TECHNICAL REPORT SERIES

The Future of Manufacturing in Europe 2015-2020
The Challenge for Sustainability

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The Challenge for Sustainability

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Nanotech backers back off!

Nanobuild Ltd. issues liquidity warning

NANOTECHNOLOGY

New York: Nanobuild, the world's largest nanotech RTD company, was forced to issue a liquidity warning yesterday, as NIG, the association of users of nanoelectronic products, announced their intention to curb funding schemes for nanoelectronics research. The announcement comes as the latest in a series of similar revelations of major manufacturers this year.

"The current situation is anything but easy" said Jan Binkhorst, CEO of Nanobuild, at yesterday's presentation of the half-year results. Nanobuild concentrates on nanodevices for electronic applications. The company's shares fell more than 25% yesterday in late trading. The Advanced Technology Stock Index dropped 8%.

Nanotech research firms have been the high-flyers on the stock markets over the last five years. Now many of them are struggling to keep their research activities going. With almost all Wall-Street-listed nanotechnology firms reporting diminishing returns over the past 12 month, the sector is on the brink to get 'nanomized'.

Analysts say that there are several reasons for the downturn. Andrezej Borkowski, chief analyst with Innovation Unlimited, the Warsaw based research think-tank, explains: "Some of the expectations in nanotechnology are only realistic on the long run. In the current difficult economic climate, firms concentrate more on short-term goals."

After the initial enthusiasm about the potentially unlimited opportunities of nanotechnology, widespread caution is now common among executives and investors. Progress has been made in nanotechnology, especially with regard to smart materials. However, more complex nanotech applications are still far from the marketplace. Nanoelectronic components, for example, lack reliability to be commercially viable. The lack of internationally accepted measurement and testing standards is another reason why producers abstain from investments. "Metrology is one of the areas that governments need to address more aggressively. And the framework for the protection of Intellectual Property needs to be improved", says Borkowski.

However, the recent plunge of stocks seems not to be supported by long term prospects. "Nanotech is the future. A lot of progress has been made with smart, functional materials and health applications. It is primarily in nanoelectronics where we see the market collapse", says Borkowski.

According to analysts, the lesson to be learnt from faltering nanotech stocks, is that the policy framework has to be set right: Pushing the technology with the expectations of quick returns on investments is unrealistic in nanotechnology. First there needs to be strong emphasis on pre-competitive research, as Europe and the US did early in the century.

Moreover, it is worthwhile thinking about the demand side at an early stage and to create lead markets. Here, the comparison between the US and Europe is instructive. "In the US, military funded nanotechnology research addressed clear objectives. They set up programmes for combat textiles and virus-detection tools, for example. This had major impacts on innovation in the health sector. This strategy has paid off", says Borkowski.

The Nanopharma Research Program has been another case of US success. "We can see an increasing market-share of US products in medical technology such as intelligent drug delivery systems", says Borkowski.

But Europe also has its strongholds in nanotechnology, especially in catalysts and hybrid materials. EuroCatalysis provides nanocatalysts for the chemical industry worldwide. "We make good profits with nanocatalysts and help Europe's chemical industry maintain the competitive edge", says EuroCatalysis spokeswoman Ana Oliveira.

US bullet proofs win shoot out

Nantex vests EU force

NEW POLYMERS

Brussels: Europe's UN peace keepers and the Rapid Action Force will soon be equipped with a new generation of functional fabrics for military uses.

Nantex, the US producer of functional fabrics and intelligent textiles, won the bid to deliver high-strength, ultra-lightweight bullet-proof textiles for the 100,000 strong EU force. "This is a big success for us", says Nantex CEO Samuel Edwards, "since the defence goods markets are still very much home matches. This time, though, superior technology won".

Conventional bullet-proof vests and equipment are heavy and often fail to protect soldiers adequately. The new fabrics are ten times lighter than previously used materials. The excellent thermo-physiological properties allow the deployment of the same piece of equipment in both deserts and the arctic alike.

The new clothing uses embedded sensors to monitor and exchange the physiological data of the soldiers with a central command station. The high performance and reliability of the new textiles has already been proven over the past five years in the US army.

"Show me the way to the next … sushi bar"

CNV presents voice-controlled car navigation

AUTOMOBILE INDUSTRY

Paris: The first standard series car with personalised, voice-controlled navigation was introduced at the Paris Motor Show.

The Car Scout of the CNV 8 is fully capable of listening and speaking and has Internet access with personalised re-configurable colour displays mounted in the windscreen by using new smart materials. This brings greater comfort than the visual driver information systems already available for decades in standard cars.

"As soon as you say the name of your favourite sushi bar in town, the navigation system will indicate which is the best way to take to go there, taking into account the real-time traffic situation in your area", says CNV spokeswoman Gordana Jancic. The model offers Internet and a wide range of office tools, such as voice-controlled e-mail and word-processing.

The Car Scout is standard equipment in the CNV 8 model series. In the more economical CNV 4 series customers pay a premium for the extra.

VMS profits hit peak

Demand soars for digital prodution tools

SIMULATION

Warsaw: Net profits of digital planning software provider VMS rose by 25% in 2015.

With innovation and design cycles becoming shorter, industry has widely adopted simulation and virtual planning tools to become more flexible and consumer focused. Erik Larsson of VMS explains: "It is no longer feasible for manufacturers to optimise each production step individually. Companies realise that production as a whole is more than the sum of its parts."

The key to integrated factory planning is the visualisation of data. VMS offers sophisticated computer models that allow for the visualisation of all elements of production. "With a simple command, a production manager can access real time data in a strikingly simple way. At the same time, they can easily simulate change-over and how certain events affect the operation of plants", says Larsson.

The clients of VMS come from every manufacturing sector. "If a manufacturer wants to survive under global competition cutting planning costs is a must", says Larsson. The potential for efficiency improvements is astonishing. "With integrated plant simulation, the time to produce a car has been reduced by 75% over the past two decades. In the chemical industry, too, simulation can improve the operation of plants dramatically", says Larsson.

Local Standard

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The Regional Daily - Business Section

EU Troika signs Industrial Co-operation Pact with Neighbour States

Opportunities for investors in Belarus, Ukraine, and Russia

ENLARGEMENT

Kiev: After three years of negotiation, the EU Troika yesterday signed the Economic Stability and Industrial Development Agreement with its Neighbour States Ukraine, Belarus, and Russia. The breakthrough in the talks happened at the Presidency Summit last December in Nicosia. The East European Member States were finally granted additional funds for infrastructure projects after long lasting resistance within the European Union. The net contributors to the EU budget have been for a long time reluctant to agree on paying the bill.

The pact was warmly received at the European Industry Association headquarters in Brussels. The pact provides development funds worth a total of Euro 300bn over the EU budget planning period 2017-2023. The new agreement provides incentives and financial support for stronger EU industry engagement in the 'New Eastern Europe' economies to catch up with 21st century economic structures.

Apart from transport and communication infrastructure investments, the agreement will provide funds to modernise power-plants, steel works, refineries and chemical sites which account for the most significant share of pollution sources in the Neighbour States. Improving co-operation on industrial research is also an important part of the new agreement.

Henning Schermann, of the European NGO platform CitizenAct, criticised the pact, saying it does not sufficiently take into account environmental and social development issues. "30 years after the Chernobyl disaster, Europe is still not able to support Ukraine to decommission their nuclear power plants", says Schermann.

Fostering diversity vital for innovation, says Cengiz

Governor calls for more active EU

INNOVATION POLICY

Stuttgart: The current president of the Representatives of the European Regions with the European Union, Anne Cengiz, called for a more active and co-ordinated EU innovation policy, to strengthen innovation capabilities and help regions stay competitive.

In yesterday's speech, delivered at the European Automotive Association annual conference, Ms Cengiz stressed the crucial interplay between European and regional level policies. "Europe's regions are role models when it comes to stimulate research and innovation", said Cengiz, "Strong regions and thriving industry clusters are the basis to make innovation happen. However, we must not ignore that local initiatives need backing from Brussels to ensure that regional diversity works for the benefit of European businesses and customers".

Ms Cengiz mentioned the European Commission's new Regional Manufacturing Innovation Partnership programme as an important step forward. "European research needs to bring together the centres of excellence and help create lead markets". More explicitly on automotive production, Cengiz referred to the Distributed Production Platform Initiative (DPPI). This strategic activity was part of the *European Virtual Manufacturing Initiative 2020* initiated by European car producers with EU support. The DDPI is one of the cornerstones of Europe's current leading role in automotive production.

With reference to industry sectors that have less well performed in recent years, Ms Cengiz concluded: "To stay competitive we need more DPPIs in Europe".

Digital production in Europe of the Regions

How global manufacturers cope with Europe´s complexity

PRODUCTION SYSTEMS

Paris: There has been much rhetoric about the Common European Market. However, multilevel governance and having the ear close to European citizens had its price: if one looks carefully, one cannot deny the persisting patchwork of fragmented markets created by specific regulation in the regions that constitute Europe.

For global manufacturers this situation creates a major challenge for supply (and demand) chain management. Producers aim to realise economies of scale without centralising production. With the limitations of congested transport infrastructure in the main industrial regions, and the need to organise production networks locally, the world's leading manufacturers have adopted ICT solutions to manage increasingly complex production networks digitally.

"Manufacturers need to be able to work on the basis of a shared, comprehensive, and transparent pool of data and knowledge to integrate processes, operations, production sites and their relations to suppliers and clients", says Marta Sanchez of Interdata. "The operations of small suppliers are electronically linked in real time to a business integrator", says Sanchez.

Recent advances with self-integrating components and systems have made the new approach feasible. "With this new technology we can at last create a real-time seamless production web, that both allows for central co-ordination, monitoring and management, and – at the same time – enables the flexible delivery of products and services according to local requirements", says Sanchez.

PetroBNL high-capacity cracker site operational

Permits issued after up-hill struggle

CHEMICAL INDUSTRY

Rotterdam: PetroBNL was granted an operating permit for the world's largest and most modern cracker site close to Rotterdam. PetroBNL's CEO Michael Kavanagh clearly expressed his relief after the decision of the appeal panel was announced. "Despite our commitment to sustainable development legal and public relation procedures have been difficult", said Kavanagh. Yesterday's verdict is the punch line for more than three years of planning, negotiations and court procedures between the company, authorities and citizen groups.

With building permissions and operating licences for new plants being subject to tight regulation, the petrochemical industry has witnessed strong spatial concentration in recent years. "Today, there are only few, but hypermodern, chemical industry clusters left. PetroBNL is top of the league", said Kavanagh.

All major European petrochemical plants are now located close to ports to reduce transportation and logistic costs. Over the past two decades industry has also heavily invested in process intensification to modernise production sites. "In economic terms, concentration and plant intensification makes sense. Of course, this needs to be linked with flexible planning and operation tools to meet the needs of our clients", says Kavanagh.

Since European producers have steadily moved towards higher value specialist chemicals, centralised production of petrochemical had to be better integrated with down-stream fine chemical processes.

With increasing demand for small batch specialist chemicals there is strong pressure on the industry to push ahead with miniaturisation of chemical processes and to make production more flexible. "A lot of progress was being made in smart materials, membranes, integrated sensors, microfluids, automation and process control. These were some of the key elements to make microreactors feasible. The positive side effect is, that plants have become more environmental friendly and safer to operate", says Kavanagh.

Technology trends also ask for new approaches to multidisciplinary training and research. "It is crucial not only to invest in technology, but also to prepare your staff. At the end of the day, people are the key to sustained success", says Kavanagh.

SUSTAINABLE TIMES

The Daily Global Development Newspaper

European edition
Price: 6.40 euro, 4.60 ICU

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WTO talks on intrusive technology resumed

International accord on consumer protection standards in reach

SOCIETAL IMPACTS

Kuala Lumpur: Daniela Muller, chief negotiator on consumer protection of the Global Consumer Alliance (GCA), called on Governments and the World Industry Council for more flexibility to reach final agreement on internationally binding privacy and data protection standards for intrusive information and communication technologies.

The tripartite discussions of governments, industry, and consumer groups are being resumed after two months of stalled talks that allowed partners to reconsider their positions.

The contentious points still to be solved include the transfer of personal data and self-restriction of industry to abstain from certain intrusive technology solutions.

The talks started two years ago under the patronage of the WTO. They came after the eruption of the surveillance scandal in the US, when surveillance and monitoring data records over behaviour patterns from thousands of employees were used to identify 'untrust-worthy' personnel. On the basis of the analyses, employees profiled as 'security risk' were then unlawfully dismissed.

With the widespread use of personal electronic devices such visual phones, and personal identification tags, a vast range of legal questions has emerged with respect to the collection, use, access, exchange, and combination of personalised data. With people screened and monitored almost everywhere today – by using their mobile phone, PDA, credit card, or by person identification devices in public areas the opportunities for fraud and unauthorised use of personalised data has grown as well.

Up to now, countries have implemented their own standards. With increasing international cooperation on environmental, social and civil society issues global standards seem desirable. However, progress has been slow so far.

In particular, the need to strike the balance between privacy rights and public security complicates the matter. When does the public interest justify the transfer of data to governments? "After the terrorism concerns ten years ago, when almost any infringement of privacy rights was justified as a legitimate means to fight terrorism, we now need to seek a better balance", says Muller.

Jacques Klein, who represents the World Industry Council in the talks, pointed out that a final agreement can be assumed within weeks. "We are getting there", said Klein, "however, we need to make sure that the accord does not impede research and progress in ICT and ambient intelligence technology."

Record bio-feedstock demand for polymers in EU

Bio-based production up 24%

BIORESOURCES

Rotterdam: For the first time in history, the use of bio-feedstock, mainly ethanol derived from bio-mass fermentation, outpaced the use of fossil feedstock for the production of mass-polymers in 2016. The data issued yesterday by the European Polymers Association (EPA) showed a 2.2% increase in production of polymers compared to the previous year, to a total of 383m tonnes. The demand for fossil-oil based feedstock dropped 4.1% in the same period. Bio-mass ethanol production soared 8.7%. "This indicates a major shift towards a more resource conscious mass-polymer production we have been witnessing over the past decade", says EPA president Erkin Basaran.

Also bio-polymers gained market share in 2015, amounting for almost 8% of total polymer production in the EU. Even though the production of bio-polymers still requires non-renewable feedstock, the energy balance clearly speaks for bio-polymers. "Over the past five years the EPA members increased bio-polymer sales at a rate of more than 12% per annum. The plastics producers have made a significant contribution to Europe being able to meet its Kyoto II targets", says Basaran.

Automotive manufacturers agree on fuel cell standards

Fuel cell powered vehicle systems breakthrough expected

FUEL CELLS

Detroit: A standardisation agreement on fuel cell components for motor vehicles has been signed by the three major global automotive manufacturer groups. The move is believed to substantially stimulate market penetration for fuel cell powered cars and trucks and bring down production costs. Changes in legislation that now provide for heavy tax incentives for buyers of zero-emission vehicle seem also have been instrumental for the progress made.

Over the past decade, industry has solved the critical technological issues that impeded the diffusion of fuel cell powered vehicles in the past. Compared to the prototypes available ten years ago, today's fuel cell stacks are built of lightweight materials and a compact, on-board fuel processor. Carbon nanotube technology made lightweight hydrogen storage feasible.

"Major technological improvements were made to make the systems more durable and reliable. This was an indispensable prerequisite to get market acceptance from our clients", said Customised Ride CEO Hermann Schuster. "The manufacturing costs have fallen by 85%. However, all producers have so far used their own standards for fuel cell stacks, chassis design and storage system, which basically tied you to a single supplier", adds Schuster.

The new agreement foresees that the joint standards for fuel cell powered cars will be in place by 2020. By then, the power-train components of new cars will be interchangeable. The vehicle manufacturers themselves will benefit twice from the standards, since virtually all big players have set up mobility provision subsidiaries in recent years.

New EU incentive scheme for global clean production

GLOBALISATION

Brussels: The European Commission has proposed a new incentive scheme to facilitate clean production and discourage the export of industrial risks to countries outside the EU. The proposed scheme suggests tax breaks for companies which can prove that they apply the EU standards on their non-EU production sites. The tax breaks are the bigger, the more the site's emissions fall below the overall industry average in the respective country. WTO's Global Release Inventory for Hazardous Substances, to which all WTO members contribute, serves as reference data source.

The Communication is a firm response on the EU Sustainability Report which concluded that not all is green with Europe's industry, if one takes a careful look at subsidiaries and ventures abroad. "Over the past decade European companies relocated resource and energy intensive production to catch-up economies and developing countries. There, production standards and wages are still much lower. But if we want to be taken seriously with our sustainable development policies, we can't apply double standards", explains Freddy Bosmans of the European Commission.

Electronic waste records show strong improvements

WASTE PREVENTION

London: Electronics manufacturers are among the most successful firms at waste reduction, new data indicates. When the EU Directive on Waste Electrical and Electronic Equipment was introduced, computer manufacturers adopted an ambitious extended product reliability (EPR) scheme. The scheme covers life-cycle management, design for disassembly, leasing and take-back arrangements and waste minimisation partnerships. Making also sophisticated smart materials and composites complying with the scheme proved to be the most challenging issue.

The achievements have been compelling: Fifteen years ago, each European citizen disposed 14 kg of electronic waste per year, of which a considerable amount contained hazardous substances. Today, the average European 'produces' a mere 1.5 kg per year.

Focus Europe

The European Manufacturing Industry Monitor

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Price: 5,80 euro
Brussels, 11 March 2016

Cleantech sweeps China in environmental technology scoop

Deal worth 350bn euro signed to revamp manufacturing sites in Liaoning

CLEAN TECHNOLOGY

Benxi: Times have not always been so rosy for European engineering companies as they are now. Yesterday, Cleantech CEO Nikola Dobrev, and the Governor of the Province of Liaoning, Yu Chuan Ping, signed the biggest environmental technology export deal between the EU and China so far.

The deal will safeguard thousands of engineering jobs in Europe and gives a fresh boost to increased technological cooperation with the largest Asian economy.

Over the next ten years Cleantech will provide cutting-edge environmental know-how and technology for clean production, emission control equipment, sensor technology and recycling know-how to help modernise production sites in the pollution-stricken Liaoning province.

Since the economic reforms of the 1980s and the creation of the Economic and Technological Development Zones (ETDZ), foreign investment and industrial activity soared in China. However, economic success came at a high environmental and social price. Manufacturers still use outdated technology and pollution in cities has become almost unbearable.

Among the bidders were three other European-led consortia, as well as two US providers and the Japanese company Mitsubishi. Europe's leading position in advanced environmental production technology and its ability to offer integrated solutions turned the balance to the Cleantech consortia.

It is hard to believe, but only a decade ago, many European process technology firms such as Cleantech had been close to economic collapse. The acceptance of the Commission's proposal to introduce strict energy and resource efficiency standards even after the US pulled out of Kyoto, unwilling to negotiate any further international accord on environmental social and issues, gave exporters a hard time.

"More than once we asked ourselves: Are we really going in the right direction with our high environmental conscience, or are we only losing out on business opportunities to our competitors overseas?", Dobrev says in hindsight.

"Europe on the one side and the US and Asia on the other were going in completely different ways, after it became clear that oil resources are not going to run dry and energy prices would stay low, at least in the short and medium term", Dobrev says.

In those years of transition, stimulating demand for environmental technology on the home market was crucial. With support from European research funding schemes and an active industrial policy orientated towards long-term sustainable growth, Europe was able to create lead markets for innovative, environmentally friendly industrial processes.

"A lot of progress has been made in the last decade to increase energy and resource efficiency in the basic process industries. Hazardous substances have been phased out and integrated product design has become more than a buzz-word", says Terttu Valtonen of the European Industry Sustainability Forum (EISF).

The turning point came with increased awareness of industrial pollution in the US and the vastly growing economies in the Far East. For some years, the export market has been booming, a development that first took many analysts by surprise. The explanation is simple though: "Europe has superior technology to offer and we will see a sustained boom in export for some time to come", concludes Valtonen.

Semiconductor boom in Europe

EU leads the clean system-on-chip market

ELECTRONICS

Copenhagen: For many years, critics have rallied against the high European environment and health standards compared to those in the US or Asia. It seems however, that regulation can also stimulate innovative solutions, as the recent semiconductor boom suggests.

It was feared that strict EU regulation on toxic chemical use would drive semiconductors production out of Europe.

Against all odds, however, the industry has flourished over the past years. "We succeeded with product design and processes that have a clear advantage for the environment", says Jens Frederik Laursen from EMS European Micro Systems. "Dedicated research on polymer transistors led Europe to become world leader", says Laursen. Polymer components are more resource efficient and require less hazardous materials than their silicon based counterparts. Although prices are higher, they do have functional advantages.

Europe's stronghold in semiconductors is in the higher price range. Europe provides system-on-chip products that integrate sensors and sophisticated software for the automotive sector, health care, industrial automation and environmental monitoring.

Automation and process integration in manufacturing can be driven far beyond the limits ten years ago with the available technology. Each single device in a factory – regardless whether part of a robot, a pump, a nozzle, or a quality control instrument – reports its status continuously to the control station. It reports either 'I am feeling fine today', or 'I had a small problem, though I checked that myself and here is the report', or 'I need maintenance'.

Besides the EU's ambitious environmental policy, the proactive approach towards setting standards for industrial software tools for embedded systems was instrumental in the boom in the industry.

"A shared software language makes components, tools and production systems communicate digitally. The network effects by working on the basis of a common industry standard are huge", says Laursen.

ITS network in Rome opened

Clean cars and ICT to ease traffic problems

URBAN TRANSPORT

Rome: One of the most ancient among Europe's capital cities, Rome, now has its 21st century Intelligent Transport System (ITS). The Eternal City has been notorious for its chaotic traffic for decades – the result of legions of cars, trucks and scooters that populate the city day in, day out. Driving in Rome has been risky, noisy, and dirty: a real gladiatorial endeavour!

In the follow up of the EU CIVITAS initiative for the promotion of clean urban transport, Rome has up-graded public transport facilities and set up the Rome Metropolitan Traffic Management and Control Authority. Among the measures taken are zero-emission car-only access and congestion pricing. Residents owning cars are eligible for a seasonal public transport ticket.

To access Rome by car vehicles need to comply with the European zero-emission vehicle specifications. The movements of all vehicles are automatically monitored and drivers are charged according to vehicle type, the distance travelled, traffic situation and pollution levels. New pattern recognition technology makes it possible to charge also according of the number of people in the car.

"We expect a more efficient use of our traffic infrastructure and better balance between public and private transport", said Paola Pellegrini, the Mayor of Rome, at the official opening. "Citizens and our guests should be able to enjoying the city, regardless whether they travel by car, taxi, metro or bus."

Executive summary

Aims and objectives of the FutMan scenarios

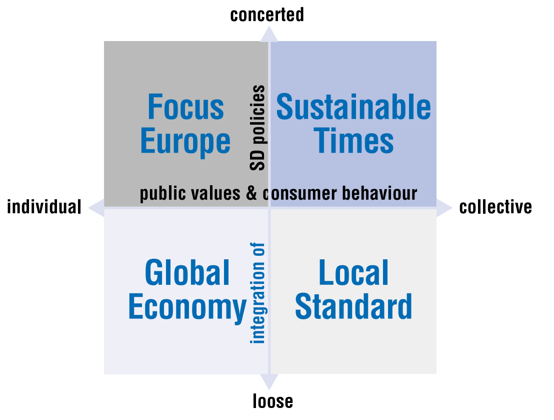
The scenarios on the Future of Manufacturing in Europe 2015-2020 (FutMan) offer imaginative pictures about potential socio-economic developments and future technologies that are likely to shape the European manufacturing sector over the coming years. The scenarios highlight important trends, possible trend-breaks, critical challenges and opportunities and present four possible visions of manufacturing in Europe in 2015-2020.

The scenarios aim to map the space for developments in the coming years based on the personal views and judgements of the expert group involved in the scenario building exercise. The FutMan scenarios should be used as a tool to stimulate strategic thinking about policy options in order to be prepared for the manufacturing challenges ahead. The scenario process focused on four manufacturing sectors – electronic components; measuring, precision and control instruments; basic industrial chemicals; and motor vehicles – and most of the information provided in the scenarios refers to these sectors.

The scenarios are structured along two qualitative dimensions of change. The first dimension relates to the modality of policy making. It includes issues such as geo-political developments, the balance between central decision-making and subsidiarity in Europe, and the rate of co-ordination between different policy areas. The second dimension refers to prevailing public values, consumer behaviour and demand patterns. The dimension also includes issues of public acceptance of new technology and backing of policies in support of sustainable development.

Each FutMan scenario consists of a description of the socio-economic context and technological developments and trends that might occur under the given framework. Additional information is provided on the state of the four FutMan case study sectors in the scenarios. Each FutMan scenario is illustrated in form of a purely fictional 2016 business newspaper front page to help the reader to understand the scenario, and highlight specific socio-economic and technological developments.

Figure 1: *The scenarios on the future of manufacturing in Europe 2015-2020*



Key features of the FutMan scenarios

Global Economy: In this scenario, consumers have pursued personal utility without paying too much attention to environmental and social impacts of production and consumption. The free market has been considered the most effective way to allocate resources and to achieve sustainable development. The World Trade Organisation and the interests of large multinational companies shape international trade policies. The European Union's and Member States' influence on global level is rather weak. Policy-making principally aims to strengthen market mechanisms and competition. Policy objectives have been set on specific levels with little emphasis on the integration across institutions or policy fields. In technology areas in which global competitors have financed large mission orientated RTD programmes, Europe is at risk of falling behind. Technology progress has been uneven and progress in nanotechnology has not fully lived up to expectations. The private car has retained its principal role as status symbol and means of mobility. Manufacturers focus on customisation and individualisation of products. New ICT tools have increased the efficiency of product and process design. Environmental progress has been made incrementally as companies have aimed to cut costs by making more efficient use of energy and resources.

Industry structure is highly specialised and diverse in the Global Economy scenario. Product liability compensates for safety and environmental standards. Court litigation becomes a source of product innovation – and a reason for the lack of it. Voluntary industrial agreements and self-compliance of industry on basic environmental and safety standards are the main policy instruments to stimulate sustainability. The engineering processes are assumed to be quick and flexible. The adoption of nanotechnology is rather slow because there are no incentives to establish international standards. There are few incentives for the industry to achieve compatibility between devices and different platforms. The scenario favours short-term industrial research activities. Energy intensity of production remains relatively high, though energy and resource efficiency improve since manufacturers aim for cost reductions. There is little prospect for the adoption of radically new approaches such as hydrogen fuel cell technology. Problems in the enforcement of recycling practices inhibit the adoption of recycling.

Local Standard: In this scenario, local authorities have gained new powers. Regional governments determine policy priorities and drive regulation. European institutions are not in a position to co-ordinate the diverse interests of regions and Member States effectively. The civil society, represented by a wide range of NGOs, has become an important player in policy-making processes. Consumer and citizen groups push their agendas on local and environmental issues. The transport network has been suffering from gridlocks due to shortfalls in investment and opposition to new infrastructure projects. The economic disparities between European regions and between Europe and its neighbours remain high. However, at local level diverse and creative regional clusters – new sources of innovation – have emerged. Multiple local markets have surfaced, linked and co-ordinated through ICT. Complex systems management tools help industry to cope with a challenging business environment. Some risky industry sectors face public opposition to the construction of new plants and witness the relocation of production abroad. However, strict environmental regulation has also lead in some regions to the fast adoption of radically new manufacturing approaches and concentration of manufacturing activities in industrial clusters to retain production: localised alternative energy production concepts have been realised and new small-scale production systems have reached application stage.

The Local Standard scenario implies both the centralisation and the decentralisation of manufacturing operations depending on sectors, processes and products. Regional demand structures require new solutions for flexible specialisation in manufacturing. Industry adopts new design strategies to focus on modular, simpler, and robust components. Intelligent logistics plays a key role. In some regions consumer choice drives manufacturers towards flexible specialisation and cleaner, more socially responsible production. At regional level specialised advanced technology clusters emerge, though overall public acceptance of new technology which might cause negative second order effects remains rather low. Since there is little trans-regional co-ordination of policies broader transitions such as the hydrogen economy are unlikely to materialise in this scenario.

Sustainable Times: In this scenario, European citizens support government co-ordination to reconcile the economic, environmental, and social dimensions of sustainability. A global governance system has emerged that promotes sustainable development. The European Union defines and implements clear sustainability policies based on broad stakeholder participation, globally and between national governments. Both market incentives (e.g. energy taxes, emission charges, other financial incentives) and regulation (market regulation, performance and direct regulation) are used as policy tools to foster sustainability. Industry is an active partner, closely collaborating with governments and the civil society. Emphasis is given to socially responsible technology development. European manufacturing has been able to break the links between growth and resource use.

Industrial change has been occurring at a fast pace, enabled by linking successfully technological opportunities with organisational and social change. The energy system is undergoing the transformation towards renewable resources. Large infrastructure investments have been made to create the hydrogen economy. Bio-resources have begun to replace partly non-renewable materials. New forms of mobility systems have emerged and the dominance of the internal combustion engine has been challenged by fuel cell technology. Manufacturing companies focus on the provision of services rather than selling products.

In the Sustainable Times scenario the notion of competitiveness is broadened and takes into account environmental and social aspects of production and consumption. Industry seeks major technological breakthroughs in order to de-couple material and energy use from production (e.g. bio-materials, renewable resources). Renewable energy and bio-resources help reduce greenhouse gas emissions. The industry strives for the optimisation of product life-cycles, introducing full lifetime control and management for their products. The manufacturing industry strongly pursues service-orientation in product design, and the product becomes less important within the value chain. The scenario requires a highly qualified labour force with new skills to operate and manage sustainable production systems. Rebound effects due to lack of public acceptance of new technology (e.g. ICT applications or nanotechnology) are unlikely since governments and industry pay attention to the environmental and social implications of new technology when designing and implementing their strategies.

Focus Europe: In this scenario, citizens make governments responsible for the achievement of sustainable development. Individualist values prevail. Europe has emerged as powerful actor to guide societies towards sustainability. Europe has pursued a strategically targeted industrial policy, aimed at creating lead markets for sustainable technologies. This approach proved to be successful, creating new export opportunities for European manufacturing industries. Strong emphasis is given to integrated utility of policy measures (i.e. balance economic, environmental, and social utility in sustainable development). Discussions between regulators and industry about adequate performance goals (i.e. What is Best Available Technology?) and the most appropriate means to implement policies (regulation, self-regulation, standards, taxation, fiscal incentives etc.) have led to rather slow policy implementation processes. At international level, Europe is confronted with new competitors, especially from Asia (e.g. China and India). The WTO has facilitated international trade, though there has been little willingness of WTO members outside Europe to take environmental and social issues on board. Since behaviour patterns of consumers have not changed significantly, the scope for broader socio-technical innovations is limited. Application of new technology follows more traditional trajectories and does not break societal, technological or infrastructural lock-ins. For example, the zero-emission-car based on the internal combustion engine has become reality but the problems associated with car-use prevail. Advanced ICT is implemented in both the public (e.g. intelligent transport systems) and the private and industrial sphere (e.g. for control, surveillance and tracing applications).

In the Focus Europe scenario, regulation provides incentives for industry to invest in sustainable manufacturing solutions. Innovation is geared towards resource efficiency and clean production. Well designed and coordinated policies drive technology development towards lower carbon dioxide-intensity. Strong policy support for large scale European research leads to more top-down innovations. However, the scenario favours developments along existing application trajectories. Opportunities offered by new technology cannot be fully exploited, since short-term cost-effectiveness does not favour radical innovation for sustainability and consumer attitudes do not support them either. The priority given to strategically important sustainable technology development strengthens Europe's competitive advantage in advanced manufacturing technologies. Industry works hard to attract and keep personnel experienced in using advanced manufacturing tools, managing virtual factories, using simulation methods, etc.

Scenario implications and conclusions

The scenarios on the Future of Manufacturing in Europe 2015-2020 highlight important developments, trend breaks, challenges and opportunities for a sustainable European manufacturing future. The scenarios suggest that the interplay of a variety of drivers – most notably related to globalisation, new technology, market demand, public values, fiscal measures, regulation and overall societal change – will contribute to shaping the future landscape of manufacturing in Europe. Many of the driving factors can be shaped and influenced (within limits) by European policy to support of achievement of the goals and objectives laid down in the European strategy for sustainable development.

The conclusion to be drawn from the analysis of the scenarios is: Whether sustainable manufacturing will become a reality seems to be hardly a question of technological opportunities alone. New technology, socio-economic factors, and the policy framework will jointly determine the dynamics of change. The scenarios indicate that progress towards sustainability will depend on the successful alignment of technological, organisational, and societal factors that are required for 'system changes' towards sustainability. The scenarios suggest that the main obstacles to achieve progress towards sustainable manufacturing seem to be primarily located in the political and market arena, rather than being caused by a lack of technological opportunities.

The interfaces between the various technological, socio-economic, and policy factors presented in the scenarios point to potential triggers for system changes towards a more sustainable manufacturing future.

Table 1: Socio-economic features of the scenarios on the future of manufacturing in Europe 2015-2020

	Global Economy	Local Standard	Sustainable Times	Focus Europe
Global governance	WTO enforces free competition. Global social and environmental accords watered down.	Limits to globalisation due to lack of public acceptance. Emergence of new regional protectionism.	Emergence of global governance bodies to promote sustainable development.	WTO governs international trade. EU sets goals and pursues SD without international backing.
EU policy integration	Low integration of SD policies. Reliance on market mechanisms and industry actions to achieve SD.	Low integration of SD policies. Regional interests set policy agendas and priorities.	Strong integration of SD policies between levels of governments. Regulation and market incentives.	Integration of SD policies with strong role of EU. Emphasis on cost-effectiveness of policies.
Consumer behaviour	Individualism and pursuit of personal utility. Highly individualised demand patterns.	Strong perception that community values and local dimension are crucial to achieve SD.	Community values and global dimension emphasised. Demand shifts from products to services.	Individualistic values dominate. Regulation corrects 'distorted preferences' of economic actors.
Innovation policy focus	Strengthen competitiveness and innovative capabilities of industry.	Create and strengthen regional and local innovation systems.	Tackle key societal challenges related to sustainable development.	Concentrate on strategically important research related to SD.
Transport / energy	Liberalised, oligopolistic markets. Low energy prices. Little emphasis on renewable resource use.	Regional monopolies. High energy prices. Fragmented transport infrastructure and gridlocks.	Mixed public-private markets. High energy prices. Heavy investments in renewables.	Liberalised markets. Low energy costs. Little public investments in infrastructure for renewables.
Sustainable development	Strong emphasis on the economic pillar of SD. Growth seen as the prerequisite for SD improvements.	Policies mainly responses to local pressures by various interest groups. Regionally patchy picture.	Strong emphasis on the environmental and social pillars of SD guided by precautionary principle.	Aim to balance SD pillars through integrated policy assessment tools. Strong technology focus of SD.
Education system	Partial privatisation of the public education and training system. Multitude of private schemes.	Regional responsibility for education co-ordination. Industry involved in training schemes.	Governments retain lead role in education. Strong emphasis to strengthen EU knowledge base.	Co-ordination of public and private education schemes to improve the economy's knowledge base.
Higher education	Strong emphasis on scientific excellence along traditional disciplinary boundaries.	Diversity in education and training schemes, reflecting regional legacy and diversity.	Strong emphasis on interdisciplinary training, soft-skills, and problem solving capabilities.	Strong emphasis on scientific excellence, cross-cutting traditional boundaries of disciplines.
Labour market	Little co-ordination of labour market and migration policies. Widening spread of labour costs.	Regional initiatives to balance labour supply and demand. Large regional labour cost differences.	Co-ordination of labour market and migration policies. Emphasis on tackling labour market imbalances.	Labour market and migration policies coordinated by EU. Increase of overall labour mobility.
Social security	Social security is increasingly left to the individual's choice and responsibility.	Regional differences prevail. Social security becomes part of compensation schemes.	Harmonisation of social security system at EU level. Social security remains in the public sector.	Mixed public and privatised social security system within a compulsory framework.

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1. Introduction to the FutMan scenarios

1.1. Project background

This scenario exercise was organised in the framework of the project 'The Future of Manufacturing in Europe 2015-2020 – The challenge for Sustainability' (FutMan), financed by the European Commission Directorate General Research (DG RTD) under the Fifth Framework Programme for research, technological development, and demonstration activities (FP5). The project was composed of a consortium of European research organisations.[1]

The project was addressing the question in which areas related to manufacturing Europe will have to be competitive in fifteen to twenty years time in order to meet its citizens' needs and the challenge of sustainability. Achieving sustainability in manufacturing will require the integration of adequate research, technology development and innovation efforts. For this reason, in the Sixth RTD Framework Programme (FP6), the European Commission envisages actions, focusing on innovative approaches in high-technology areas for the future of European manufacturing. The FutMan project is to provide support in outlining future trends of the European manufacturing industry and give orientation for future RTD priorities and to develop well-substantiated actions in support of sustainability.

The FutMan project was focusing on the FP6 priority research themes nanotechnology and nanosciences, knowledge-based multifunctional materials, and new production processes and devices. Besides technological and RTD developments, the project took into consideration a wide range of social aspects and governance issues, which are likely to impact on the context of manufacturing in the period 2015-2020. The main objectives of this project were to provide a soundly based:

- prospective mapping of the major technological developments in manufacturing taking into account both technology push and socio-economic pull influence.
- prospective mapping of the contextual factors that are required to exploit technological developments, (e.g. emerging skill requirements, governance).
- assessment of Europe's current and potential strengths and weaknesses with analysis of emerging challenges and recommendations for policy orientation.

Conceptually the project segmented manufacturing activity into three strands: materials, industrial approaches including transformation processes, and the structure of industry including governance issues. The mapping exercises were carried out in each of these three strands. In addition, the project partners carried out case studies in four key sectors of manufacturing in Europe to integrate and focus the results from the analysis of the three strands. The sector chosen were: electronic components, measuring, precision and control instruments, basic industrial chemicals, and motor vehicles.

1.2. FutMan scenario aims and objectives

Scenarios refer to rich descriptions of plausible future states based on a set of key factors. The aim of the scenario exercise within the overall FutMan project was to develop coherent long-term visions of 2015 to 2020 European manufacturing that can be used as a basis for strategic planning. The scenarios on the Future of Manufacturing in Europe 2015-2020 (FutMan) offer imaginative pictures about potential socio-economic and technological developments in the future that are likely to shape

1 IPC-Irish Productivity Centre (IR); European Commission, IPTS-Institute for Prospective Technological Studies (ES), ARC Seibersdorf research (AT), CM International (FR); PREST-Policy Research in Science, Engineering and Technology, University of Manchester (UK); Fondazione Rosselli (IT); Jerome Casey and Company (IR); ISI Fraunhofer-Institut für Systemtechnik und Innovationsforschung (DE); Institute for Manufacturing, University of Cambridge (UK).

the European manufacturing sector. Each scenario includes technological, economic, environmental and socio-political factors.

Scenarios are not predictions. In fact, the FutMan scenarios are meant to provide the context in which the challenges of European manufacturing and the robustness of policy strategies can be discussed and tested. The scenarios highlight important trends, possible trend-breaks, critical challenges and opportunities and present four visions of manufacturing in Europe in 2015-2020. The scenario building process paid particular attention to the goals and objectives of the sustainable development strategy of the European Union.

The FutMan scenarios are not meant to provide mutually exclusive futures. Some of the technological and socio-economic issues described in one scenario might also happen in other scenarios. The scenarios principally aim to map the space for developments in the coming years. The FutMan scenarios should be used as a tool that aims at stimulating and supporting strategic thinking about policy options to be prepared for the manufacturing challenges ahead.

Since the FutMan scenario exercise focused on four manufacturing sectors – electronic components; measuring, precision and control instruments; basic industrial chemicals; and motor vehicles – most of the information gathered in the scenarios exercise refers to these sectors. Important developments in other manufacturing fields that are currently emerging (for example in aeronautics, the textile industry, food and beverages, pharmaceutical, and medical instruments) might therefore not be adequately covered by the scenarios presented in this report.

1.3. Methodological approach

The FuTMaN scenarios were developed and tested in three interactive workshops drawing on the views and judgements of the more than 50 experts involved in the scenario building exercise.[2] The process was managed by the European Commission Joint Research Centre's Institute for Prospective Technological Studies (IPTS) in Seville.

In the first stage of the process the experts identified and discussed the key technological, economic, societal and political drivers, trends and breakpoints that are likely to shape the future of manufacturing in Europe (STEEP analysis). The factors were clustered and the experts retained the key drivers that were considered to be most relevant for manufacturing in Europe. In a second round of the selection process the experts assessed the uncertainty that is associated with of the developments of each of the key drivers. The factors that were considered to be most important – and at the same time most uncertain[3] – were chosen to develop and describe four socio-economic framework scenarios.

In the next stage of the FutMan scenario process, the participants elaborated specific implications for the four case study sectors, taking the socio-economic framework scenarios as starting points. The participants discussed the likely state of their sector under the scenario assumptions. The discussion focused on the areas of activities and challenges industry would concentrate in a certain scenario framework. The experts then identified future technology needs, as well as the research priorities linked to the scenarios.

The final stage of the scenario process was used to validate the preliminary results of the exercise with the expert group, including representatives of European Commission services. In addition, the scenarios were elaborated further, especially in relation to their implications for research policy priorities at European level and the format of their presentation in this report.

Finally, the illustration of the FutMan scenarios in form of purely fictional business newspaper front pages of the year 2016 were drafted and tested with the FutMan project partners, the experts involved in the scenario exercise and targeted users in European Commission services.

2 The full list of the experts involved in the FutMan scenario exercise can be found in the Appendices to this report.
3 In this context "uncertainty" refers to how foreseeable it seems to assess the direction of change and the value of a key driver on a 15-20 year time horizon.

2. Drivers and challenges for European manufacturing

2.1. Drivers for European manufacturing

The European manufacturing sector is likely to undergo dramatic changes over the next two decades. This section sketches the outcomes of the in-depth discussion on the main driving forces for manufacturing in Europe that emerged from the scenario building process on the drivers and challenges that are likely to shape the future of manufacturing in Europe. Technological, environmental, economic, political and social factors will shape the future of the industry. In turn, industrial change driven by new technological opportunities will impact on the socio-economic structures in Europe, contribute to sustainable growth and improve quality of life for European citizens. The key drivers of change in European manufacturing principally relate to:

Globalisation and an increasingly competitive business environment

The European manufacturing sector will be confronted with an increasingly competitive economic climate and global competition. The pressure on industry to successfully compete in globalised markets will require rapid responses to continuously changing business environments. Geo-political factors, such as the future balance of economic and political powers between the main economic regions, the emergence of new economic powers (for example China, India, Korea, Malaysia, Indonesia, and Brazil), global priorities in the governance of trade (e.g. WTO), political instability and threats of terrorism and armed conflicts that may limit energy and resource availability are also likely to bear heavily on manufacturing.

Socio-demographic change

The ageing European society and increased cultural diversity as a result of immigration and the enlargement process in the European Union will affect many industries, especially the health care sector, providers of personal services, and the consumer product industry. It is also very likely that the manufacturing sector in 2015-2020 will be confronted with a considerably older workforce compared to today. The issue of workforce mobility and the availability of skilled personnel might become a critical factor for manufacturing. Manufacturing will be called upon to provide solutions for new societal needs and the challenges of the ageing Europe and a culturally more diverse society.

Environmental issues and sustainability

The environmental burden of processes and products is likely to be the subject of increased public scrutiny in the future. The manufacturing sector may have to comply with stricter environmental regulation and might be confronted with new policy incentives to improve environmental performance. The priorities and policies to balance the environmental, social and economic dimensions of sustainable development will influence strategic decision making in manufacturing companies. Changes in consumer preferences and market demands may require the design of more sustainable products and services.

Societal values and public acceptance of technology

Recent debates on ethical implications of science and technology (e.g. stem cell research) or the reluctance of citizen in many European countries to accept nuclear power as a means to cut CO_2 emissions have highlighted the need to take public concerns seriously when science and new technology is adopted and exploited. Nanotechnology and new ICT clearly have the potential to spark future debates on the risks of new technology. Security issues might also become increasingly important and may conflict with privacy concerns (e.g. through ubiquitous computing).

These issues may affect manufacturing industry in that the successful marketing of new products and their acceptance by consumers and citizens will depend on their values, attitudes, needs, skills and experience with the features of new technological products and services.

The regulatory environment and the system of European governance[4]

The regulatory environment and the emerging governance system in Europe will also drive developments in manufacturing in the future. Today it appears to be rather unclear how the distribution of power and policy making authority between regional, national, European and international levels will look in twenty years time. This holds even more for the integration and co-ordination of different policy fields and participation of stakeholders in a multilevel European governance system. The modality of policy making in Europe, which principally refers to the goals, objectives, priorities, and instruments for implementation of a broad set of policy fields affecting manufacturing (e.g. trade, industry, competition, labour market, education and training, environment, health and safety, security, consumer protection and security regulation) might trigger and facilitate change in the manufacturing industry.

Advances in science and technology[5]

Technological progress in fields such as materials science, microelectronics and information technology, biotechnology and nanotechnology will enable manufacturers to innovate and offer better products and services to their customers in the future. Innovative production processes will change the scope and scale of manufacturing, and the organisational pattern in industry. Nanotechnology in particular, and the increasing convergence of physics, chemical, and biological sciences provide prospects for a wide range of product and process innovation. Progress in these RTD areas might also require completely new sets of skills and may change our understanding of production and consumption. The intensive uptake of new information and communication technology might alter the role and spatial allocation of the various actors involved in the manufacturing chain (from product design and processes to physical distribution).

2.2. Challenges for European manufacturing[6]

The socio-economic and technological drivers pose various challenges for European manufacturing in the future. Industry and policy makers need to reconcile policies and approaches with the objectives of sustainable development and to address these challenges proactively and on time.

In the following subsection, the main challenges discussed in the FutMan scenario exercise are presented. Whereas industry and policy makers will have to tackle the described challenges in each scenario, the instruments and specific industrial approaches will depend on the wider socio-economic framework conditions. Likewise, the relative importance of a specific challenge for industry may differ between the scenarios.

Increase supply chain efficiency

Global competition will put pressure on European industry to provide new products and services individually tailored and based on cutting-edge technology with higher quality, distinctive features and better prices. Time-to-market is likely to decrease considerably. This process will require new concepts for the organisation of supply chains and offer new business opportunities for manufacturers (Agility Forum, 1997). Virtual and flexible production

4 For more detailed information on future manufacturing drivers and developments related to societal change and governance see: Miles, Weber, and Flanagan (2002).

5 For more detailed information on future manufacturing drivers and developments related to new materials, industrial processes and the organisation of industry see: CM International (2002); Flanagan *et al* (2002); ISI Fraunhofer *et al* (2002).

6 For more detailed information on future manufacturing challenges and developments in the FutMan case study sectors see: Institute for Manufacturing (2002); Leitner, Green, and Malik (2002); Roveda, Vercesi, and Lindblom (2003); Wengel, Warnke, and Lindbom (2002).

networks are among the concepts to increase the efficiency of the supply chain. Production is likely to become more customer-tailored and increasingly service-intensive, which will also have consequences for supply-chain management. Manufacturers may have to acquire new technological and business competencies (e.g. those required for high-quality service provision; feed back loops between customers and design processes).

Life-cycles and time-to-market will also become even shorter (CVMC *et al.*, 1998). New technology could significantly alter producer-user relations (Cahill, 2001a). ICT adoption might change the organisation and spatial distribution of manufacturing networks (CEC, 1999, Ernst, 2002). For example, customisation of products could take place in local markets as manufacturers apply sophisticated postponement strategies. New organisational architectures in manufacturing might emerge with a rather small number of large scale component manufacturers that are globally distributed, and a large number of regional and local companies for assembly and product finishing linked to local markets. Virtual and network companies linked through instant data-exchange might become reality in the next twenty years. In response to market pressure, manufacturers will be looking for new opportunities to expand beyond already saturated markets – particularly by adding service components to their products. As a consequence, manufacturers might give more attention to the development of integrated product-services. If such a trend gains momentum, manufacturers will have to acquire new technological and business competencies.

Minimise the environmental burden of production and consumption

Necessary improvements with regard to the environmental burden of production and consumption (e.g. resources use, emissions, waste and by-products posing risks to the environment and human health) over the whole life-cycle is likely to challenge the way products are being produced and industrial processes operated (WTEC, 2001). Industry needs to give attention to extending the lifecycle of products through recycling and to the substitution of hazardous substances and materials. The use of new materials in process technologies may improve efficiency (CEC, 2001c). Europe could strengthen its competitive advantage in sustainable manufacturing by the adoption of new, alternative materials that allow the conservation of resources. Closely related to resource conservation is recycling of materials. In some cases recycling processes themselves face both environmental and economic challenges. Recyclability might be better incorporated into product design, to make disassembly of products at the end of their lifecycle easier. More easily recyclable and reusable materials could also be used. Improved process design and more efficient process technology may also contribute to improved resource efficiency (UK Cabinet Office 2001).

Although radical environmental innovation in manufacturing might be potentially the most sustainable ones (e.g. transition towards renewables, closed production and consumption chains, dematerialisation of production), they represent significant investment and risk for the manufacturing industry in the short run. Unless environmental innovation can demonstrate clear market potential, its uptake may be slow. Consequently, weak market forces remain a challenge, and the role of regulation (including international agreements on trade, the environment and sustainable development) remains an important driver of environmental progress. Consumer associations and the civil society may put increasingly pressure on policy makers if industry fails to act on reducing the health, safety and environmental risks and burdens of production.

A stronger orientation of individual, corporate, and societal attitudes towards sustainability might make change easier (CEC, 2002a; CEC, 2002b; CEC, 2002c). The use of management tools such as life-cycle-analysis and environmental management systems may also contribute to more efficient production processes and products. More attention might be given in the future to implement corporate social responsibility policies in manufacturing companies.

Integrate new knowledge and improve workforce skills

Another upcoming issue for sustainable manufacturing is enhancing knowledge integration and organisational learning (Vickers, 1999). This challenge relates to the better integration of human and technical resources, information and knowledge management, innovation management, training of workforce through new training tools and methods, multidisciplinary approaches and the improvement of 'soft-skills' such as communication (CVMC *et al.*, 1999).

A broader notion of manufacturing will require linking material and information flows within networks of suppliers and customers more effectively, posing new challenges for information and knowledge management. Success in manufacturing might depend increasingly on the performance in managing knowledge and complex networks. Data on all aspects of the value chain needs to be integrated and processed in real time in order to support both day-to-day business processes and long-term decision-making. Within factories, demand will grow for ICT-supported process optimisation, integrating hardware, software, operators' knowledge and after-sales services. If flexible production partnerships become more important, it can be expected that companies increasingly need to adjust the size and skills of their workforce.

It is likely that innovation processes in the future require intense internal and external collaboration to capture in-house knowledge, feedback from users, information provided by suppliers and a vast array of data from external knowledge sources (IMTI, 2000; Cahill, 2001b). If multidisciplinary teams become more common, especially in high-tech production sectors, staff need to broaden and share their knowledge and they need to understand the vocabulary and fundamental concepts of those with whom they collaborate.

Socio-demographic change in Europe will probably confront manufacturers in 2015-2020 with a considerably older workforce (Coomans, 2002). The emphasis of labour market policy is likely to shift from managing quantity to building quality. The availability of a skilled workforce is likely to become a critical factor in manufacturing, with companies competing to maintain human resources. The manufacturing sector will seek staff who are able to work in flexible environments and collaborate in multi-disciplinary teams. Increased workforce mobility might offer both an opportunity and a threat to manufacturing companies, since the knowledge of individuals cannot easily be maintained when they leave or change jobs. Industrial training and lifelong learning are likely to become critical for manufacturing companies to remain competitive. The new skills will have to deal both with new technology (such as nanotechnology and ICT) and also with interdisciplinarity and knowledge management (IWGN, 2001; European Parliament, 2002; CEC, 2001c).

Assuming that industrial training and lifelong learning become critical issues for manufacturing companies, the education system faces pressure to adapt and introduce training on new skills starting from the school system up to the university level and postgraduate courses. This raises the question how labour market policies and publicly funded training programmes, can be better targeted to transfer competencies more effectively. Companies might be urged to create more links with the education system. This also implies the foundation of new courses at schools, universities, and industrial training organisation to meet the needs of industry.

Anticipate new market and societal needs

New customer demands and new societal needs will put pressure on industry to come up with new products and services. New market and societal needs refer to areas such as safety and security, health care and health technology, energy supply and transportation. Industry and the manufacturing sector will also have to contribute to make Europe more knowledgeable and to prepare its member states to compete in the global digital economy. This has been highlighted by the Lisbon process and various 'e-programmes' (e.g. e-Europe, e-Europe+) on the European level that call upon industry to make their contributions to attain its objectives.

Further increases in the life-time expectation of Europeans will lead to rising demand for affordable health services and technology to improve quality of life. Security is another key issue for the future. Rising social disparities and the culture of individualism could lead to higher crime rates. International and domestic security threats by terrorism and organised crime not only necessitate political responses, but new technological solutions and products for security and defence. Finally, the enlargement process poses a challenge for European industry in the coming years. The accession countries represent new market opportunities and locations for production. At the same time Europe is becoming increasingly culturally diverse, a process that can open new business opportunities for the manufacturing sector (CEC, 1999).

2.3. Future key technologies for manufacturing

In the FutMan scenario exercise the experts identified key technologies for the industry sectors electronic components; measuring, testing, and control instruments; basic chemical industry and motor vehicles that are likely to shape manufacturing in the future. Table 2 summarises the areas of new technology and their applications which were identified in the scenario exercise.

Advances in science and technology, especially in materials science, microelectronics and information technology, biotechnology and nanotechnology will profoundly affect manufacturing and help manufacturers master the challenges ahead.

In general, manufacturing technology can be expected to become multidisciplinary as the boundaries between the sciences getting blurred. With the cross-fertilisation of inorganic sciences and biotechnology new approaches and processes for production might become reality. If current problems in developing and applying nanosciences and nanotechnology to industrial applications can be overcome, new manufacturing techniques might radically change both the scope and scale of manufacturing.

In recent years, advances in materials science have already led to the development of new products and improved services. New ceramics, polymers, metal alloys, bio-materials and hybrids have been increasingly used in sectors such as medicine, aeronautics, and ICTs. In the future, knowledge-content materials, providing new functionality and improved performance, raise the prospects for product and process innovation in manufacturing. Meeting new demands and product requirements in key sectors like health care (e.g. bio-compatible materials, bio-mimetic materials for prosthetics) (Antón *et al.*, 2001), the automotive and aeronautics sector (e.g. lighter and stronger materials for frames) (Powell *et al.*, 1999), chemicals (e.g. new catalysts, biochemical sensors, new reaction and process design) (ACS *et al.*, 1996) and the electronics and ICT industry (more powerful and smaller computers) (SRI, 2002) depend to a great extent on future advances in materials science. The availability of advanced materials will enable the production of smaller, smarter, multi-functional, and more easily customisable components and products. New materials may also play an important role for stimulating and enabling technology development in other high-tech industries such as the ICT sector. Finally, they may provide the basis for sustained innovation in more traditional sectors like construction (e.g. lighter and easy to assemble materials).

There are some indications that the miniaturisation of semiconductors might slow down in the mid-term since the currently available technological approaches seem no longer suitable to further reduce the size of integrated circuits (ITRS, 2000). In combination with advances in material science and computing technologies, nanotechnology could facilitate the development of new computing devices, and new ICT production processes. However, these concepts rely on the control of the properties of individual atoms and molecules, and they involve mechanisms which are at the time being far from being fully understood (Antón *et al.*, 2001). Past experience suggests that the average lead time for basic science maturing into marketable technology is about ten to fifteen years. Thus, it can be assumed that devices available for manufacturing applications in 2020 will be based on scientific progress made in the next few years.

Table 2: *Key manufacturing technologies 2015-2020*

	Key manufacturing technologies 2015-2020
Nanostructured and hybrid materials	- Nanomaterials with new characteristics, e.g. scratch resistant, self repairing materials, substitutes for additives, low weight – high strength, etc. - Nanosensors and nanodevices - Nanomanipulators and interfaces - Biosensors for control devices; DNA-sensors - Intelligent multifunctional materials for improved performance of instruments - Hybrid materials and components (integrating biotechnological devices)
New polymers	- Bio-polymers (e.g. for polyethylene-substitution, poly lactic acid) - Bio-degradable polymers - Polymers to replace silicon in electronic components - Polymers for light-emitting diodes and displays
New catalysts	- Nanostructured catalysts - Enzymatic and bio-catalysts - Catalytic distillation
Other materials	- Materials for all product lifecycle: disassembly, recycling, waste management - Smart / intelligent materials which could act as sensors by design - New materials for joining technologies - Lightweight materials (metals, polymers, carbon-glass fibres and composites) in design, handling in production, recyclability and dismantling - Aluminium and magnesium materials for manufacturing
New process technology	- Flexible manufacturing and control systems; decision support systems - Human / technology interfaces (e.g. common platforms for data management, for simulation, storage of data) - New generation of instrumentation for analysis, control, manipulation and manufacture at nanoscale (e.g. nanometrology) - Engineering support for characterisation, testing, up-scaling and eco-design - Interactive decision-support expert systems - Reconfigurable design (in order to make the agents compatible with the new reconfigurable machines) - Monitoring technology and distributed computing - Sensor technology - Net shape processes like hydro forming - Plant and process intensification
New chemical processes	- New membrane technology - Micro-reaction technology - High throughput technology - Reduce production steps in chemical processes - New bio-processes: use plants as chemical reactors (genetic engineering) - Stereo-selective (chiral) chemistry - Proteomics and genomics for pharmaceuticals and health care applications
Processes for improved recycling and resource use	- Processing technologies for all product lifecycle including disassembly, recycling, waste management - Design for closed-loop supply chains - Eco-design of product-service systems with embedded sensors - Optimisation of disassembly processes / smart disassembly / recycling
New product and process design technology	- Design for low capital cost production processes - Virtual reality labs - New product architecture (platforms, modules, services) - Distributed production; smaller & local final assembly sites - New processes for visualisation – visualisation within distributed networks - Modular design for products and production - Financial engineering for plants: build & operate-models

Modelling and simulation tools	- Modelling and tools to support the design, installation operation and maintenance of novel infrastructures and systems - Simulation of vertical factory integrated systems - Modelling and simulation, based on advanced complex system theories - Replacement of sensors by simulation tools - Molecular design techniques; combinatory chemistry - Modelling and simulation of advanced plant-wide control
Technologies for monitoring and security	- Tele-prevention and tele-maintenance/ remote maintenance - Tagging, tracing and monitoring of products and materials - Information security/ encryption technology - Information systems - Smart cards for identification, payment and access. - Solutions which allow interoperability of security systems - Solutions for personal data protection / access / monitoring
New ICT for products and processes	- Ambient intelligence/ embedded systems - Ubiquitous and pervasive systems - Update software/ function with wireless communication systems - Device and product assistant systems - Information management and communication systems - Expert systems (in order to exploit tacit knowledge and to integrate different types of knowledge effectively) - Fuzzy systems – extension of artificial intelligence - Hidden software solutions - Advanced software techniques (e.g. in order to increase the capability of information processing and to reduce the number of agents)
New approaches to logistics and supply chain co-operation	- Logistics optimisation systems - Logistics for fleet management and product maintenance - Design methods for service sale-of-use - Providing technology intelligence for SMEs (i.e. materials) - Methodology for corporate technology assessment
New energy sources and raw materials / fuel cell technology	- On-board hydrogen storage system for safety and functionality - Fuel cell/ hydrogen - Fuel cell technology large scale production - Clean fuel systems and supply infrastructure (clean energy supply) - Chemical industry: methane, methanol, and carbon-dioxide feedstock - Bio-feedstock (e.g. corn for polymer production – polylactic acid) - Renewable energy resources (i.e. windmills, solar cells) - Batteries technology - Photovoltaic cell technology

3. FutMan scenario dimension and features

3.1. The structuring dimensions of the FutMan scenarios

The scenarios on the future of manufacturing were structured around two qualitative dimensions of change. The first dimension comprises issues related to the *modality of policy* (integrated versus loose) and the second dimension subsumes issues related to public values, consumer behaviour and demand patterns (individual versus collective). These two clusters of key drivers were used to elaborate on the socio-economic scenario characteristics (see Figure 2).

The direction and pace of scientific and technological progress was also identified to be of crucial importance for the future state of manufacturing in Europe. For methodological reasons technological change was considered within the socio-economic scenario assumptions rather than using it as a structuring dimension for scenario development.[7]

Modality of Policy

An 'integrated' modality of policy refers to the deliberate co-ordination between different governance levels and policy fields. Among the issues that are considered under this dimension are for example *geo-political factors*, such as the future balance of economic and political powers between main economic regions (e.g. taking also into account China, India, etc.). There are a number of *international organisations* (e.g. UNO, WTO, ILO) that may provide fora for negotiating regulations between governments, industry and the civil society on international trade and economic development. Future regulations could be solely focused on ensuring free markets globally. Alternatively, global governance could take environmental and social issues into account in trade regulations. The *future regulatory environment* in Europe will depend on the governance system and the distribution of powers between EU, national and local levels (e.g. balance between central decision-making and subsidiarity), and whether and how different fields of policies and measures will be integrated (e.g. level of co-ordination between economic, environmental and social policies). The mode of policy will influence industrial activities and can facilitate or impede innovation and competitiveness in manufacturing. Governments can also set different policy priorities, adopt different approaches to policy making and favour a different policy mix in policy fields related to sustainable development (e.g. control of the environmental performance of industry, regulation of processes and products safety, etc.).

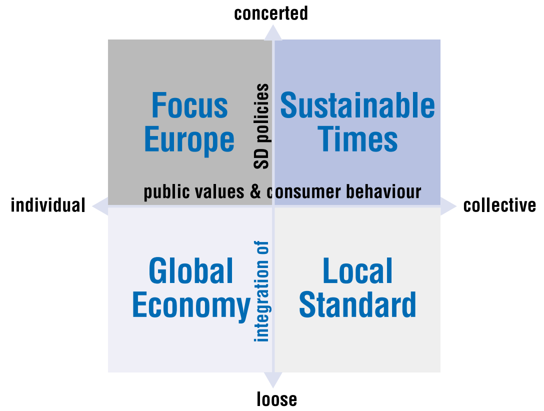
Public values, consumer behaviour and demand patterns

This structuring dimension includes issues mainly prevailing public values and consumer preferences that shape consumption patterns. A considerable number of the ideas championed to establish more sustainable forms of production and consumption (e.g. transition towards a service economy, closing production and consumption loops, etc.) intrinsically assume and depend on underlying changes in consumer behaviour. Attitudinal change at both individual and corporate levels remains therefore an issue for sustainable manufacturing. There might be also more attention in the future to implement corporate social responsibility policies in manufacturing companies. The development and direction of market forces remain an important issue for sustainable manufacturing. Further, demographic change (most notably through ageing and migration) will directly or indirectly influence industrial activities.

7 Clearly, technological change in manufacturing has an internal and an external dimension. To avoid circular reasoning in the scenario process, technology was mainly treated as an internal factor that is shaped and influenced by the external key drivers. However, it goes without saying that technology change in manufacturing has also strong external characteristics.

Manufacturing will be called upon to provide products and services for new societal needs and changing demand structures of tomorrow's Europe. Public values and consumer behaviour are particularly relevant in fields where adverse effects on human health or on the environment of new technology cannot be fully eliminated. Experience in the past (e.g. genetically modified food, nuclear power) suggests that cultural factors, public values and consumer preferences influence the adoption of technology significantly.

Figure 2: Structuring dimensions of FutMan scenarios



3.2. The socio-economic features of the FutMan scenarios

The main socio-economic characteristics of the socio-economic framework scenarios based on the structural dimensions presented above are presented in Table 3 (see pages 26-27). The table provides information on the characteristics of the four socio-economic futures developed in the FutMan scenario exercise. The different combinations of the factors' characteristics are not exclusive. They rather provide the scope for plausible visions on possible future technological and socio-economic states drawing on many individual drivers and factors. They should be considered as a platform to stimulate thinking on policy and technological options on the future of European manufacturing in 2020.

Table 3: Socio-economic features of the scenarios on the future of manufacturing in Europe 2015-2020

	Global Economy	Local Standard	Sustainable Times	Focus Europe
Global governance	WTO and multinationals enforces free competition. Global social and environmental accords watered down.	Limits to globalisation due to lack of public acceptance in regions. Emergence of new international and local protectionism.	Emergence of international governance bodies to promote sustainable development. WTO adopts social and environmental criteria in trade agreements.	WTO governs international trade and stimulates global competition. EU sets SD goals and pursues SD without international backing.
EU policy integration	Low integration of SD policies. Reliance on markets, voluntary industry commitment and as little as possible policy intervention to achieve SD.	Policy agendas are strongly influenced by regional interests and priorities. Limits to trans-regional coordination of SD policies.	Strong co-ordination and integration of SD policies between EU, Member States, and regions. Balance between regulation and incentives.	Strong EU co-ordination of SD. Emphasis on cost-effectiveness of SD policies. Policy provides fiscal incentives for industry.
Public values/ consumer behaviour	Emphasis on individualism and pursuit of personal utility. Highly individualised demand patterns. Broad variety of products and niche markets to meet various consumer needs.	Strong perception of crucial role of the civil society and the regional dimension to achieve SD. Companies pay attention to corporate responsibility and support local communities.	Community values. Individual aim to balance environmental, economic, and social aspects of SD (including global issues). Demand supports shift from product to service economy.	Individualistic values dominate and determine consumer behaviour. Regulation aims to correct 'distorted preferences' of consumers and industry.

Table 3: *Socio-economic features of the scenarios on the future of manufacturing in Europe 2015-2020 (Cont.)*

	Global Economy	Local Standard	Sustainable Times	Focus Europe
Innovation policy	Priority given to strengthen industry's competitiveness and innovation capabilities.	Priority given to strengthen regional and local innovation systems; national and regional programmes dominate.	Innovation policy aims to tackle key societal challenges (e.g. health, mobility, energy, etc.) in relation to SD.	Priority given to mission oriented, strategically important RTD programmes in new technology areas.
Transport / energy infrastructure	Liberalised transport and energy markets with the emergence of oligopolistic players. Low energy prices. Little emphasis on transformation towards use of renewable resources.	Re-emergence of regional monopolies in the energy sector. High energy prices. Transport infrastructure regionally fragmented with bottlenecks and gridlocks.	Mixed public-private markets. Regulation of the energy market to increase overall efficiency. High energy prices. Strong public investments in infrastructures for renewable resources for energy provision and transportation.	Liberalised transport and energy markets. Regulation aims to avoid monopolies and favours competition. Low energy costs. Research investments in renewable resources but little infrastructure investments.
Sustainable development	Strong emphasis on the economic pillar of SD. Growth seen as the prerequisite for any further sustainable development improvements.	Policies mainly respond to bottom-up pressure by interest groups. Regionally diverse situation as regards the balance between the three SD pillars.	Strong emphasis on the environmental and social pillars of sustainable development. Precautionary principle guides policy and industry actions.	Policies aim to influence consumer demand and industry by regulation and market incentives in support of SD. Strong technology focus.
Education system	Partial privatisation of the public education and training system. Multitude of private initiatives for higher education and industrial training.	National and regional responsibility for education co-ordination. Industry and associations involved in sector specific training initiatives.	Governments retain their lead role in education. Strong emphasis on strengthening the knowledge base and further education in Europe.	Co-ordination of public and private education schemes to increase industry's knowledge base. EU-wide training certification system.
Higher education	Strong emphasis on scientific excellence in education and training schemes within traditional science disciplines.	Diversity of education and training schemes, reflecting regional legacy and diversity.	Strong emphasis on interdisciplinary training, soft-skills, and problem solving capabilities.	Strong emphasis on scientific excellence in education and training schemes, cross-cutting science discipline boundaries.
Labour market	Little co-ordination of labour market and migration policies. Widening spread of labour costs between skilled and unskilled workers. Greater responsibility of individuals to make sure they are employable. Higher total labour turnover.	Little co-ordination of labour market and migration policies. Regional and industry initiatives to balance labour supply and demand. Widening spread of labour costs between regions. Labour mobility increases for high-skilled personnel.	Co-ordination of labour market and migration policies. Strong emphasis on tackling labour market imbalances in Europe. Focus on life-long-learning and re-training. High labour cost economy with decreasing demand for unskilled labour.	EU co-ordination of labour market and migration policies. Policies aim to attract non-EU specialists in areas of labour shortage, but otherwise restrictive. Policies aim to increase overall labour mobility within Europe.
Social security / labour costs	Social security increasingly left to the individual's choice and responsibility. Disintegration of legacy national schemes.	No harmonisation of EU social security systems. In some regions, social security becomes part of corporate compensation schemes.	Harmonisation of social security system at EU level. Provision of social security is perceived as a government responsibility.	Mixed public and private social security system where the individuals are responsible for choosing their scheme, within a compulsory framework.

4. Four scenarios on European manufacturing 2015-2020

4.1. GLOBAL ECONOMY

General scenario description

Consumers have pursued their personal utility without paying too much attention to environmental and social impacts of production and consumption. The free market has been considered the most effective way to allocate resources efficiently and to achieve sustainable development. Policy-making has been based on a 'small government' rationale. It principally has aimed to strengthen market mechanisms and competition. Policy objectives have been set on sector levels with little emphasis for integration across institutions or policy fields. Compared to its global competitors, Europe is under heavy pressure. Technology progress has been uneven. In particular, nanotechnology has not fully delivered yet on its more ambitious promises due to a lack of concerted policy action. The private car has retained its principal roles as status symbol and means of individual mobility. Manufacturers have focused on the customisation and individualisation of products. New ICT tools have increased the efficiency of product and process design. Environmental progress has been made incrementally as companies aim to cut costs by making more efficient use of resources.

Global factors, governance in Europe, and consumer behaviour

In the Global Economy scenario, the European Union and its Member States have emphasised strongly the role of market forces and free competition as the key enabler of economic development and technological innovation. The World Trade Organisation and the interests of large multinational companies shape international trade policies. The European Union and Member States influence on global level is rather weak. The global free market has been relied upon to solve environmental problems and to achieve sustainable industrial development. Likewise, markets have been relied upon to facilitate, co-ordinate, and transfer technological innovation. Voluntary industrial agreements and self-compliance of industry on basic environmental and safety standards are the main policy instruments to stimulate sustainability. Science and technology has been viewed as a crucial factor to sustain the cutting-edge in globalised markets. Public values are strongly individualistic and consumers pursue their personal utility.

RTD policies and technological change

Technological progress provides a mixed picture. Material sciences have been making progress in areas such as new, high-performance catalysts, building on the strengths of Europe's chemical industry. However, in other strategically important technology fields, the European Union is at risk lagging behind its competitors, since there has been little scope on long-term focused and mission oriented RTD programmes in areas such as nanotechnology or bioinformatics. Governments have aimed to stimulate industrial RTD investments in radical new technology, though the private sector concentrated on projects that pay off in the short-term. Europe has also been challenged by the new economic powers such as China and India. Manufacturing in Europe has benefited from RTD spin-offs from the other regions. The lack of integrated European RTD policy initiatives has restrained Europe's competitiveness and provided no incentives for the creation of lead markets. This has lead to bursting bubbles in the emerging technology stock markets.

Nanotechnology applications in the materials sector (e.g. nanocatalysts in the chemical industry) have become available. More radical nanotechnology applications (e.g. self-assembly, nanocomputing, molecular design, etc.), are still in their infant phases in research labs rather than embedded in products one can buy on the marketplace. Despite investments by electronic component manufacturers in nanotechnology research, nanoelectronic devices are not yet technologically and economically feasible, since silicon technology has proved to offer still significant room for innovation. Another problem for nanoelectronics has been the failure to establish internationally accepted standards for the measurement and testing of nanodevices.

Transport, mobility and energy supply

Individual mobility and the use of the private car has remained its symbolic status of an object to express personal identity. Affluent consumers buy highly customised and comfortable cars, equipped with cutting-edge electronic devices. New features have been added to the cars to increase their infotainment and office functions. The provision of new functionality in the cars has counteracted measures to reduce weight and energy consumption of the vehicles.

The state of the environment

Environmental progress has been made incrementally. Improving the energy and resource efficiency for cost reasons has been a must for industry to sustain its competitiveness, as is the intensification of industrial processes. However, no major changes have been made with regard to production paradigms: emissions and waste have grown with increased economic activity, even though the growth curve has become flatter.

Developments in manufacturing

The manufacturing sector has been facing a strongly cost-driven environment with fierce global competition. The industry has been under intense pressure to reduce costs and improve production efficiency. In order to cope with intense competition, industry has vigorously pursued further increases in productivity and reduction in time-to-market.

The production system has moved towards customer tailored production. Product innovation in manufacturing is characterised by interaction between suppliers and customers in the design phase to enable easy customisation according to individual customer needs. Producers offer their clients a wide range of options with high extra value. Product differentiation and adaptation has become the standard business strategy, with the aim of providing individually customised products. Global marketing and distribution networks have been set up to commercialise products all over the world.

The growing presence of embedded systems (the result of progress made in new materials and sensors in electronic components) has enabled new forms of information and knowledge management along the value chain. Information and communication technology has allowed the handling of vast amounts of data in distributed production networks. Advanced knowledge management tools have facilitated the co-operative development of new products (i.e. simultaneous engineering) within virtual factories. Industry has put emphasis on the development of intelligent man-machine interfaces (e.g. common platforms for data management, distributed storage of data, etc.). Expert systems and artificial intelligence applications have been developed in order to exploit knowledge and integrate different new types of information in the production process.

The design and engineering process for new products has been made faster and more flexible. Modelling and simulation tools, based on complex systems modelling have become standard in manufacturing. New visualisation tools have provided synthetic, easy to comprehend, visual information for designers, managers, and operators who need to assess on-line and in real time large amounts of data within distributed production networks. Manufacturers have focused on further automation of production. Automation has required more sophisticated concepts for process design and monitoring. Advanced process and product reliability techniques have been increasingly adopted by industry, as well as technologies related to plant surveillance, security and incident management.

4.2. LOCAL STANDARD

General scenario description

Local authorities and regional governments have gained new powers. The new European regionalism puts limits on policy co-ordination in Europe. European institutions face severe difficulties to co-ordinate the interests of regions and Member States. The civil society has become an important player in policy-making, especially at local level. Consumer and citizen groups push their agendas on local and environmental issues. The transport network has been suffering from bottlenecks due to shortfalls in investment and local opposition to new projects. The economic and social disparities between European regions and between Europe and its neighbours have not lessened. Whereas in some regions the society has shown a high level of awareness to environmental and social issues, in other regions economic and employment considerations have attained more attention. At local levels some very creative environments – new sources of innovation – have emerged. Complex systems management tools have helped industry cope with a challenging business environment. Strict environmental regulation in certain regions has partly led to the concentration of production sites which offer favourable regulatory conditions, partly to the adoption of radically new manufacturing approaches to retain production, and partly to the relocation of production abroad.

Global factors, governance in Europe, and consumer behaviour

In the Local Standard scenario, local authorities and regional governments have gained a powerful role in key policy areas. Regional governments determine policy priorities and drive regulation. The voice of Europe at international level has not always been harmonious. The European governance system has aimed – not always successfully – to provide co-ordination and reconciliation between sometimes conflicting interests. European regions have competed within the general European market framework. In line with the subsidiary principle the regions have developed their own specific policies related to sustainable development (e.g. industry policy, environmental policy, consumer protection standards, RTD policy, taxation, etc.). The EU decision making process is complex, slow and makes incremental process.

Consumer and local grassroot groups have become influential on local and regional levels. They successfully voice their concerns and call for action on environmental and social issues. Citizen groups have also campaigned for limits to unregulated globalisation, and for more environmentally benign economic and industrial policies. The attention citizens pay to environmental and health issues on local levels has been reflected in the regulatory framework. Strict but regionally diverse regulatory frameworks have changed the organisational structure of the manufacturing industry.

RTD policies and technological change

The co-ordination of RTD policies at European level is loose in the Local Standard scenario. Political support for strategic research investments (e.g. large research facilities, critical mass research infrastructure) has to be created on a case to case basis. Time consuming co-ordination processes put restraints on pro-active EU innovation policies for support infrastructures. In sectors which draw heavily on metrology and standardisation (e.g. electronics and instrument engineering) there is the risk that Europe will fall further behind in comparison to its competitors in the US and Far East. However, regional competition and the diversity on local levels have also stimulated innovation, technology development and transfer of innovative solutions locally.

Transport, mobility and energy supply

Due to high infrastructure costs and public resistance to the construction of new roads the European transport system has become increasingly congested. Local citizen groups have lobbied successfully for imposing restrictions to freight transit across the European Union. The measures taken have channelled international traffic and put constraints on interregional transport, especially in ecologically sensitive regions (e.g. trans-Alpine transit). Public opinion no longer accepted transport of dangerous goods on the road and rail network. New means of transport (e.g. pipeline systems) have been sought to overcome the barriers and obstacles in a congested Europe.

The state of the environment

With the emergence of local "islands of sustainability" the quality of the environment has improved in certain European regions, however the overall picture remains uneven. Due to the heavy pressure on the existing transport infrastructure, the long-distance transport intensity of production and consumption shows significant improvements. Regulation has facilitated the phasing out of hazardous products and processes and has led to the adoption of innovation production technologies (e.g. mini-plants, virtual design and production) and new infrastructures (e.g. local renewable energy provision networks).

Developments in manufacturing

In many industries manufacturers are under heavy pressure to improve their environmental performance. Local innovation initiatives have broadened the scope for new product and service development and new environmentally friendly concepts of product use and service provision have emerged. An increasing number of citizens buy locally, respectively regionally manufactured products.

The rather fragmented European political framework has created a complex business environment for internationally active manufacturing companies. Manufacturers have put great efforts to reconcile regional regulation and consumer demand patterns with efficiency requirements in design, product development, processes planning, and integration of the supply chain. The different global and local driving forces have created multiple local markets. Manufacturing companies have realised the need to adapt to local requirements while – at the same time – finding ways to achieve economies of scale. The creation of efficient logistic chains has become a central issue for the trans-regional shipment of goods. The production sector and the logistics industry have been challenged to find new ways organising their supply chains in order to cope with these framework conditions.

Manufacturing has developed long-life and easy-to-upgrade product platforms. Customisation of the products takes place in the local and regional markets as manufacturers have adopted sophisticated postponement strategies. Standardised and modularised semi-finished products are shipped to local plants and assembly sites. The design and production concepts, which have emerged, draw on advanced complex systems management tools. Information and communication technology solutions for data sharing in complex production networks have made multiple local production organisationally and technologically feasible.

Industries perceived as risky by the public have partly been relocated. In the chemical sector, for example, production sites have been chosen close to the big European ports with attached large-scale chemical industry complexes.

Despite the complex regulatory and economic environment, manufacturers have maintained production in Europe even if production networks are more regionally and locally organised. They take advantage of the availability of highly skilled personnel and the size of the total European market. To get permissions for the construction and operation of new plants manufacturers have invested in new organisational and technological solutions such as mini-plants. With this new production concept, small scale and highly customised local fabrication has become feasible, in line with strict environmental and safety regulations.

4.3. SUSTAINABLE TIMES

General scenario description

European citizens support the government's co-ordinating and regulating role to reconcile the economic, environmental, and social dimensions of sustainability. A global governance system has emerged that promotes sustainable economic development. Industry has been an active partner in sustainable development, closely collaborating with governments and the civil society. European manufacturing has been able to break the links between economic growth and resource use. Socio-economic change has been occurring at a fast pace, enabled by successfully linking technological opportunities with organisational innovation. The energy supply system is in transformation towards renewable resources and fuels. Bio-resources have started to replace non-renewable materials. The material design for low-resource intensive production processes takes into account recycling, de-composition, and after-use treatment. New forms of mobility systems have emerged and the internal combustion engine's dominance in vehicles has been challenged by fuel cell technology. Manufacturing companies have increasingly focused on the provision of services rather than selling products. Novel applications of information and communication technology have supported the transition towards the service economy.

Global factors, governance in Europe, and consumer behaviour

In this scenario the European Union has adopted a policy approach towards sustainable development that strongly emphasises multilateral action on economic, environmental, and social challenges (e.g. climate change, environmental consequences of the catching-up process in developing countries, etc.) in accordance with the international community. The emergence of global level governance systems supports world wide sustainable development. International organisations that govern political, social and economic issues such as the UN, the WTO, and the International Labour Office, etc. have become increasingly important. They have become the main fora for negotiations between governments, industry and the civil society. Within the EU, the European institutions define and implement clear sustainability policies based on broad stakeholder participation, both globally and between national governments. Both market incentives (e.g. energy taxes, emission charges, other financial incentives) and regulation (market regulation, performance and direct regulation) are used as policy tools to foster sustainability.

RTD policies and technological change

The role of research and technology has been to provide solutions for these societal ends. Product development and demand has been stimulated by the public sector. New business opportunities have arisen from novel technologies (e.g. nanotechnology, renewable energy and biomaterials, fuel cells). The public sector has aimed to stimulate both organisational and technological innovations, which are considered as necessary to achieve system changes. Public incentives have aimed to resolve conflicts between personal utility and the overall public benefit which in the past often had impeded the adoption of superior solutions. Through the support of transformation processes (e.g. with respect to energy supply, material intensity of production and consumption, feedstock for chemicals, mobility, etc.) public policy has de-linked economic activity and environmental and social impact. Organisational and social innovations have altered the design and the provision of products of services. Europe has succeeded in creating lead markets for innovative product-services.

Transport, mobility and energy supply

New infrastructures and service providers have emerged in the transportation sector. Car manufacturers offer customised mobility services and do not just sell cars but are marketing mobility solutions. The automotive industry has focused on vehicle safety, zero-emission vehicles, alternative fuels and fuel-cell technology. The new patterns of vehicle use have changed car design requirements. Personal vehicles offer new features and service dimensions, including for people with special needs. The car is no longer at the centre of personal transport. The boundaries between private and public transport have become increasingly blurred. The concept of mobility has been replaced by accessibility as guiding principle for the organisation of the transport systems. New mobility services have been tailored to the users' needs. High-quality inter-modal public transport and freight transport solutions have been developed. The public sector has supported key players to provide new infrastructure needed to replace fossil fuel consumption, such as infrastructure for bio-fuels and hydrogen fuel cells.

The European energy system has shifted gradually towards the use of renewable resources (e.g. bio-mass, wind, sun). Fuel-cells have become widely available for stationary applications. The changing energy supply system has had strong implications for manufacturing, especially for the motor vehicle and the chemical industry. Europe has taken the opportunity to fully exploit localised and renewable energy technology and production. Europe has become the world leader in this technology area.

The state of the environment

There are strong improvements in the state of the environment and Europe has been duly on its way to achieve the goals and objectives of the European sustainable development strategy. Altered consumption patterns and strong service orientation in industry have resulted in increasing dematerialisation of production. The ongoing transition towards renewable energy resources has contributed to radically reducing carbon-dioxide emissions in industry and the transport sector. Since industry and governments take the pre-cautionary principle and the environmental and social dimensions of sustainable development very seriously structural improvements, such as a more balanced regional development in Europe have been achieved. The European model for sustainability development is actively promoted in other global regions.

Developments in manufacturing

The manufacturing industry has considered its role as a responsible actor and corporate citizen, working together with governments and consumers to solve problems on local and global levels. The industry has closely co-operated with governments on regulation in support of sustainable development. Public health and safety, as well as ethical concerns have played an important role in technology development.

Manufacturing industry has sought to reduce material consumption through design, re-use, and recycling measures. Life-cycle optimisation of products and services has become a key feature in manufacturing. Industry has aimed at radically improving resource efficiency and de-materialising production. Producers have adopted product stewardship programmes. Disassembly processes, taking into account the total product life-cycle are optimised. Material-intensive single-use products have been increasingly substituted by knowledge-intensive services. Consumers have been willing to buy services rather than products. There has been a strong trend towards the convergence between device producers and service providers. A leasing and rental market for high price consumer goods has emerged. Service providers have taken advantage of standard designs and low maintenance technology. The introduction of mandatory systems for take back and recycling has required manufacturers to invest in lifetime control of their products. This, in turn, has stimulated innovation in modular design, re-use technology, collection and separation technology, and reprocessing.

Public funds have supported mission-oriented research activities in bio-materials. Bio-degradable and renewable materials have been developed for high-volume products (e.g. bio-polymers) and fine chemicals. Bio-materials have become an economically feasible alternative for fossil resources in the petrochemical industries. Fossil feedstock (i.e. oil and gas) has been partly substituted by basic bio-material products coming from agriculture. Although not representing a large proportion of total fuel use in Europe, bio-materials have been successful in finding application niches in European and external markets.

New electronic components have offered new ways to integrate of human and technological resources in products and production processes. More sophisticated measuring and sensing devices have decreased material use and the environmental burden of manufacturing. Consumer products and industrial applications take advantage of embedded intelligence and sensors based on advanced knowledge-content materials. Critical to the development and acceptance of the new service and product provision concepts has been the use of ICT in a socially responsible way, taking into account privacy concerns.

4.4. FOCUS EUROPE

General scenario description

Citizens see governments being principally responsible to achieve sustainable development. Individualist values and behaviour prevail among European consumers. The European Commission has emerged as a powerful actor to guide society towards sustainability. Its policies are guided by the principle of integrated utility of policy measures (i.e. balance economic, environmental, and social utility). European policies have increasingly introduced fiscal instruments to create incentives for sustainable production in industry. Europe has pursued a strategically targeted industrial policy to facilitate the development of environmentally benign products and services. As a result new business opportunities emerged for European manufacturers in international markets. At international level, Europe has been confronted with new competitors, especially in Asia (e.g. China and India). International trade has been facilitated through the WTO, though there has been little international support for European demands to take environmental and social issues on board. Since behaviour patterns of consumption have not changed significantly, the scope for broader socio-technical innovations have been limited. New technology has not been able to break socio-technical lock-in situations and innovation has followed rather traditional trajectories: For example, the near zero-emission-car based on the internal combustion engine has become reality. However, the shortcomings associated with individual mass mobility and freight transport prevail. Ambient intelligence has been widely implemented in both the public (e.g. intelligent transport systems) and the private and industrial sphere (e.g. for control and surveillance applications).

Global factors, governance in Europe, and consumer behaviour

In this scenario, the European Union has taken the lead with regard to sustainable development. Europe has implemented sustainability policies for manufacturing, in which it has presented a vision of a highly competitive industry that at the same time actively pursues the minimisation of negative environmental effects and safety risks. There has been strong emphasis on the role of new technology to achieve these objectives. The European Union has imposed legislation that sets clear performance and efficiency standards for industry to meet sustainable development goals. However, discussions between regulators and industry about adequate performance goals (i.e. What is Best Available Technology?) and the most appropriate means to implement policies (regulation, self-regulation, standards, taxation, fiscal incentives, etc.) have led to rather slow pace of policy implementation.

The main competitors at global level, the United States and the emerging economies in East Asia, have not followed Europe's approach to reconcile economic growth and environmental protection. Europe's industry has invested in eco-design production techniques to increase resource efficiency and has reduced the direct and indirect impacts of production on the environment. The lack of international harmonisation on environmental issues initially created problems for European manufacturers. However, new market opportunities have also emerged, especially in the fast growing Asian export markets for environmentally benign technology. With worsening pollution related problems in other world regions, especially in India and China, exports are booming.

RTD policies and technological change

Targeted European technology policy has fostered industrial innovation. Co-ordinated support of EU policy for higher education and research systems has reconfirmed Europe's position as a key player in a global manufacturing product market. Both industry and the public sector have paid attention to strategically important technology fields and cross-cutting science themes. Industrial policy and RTD priorities have focused on instruments to further strengthen Europe's competitive advantage in sustainable manufacturing, such as the reduction and substitution of dangerous substances in industry, the development of new advanced materials, clean production processes, and ICT applications. Europe has also been successful with developing new materials while finding innovative ways to reduce emissions, the use of hazardous substances and the generation of waste in the production processes.

Transport, mobility and energy supply

The public sector supports large scale demonstration schemes for alternative fuels (e.g. ethanol and bio-diesel). The optimisation of the internal combustion engine and successful introduction of hybrid systems contributed to a more energy efficient transport sector. Policies have mainly been geared towards finding technological solutions to existing problems (e.g. related to transport congestion) without trying to influence consumers' behaviour and preferences or invest in new infrastructures. As combined heat and power cycles for energy supply and more efficient production techniques became standard in industry, energy consumption per value unit decreased strongly.

The state of the environment

The state of the environment has improved due to the wide-spread adoption of innovative environmental technology, cleaner production and waste minimisation measures. Also Europe's greenhouse gas emission record indicates major steps forward due to energy efficiency measures. However, there has been an underlying tension between prevailing individualistic consumer preferences and the potential of change provided by new technologies. It has not been possible to fully exploit the innovative potential of new technologies, since more radical innovations would have required also organisational (and behavioural) change. This lack of scope has limited the de-materialisation of production and consumption and the implementation of new product-services.

Developments in manufacturing

The manufacturing industry has devoted considerable financial and human resources to research and innovation on the substitution of hazardous materials and processes. Industry has replaced dangerous substances such as heavy metals and organic solvents in manufacturing processes. In the chemical industry energy and resource efficiency have been improved by reducing production steps. Intelligent process engineering and sustainable chemistry have been introduced. However, the energy system and industry is still based on fossil resources.

The electronic components industry has succeeded in developing new generations of micro-processors based on ink printed circuits for systems-on-chip solutions, advanced embedded software products and better sensors. The strong European automotive and industrial automation sectors have created demand for innovative electronic components in the first place. They have been among the first users that replaced silicon semiconductors for specific automotive applications (e.g. the flexible nature of organic polymers allows a higher degree of customisation, higher reliability, reduced energy consumption, easier to recycle low cost polymer substrates). An important prerequisite for successful market penetration has been the establishment of standards for software tools in embedded systems.

The manufacturing sector has introduced sophisticated sensors and measuring instruments in production processes. Sensor and actuator agents have been increasingly embedded in manufactured products, especially for digital production management, quality control and maintenance. They have created new market opportunities for the electronic components sector and for the measuring, precision and control instrument sector. For industry applications, the electronics and instrument engineering sectors have met the demand for distributed sensing and intelligent networks, for example for the management of production processes and environmental control. Ambient intelligence and ubiquitous computing solutions have been utilised to improve public services in areas such as transportation (e.g. for transport management and control systems) and public security. New sensor and control technology has been installed in control, identification and surveillance systems (e.g. tagging technology for goods and identification technology for individuals) in industry and the public domain.

Individual and unrestricted mobility is a key value for citizens. Policy has not aimed to challenge this. The car industry has focused on the design of clean cars and safe vehicles, without changes in the dominant power-train concepts. The industry has improved active and passive safety of vehicles, and has developed fuel-efficient, near zero-emission engines. The car industry has been the main driver in the development of lightweight materials and weight-efficient construction. Self-diagnosis technology has optimised the servicing and maintenance of cars. Powerful sensor technology and the integration of electronic components have supported innovative product development. Drivers are also supported by road telematics infrastructure.

5. Conclusions

The scenarios on the Future of Manufacturing in Europe 2015-2020 highlight important developments, trend breaks, challenges and opportunities for sustainable European manufacturing in the future. The FutMan scenarios suggest that the interplay of a variety of key drivers – most notably related to globalisation, new technology, market demand, public values, fiscal measures, regulation and overall societal change – will contribute to shaping the future landscape of manufacturing in Europe. While certain drivers, for example global developments, are largely independent of the European policy arena, other factors can be shaped and influenced by policy measures at European level to support of achievement of the goals and objectives laid down in the European strategy for sustainable development.

The main conclusion to be drawn from the analysis of the scenarios is: Whether sustainable manufacturing will become a reality seems to be hardly a question of technological opportunities alone. New technology, socio-economic factors, and the policy framework will jointly determine the dynamics of change. The scenarios indicate that progress towards sustainability will depend on the successful alignment of technological, organisational, and societal factors that are required for 'system changes' towards sustainability in European manufacturing. The scenarios suggest that the main obstacles to achieve progress towards sustainable manufacturing seem to be primarily located in the political and market arena, rather than being caused by a lack of technological opportunities.

The interfaces between the various technological, socio-economic, and policy factors presented in the scenarios point to potential triggers for system changes towards a more sustainable manufacturing future. The analysis of the scenarios suggests the following conclusions to be drawn:

Sustainable manufacturing will only become reality if lead markets for sustainable products and services can be created

The scenarios indicate that the approach manufacturers will adopt to strike the balance between the three pillars of sustainability might vary considerably depending on the socio-economic framework. European manufacturers will actively pursue sustainability objectives only if they can anticipate new market opportunities. Without new market and policy incentives, manufacturers are more likely to concentrate on short-term economic performance improvements, rather than pursuing long-term sustainability goals. In such a scenario, sustainability in manufacturing might be compromised, or it will only emerge as an unintended side effect rather than being the results of a balanced industrial policy approach. Such a situation is highlighted in the Global Economy scenario. The creation of market opportunities for sustainable products and services will require the successful alignment of technological, organisational and social innovations to overcome rigidities and technological lock-in situations.

Different policy priorities will support different technology trajectories

The scenarios suggest that the future challenges for manufacturing can be quite clearly identified on a fifteen-year time horizon. However, the adoption pattern for new technology and their specific characteristics are less certain and will be shaped by the socio-economic framework, policy priorities and consumer demand patterns. The specific applications of technology will mirror industry's approaches to balance competing challenges (i.e. related to global, economic, regulatory, and consumer pressures). The scenarios point to different possible development paths that might be followed in the future. The scenarios challenge the idea that new technology will automatically revolutionise the way Europe produces and consumes and stress the importance of socio-economic and political factors. Without sufficient policy and consumer stimulus current practices in manufacturing might prevail and direct technology development along existing technological paths, rather than lead to the creation of more sustainable production and consumption patterns. Undoubtedly, there is still significant potential for improving the sustainability record of industry along existing trajectories, even though investments may show diminishing returns in the future. More radical manufacturing innovations will require socio-economic and policy changes to accompany technological change (e.g. transformation towards renewable resources, mini-plant manufacturing, etc.). The transition from supply-side (i.e. selling products) to demand-side (i.e. deliver services) manufacturing, in particular, will necessitate new approaches for gaining momentum. Environmental and market regulation and public support for the provision of new infrastructure are also critical issues to make system change happen.

Europe's manufacturing industry shows promising strengths that policies for sustainable development can exploit and build upon

The scenarios point to promising strengths of Europe's manufacturers that help realise the vision of sustainable development. In the scenario exercise the automotive industry and the chemicals sector emerged in particular as precursors for sustainable manufacturing. Europe can build on its competitive advantages and help industries create lead markets for more innovative sustainable products and services. European policies can foster the creation of lead markets by stimulating demand, fiscal incentives, (environmental) regulation and by reducing investment and market uncertainties (i.e. investment in new infrastructure).

Transition towards renewable resources will require sustained public backing

Whilst raising resource efficiency is clearly in the interest of the manufacturing industry and progress is likely to materialise in all scenarios, the transition towards renewable materials and energy resources will be far more challenging. Improvements in industrial resource efficiency are even likely if energy and resource prices remain on low levels over the next fifteen to twenty years. Plenty of efficiency improvement measures do not require new energy or material sources: modelling and simulation, micro-production technology and improved process technology will help industry to reap the benefits of new technology. In contrast, raising the use of renewables is likely to depend on high energy prices. The transition towards renewables will also require strong public commitment, especially to finance infrastructure, and is likely to continue far beyond the 2020 time horizon. In the medium term, bio-resources are more likely to substitute non-renewables in existing production chains rather than building the starting point for radically new manufacturing processes. Increasing the use of bio-resources significantly will require significant research resources, supportive regulatory frameworks, and investments in infrastructure.

Widespread technological and organisational change in manufacturing due to nanotechnology adoption might happen beyond the 2015-2020 time horizon

Both due to envisaged technological limitations and legacy structures in the economy and society, nanotechnology seems to be unlikely to radically change the patterns of manufacturing on the 2015-2020 time horizon. Whilst on the long term, nanotechnology has the potential to alter production patterns dramatically and provide strong support for sustainable development, on the short and medium-term the expectations about nanotechnology's contributions to sustainable development should not be overstated.

Nevertheless, nanotechnology research proves of utmost strategic importance for Europe.

Sustainable manufacturing will require a dialogue between governments, industry and society on the impacts of new technology

The potential risks of new technology need to be taken into account to ensure public acceptance. The scenarios confirm the high potential of ICT (on the short and medium term) and nanotechnology (on the long term) on manufacturing processes and the future organisation of the industry. However, new technological progress in ICT and nanotechnology will undoubtedly create new challenges and risks too. Policies towards sustainable manufacturing need to take into account issues related to the potential risks of new technology. Among the questions that need to be addressed are: How does ubiquitous computing and ambient intelligence increase the risks for unlawful and intrusive practices? What are the effects of ICT in future production processes and embedded in product devices on privacy and identity? Where are the potential conflict lines between public security and privacy? What are the risks for the environment of the widespread use of nanostructured materials? What are the consequences of the hydrogen economy for occupational health and safety and public hazard management? How does the increased complexity of new materials and smart devices affect resource efficiency, life-cycles, recyclability and waste treatment? What are the long-term consequences of the transition towards renewable resources? Policy makers need to pay attention to these questions. Second-order-effects of new technology must not be omitted. If industry and governments fail to engender trust among consumers and citizens, public opposition may impede the adoption of new technology. The adoption of the precautionary principle in technology development may help avoid unintended negative effects in the future.

Globalisation means that sustainable development has a strong global dimension

Sustainable manufacturing in Europe is affected by various global factors and has a strong international dimension. The scenarios indicate that global drivers of change can potentially both ease or reinforce international and European disparities. If global governance of trade (e.g. by WTO) remains mainly confined to open markets and facilitate global competition, existing strengths and weaknesses of nations and regions might become even more pronounced in the future. By the same token, progress towards sustainability might be limited. In contrast, if environmental and social issues become part of global economic and trade agreements, the global exchange of products, services and new ideas can contribute to a more balanced and sustainable industrial development.

RTD policies can only be one element in a broader, concerted policy approach for sustainable development

Innovation for sustainable manufacturing requires paying attention to the interfaces between RTD policies with other critical policy fields for innovation. RTD policies can only be one – but crucial – element in a broader, concerted policy approach needed to make sustainable development happen. Strong emphasis needs to be placed upon the management of the interfaces between RTD policy and other policy realms (e.g. competition policy, intellectual property rights, standardisation, education and training, environmental policy, labour market, employment and social policy) to facilitate the creation of a truly sustainable European manufacturing industry. Fiscal instruments and incentives, such as tax regimes (e.g. energy, emissions) and capital write-off regulation, are likely to play a more prominent role to facilitate sustainability in the future.

Both diversity of innovation systems and research excellence in European will back sustainable development. On the one hand, diversity of academic and industrial research can create innovative local clusters. On the other hand, policies can promote critical mass research, scientific excellence, and the transfer of knowledge within the Europe. Strong regional policies combined with co-ordination of strategically important RTD topics at European level provide the best prospects for industrial innovation in support of sustainable development.

Standardisation, metrology, and intellectual property rights will be critical enablers for the successful adoption of new manufacturing technology

Industrial standardisation, metrology and intellectual property rights (IPR) emerged as future key challenges to be meet for the successful exploitation of new technology. Innovation processes will become increasingly multidisciplinary. The need for knowledge exchange and networking in RTD across organisational boundaries will increase the pressure on the current IPR framework. Tackling future metrology needs, especially related to nanotechnology (i.e. standards on measurement, testing, quality and performance of nanotechnology devices) are certainly critical issues for instrument engineering and the electronic industry. Other industries are affected too: in the automotive sector standardisation, for example, and interface management seem to be crucial for the long term success of alternative propulsion systems.

Multidisciplinarity will be key to achieve radical innovation breakthroughs

The FutMan scenarios point to variety of technological opportunities which can only be taken advantage of if new skills and competencies can be made available. Sustainable manufacturing will require highly trained scientists and engineers who are able to co-operate with colleagues from other scientific backgrounds. In this respect, the notion of interdisciplinarity should not be defined too narrowly and aim to include socio-economic and policy issues to overcome the existing barriers towards sustainability. Sustainable development is hardly conceivable without a broad problem sensitivity of those in industry, research, governments and the civil society who contribute to the shaping of innovation. University education and vocational training schemes should raise the awareness and problem solving capacity of students for integrating 'non-technical' issues in research questions and pay more attention to the transmission of 'soft skills'.

Appendix 1: Summary of the FutMan Scenario working groups

During the FutMan scenario workshops the experts discussed in four working groups how their sector would evolve provided that the socio-economic assumptions in the respective FutMan scenarios would come true. The experts discussed the key challenges for their manufacturing sector in the scenarios and the likely approaches industry would take in order to remain competitive. The experts also deliberated about science and technology requirements and priorities that are likely to prevail in the scenarios. Appendix 1 sums up the consolidated results of the exercise.

Electronic Components[8]

The electronic component sector consists of the main categories semiconductors and electro-optical components, passive electronic components (e.g. capacitors, inductors, ferrite) and electromechanical components such as printed circuits, relays and switches (NACE 32.1). The most important of these categories are semiconductors and electro-optical components. The semiconductor industry is dominated by few large and world-wide operating companies, with American and Far-East based corporations strongly placed in the electromechanical components sectors and the passive electronic components sector smaller sized and large companies are widely distributed over the Member States of the EU.

The semiconductor industry in particular is a highly dynamic sector with short product cycles and strong increases of product performance. In 2001, the world sale of semiconductors amounted to €145 bn. In addition, around €55 bn of revenue were generated from the sales of semiconductor equipment and materials. It is a highly capital-intensive industry, with high fixed and low variable costs. Transport costs play a minimal role. The sector is RTD intensive with about 16-18% of revenues spend on research.

Sector drivers and challenges

The minimisation of the environmental burden in the sector will entail a number of challenges and associated activities. Against a background of increasing complexity of activities, energy consumption will continue to increase. The challenge of the “clean” environment will extend beyond Europe, with global issues becoming more important. Recycling will assume greater significance, with emphasis placed on the recycling of both packaging and power units. The proliferation of the use of mobile and other devices give rise to concerns of potential health risks.

In terms of the challenge of the integration of new knowledge, challenges are presented by the limits of miniaturisation and quantum mechanics, by new materials and the tension between developing software skills and hardware solutions. Automation and increased complexity will require new workforce skills.

In the electronic components sector, it is debatable whether there are strong differences with respect to key technologies between the four different FutMan scenarios. The differences are likely to be a matter of degree and characteristics of adoption. Essentially, the same sorts of technologies are likely to emerge in each scenario, but the degree of uptake and diffusion, and the nature and extent of applications for these technologies, would vary.

While, at the general level, modularisation could be seen as a kind of technical minimalism, in the electronic components sector, it could imply the reverse, with modular components allowing the development of ever-more complex products.

8 This section draws upon the working group summary drafted by Kieron Flanagan.

Also of major significance to this sector are issues of software and embedded systems.

Ubiquitous or pervasive systems, including the continuum from ubiquity (with even the most common, low value objects being "tagged" with microprocessors) to a more conservative vision in which a range of embedded sensors in the product environment provide much of the same functionality. Clearly, the likely extent of ubiquity is a major question for this sector, and it might be that in some scenarios full ubiquity may be less attractive to consumers than in others. In this context, the monitoring of people for health, surveillance, marketing and market research purposes is a possible driver for the electronic components sector.

Alternative transport and mobility models for the different scenarios may make particular demands on electronic components, such as shared transportation systems, or leasing or rental models for cars. Different scenarios might see different uses of embedded systems and transport telematics (e.g. for charging, monitoring or control). In each case there would be a demand for components.

To support the developments envisaged in the scenarios, there is a possible need for a new design paradigm for software. It would incorporate design for security, reliability, as well as completely new approaches from artificial intelligence research.

The available experience with recycling of computer equipment underlines the need for design for disassembly in order to reduce recycling costs. Less wasteful design practices (e.g. in which the use of metals is reduced) would actually make recycling less economically feasible. This could require a new concept of recycling, beyond a simply economic process. In tandem new concept of production and design are necessary, one example being that recycled plastics from redundant PC equipment are not used by computer manufacturers for new equipment because the plastics do not meet the high standards sets by the producers. This emphasises the difficulty of closing loops in the production chain without coordinated action.

There is a tension between resource conservation and the concept of ubiquitous sensors, processors, actuators, etc. To reconcile the need to conserve resources with the desire to embed intelligence and sensory capacity into objects and the environment will require new ways of designing, producing and using/consuming embedded components and the objects in which they are embedded. There is a similar tension between design for multifunction or design for miniaturisation and design for disassembly/recycling. An expansion of solar electricity generation could drive demand for components. As for nanotechnology, it is unlikely that this emerging technology area will have widespread economic impact on the time-scale considered.

Sector scenario outlook

Global Economy

In the Global Economy scenario, the key features are: a good perception of and a tendency towards aversion of liability and risk, leading to technological conservatism; a highly specialised but diverse industry structure; the emergence of a free chaotic system of economic activity and its governance, a fast reactive policy system; high energy intensity of production in relation to other scenarios; and the domination by private cars that are tailored to customers needs and personal utility in a congested road infrastructure. The design or importation of disruptive technologies for niche applications will be an important pattern in this scenario. Also services will be embodied in products, while modularity and embedded systems will be important drivers to build up complex 'mass customised' products.

Industry structure will change towards new forms of virtual vertical integration, dominated by those who own the intellectual property rights. Production will be driven by new consumer requirements and products will be more user friendly, containing for example voice and speech processing technologies. There will be a greater tendency towards embedded systems and self-service embodied in products. The adoption of recycling will be inhibited by problems in the enforcement of obligatory recycling practices.

Local Standard

The Local Standard scenario is characterised by the responsiveness of policy to pressure groups and divergent policies at regional and local levels. A "not in my backyard" attitude of citizens prevails and public concerns over nanotechnology and the use of ubiquitous ICT make leaps in these areas less likely to occur. Consumer choice will drive manufacturers towards cleaner, more ethical production at local level and flexible regional specialisation of production. Modular, robust components will be important, but in this scenario the expectation is that these would be for the production of simpler systems. Broader systems change towards sustainability may occur at a later stage in this scenario, while disruptive technology may also be late in appearing. This scenario might still see a shrinking environmental footprint of European industry, but without a fundamental de-coupling of the unwelcome symptoms of economic growth from growth itself. At the extreme this could amount to a turn away from industrialisation and technology and towards more traditional models of existence/subsistence.

Transport infrastructure is likely to be particularly vital to a decentralised, flexibly specialised economy, however severe logistics challenges are likely the consequences of localisation in the Local Standard scenario.

For nanotechnology, there will be difficulties with public acceptance and with the likely fragmentation of research activities. However, nanoprocesses require new underlying engineering science and a big research effort. It is likely that specialised nanotechnology clusters will emerge. In smaller countries and regions, a niche strategy will be more appropriate for the development and application of technologies. The question remains of what will be the generic technology for these clusters.

Sustainable Times

In the Sustainable Times scenario, the main characteristics are a greater control of society by itself. A common language between scientific disciplines will emerge and facilitate multidisciplinary research. Dangerous production sites might be closed or transferred to off-shore locations. Europe's future competitiveness might be characterised by a slow-down in innovation rates. Emphasis is given to increase energy efficiency and products will be designed and built to facilitate recycling. Technological development will concentrate on bio-materials for chemicals, and bio-inspired materials. ICT will also be important, helping to reduce the demand for, or substitute for travel, as well as in the development of ambient intelligence for control applications.

In the Sustainable Times scenario industry, consumers, governments and the civil society will jointly shape the nature of manufacturing activity. The issue of public acceptance of new technologies plays a significant role in this scenario. Nanotechnologies can be developed and applied taking into account public concerns. There is a need to build greater confidence and trust between actors.

Focus Europe

In the Focus Europe scenario, the main defining features were summarised as the acceptance of "big" government by the citizens; the perception and acceptance of liability and risk as important issues for manufacturers; the shift towards greater multidisciplinary and integration of European research; co-ordination between policies aiming to make markets work; and the internalisation of external costs in production and consumption. The main technological developments drawing on electronic components would include diagnostic technologies and controls, and aspects of nano- and biomaterials. The large-scale application of research in the latter areas to solve major social problems in health, food safety etc, is likely to achieve greater public acceptability in the Sustainable Times and Focus Europe scenarios.

In the Focus Europe scenario, developments in nanotechnology will be carried out in collaborative networks. Also the highly regulated nature of this scenario means that there is greater demand for measurement and control technology. This could lead to problems with public acceptability of products and processes. In the development and application of recycling technology, the collection of waste and recyclable material will be a barrier to re-cycling.

Measuring, precision and control instruments[9]

The measuring, precision and control instruments sector covers the manufacture of instruments and appliances for electronic measuring and recording equipment, checking, testing, automatic control and navigation and optical precision instruments (NACE 33.2 and 33.4). The sector can be thought as pervasive enabler that has significant impact on the development of the broader economy. Products of the sector are applied both directly and as process control and diagnostic tools in such diverse industries as automotive production, telecommunication, environmental engineering, chemical and pharmaceutical industry and knowledge intensive business services. Socie tal factors, such as consumer behaviour and public values have indirect impact on the structure and the performance of the sector and of its dynamics rather than affect the sector directly. For instance the monitoring of environmental regulation (e.g. lower emission rates, reduction of pollution of industrial activities) requires more sophisticated measuring and sensing devices.

Key drivers and manufacturing challenges

The output of the sector plays a critical role in the increasing performance of manufacturing systems (i.e. in terms of flexibility, adaptability, productivity, and effectiveness), and instrument engineering products allow the development of new types of relationships between machines and their environment (human and physical). The sector is highly depending on global economic trends and especially on investment activities of manufacturing industry outside Europe, particularly in the United States. Therefore, the long-term prospects of the European producers depend on the ability to compete globally, against U.S. and Swiss companies in high technology products, and against Asian producers at the lower end. There is a fear that European companies might relocate production. Motivations for relocation might be manifold. For example, the main markets of the sector are outside Europe. Further, shortage of specialised labour may require instrument engineering companies seek for spatial proximity to 'expert pools'.

Moving on from the general characteristics of the sector working group, the participants identified important driving forces for instrument engineering. Improvements in material science and material engineering could foster developments in this sector, because many measurement and control devices and systems could be fully exploited only after the discovery of new materials (e.g. hybrid materials). The use of nanomaterials (e.g. nanosensors) could simplify the testing and measurement procedures. And vice versa, the sector can contribute to the development of nanoscience and nanomanufacturing with producing devices for measurement and analysis of structures with nanoscale dimension (e.g. ultra-thin layers, ultra-precise handling of surfaces).

Measurement and testing procedures as well as industry standards are crucial to ensure the compatibility of processes and products with functional and performance requirements. Furthermore, the adoption of new technologies (especially nanotechnology) in manufacturing is likely to depend on the availability of measurement systems and testing procedures as pre-requisites for reliable and inter-

9 This section draws upon the working group summary drafted by Claudio Roveda and Kieron Flanagan.

changeable devices. It would be essential to have measurement and testing systems in place for product developments that contain nanotechnology applications. Sectors such as precision engineering, micro-electronics and biomolecular technology depend on metrology as a prerequisite to exploit nanotechnology. Such procedures are required to ensure that quantitative results are comparable, and they are essential to establish reliability and to create confidence among users.

Increased government investments in scientific institutions and public labs could induce higher demand for the sectors' outputs. Another important driving force for the sector is the regulatory framework (e.g. stricter emission norms, fulfilment of environmental standards, employer and consumer protection). More sophisticated measuring and sensing devices, sensors embedded in industrial products and use of multi-materials can contribute significantly to minimise of the environmental burden with saving energy and resources used in manufacturing processes. New measuring and sensing devices can also support the integration of the knowledge through networking solutions with integrating human and technological capabilities.

One of the major challenges for the sector is how to keep producers in Europe. Key instruments engineering companies may move closer to their clients located in the US or East-Asia where the major mass-production plants are located. Another important challenge is how to secure the labour supply for the sector in Europe. New combination of skills, more multidisciplinary research and education is required to sustain the global competitive position of European companies. Integration of disciplines is therefore necessary for further development of the sector. Company level training will play a crucial role, because employees acquire the specific knowledge on site which usually takes several years of work experience. Training programmes can also be directed towards end-users to demonstrate the effective use of devices (with features and performances radically different from the current ones) as well as to learn from users' experience. Networked European basic research facilities are the potential sources of the integration of knowledge. Adequately funded co-operative research programmes can help exploit the large amount of scientific results and (tacit) knowledge stored in individual research institutions.

Measuring, precision, and control instruments contribute significantly to the increase of the efficiency of the supply chain in manufacturing (e.g. in automotive and chemical industry). The users of the products of this sector highly influence the design, characteristics and specification of the output which are mostly tailor-made, unique and self-contained with specific characteristics. 'Mass-high-precision' production could be a threat for the sector in twenty years time if the industry would witness the widespread use of self-assembly at nanoscale which needs radically different measurement and control equipment.

The workshop participants were not able to agree how the future structure of the sector will look in fifteen to twenty years time horizon. They assumed a possible industrial structure of the sector that will consist of few large global companies (possibly some of them will be European) surrounded by a quite large number of middle and small sized companies. In this projection, large companies will be specialised in developing basic technologies, strongly engaged in co-operative research with universities and research institutions.

Sector scenario outlook

Global Economy

This scenario was seen to be more conservative, characterised by incremental technological development but quick diffusion. This could happen because of the failure to establish internationally accepted standards for radically new measurement and testing devices.

Products of the sector will contribute significantly to the improvement of the energy and resource efficiency and the overall increase of productivity in manufacturing through more intelligent man-machine interfaces, expert systems and artificial intelligence applications which support the exploitation of knowledge. Instruments for modelling, simulation and visualisation as well as sensing devices for road telematics will support distributed production networks. Instruments for plant surveillance, security and incident management will support the effective management of production networks.

The industry structure will change through vertical integration. In this scenario the 'stronger will win' concept prevails (US-model) which means that market mechanisms could lead only longer term to the implementation of the sustainable development policies. Sector-specific research (e.g. metrology and optics) and dominant companies will concentrate in the US and East-Asia. Europe's measurement, precision and control instrument sector might fall behind in the Global Economy scenario.

Local Standard

In this scenario, industry drives innovation and policies remain divergent at regional and local levels. Transport infrastructure and intelligent logistics are likely to be particularly vital to a decentralised, flexibly specialised economy. In smaller countries and regions, a niche strategy will be more appropriate for the development and application of technologies. For nanotechnology, there will be difficulties with public acceptance and with the likely fragmentation of research activities. In this scenario the European instrument engineering sector will be probably less competitive in comparison to the US and Far-East because of difficulties to ensure support for strong public development and standardisation initiatives in the field of metrology.

Sustainable Times

The sector supports disassembly processes with the provision of separation technology. Sophisticated measuring and sensing devices contribute to the decrease of material and energy use of overall manufacturing activities. In this scenario there will be higher demand from the industry side for the products and services of the sector. On one hand, industry buy-in, use and substitute old technologies and products in higher amount than in other scenarios. On the other hand, the issue of public acceptance of new technologies plays a significant role, as public acceptance is key for innovation in this scenario. Therefore, there is a strong need to build confidence and trust between actors. New mobility services in transportation and the necessary developments for bio-fuels and hydrogen fuel cells open new opportunities for instruments engineering companies. However, the scenario raises questions about the future competitiveness of the European manufacturing industry unless global co-ordination between the main economic blocks can be achieved.

Focus Europe

Active technology policies and strong support of the European research and education systems will lead to more top-down innovations. With external costs increasingly internalised in the price of new products and services, producers may face cost barriers and high-tech products might be more expensive. This scenario might imply a more competitive European industry, where more potential exists for the development of new technology in the measuring, precision and control instrument sector. The increase of competitiveness of European firms in the sector is based on legislation on performance and efficiency standards set by European Union. Companies use sophisticated sensing, control and measurement instruments in production processes. New sensor and control technology has not been installed only in environmental control, but also in identification and surveillance systems. In car manufacturing there are many new application fields, for example devices for the control of near-zero-emission cars, self-diagnosis technology for service optimisation and vehicles maintenance.

Basic industrial chemicals[10]

The NACE class 24.1 *basic industrial chemicals* comprises a heterogeneous conglomerate of

10 This section draws upon the working group summary drafted by Jerome Casey and François Farhi.

chemical industry activities ranging from high volume petrochemicals, bulk polymers and fertilisers to low volume special and fine chemicals such as dyes and pigments. Basic chemicals require further treatment within the chemical industry itself in order to be converted in downstream chemicals for industrial use, agriculture of consumer markets. The basic chemical industry produces intermediary goods, i.e. its products are mostly used as inputs by other industries. Only 4% of basic chemical output is sold directly to consumers and more than 40% is sold directly to other chemical industries such as paint manufacturers, plastics and rubber goods producers, etc. The electronics industry is the largest consumer of petrochemicals. The automotive industry is one of the largest users of organic chemicals due to the importance of plastics in car production. The largest end-user of inorganic chemicals is the fertiliser industry, using large amounts of ammonia, sulphuric acid and phosphoric acid.

Key drivers and manufacturing challenges

The driving forces and sector specific challenges vary considerably between the bulk and fine chemicals sectors. To discuss the differences within the chemical industry in more detail, the participants drew a line between petrochemicals and bulk polymers on the one hand, and fine chemicals on the other. Then they highlighted similarities and differences between them.

Important drivers for the petrochemical sector are fiscal policies such as tariffs, taxes and quotas. Geopolitical stability and energy prices are also important issues. Furthermore, the regulatory framework, such as environmental regulation, plays an important role in the decision making process of multinational petrochemical companies. The availability of RTD resources is more relevant for the fine chemicals sector. Since in countries like China or India highly qualified RTD-personnel will be available, the Far-East could gain a competitive advantage in the future. In both chemical sectors the future development of the markets in the USA, Europe and East Asia will play an important role in the location of the industries.

Whereas the petrochemical sector is very capital intensive and less labour and RTD intensive (RTD usually amounts for less than 1% of total costs), the fine chemicals sector spends 3-5% of their costs on RTD. Also labour costs play a more significant role in the fine chemicals industry. Product development in fine chemicals in the future will be characterised by customer tailored products adding more value for the user industries.

Since the petrochemical industry in Europe is based on naphtha feedstock, Europe has a stronger role in fine chemicals compared to the USA. Naphtha crackers produce more by-products which build the basis for downstream fine chemical production. With more flexible demand patterns in the future, more flexible processes will be needed. The growth prospect for the fine chemicals sectors in the next two decades is considered to be more than twice the rate GDP-growth, double the rate to be expected for the petrochemical industry.

Deregulation in the 1990s encouraged the petrochemical industry to seek new approaches to energy supply contracting. Pipelines were built between the UK and the Netherlands to take advantage of better gas supply contracts provided by UK gas companies. Likewise, some Dutch petrochemical plants obtain electrical power from France. In the petrochemical industry a trend towards the co-generation of heat and electricity at refineries will emerge.

The petrochemical sector is energy intensive and its development strongly influenced by feedstock availability and energy prices which are set on global level. Prices and availability of raw material resources that account for 70-80% of production costs are the determining factors that shape the industry. Increasing energy prices in the future could create a market for C_1-feedstock (i.e. methane, methanol).

The main market for petrochemical products is still Europe, whereas there might be a trend to shift production to oil-producing countries or countries in the Far-East where the industry anticipates the emergence of strategically important new markets. The sources of technology in the petrochemicals sector are in Europe and in the United States.

With regard to logistics, the trend in the petrochemical industry will lead to less inland crackers and a concentration of production at large-scale, intensified petrochemical sites in coastal areas close to the big harbours. Pipelines will also become more important in order to reduce other forms of land transport of feedstock and basic chemicals. In the fine chemicals sector the logistic structures in the future will be customer-orientated with decentralised production for a wide range of products in order to avoid transportation costs (e.g. for products that 'contain' large amounts of water or are of low density like styrofoam).

The production of customised polymers will be key for the long term competitiveness of the petrochemicals sector. More application development is needed to achieve success with customised polymers. A further technological challenge is the development of new catalysts for methane- and other C_1-feedstock. With respect to hydrogen as main energy source, new processes for the production, distribution and use of hydrogen need to be developed. The production of methanol poses another major challenge in the future. Breakthroughs in the direct production of methanol could facilitate the shift to C_1-feedstock in the long run and provide cheap energy sources for fuel cells. More effective technological solution for separation processes (e.g. H_2-separators) taking advantage of progress in membrane technology will emerge, driven by fuel providers which currently invest heavily in fuel cell development.

In the fine chemicals industry, nanopowder technology and new production concepts such as soft-chemistry, ionic solvent and sol-gel processes might be adopted by 2020, provided that processes can be sufficiently up-scaled. Hybrid materials and mixed materials (e.g. metals, ceramics, polymers) will have become a critical market for fine chemicals by then. High throughput technology for the development of new materials and pre-products for pharmaceuticals will become important.

The fine chemicals sector will benefit from enzymatic catalysis and GMO-engineered chemicals. New modelling and simulation techniques will support the design of new chemicals and chemical processes. In the 2020 time frame bio-feedstock is unlikely to be of any broader significance for the petrochemicals sector. In the fine chemicals sector, though, some types of bio-feedstock, such as olio-chemicals already exist for niche-market applications.

More generally, both the petrochemicals and the fine chemicals sector will face the challenge of streamlining design, manufacturing and use of products and services. New metrology needs and nanotools for production will become important issues in the future. In both industries a new design rationale will emerge that builds upon a strong model-based approach both for process and product development in order to optimise asset utilisation. Process intensification will lead to more compact and complex plants which will pose new challenges for plant-wide control technology and might, in turn, require a more flexible regulatory framework (e.g. with regard to obligatory shut-downs and inspections). Online monitoring and non-disruptive and non-destructive measurement techniques will become critical components of process intensification.

Sector scenario outlook

Global Economy

In this scenario industry is reactive to external influences (e.g. regulation, international competition, oil prices, etc.). Liability and risk perception are the main drivers for manufacturing. In order to limit the risks for liability claims rather conservative designs might evolve. The scenario assumes a free and 'chaotic' economic and societal system, supported by fast and active policy initiatives (not co-ordinated though). New disruptive technologies may create opportunities for niche markets. These technologies can then be bought in for other application areas. This scenario provides potentially a very innovative environment for short term activities. However, it is unclear whether it inhibits or facilitates long term investment in new technology. For some of the technology priority areas in this scenario public funding might be needed to achieve breakthroughs.

In this scenario the development of new nanostructured catalysts can be expected since the competitive environment gives companies a free ride for innovative product development. New materials, especially polymers for electronic components (e.g. printable circuits) are likely to become available, as well as intelligent adaptive materials. The industry will focus on hybrid nanobased materials with improved qualities (hardness, low weight, scratch resistant, etc.). Besides, the scenario offers spin-offs from military research programmes (e.g. smart textiles, lightweight batteries, etc.) to be exploited in the civil sector.

As far as chemical processes are concerned, high throughput technology is expected to make progress in this scenario, as does computational chemistry, stereo-specific chemistry and bio-catalysis. Lab-on-chip technology will mature and industry is likely to seek for genetic engineering applications for new bio-enzymatic reactions. Pressure to increase resource efficiency will force the industry to make better use of by-products of chemical processes.

The increased global competition will force the chemical industry to shorten their planning and product development time from lab to production. Integrated plant design and plant control solutions will be adopted. New process and plant monitoring techniques and real-time monitoring tools will help increase overall productivity, efficiency, plant safety and security.

Local Standard

In this scenario one can assume 'consumer schizophrenia'. Policy making is responsive to pressure groups, and policies are divergent on regional and local levels. Strong consumer protection regulation can be assumed, reflecting public concerns. In some regions, the development of new products and services is strongly driven by consumer choice towards a more clean and ethical production. The predominantly regional demand structures require new solutions for flexible specialisation in the manufacturing industry. Industry might adopt strategies to focus on modular, simple, and robust components for their products and services. Intelligent logistics plays a key role in the scenario. Furthermore, the industry will aim to add value to existing assets and resources.

Due to high pressure to innovate, CO_2 as feedstock might become feasible, although the technology is currently still far away from industrial application state. On local levels production sites will have to demonstrate and communicate high safety standards. To ensure safe chemical production, the supply chains are likely to become more integrated with minimum intermediate transport and storage. Localised and alternative energy production concepts will develop and new small scale production techniques for special chemicals production will reach application stages. The public resistance to building new plants assumed in this scenario may lead to the concentration and intensification of already existing petrochemical sites.

Sustainable Times

In this scenario a shared multidisciplinary language between industry, citizens and governments on sustainable development has emerged. The industry is proactive and with a strong prospective orientation. Dangerous processes and the production of dangerous materials move offshore. The scenario assumes a reduction of personal mobility. Trust between government, industry and the public is essential to make the scenario work. The scenario assumes the scarcity of non-renewable, fossil feedstock and energy sources. Bio-materials for new chemicals will develop and bio-inspired materials may emerge. The industry seeks for major technological breakthroughs in order to de-couple material and energy use from production (e.g. new product and process designs). The reduction of personal mobility and goods shipment seem to be only possible assuming the widespread use of ICT to substitute and optimise mobility and transport demand.

The Sustainable Times scenario witnesses the emergence of new photo cells for industrial solar energy production and the development of hydrogen fuel cells. Fuel cells become economically feasible due to the internalisation of environmental and social costs of conventional energy sources and significantly increasing energy costs. New catalysts will help to improve energy and resource efficiency of chemical production. New separation technology (membrane technology) will also contribute to more efficient chemical processes. Modelling and simulation tools will be systematically used in product and process design. For niche products the industry will experiment with bio-based feedstock. Greenhouse gas emissions will be reduced through using bio-mass based feedstock (e.g. ethanol) for polymers. The chemical industry will strive for the optimisation of product life-cycles and will provide in close co-operation with customers a higher service component with their products. Large investments will be made to create a new pipeline infrastructure for feedstock since public pressure urges the industry to abandon the transport of dangerous substances on rail or motorways.

Focus Europe

The key issue in this scenario is whether the citizens are going to accept 'big government'. Liability and risk perception are critical issues, and European research is likely to move towards the integration of multidisciplinary research. Co-ordinated policies ensure that markets work and external costs are being internalised into the prices of products and services. Fiscal instruments, such as taxation and tariffs are important drivers. The key technologies in this scenario are diagnostic and control technologies, as well as new nano- and bio-materials. Furthermore, the industry focuses on sustained resource efficiency.

In this scenario progress on C_1-feedstock technology can be expected. In order to decouple production and energy demand co-generation of energy (electricity, steam) will be widely adopted by the industry. Government regulation provides the incentives for the industry to reduce greenhouse gases. Plastic waste will be widely used to produce energy for plants and households in combined heat and power incineration plants. The public sector supports the industry with the provision of an efficient collection infrastructure. New catalysts based on nanostructured materials will gain high attention by the industry in order to reduce the chemical industry's energy consumption. Smart materials will be used for health application and other sophisticated products of public interest (e.g. real time monitoring for security, safety and control applications).

Regulation and market pressure will force the industry to adopt process technology improvements. Simulation will become a standard technique for product and process design and management. Simulation and modelling will contribute to minimise material and energy use in the design process while meeting specific customer requirements. Computational chemistry will be used to calculate the chemical properties and reaction kinetics without prior experiments and costly pilot applications at an early development stage.

Motor vehicles[11]

The motor vehicles sector (NACE 34.1, 34.2) covers the manufacture and assembly of motor vehicles, and the manufacture of motor vehicle engines. Motor vehicles include passenger cars as well as commercial vehicles. All volume car producers also operate in the commercial vehicle market, especially the light commercial vehicle market. The motor vehicle sector contributes from 4% to 8% of the GDP and accounts for 2% to 4% of the labour force in OECD countries. The motor vehicle sector leads all other industrial sectors in RTD investments. In addition this sector has a direct impact on a variety of other industries ranging from raw material and component suppliers, to machine manufacturers, research and technology institutes, car repair shops, retailers and financial institutions.

11 This section draws upon the working group summary drafted by Matthias Weber.

Sector drivers and challenges

In the next years the motor vehicles manufacturing sector has to deal with a number of challenges. Some of the major challenges include controlling the impact on climate change, improving air quality and promoting sustainable development in the supply chain.

Among key drivers and challenges for this sector, supply chain efficiency is understood in a broad manner that comprises product development and design renewal, dealers and post-sale services. For example, different product architecture in the sense of modular design has important implications for manufacturing processes because the precise integration of the components represents a major challenge. Modular and individual designs, together with reliable, cost-effective manufacturing need to be applied to offer the customer a broad and affordable range of products. This evolution, together with continued outsourcing, will transform vehicle manufacturers mainly into systems integrators. As products become increasingly similar in their quality and design, you compete mainly between industrial systems. The suppliers will assume more responsibility for the final product providing additional services in manufacturing or product development. A closer co-operation with suppliers allows for broad-ranging measures towards the creation of a comprehensive vehicle-recycling infrastructure. In general, the challenge for the future of car manufacturing is to promote sustainable development in the supply chain. New electronic components and ICT will drive and affect technological development in the motor vehicle industry.

As far as the minimisation of the environmental burden is concerned, the key drivers for car manufacturing include the introduction of lightweight materials. The mandatory take back of old cars would ensure that manufacturers go for life-time control of their products. The growing presence of embedded systems will require new forms of knowledge integration in design, processes and products. The growing scientific foundation implies a higher degree of codification, facilitating spill over effects between companies.

Knowledge management is a way to improve the process of co-operative working (e.g. simultaneous engineering) and to integrate new knowledge. Here the main problems are data handling, data integration, and the protection of knowledge. The improvement of workforce skills will be important.

General scenario outlook

The motor vehicle manufacturers have a significant impact on financial markets around the world, and this sector is considered, in many ways, as barometer of overall economic performance. On the other hand, the international financial markets have a significant impact on the car companies. Companies are assessed by investors on global performance indicators. This will significantly influence the management of car companies, leading to more transparency regarding their economic, environmental and social performances.

However, the motor vehicle sector is associated with a variety of negative influences related to manufacturing processes and the use of vehicles. Vehicles are responsible for air pollution and contribute to the deterioration of air quality, this is of great public concern and has put vehicle manufacturers under pressure to satisfy global customer demand while minimising environmental and social impact to the greatest extent.

Motor vehicles manufacturing facilities are potential sources of emissions of harmful substance, accumulation of waste material, and consumption of energy and water. Environmental considerations must be integrated into the decision making process when manufacturing facilities are updated or new facilities are planned to meet the growing demand for motor vehicles. In order to move efficiently and effectively people and goods, it is necessary to optimise interaction of different means of transport at both the inter-modal and intra-modal levels.

The challenge of sustainable development requires new forms of partnership and co-operation with governments, institutions and private companies in the form of public-private or private-private partnerships, and a close co-operation with the mineral oil industry for the provision of cleaner fuel is desirable. In this respect, vehicles and fuels should be treated as a system.

The increasing use of information technology reduces design and development times and improves process flow. Individual product steps can be linked more smoothly through integrated supply chain management based on workflow management solutions.

One key factor in the success of the motor vehicle manufacturing consists in the increasing co-operation with suppliers. Suppliers are responsible for no less than 70% of the output chain in the automotive industry. This reduces in-house production by manufacturers. The reason for this is the trend towards ever-greater specialisation in conjunction with growing model line-ups, niche offerings and the increasing number of feature and equipment variants.

In relation to research and technology priorities, it is necessary that the sector captures the potential improvements of those solutions that will be of dominant importance in the next decades. Electronics and communication systems are important devices for driver assistance, enhanced safety for road users and infrastructure support for incident and efficiency management and for on-board services and infomobility applications. Research on material use, powertrain technology, and vehicle design technologies have medium term impact on the efficiency of the future vehicle. The same is valid for advancements in manufacturing and production to guarantee efficient production for affordable products. The issue of sustainable supply and use of raw materials and energy will be important issues. Fundamental material and energy studies, including life-cycle-costs, stable and controlled supply infrastructure, recycling, are needed to improve the future sustainable mobility and transport system.

On-going improvements will lower the overall life-cycle-costs of the vehicle. However, the large number of vehicles will make the total resource usage an ongoing challenge. Therefore, material and manufacturing aspects need to be considered as integral parts when designing the vehicle, e.g. low friction, lightweight and high temperature material for powertrains, crashworthy vehicle body constructions using lightweight material. Resource usage (energy and material) needs to be further addressed through even more lean and efficient manufacturing, energy-efficient operation and recycling, resulting in substantially reduced life-cycle-cost (in manufacturing, operation, recycling, disposal) for the vehicle compared to the situation of today.

The future of the European motor vehicle industry will depend on global developments in the automotive sector. Therefore one should not overrate the weight of EU-policies. Too much depends on how markets and technologies will develop in other parts of the world. The expert group stated that the different socio-economic scenario assumptions could be realised in different markets or world regions. In this context it seems important to note that many countries outside Europe (i.e. less developed countries) face a different type of problem pressure and demand on automotive manufacturers than is the case in Europe. This may imply a greater need for more integrated mobility management systems and different types of vehicles. One cannot exclude the possibility of less developed countries leapfrogging Europe rather than just following the same development path. For many alternative mobility options the technologies exist, but not yet the markets and the demand for them.

There seems to be a clear trade-off between customisation and short delivery times, at least in the mass production mode. Once it is possible to switch to "batch" production in automotive manufacturing this may be different, but it depends on future material technology and major capital-intensive production machinery (e.g. for welding).

Some experts argued that fuel cell technology may not be in widespread use in 2015-2020 since there are more cost-effective solutions much easier and earlier available that would allow to reduce energy consumption. This raises the issue, why to encourage hydrogen based fuel cell technology when internal combustion engines are clean nowadays. The only driving force towards hydrogen seems to be the objective to reduce global warming and to reduce Europe's dependency on fossil fuels. Fuel cells would require a high degree of policy co-ordination due to its infrastructure components. European governments would therefore need to act and to lead technology and infrastructure development. Although industry could probably do it itself, it seems to be too much locked in the internal combustion engine paradigm.

The two major policy decisions ahead are thus related to the hydrogen-option and the mobility provision option, with inter-/multimodality being a special way of providing mobility which is more likely to happen in a concerted scenario, whereas as single-mode mobility provision will prevail in a loose policy co-ordination context. These two required fundamental changes will also depend on oil-prices and mid-term strategies of petrol companies. Since the transition towards a hydrogen-based infrastructure requires time, the next five to eight years will determine the path Europe will take.

The expert group identified three broad future technological trajectories for the car manufacturing sector and mapped these onto the four baseline scenarios. The three trajectories could happen under different time-horizons but are not mutually exclusive. The main elements of three trajectories are:

Multi-Local Society: This technology trajectory requires a radical change in the society that should be based on strong community values and consumer behaviour, as well as completely new patterns of production and consumption where the diversity in different European regions has contributed to create specialised poles of production. The Multi-Local Society development path seems to be viable only in the Local Standard and Sustainable Times scenarios and would require more than twenty years.

Mobility Provision: This development path aims to optimise transport and mobility building upon the existing infrastructure with some upgrading. It seams to be feasible to realise this development path within a ten-year time horizon. The realisation of Mobility Provision as dominant technology trajectory in the motor vehicle industry could find supportive environments in the Focus Europe, Sustainable Times, and Local Standard scenarios.

Eco Car Manufacturing: This trajectory requires a new power-train paradigm based on fuel cells powered vehicles and heavy investments in the hydrogen economy and infrastructure. It probably requires a longer time horizon for its realisation (around 20 years) and seems to be feasible only in the Focus Europe and Sustainable Times scenarios.

The three trajectories refer to certain policy portfolios and priorities, as indicated in the following Table 4.

With regard to the future capabilities of companies to pursue the respective trajectories, the Multi-Local Society trajectory would require being able to organise production locally, though with trans-local control and overall co-ordination. This could lead to some sort of franchising model, where first tier OEMs provide brand and the 'recipe' of production, but the actual assembly is done locally. Much RTD would be needed also to realise the mini-plant concept. IPR could become either a very important issues (e.g. in technology areas where new types of intellectual property needs to be protected) or even irrelevant (if open source solutions emerge). The emerging build-operate model for new assembly sites would require car manufacturing to adopt a more integrated local production component than in today's 'on demand' production model. Economies of scale would still exist in this trajectory, especially as regards RTD, even if decentralised production emerges.

The technologies required in the Mobility Provision trajectory do essentially already exist today, though their uptake is very much dependent on supportive transport policy, the availability of standards and organisational innovation.

In the Eco Car Manufacturing trajectory, manufacturers would prefer to go immediately for

Table 4: Policy portfolios and priorities in support of future Motor Vehicle trajectories

	Multi-local society	Mobility provision	Eco-car manufacturing
Transport policy	- Less long distance freight transport	- Transport policy (standards) soft part	- Infrastructure
RTD policy	- Reshaping of industry - Franchise production - Mini-plants - IPR (Intellectual Property Rights)	- Soft factors (Technology Assessment) - Integration of technology and system design - Planning, scheduling, controlling security systems - New materials	- Components car infrastructure through SMEs - Need development for storage safety features - Infrastructure
Energy policy	- Decentralise power generation		- Hydrogen - Infrastructure
Competition policy	- Decentralise jobs - Different labour market policy	- Incentives - Taxation - Security / safety - Social exclusion	- Lead market concepts - Competition issues

hydrogen rather than adopt intermediate solutions such as methanol, in order to keep the chemical industry out of the business. This trajectory requires an energy infrastructure based on renewables to ensure positive effects for sustainability. In the Eco Car Manufacturing trajectory, SMEs could produce particular components and subsystems that require highly specialised knowledge and RTD. Car manufacturers could outsource these RTD functions, but keep / share the IPR. In this trajectory big car manufacturing players are likely to dominate the scene, however it would give SMEs a key role to play in the innovation process. It is not certain that assembly would remain in Europe if this trajectory is pursued, since RTD and electronic systems integration could also be supplied from outside Europe.

However, for their realisation the three trajectories would require policy interventions in different policy areas, beyond research policy, to facilitate and support developments. As illustrated in the table below, policies that will be affected by the trajectories include RTD policy but also transport policy, energy policy and economic and employment policies.

The policy portfolios and approaches will shape future technological opportunities and research priorities. The following table summarises some of the key technology and research fields that are likely to be pursued under the respective trajectories.

Many of the technological developments mentioned could occur in all scenarios. However, there would certainly be differences in terms of: timing; detailed shaping of the dominant design; and degree of diversity of technologies in the scenarios. For example, new competitors will emerge for the automotive manufacturers as electric motors become a key component for future vehicles. The 'on-demand' production model may also lead to a declining role of the current manufacturers. What will remain, however, is the key automotive manufacturers function with respect to the integration of the control systems, i.e. what integrates the entire vehicle even if assembly and key components are being out-sourced. Closer co-operation/merging with the main electronics groups could be an interesting element of the scenarios. The electrical power-train is possible and even likely in all scenarios.

Global Economy

In this scenario, social inequalities in society become more distinct. The well-off individuals dominate the demand patterns. The car retains its central role in society and technology development in power-train technology concentrates on more powerful but efficient engine concepts. The main objective is to maximise utility for those who can

Table 5: Trajectory specific technology and research priorities in the motor vehicle sector

Trajectory	Technology and research priorities
Cross-cutting themes	- Net shape processes like hydro forming - New materials for joining technologies
Multi-Local Society: Focus on industrial, competition and regional development policy	- Lightweight materials and structures offering disassembly & re-use - Design development processes for vehicles that allow low capital cost production processes - Virtual reality lab: laboratory where the suppliers, experts and industries can define the shape, the assembly, of the vehicle. - New product architecture (platforms, modules, services) to create distributed production - Modular production - Smaller & local final assembly sites - Financial engineering for plants/ build/ operate -models
Mobility provision: Focus on transport policy and standardisation	- Organisation modelling and tools to support the design, installation operation and maintenance of novel infrastructures and systems - Payment systems - Simulation vertical factory integrated systems - Logistic optimisation systems - Solution oriented partnerships building methodologies - Financial engineering for plants/ build/ operate –models - Methods to keep control of individual products during total lifetime - Modular vehicle design for easy upgrading of more durable vehicles - Device assistant system (speed warning, keep lane) - Modular components (tele-prevention) - Update software/ function with wireless communication system - Recycling of components - Information management and communication systems - Systems for payments for function - Information security (encryption). Information system mobility &secure, smart cards for identification, payment and access. - Design methods for service sale-of-use - Technology intelligence for SMEs (i.e. materials) - Logistics for fleet management - Organisational models
Eco-car manufacturing: Focus on RTD and technology policy	- Fuel cell/ hydrogen - Fuel cell technology large scale production - Clean fuel systems and supply infrastructure (clean energy supply) - Lightweight materials (metals and composites) in design, handling in production, recyclability and dismantling - Lighter materials (polymers, carbon-glass fibres, Al, Mg) new applications - Materials and processing technologies for all product lifecycle including disassembly, recycling, waste management - On-board hydrogen storage system for safety and functionality - Design methods for service sale-of-use - Technology intelligence for SMEs (i.e. materials) - New typologies of cars - Methodology for corporate TA (ecological and social dimension; technology management for sustainability)

afford it. The trends in market demand might favour bigger and heavier cars with sophisticated information, navigation, and entertainment systems in the top-calls product range. Innovative technology is used to feed and process information to the driver and to shield him from unwanted contacts. In this scenario, the car driver becomes even more the 'king of the road'. The scenario assumes tough competition between few global motor vehicle producers. There are little incentives for compatibility between devices and platforms of different producers. Product liability is an important issue in this scenario, and court litigation is the key to product innovation – or the reason for the lack of product innovation.

System change is not likely to happen in the scenario and the socio-economic scenario assumption will not support the adoption of radically new approaches towards transport and mobility, such as hydrogen fuel cell technology, optimisation of intermodal transport networks, and new mobility service models.

Individual cars will be customer tailored. There will be increasing opportunities for mass market automobiles with new functions and market differentiating features regarding increased security, comfort, entertainment, etc. Consumers who can afford it buy interactive, highly comfortable cars equipped with infotainment devices.

The engineering processes in this scenario are assumed to be quick and flexible. Due to local skill shortages, the scenario may requires the relocation of skill intensive segments of the production chain to regions where skilled labour force is available. Manufacturers will put emphasis on further training of the workforce in order to keep their personnel.

Local Standard

In this scenario the experts assumed the decentralisation of manufacturing operations in the motor vehicle industry. Local utility will drive consumer behaviour towards car use and mobility. There will be no large scale investments in transport infrastructures at trans-regional level and the hydrogen economy is rather unlikely to emerge in this scenario. Technology development is likely to concentrate on increasing efficiency to compensate for higher fuel prices. Industry will also focus on technologies to improve the maintenance, repair, and remanufacture of vehicles. On local levels isolated innovative solutions to transport problems might occur. The IPR problems remain unsolved.

Some components production will still depend on large scale plants. However, there will be a strong restructuring and decentralisation of assembly and disassembly which implies major changes in the organisational structure for assemblers. Full lifetime control of vehicles and product liability will be part of selling vehicles because of the high degree of awareness of citizens. In general, this might lead to simpler and more harmonised vehicles design to allow for reconfiguration and local assembly. Modular design approaches will be developed to meet different demands at local levels.

Local authorities become more and more powerful on issues related to environment regulation. The industry has to be able to adapt to the local social demand patterns. Vigilant consumer groups could place irrational constraints on production in this scenario and hamper investment decisions of the manufacturing industry. On local levels, however, novel innovative product-services for the green mass market might emerge and grow significantly. Car sharing and car pooling could become dominant patterns of vehicle use on local levels. The product innovation in the motor vehicle sector is likely to concentrate on intelligent socialiseable vehicles; process innovation might focus on localised solutions.

Sustainable Times

In this scenario, the participants assumed that fuel cells and the hydrogen economy is a reality. In terms of dominant technology, the fuel-cell hydrogen stake is gradually replacing the internal combustion engine. The citizens trust their governments. Consumers question their own needs and base their purchasing decisions on broader societal considerations. The term competitiveness has a broader than economic meaning in the Sustainable Times scenario. The car loses its principal role as status symbol and public transportation revives. Multi-modal and intelligent transport solutions become available. Authorities introduce stricter speed limits and aim to shift attitudes and behaviour of citizens. Also the new Member States buy in the new model of mobility provision in which sophisticated ICT applications reduce mobility demands. Industry introduces full life time control and management for their products.

In this scenario, one can assume a decreasing mobility demand and a decentralised approach to mobility provision as well as to vehicle manufacturing. The manufacturing industry will strongly pursue service-orientation in product design. However the scenario requires a shift of attitudes in society. Given the awareness of citizens on environmental and social implications of mobility, there is no rebound effect to be expected from the deployment of ICT in transport and mobility services. Voluntary agreements between governments and industry would be a very effective policy instrument in this scenario, due to the co-operative behaviour implicit in the assumed responsible citizens and industry behaviour.

Vehicle manufacturers move towards the introduction of new mobility services that sell the journey rather than the product. Similar to developments in the telecom sector today, one can assume a move towards the convergence of infrastructure providers, device producers and service providers. Overall, the importance of the car in the mobility value chain would decline.

The scenario requires a highly qualified labour force with new skills with regard to design, organisation, and management of complex production systems. The scenario provides a golden opportunity for European renewable energy technology in which it already holds world leadership today. New pricing schemes will create incentives to save and substitute fossil fuels. The shift from product 'vehicle' to mobility services will shift the industry's attention towards public transport or completely new mobility services.

There is a high potential for integrated and intermodal transport chain services due to highly integrated infrastructure. The scenario opens the possibility of Europe to become the lead market for a new socio-technological transport and mobility paradigm. However, there is also the risk of mismatch with developments at global level if this process is not being actively supported by governments. The Sustainable Times scenario allows for solving the conflict between personal costs and public utility (an issue that often limits the adoption of socially more favourable technological solutions) and it facilitates the creation lead market for clean transport technologies.

Focus Europe

Under this scenario there seems to be not much scope for broader system change. However, the following might occur in the Focus Europe scenarios: The governments set targets and standard taxation all over Europe. They require producers to reduce the emissions of new vehicle drastically (e.g. 80% of today's best available technology). In general, government regulation moves towards performance specification that might favour making technologies more efficient rather than promoting radically new ones. Drivers pay per kilometre and marginal costs pricing has been introduced widely. Co-ordinated policy at EU level brings about marginal cost internalisation in all transport operations. Taxes and road charges are used to reduce the negative effects of transport on society as a whole as well as transport users. A progressive CO_2-tax is introduced all over Europe. Europe succeeded with its implementation of the Galileo GPS system. This paves the way for large scale road telematics application in transport control and management systems. With regard to e-safety, governments also take the performance regulation approach and require industry to develop solutions. Clean energy provision for environmental sustainability is being enforced. The scenario assumes oligopoly market structure: energy companies, car manufacturers and oil companies share the market and use their market powers to prevent new entrants to enter the markets.

The enforcement of the Integrated Product Policy (IPP) leads to new vehicle design and distribution / redistribution systems for cars. The car recycling industry is monopolistically or oligopolistically structured. Novel car systems and components for e-safety, e-security, e-payment, e-emissions control, and e-navigation are widely available in this scenario. Manufacturers are in advance of regulation, but would need a regulatory pull to create real demand. The critical issue in this scenario is whether citizens are willing to accept 'Big Government' type of interventions that dominate the Focus Europe scenario.

In the Focus Europe scenario, integrated sustainable policies might be similar to the Vision Zero policies already introduced in Finland and Sweden. Mobility is considered as an integrated socio-technical system that includes the driver, road, and the vehicle. Powerful cars are still wanted though. There is strong company engagement to define and implement mobility policy strategies. The main product developments would be orientated towards energy saving and the clean production of cars. Concerted policies drive technology development towards the development and use of lighter materials and lower CO_2-emissions. The new cars would provide customers 'oriented individuality', which includes individualised cars with increased service dimension (the 'hyper serviced car'). Many small assembly sites spread all over the world closer to the market. The priority given to radical science-based innovation strengthens Europe's competitive advantage in advanced manufacturing technologies, car electronics, product design tools and in materials sciences. Technology policy aims at picking technological winners. The adoption of cross technology breakthroughs will depend on whether the products can stimulate and meet market needs.

In the Focus Europe scenario, unskilled labour force in car manufacturing will still be needed. However, industry has to try hard to attract and keep key personnel, trained and experienced in using advanced manufacturing tools, manage virtual factories, able to use simulation methods, etc. The EU-wide training certification system reinforces skilled labour mobility in a multicultural and multi-language Europe.

Scenario specific technology priorities

In the course of the FutMan scenario workshops the experts discussed the impact of the socio-economic assumption in the four scenarios on the industrial technology priorities to tackle the challenges the scenario poses for European manufacturers. The following tables indicate possible research and technology priorities in the four FutMan case study sectors per scenario. It should be mentioned that the differences between the scenarios represent differences in emphasis rather than distinct technology paths.

Table 6: *Global Economy – Industry priorities*

	Electronic components	Instrument engineering	Basic industrial chemicals	Motor vehicles
Products	- More customised end-products - Highly individualised products - requirements for modular sub-assembly with renewable components - Small runs development - Disposable (small) products - Nanobased throw away products - Low sophistication of sensors - Modular, re-usable components, subassemblies	- Multi-functions agents for invisible interfaces between consumers and product design systems (e-commerce, etc.) - Modular devices - User friendly interfaces - Self-services embodied in products - Augmented reality systems	- New catalysts development - New materials (polymers) for electronic components - Intelligent adaptronic materials - Hybrid nanobased materials - Spin-offs from military research programmes (e.g. smart textiles, light weight batteries, etc.)	- Modular components prefabrication - Use of electronics
Processes	- Refined old technologies - Highly automated mass production - Flexible (but centralised) design and manufacturing / assembly - Less energy intensive processes	- Information storage on every products – change of design processes - Use of disruptive technologies designed for niche applications	- High throughput technology - Computational chemistry - Stereo-specific (chiral) chemistry and bio-catalysis - Lab-on-chip technology - Gene manipulation and new bio-enzymatic reactions - Efficient use of by-products due to market pressure	- Flexible production - Mass customisation - Virtual reality labs (visualisation) - Organisation modelling - Embedded systems - Modular production (i.e. change colour panel)
Organisation of industry	- Dominance of small companies specialised on specific segments - Transport small amounts	- Highly specialised but diverse industry structure - Dominance of small companies specialised on specific segments	- Integrated plant design and plant control - Shorter planning and product development time from lab to production - New process and plant monitoring techniques /	- Virtual companies - Vertical integration (dealers) - Interdisciplinary team working - Communication skills - Data mining and information management

Table 7: Local Standard – Industry priorities

	Electronic components	Instrument Engineering	Basic industrial chemicals	Motor vehicles
Products	- Intelligent control systems for multi-local Society - More standardised products - Solutions for avoiding 'electro-smog'	- Custom-tailored products - Multi-functions agents for invisible interfaces between consumers and product design systems	- CO_2 as feedstock	- Build and operate models (for leasing and renting) - Smart materials - Intelligent polymers - Aluminium and magnesium application
Processes	- Mini-plants - Cheaper, less energy intensive processes - More attention to recycling and reuse than in Global Economy - Manufacturing control system change to handle smaller runs	- Ubiquitous monitoring with cheap bio-sensors - Manufacturing control system change to handle smaller runs - Intelligent logistics	- New small scale production techniques for special chemicals production	- Disassembly and recycling - Embedded systems - Use of electronics - Data mining and information management - Organisation modelling - Design closed loop production
Organisation of industry	- Production of components at customer site (by contractor or by customer themselves) - SME-based networks / clusters - Underdeveloped countries would play significant role - Agile and volatile sector	- Customers base may fragment as production becomes distributed - More emphasis on small sites and service networks, users - Multi-local manufacturing - Fragmentation of firms and dominance of global players coming from US and Asia	- Ensure safe chemical production (i.e. integrate chemical production chain with minimum intermediate transport and storage) - Localised and alternative energy production - Expand existing chemical plants	- Interdisciplinary team working - Virtual companies - Communication skills - International' thinking

Table 8: Sustainable Times – Industry priorities

	Electronic components	Instrument engineering	Basic industrial chemicals	Motor vehicles
Products	- Optical electronics - New sensors for control systems - Biosensors connected to databases for screening of society (lab on chip) - Solar batteries - Nanomachines will flourish	- Detection systems to measure emission / waste from manufacturing processes - Networks of agents for various applications (environment, mobility, etc.) in Ambient Intelligence	- C_1-feedstock - Use of plastic waste to produce energy for plants and households - New catalysts to reduce energy consumption of chemical processes - Smart materials for health and more sophisticated products	- Modular component prefabrication - Embedded systems - New mobility concepts - Driver assistance systems - Fuel cells, hydrogen technology and storage systems - Smart materials; polymers - Lightweight materials/ construction - Aluminium and magnesium application
Processes	- Next generation of lithography - Closed-loop (e.g. printed circuit) and recycling in some areas, but also throw away products - Centralised design and distributed assembly processes - More complex recycling systems	- Tele-presence and augmented reality - Virtual prototyping - Complex recycling systems - Automatic dismantling - Nano-processing to being towards the end of the period - Diagnostic technologies and controls	- Simulation tool development - Decoupling of energy demand; co-generation of energy – electricity and steam / heat; reduction of greenhouse gases - Real time monitoring for security, safety and diagnosis applications - Decoupling of material use by materials modelling - Process technology improvements, raising energy efficiency and make chemicals safe driven by political constraints and market pressures - Computational chemistry	- Life cycle integration - Disassembly and recycling - Zero emission car and supply infrastructure. - Modular production - Life time product control - Flexible production - Low capital product development - Data mining and information management
Organisation of industry	- Location based application - Virtual design studios - Large infrastructure needed for nanosensors integration and production - More importance of the regional markets	- Virtual companies - SMEs dominate the sector - Niche-based SMEs linked to the major system suppliers - Large infrastructures for nanosensor integration and production	- Application technology management - Merging chemistry with electronics and bio-sciences	- Interdisciplinary team working - Vertical integration (dealers) - Communication skills - 'International' thinking - Payment systems - Organisation modelling - Use of electronics

Table 9: *Focus Europe – Industry priorities*

	Electronic components	Instrument engineering	Basic industrial chemicals	Motor vehicles
Products	- Optical electronics - New sensors for control systems - Biosensors connected to databases for screening of society (lab on chip) - Solar batteries - Nanomachines will flourish	- Detection systems to measure emission / waste from manufacturing processes - Networks of agents for various applications (environment, mobility, etc.) in Ambient Intelligence	- C_1-feedstock - Use of plastic waste to produce energy for plants and households - New catalysts to reduce energy consumption of chemical processes - Smart materials for health and more sophisticated products	- Modular component prefabrication - Embedded systems - New mobility concepts - Driver assistance systems - Fuel cells, hydrogen technology and storage systems - Smart materials; polymers - Lightweight materials/ construction - Aluminium and magnesium application
Processes	- Next generation of lithography - Closed-loop (e.g. printed circuit) and recycling in some areas, but also throw away products - Centralised design and distributed assembly processes - More complex recycling systems	- Tele-presence and augmented reality - Virtual prototyping - Complex recycling systems - Automatic dismantling - Nano-processing to being towards the end of the period - Diagnostic technologies and controls	- Simulation tool development - Decoupling of energy demand; co-generation of energy – electricity and steam / heat; reduction of greenhouse gases - Real time monitoring for security, safety and diagnosis applications - Decoupling of material use by materials modelling - Process technology improvements, raising energy efficiency and make chemicals safe driven by political constraints and market pressures - Computational chemistry	- Life cycle integration - Disassembly and recycling - Zero emission car and supply infrastructure - Modular production - Life time product control - Flexible production - Low capital product development - Data mining and information management
Organisation of industry	- Location based application - Virtual design studios - Large infrastructure needed for nanosensors integration and production - More importance of the regional markets	- Virtual companies - SMEs dominate the sector - Niche-based SMEs linked to the major system suppliers - Large infrastructures for nanosensor integration and production	- Application technology management - Merging chemistry with electronics and bio-sciences	- Interdisciplinary team working - Vertical integration (dealers) - Communication skills - 'International' thinking - Payment systems - Organisation modelling - Use of electronics

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Appendix 3: Scenario workshop participants

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