (iii) demonstrating application of friendly human machine production cooperation.

High precision manufacturing by plug and play

This topic is dedicated to the creation of active plug-and-play components, based on intelligent materials or combinations of passive and active materials (engineered materials) to increase the adaptiveness of production systems. The intelligent plug and play systems can feature sensing and actuator structures, adaptive control and energy harvesting to allow a high accuracy of production systems under different conditions and to overcome traditional limitations on dynamics versus precision. This includes self-adaptive and self optimizing modules.

Expected results are the simplification and user friendliness of the systems with distributed and decentralized controls.

Planning tools for open reconfigurable and adaptive manufacturing systems

Process planning and process engineering and integration are parts of the chain from design to manufacturing. Taking into account new solutions for configurable manufacturing systems, it is necessary to develop new and knowledge based tools for the support of planning. The implementation of a knowledge system in this process can be realised by a platform for process planning, which is integrated in the information and execution system of factories. Elements of this platform should be: actual data of the factories' resources and capabilities, modules and standards of processes, interactive and participative systems for process-planning, design of specific equipments for time and cost calculation, programming of machines, robots and automated systems, communication and distributed work. At the horizon, virtual-real workplaces are able to optimise and monitor manufacturing wherever in the world the processes are running at.

Acceleration of planning processes for fast and reliable manufacturing engineering in all manufacturing sectors, should be achieved through implementing this technology.

This topic must take into account the different organization of the production (insourcing, "local" production, oursourcing)

In-Situ Process Simulation

Simulation is usually an analytic instrument to find out the behaviour of systems under the constraints of usage. It is used for planning and optimising the layout of logistic and manufacturing systems and the design of machines. Future capabilities of real-time control allow the integration of simulation in the systems to analyse the behaviour in relation to situations. This demands the integration of simulation systems in Manufacturing Execution Systems (MES) as well as in machine and process control. Feed by sensorial supervision and monitoring and the actual load, it seems to be possible to look ahead on what happens and to compensate deviations of precision or to control manufacturing processes by learning for the future. These systems must be smooth (smart and fault tolerant) with human workers.

These simulations should enable the assessment of the business model together with the ROI of production investment plan scenarios.

Adaptiveness of production systems for optimal energy consumption

The main objective is the flexible adaptation of electric-fluidic energy resources for high performance drives both to production system and to process needs to overcome traditional efficiency limitations of local energy sources (hydraulic and distributed pneumatic power stations) by concepts of generating energy on demand and feed-forward strategies. A higher performance (speed, acceleration) is usually limited by a higher installed electrical power. But energy cost share in product prices increased from 10% to 20% in the last years and energy prices still increase on the market.

Research should focus on flexible drive concepts for altering demands of process conditions. Several such type of drive should be mentioned: a wide range of volume flow or velocity, mass or acceleration and jerk-free movements with regeneration of accumulated potential and kinetic energy (e.g. servo press or direct drive technology); combinations of direct electrical drives with rechargeable batteries providing highly reliable and safe energy and drive concepts. Local energy sources cooperate with production systems on the basis of new mechatronic model-based or knowledge-based motion control and real-time sensor applications to realize forward energy planning demands; co-operation of multiple main or servo drives in motion control and energy regeneration are highlighting the same relevance, as well.

New generations of adaptive production systems with increased drive or process performance of adaptive production systems by 20% and decreased local power consumption by 25% represent one of the valuable outcome in this area. Reducing waste of European energy resources in local industrial energy generation and motion consumption of production systems can be achieved as well. In the wake of drastically dwindling energy and material resources the need for such systems becomes increasingly evident in the field of new and old industrial automation systems.

3.4 Exploiting new materials through manufacturing

Introduction
Traditional and new industries are working with new materials to take advantage of increased functionality, lower weight, lower environmental burden, energy efficency as well as providing for a sustainable manufacturing base by moving to high added value prodcuts and customised production. New materials pose new challenges for cost efficient manufacturing to shape, handle and assemble complex structures that can involve macro-micro-nano scale, multiple materials combinations such as sandwich structures and composites and smart materials involving integration of sensing and actuation technology within a material (e.g. smart textiles). In other cases, there is a need to work with and more effectively integrate bio-inspired materials with conventional and new materials to meet the needs of new bio-industries and environmental targets.

The Factories of the Future initiative is concerned with making new or improved products through the exploitaiton of new materials and it does not cover manufacture of materials as an end point.

Industrial drivers
Most industrial sectors of importance to European manufacturing have a requirement for manufacturing with new materials (**the drivers**) using new and improved processes which will form a basis for future Factories of the Future. The transport sectors are driven by a need to reduce weight to improve energy efficiency as well as to provide a degree of cutomisation (particularly automotive) and key changes are required in greater use of low weight materials such as composites and in efficient use of high value added metals such as high strength steels and nickel based alloys. Moreover, the drive towards renewable energy sources is stimulating new industries able to respond to the increased demand for wind, wave and tidal, solar, fuel cells and hydrogen options.

New business models can drive to a servitised sector rather than a traditional product sector, and this changes the manufacturing implications by retaining responsibility for whole life cycle costs and increasing the drive for ease of maintenance and repair through life. New products such as unmanned air vehicles (UAVs) again introduce greater use of composites and smart materials as well as a need to manufacture at volumes more akin to the automotive sector than aerospace. New materials such as composites (and composites on a large scale) as well as photovoltaics now need to be manufactured to volumes and costs not previously anticipated, whilst ensuring manufacturing emissions are minimised.

The fashion market, in the textile, garment and footwear sectors, is a major traditional manufacturing base of Europe, where new approaches are needed to retain a global advantage for consumer and specialist products. This requires, for example, mass customisation and increased functionality as well as high flexibility and cost efficiencies. In paralell, this is a fertile ground for the development of new materials, namely technical textiles for high added value added applications, such as consumer products, construction, transportation, energy and medical, requiring 3D shaping, drapability, anisotropy in new automated factories. Design plays an important feature of the manufacturing process for tailor made solutions production, as well as considerations for a complete change in traditional industries. Integration of electronics and customisation of smart products also demand for new manufacturing conditions.

Electronics and photonics are core to many other sectors providing the ‘smartness’ into many new materials on the one hand and the intelligence to support manufacturing operations on the other, by means of improved sensing and control systems. Within Factories of the

Future, there is a strong connection between ICT and manufacturing (see Section 3.2), much of which is realised by the intelligence just referred to as well as in providing new flexible manufacturing options by increased use of laser technologies and roll-to-roll manufacturing.

The bio-inspired industries range from industrial biotech (e.g. plant, marine) to new health related products, including food processing, that utilise bio-materials such as biopharmaceuticals, stem cells and integrated biological materials with modern and new implantable and/or biocompatible materials (e.g. polymers, metal alloys). At one level there is a need to manufacture such new multifunctional mateirals into products that span a biological-physical interface.At another level there is a need to introduce good manufacturing practice for such products (automation, quality control, traceability) with volume learning from existing industrial practice. Due to the high cost of the testing and analysis phases prior to market delivery, simulation of the product behaviour made of bio-materials with the respective manufacturing process is crucial.

Spanning many of the above sectors and more, Europe is at the forefront of micro-nano-research, stimulating a new family of materials that provide the functionality to meet specific industry needs. Such materials require new manufacturing processes to convert them into products that function at the micro-nano scale particularly for volume manufacture within a safe environment. Manufacturing to combine materials with integrated macro-micro-nano-features are required to cover such processes as design, assembly, joining and reliability (e.g. new coatings on traditional substrates).

Manufacturing solution priorities

Manufacturing as a horizontal activity can contribute to these and other industrial applications with common requirements able to ensure a value contribution to a large manufacutirng base. The prioritised range of manufacturing processes able to respond to industrial drivers, which are chosen for their energy efficiency, are (**technology solutions**):

1. Net shape manufacturing for advanced structural and functional materials
The ability to manufacture new components in (near) single step operations provides for great efficiencies in energy consumption, increased yield, reduced factory space, and fewer processes as well as an ability to create new designs not possible by conventional manufacturing processes. Transferring current net shape processing (injection moulding, sintering, laser deposition) to novel materials classes, such as advanced metallics materials (e.g. high temperature alloys), functional ceramics (e.g. bioceramics, castable glas-ceramics) or composites (e.g. metal-ceramic or nanoreinforced polymer materials) will lead to completely new possibilities in the design of components and to significant savings of materials and processing costs.

2. New material functionalities through manufacturing processes
The interaction of new manufacturing processes and new materials can have a considerable influence on the quality and function of new products, providing significant added value. There are three key aspects, all of which require development of new manufacturing platforms able to transfer laboratory processes to high and/or customised volume production:

- Using manufacturing processes to integrate materials of different scale and functionality to provide completely new products with new functionalities (e.g. generation of new manufacturing chains for nanophased structures, nanoreinforced ceramic, conductive and functionalised polymers, metallic and graded materials and coatings and subsequent processing technologies to deliver step change improvements in product performance (strength, ductility, adhesion, corrosion, hardness or impact resistance), innovative tool engineering solutions for forming high added value products or systems by using smart materials…).

- Incorporating smartness into new structures by ‘manufacturing-in’ sensing and actuation technologies in new materials (e.g. electronics sensing into textile materials for use in medical or automotive sectors or incorporation of micro-parts or features in macro moulding products) to enable new functionalities or for part traceability.
- New laser wavelengths and improved understanding of light/matter interactions will enable enhanced processing of new materials. The major industrial driver for this topic is in micro applications (surface treatement) for such areas as processing new semiconductor, photovoltiac and medical components. Also joining of new materials through welding, soldering and bonding can enable multimaterial structures (metal to polymer), new designs in high strength steels and other alloys and welding of composite materials.
- Roll-to-roll manufacturing of large area and high throughput flexible plastics electronics products such as OLED for lighting, displays and technical textiles, Organic PV, Organic sensor arrays using new organic functional polymers and hybrid materials.

3. Rejuvenation and repair.
Extending life to existing and new structures as well as designing in re-use or ease of rejuvenation requires smart approaches to the incorporation of new and advanced materials. The Factory of the Future needs to address integrated design and manufacturing for re-use (rejuvenation and repair) as well as an ability to track material/product use to recover added value from new materials/components. Optimisation of life cycle manufacturing for new products incorporating new materials needs to be addressed early in the design process and consideration of supply chains to support critical system components.

4. Sustainable material processing technologies and associated sustainable product design.
New materials bring new challenges in sustainable manufacturing that require new approaches for low resource input processes and process intensification, integrated with hybrid processes as well as knowledge based processes exploiting advanced modelling and simulation techniques. These new materials include among others, “Carbon neutral” materials as well as materials for improved product quality, weight saving, improved behavior and functionality. This will then provide significant reduction of currently unused or undesirable processing emissions and new methods to process micro-nano-materials (minimising potential environmental and human health impacts). There is also a need for the development of rapid manufacturing technologies for sustainable production and recycling of process residuals that are suitable for new materials.

4. Timeline and budget

The Factories of the Future PPP covers the period from 2010 to 2013, with a total budget of €1.2 billion, half of which coming from the private sector. The dialogue in the framework of the Ad-hoc Industrial Advisory Group with European Commission officials from DG Research and DG INFSO already allowed to provide industrial input for the preparation of the FP7 Work programmes 2010. DG Research and DG INFSO are going to launch a dedicated Coordinated Call of €95 million, which can be expected to raise around €65 million of private R&D investment. This results in a total R&D investment of around €160 million into Factories of the Future PPP in the year 2010.

Table: Indicative topics in the FoF PPP Coordinated Call in Workprogramme 2010

Identifier	**Title**
FoF.NMP.2010-1	Plug and Produce components for adaptative control
FoF.NMP.2010-2	Supply chain approaches for small series industrial production
FoF.NMP.2010-3	Intelligent, scalable, manufacturing platforms and equipment for components with micro- and nano-scale functional features
FoF.ICT.2010.10-1	Smart Factories: ICT for agile and environmentally friendly manufacturing (including a Coordination Action)

The tentative budget distribution below has been made according to the preliminary definition of research priority area and number of priority R&D topics expected within each area. One tentative budgetary scenario is outlined in the tables below:

Table: Indicative budget distribution per sub-domains

Sub-domains:	**%**
Sustainable manufacturing	30
ICT enabled intelligent manufacturing	30
High performance manufacturing	25
Exploiting new materials through manufacturing	15
TOTAL	100

Table: Indicative budgetary scenario for the Factories of the Future PPP (in €million)

2010	**2011**	**2012**	**2013**	**TOTAL**
160	290	350	400	1200

5. Expected impact of the Factories of the Future PPP

The whole Factories of the Future PPP as proposed has a first direct economic impact in all issues related to innovation and research. This public-private partnership for research will stimulate the innovation activities in more European manufacturing related companies, specially SMEs, as the Factories of the Future PPP is specifically focused on this type of companies. Moreover, the research and development results will not stay in just one sector: manufacturing spreads thrugh most of the industrial sectors and therefore the new production methods, processes and technologies will reach industries across the whole Europe and beyond.

An important impact is linked to the cooperation, as requested in the Factories of the Future PPP objectives, between the academia and the industry. This research programme will further promote the joint research activities of the researchers, both from industry and from academia, towards a common goal.
Focusing in the manufacturing companies in Europe, largely represented by SMEs , there is a close link with regional clusters for diverse manufacturing sectors with an important amount of jobs. The manufacturing industries' landscape in Europe has a close relation with regional clusters of interconnected companies that provide to their specific regions a very significant amount of jobs and wealth. These regions can be identified in several areas as e.g. north of Italy, south west Poland, south west Germany, north of Spain. With the current decline of finance and real state based economy, those industrial clusters are back again the pillars of the European regions' economy.

Regarding the international aspects of the economy, such a PPP will have two main positive impacts. On one side, the export share of the European manufacturing equipment builders' will be reinforced as a result of the achievement of the Factories of the Future PPP's technological objectives. European capital equipment is renowned by its quality; improving it together with an increased environmental performance will lead to competitive advantages. Moreover, in relation to third countries, the use of this equipment will also lead to ecological and economical advantages due to a reduced environmental impact.

Impact of achieving the objectives in the sub-domain on "Sustainable manufacturing"

The first sub-domain, *Sustainable Manufacturing*, addresses objectives related to the reduction of the need of material resources, reduction of emissions and safety in manufacturing. Achieving these goals will lead to direct economic impacts such as:

Impact on competitiveness of the European manufacturing industry: With a growing concern of informed consumers and increasingly demanding legislations worldwide, the manufacturing sector, both providers and users of manufacturing equipment need to achieve more ambitious environmental goals so to keep their competitive advantage in face to other regions.

Savings in energy consumption and related operating costs, more productive European factories by means of the use of more energy efficient manufacturing systems. Decrease of CO_2 footprint of European Production Equipment life-cycle and decrease in factory processes CO_2 footprint worldwide when incorporating "European Factory" concepts

Savings from improved manufacturing systems utilisation by means of continuous sustainability tracking along the whole manufacturing chain, increased lifetime of industrial systems and structural parts and increased resistance against failure by optimized materials

Reduction of costs related to emissions (air, water, noise, etc) by means of applying self-cleaning systems and emission-free production

With the support of the Public authorities on implementing sustainable manufacturing, and as an additional spillover effect, the rest of the manufacturing industry in Europe will follow the trend set up by the first industries getting results through the Factories of the Future PPP in sustainable manufacturing.

Impact of achieving the objectives in the sub-domain on "ICT enabled intelligent manufacturing"

As far as it concerns to the Information and communications technologies in manufacturing "Intelligent Manufacturing", ICT contributes clearly to the economic growth bur Europe is still lagging behind the US. This PPP may support the European industry in catchin up this productivity difference.

ICT, whilst still playing a major role in productivity improvement, increasingly play an important role as a business value proposition differentiator. ICT if integrated end-to-end can provide clear insight and exact knowledge from data thereby supporting decision making and creating value from global networked operations ('The Virtual Factory'). This will impact on: (a) Improved efficiency of (embedded) product intelligence enabling advanced product-centric services (e.g. product authentication, IPR security, ICT-facilitated diagnosis and repair, remote performance/energy monitoring and logistics); (b) New business models and capabilities for improved management of global networked operations.

Besides, advanced automation and control is one of the key technologies to help all manufacturing sectors become more competitive, energy efficient and innovative. The size of the world market in monitoring and control is EUR 180 billion of which Europe has about a 30% share. There are more than one million robots operational in industry worldwide . The automotive industry accounted for only 36% of the 2007 supply, whilst their use in the electrical/electronics industry and food & beverages sector (the latter mainly in Europe) showed significant increases. Industrial robots have also moved away from traditional tasks like welding to handling and assembly operations. The focus of activities should not so much be on heavy industry sectors but particularly in the light industry, those market domains which until now have been "robot-resistant", e.g. co-worker robots in the food industry or "apprentice" robots in SME industries. Future production sites with a large variety of sophisticated products will have to offer flexible, short cycle time and variability controlled manufacturing capability. These manufacturing approaches ensure energy efficient, reliable as well as cost effective production ('The Smart Factory'). This will impact on: (a) Higher level of intelligence on the shop floor through context-aware, fault-tolerant, adaptable, reconfigurable interoperable, wireless and robust ICT. (b) Opening up of new market areas for next-generation automation equipment and advanced industrial robots providing a boost to both the European industrial automation and robot suppliers as well as the end user industry. (c) Development of an early European market for advanced technologies such as electronic and photonic devices, automation equipment, and robot systems.

Finally, R&D efforts addressing the front-end stages of manufacturing ('The Digital Factory'), in particular early concept modelling, simulation and evaluation, as well as the transformation of the knowledge-time curve, will ensure greater acquisition of knowledge earlier so that better informed manufacturing decisions can be taken. The handling of uncertainty is also a crucial area. This will impact on: Maintaining Europe's leadership in providing knowledge-driven platforms, tools, methodologies and lifecycle orientation to product development and manufacturing (e.g. planning, optimisation and monitoring of processes, plant configurations and assets in real time, as well as web-based engineering).

Impact of achieving the objectives in the sub-domain on "High performance manufacturing"

The world economy and society are transforming. A new international division of labour is emerging, with the rise of players such as Brazil, Russia, India and China (the so-called BRIC economies) and the increasing globalization of production. With the growing relevance of manufacturing SMEs within the European economy in terms of GDP and number of jobs, the increase of competitiveness and production flexibility became critical aspects for the survival on this changing and uncertain scenario.

For most manufacturing factories, activities such as material handling, scheduling, part setup or changeover times still occupy too large a fraction of the total time that parts are "in process" In some cases, up to 90% of product manufacturing time represents non-value-added delays. Reducing this wasted throughput time is and will continue to be a major driver for improvement on productivity.

The reliability of machines and production systems is paramount for efficient low-cost production. The key goal is to have maximum availability of machinery, producing high quality zero-defects parts at highest production ratios. In that sense, mechatronic strategies based on adaptronic systems, intelligent materials or vibration damping systems can compensate deviations on initial accuracy requirements detected by the continuous monitoring and control system.

Generally speaking, the achievement of more reliable and efficient manufacturing systems (machine tools, fixturing, cutting tools and peripheral equipment), integrating also process modelling and part's quality prediction, could entail benefits about:

- Reduction of the number of rejected components (scraps) and the amount of material used;
- Reduction of the cost and weight of manufactured assemblies;
- Increase the throughput, tool life and machining speeds maintaining repeatability and accuracy;
- Reduction of the waste, power consumption and number of finishing operations;
- Minimise or even eliminate the use of coolants (dry cutting), reducing environmental pollution around factories;
- Extend maintenance intervals;

Impact of achieving the objectives in the sub-domain on "Exploiting new materials through manufacturing"

The demands of the 21st century society for solutions of the "grand challenges" for an ever increasing use of renewable energy sources, higher standards of living, constantly changing markets and highly customised goods, as well as the risks posed by increasing energy costs and depleting resources are still unanswered. These topics are driving forces which increase markets for goods employing innovative materials with improved and incredible properties.

Factories of the Future PPP is expected to make a significant contribution to these big open issues, facilitating the development of cost effective, safe, affordable and friendly technology and production equipment for processing these new materials:

- Composite processing: automated processing (tape lying, fibre placement) of windmill blades, a process that nowadays is being made manually. This automatic placement could leave to benefits of 70% on time for producing a blade as well as a reduction of 80% on finishing operations.
- Functional surfaces obtained by microtexturing: It has been known that the functional performance of tools, workpieces, solar cells, aeroengine blades, medical implants, prosthesis and components for many industrial sectors can vary depending on what surface features are present or dominate, e.g. controlled porosity on a tribological surface can contribute to friction reduction at sliding contact interfaces.
- Development of new manufacturing technologies to handle, process and validate new materials for the upscale production of renewable energy sources, such as fuel cells, photovoltaic solar cells, thermal concentration solar systems or wind energy systems.
- Developing and characterising high throughput processes for length scale integration (micro / nano) and manufacture of components and devices with complex 3D features in a single material.
- Micro- and nanomanufacturing systems: design, modelling and simulation tools. Intelligent, scalable and adaptable micro- and nanomanufacturing systems (processes, equipment and tools integration)

6. Stakeholders involvement

The Factories of the Future PPP vision and action plan cannot be seen in a single perspective, nor realised through narrow, highly specialised approaches. An integrated knowledge community must be created, embracing a broad variety of manufacturing interests, and including as many actors as possible, such as:

- The European Manufacturing Industry: large companies, SMEs (including knowledge intensive SMEs) and midsize companies, as well as the Trade Associations. This includes both supplier companies for production technologies and customer companies.
- The European Research and Education Infrastructure: Universities and polytechnic schools, basic research centres, applied research organizations, Technology Centres and Technology Brokers.
- MANUFUTURE European, National and Regional Technology Platforms, and related Sub-Platforms.
- Other European Technology Platforms (ETPs): Sectorial European Technology Platforms, Enabling technologies ETPs, ICT Manufacturing relevant ETPs and other Trans-sectorial ETPs
- EFFRA – The European Factories of the Future Research Association.