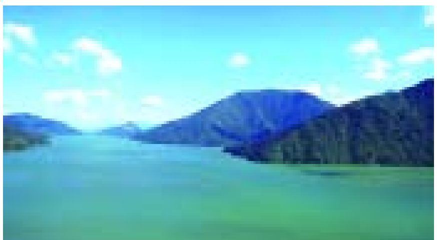
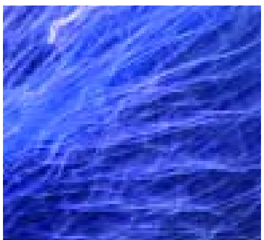
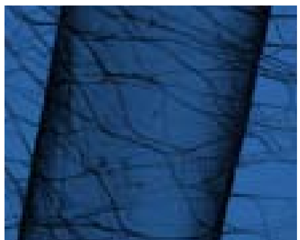
SusChem
European Technology Platform For
SUSTAINABLE CHEMISTRY

The vision for 2025 and beyond

A European Technology Platform for Sustainable Chemistry



The European model of society requires a competitive industry as a basis for growth and jobs, while maintaining its commitment to social and environmental sustainability. The European Technology Platform for Sustainable Chemistry demonstrates the great potential of industry to contribute to the broader policy agenda.

This vision paper is a commendable illustration of the joint stakeholder efforts. It forms a solid basis for the forthcoming Strategic Research Agenda to help Europe become the leader in key scientific and technology areas.

I consider myself a stakeholder in the success of this platform, both as a European citizen and as the European Commissioner for Research.

Janez Potocnik
EU Commissioner for Science and Research

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Foreword

"The European Technology Platform for Sustainable Chemistry is an ambitious initiative to revitalise chemistry and biotechnology innovation in Europe. It aims to strengthen the sustainability and competitiveness of the European chemical, biotech-based and associated industries, and contributes to meeting the Lisbon objectives for Europe.

We are very pleased to present this vision document. We are confident that it provides solid guidance in setting the strategy for sustainable chemistry research, and in creating a supportive framework for chemistry and biotechnology innovation in Europe.

This document has drawn contributions from a wide set of stakeholders, which is proof of the support and the high level of expectations and commitment to the success of this endeavour."

P. Elverding
President
Cefic - European Chemical Industry Council

F. Sijbesma
President
Europabio - European Association for Bioindustries

The European Technology Platform for Sustainable Chemistry seeks to boost the competitiveness of the European Industry by strengthening chemistry, biotechnology and chemical engineering research and development in Europe. It is a joint initiative of Cefic and EuropaBio, and was facilitated by the European Commission.

Former Research Commissioner Philippe Busquin announced the European Technology Platform for Sustainable Chemistry at a media event on 6 July 2004 in Brussels, together with representatives from Cefic and EuropaBio, and in the presence of representatives from various stakeholder groups.

The chemical industry's views on the rationale, scope and organisation of the technology platform were expressed in a document produced for the July 2004 launch event. These were intended to act as a thought-starter, and an invitation to other relevant stakeholders to participate in forging the platform's future plans.

This vision document will be a tool for all stakeholders in the chemical and associated sectors to help co-ordinate future research funding policies at European, regional and national levels. This will secure the innovation basis of the chemical industry in Europe and strengthen its role as an innovation engine in many downstream industries. Addressing innovation will be a fundamental contribution to achieving our common goal of a “knowledge-based” and sustainable European economy and will be a factor in the improvement of the industry's eco-efficiency and social contribution.

Further discussions, analytical work and consultations will lead to subsequent documents that articulate a Strategic Research Agenda for sustainable chemistry in Europe and outline implementation plans for this agenda. The initial focus is on the next EC's Research Framework Programme 7 (FP7) but will also be on the longer term and national and regional level programmes.

The European Technology Platform for Sustainable Chemistry represents a unique opportunity to strengthen EU chemistry, biochemistry and chemical engineering research. **Its mission is to contribute to successful, competitive, sustainable EU chemical and associated industries with global business leadership based on technology excellence.**

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The website of the European Technology Platform for Sustainable Chemistry can be found at:
http://www.suschem.org

Executive Summary

Chemistry is ubiquitous and is a significant factor in the improved quality of life enjoyed by European citizens today. Europe's ambitious goals of generating greater wealth while at the same time reducing emissions and conserving our natural resources can only be achieved with a significant contribution from chemistry. Better use of chemical sciences will enable our European society to become more sustainable, due to new and improved products and processes that supply new and existing products more efficiently. Indeed chemistry will contribute to solving multiple societal issues. This requires major chemical innovations driven by competitive EU chemical and associated industries that can capture their value and spread their use.

The EU is world leader in chemicals production. The industry supplies products to virtually all downstream industrial sectors, and is a major contributor to the EU economy in terms of revenues, trade balance and employment. It acts not just as a supplier of chemicals; it is also an engine for innovation for other industries, with the introduction of new materials and chemicals and their application.

However, the EU chemical industry's competitiveness is at risk due to relatively high cost of production in global terms, low market growth, and delocalisation of customer industries. Innovation and sustainability are key drivers for future competitiveness. The design and manufacturing of higher added value products and increased eco-efficiency are important factors if we are to keep a viable chemicals manufacturing base in Europe.

This would also help increase public confidence in the industry and its products and technologies.

We envision sustainable European chemical and associated industries with enhanced global competitiveness and minimal environmental impact, powered by a world-leading, technological innovative drive. It would maintain its substantial contribution to EU employment and would enjoy widespread societal appreciation. This is an important prerequisite to fulfil Europe's vision of a sustainable and competitive knowledge-based economy.

Our vision for the European Technology Platform for Sustainable Chemistry is that:

1. The European chemical and associated industries will remain competitive based on technology leadership and innovation.
2. Mastering the molecular scale (as in nanotechnology and biotechnology) will yield new generations of products with enhanced properties leading to new applications in many industrial sectors.
3. Better use of chemistry and biotechnology will enable increased eco-efficiency of the industry.
4. The industry will have a reputation as a reliable, safe, and responsible partner in society.
5. Europe will provide an effective framework for chemical and biotechnological innovation and will strengthen its excellent skills base.

Research and Development is a major source of innovation in this 'knowledge-intensive' industry. However, EU chemical R&D expenditures are decreasing and are structurally lower than in competing regions, which sometimes are better organised to capitalise on new areas of chemistry research.

There is an urgent need to boost European research, development and innovation in chemical technologies if the economic contribution of the industry is to be sustained. Innovation will be a major determining factor to secure the sector's competitiveness and consequently the competitiveness of its vast downstream customer base.

Through engagement of all relevant stakeholders in a European Technology Platform for Sustainable Chemistry, known today as SusChem, the R&D and innovation strategies proposed will provide the required broad support and facilitate implementation of the Action Plan for the Strategic Research Agenda.

SusChem will work towards this and will develop a Strategic Research Agenda in three sections: Industrial Biotechnology, Materials Technology, Reaction and Process Design. The Platform will also identify and address barriers to and opportunities for chemistry innovation that will be dealt with in the Horizontal Issues Group.

Introduction

***Chemistry** n. (pl. **-ies**) **1** the study of the elements and the compounds they form and the reactions they undergo. **2** the chemical composition and properties of a substance. **3** colloq. the attraction or interaction between people.*

Chemistry deals with the manipulation of molecules; its essence lies in the design, production and transformation of basic materials into other, often more complex, products and materials. These substances, which are derived from natural resources (crude oil, gas, natural oils, fats, sugars etc.), provide useful functionalities, and their very usefulness means they are found everywhere.

Chemicals are essential components of power-generating and storage systems, from nuclear to wind-power and fuel cells. They power and construct our transport infrastructure and help increase fuel efficiency in transport and heating. Chemicals provide essential functionalities in food production (e.g. crop protection), packaging and conservation. They also show their usefulness in security applications, medical treatment and diagnostic technologies, hygiene and cosmetics and they are an essential part of modern textiles, dyes in print and painting, computers and mobile phones and other communication devices. Chemicals play a key role in leisure and sporting goods and fashion. Chemistry is an essential part of the solution for legacy environmental issues, e.g., (bio)chemical soil and water treatment technologies that are remediating contaminated sites.

The last decade has witnessed a dramatic progress in chemical knowledge. The promise of chemistry can bring further positive changes in our society. *"Chemistry is, still, everywhere: it must be! It is the science of the real world. But, to remain a star in the play rather than a stagehand, it must open its eyes to new problems. If chemists move beyond molecules to learn the entire problem – from design of surfactants, to synthesis of colloids, to MRI contrast agents, to the trajectories of cells in the embryo, to the applications of regenerative medicine – then the flow of ideas, problems, and solutions between chemistry and society will animate both.*[1]*"* This can only become a reality if the chemical industry succeeds in transferring breakthrough laboratory inventions into the new products and services demanded by the market.

Socio-economic challenges

The world is changing and presents new opportunities and threats for the chemical industry and for our society in Europe. Globalisation, progress in telecommunication and data transfer, limited resources (soil, energy and water) and worldwide population growth with aging societies are the most significant trends determining the future of the planet.

Conflict resolution, safeguarding food and water supply, development of renewable energy resources and improvement of healthcare systems are indispensable prerequisites to achieve a prosperous and peaceful global development for an increasing world population. These objectives are best pursued through a balanced effort that takes into account economics, environmental protection and quality of life. Major contributions from the chemical industry supported by new research are necessary to meet these challenges.

Some examples will demonstrate the impact of global trends and challenges on the demands for technological development in the areas of chemical and process engineering, new materials and industrial applications of biotechnology:

- Our energy mix is currently dominated by the consumption of fossil fuels derived from oil, gas and coal. The vast majority of oil and gas is consumed to generate energy for transportation, heating and other purposes with only a relatively small part utilised as chemical feedstock. Renewable energy sources could help secure long-term energy supply and reduce carbon dioxide emissions. A major research effort is required

to provide technologies for more efficient and affordable photovoltaic devices, hydrogen generation and transport infrastructure and fuel cells;
- In addition, energy saving through process integration and new process technologies will continue to play a leading role in resource conservation;
- Efficient technologies to minimise water usage and to treat or recycle process water on a large scale are required outside and within the chemical industry. Improved logistical systems will further contribute to conservation of this important and limited resource; and
- In 2025 the world is expected to feed more than 8 billion people. This is a big challenge for mankind that can only be met through progress in crop protection, breeding and biotechnology.

The chemistry challenge

For chemistry the best is yet to come: novel anti-cancer, anti-aging and disease prevention therapies based on exploitation of the human genome; cleaner and more sustainable energy production, storage and supply; reliable and fast high capacity information storage, distribution and processing; increased food quality and production with less demand on arable land. It will provide functional materials that make our vehicles lighter and stronger and hence more energy efficient and safe, our buildings safer with lower energy consumption, and provide solutions to outstanding health problems.

The European Technology Platform for Sustainable Chemistry has been launched to bring together key stakeholders in the chemical industry and associated sectors to boost investment in chemical research, development and innovation in Europe. Innovation is key to the survival of the European chemical industry itself[5], and requires concerted action on the European, national and regional level.

The July 2004 launch of the Technology Platform was a joint initiative of the European Chemical Industry Council (Cefic), the European Association for Bio industries (EuropaBio) and the European Commission. Since then these organisations have been consulting increasingly widely with the stakeholder community in relevant sectors.

The Platform will work towards this vision and will develop Strategic Research Agendas in three sections:

- Industrial Biotechnology;
- Materials Technology; and
- Reaction and Process Design.

The Platform will also identify and address barriers to, and opportunities for, chemistry innovation that will be dealt with in the Horizontal Issues Group.

The current situation

The industry today

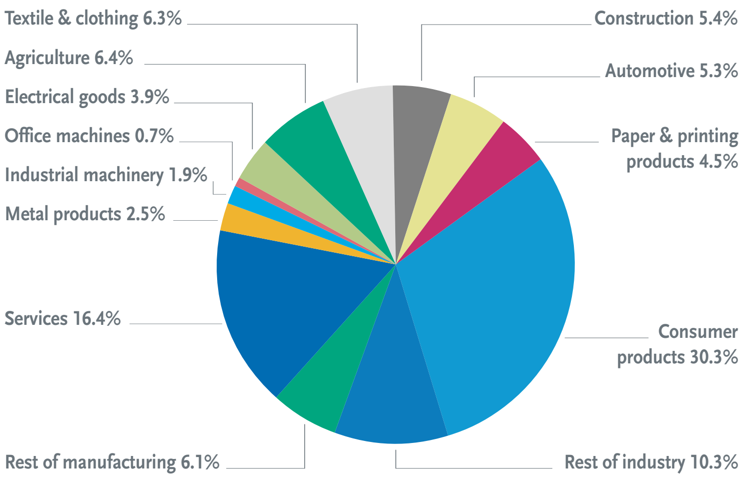
CHEMICAL PRODUCTS

The chemicals sector produces thousands of different products, and supplies them to almost all other sectors of the economy. A major share (27%) of primary chemical products is further processed within the industry itself.

The products range from basic chemicals (37.7%), through specialty and fine chemicals (28.8%) and pharmaceuticals (23.3%) to consumer chemicals (10.2%). As shown in Figure 1, the biggest industrial customers of chemicals are the metals, mechanical, electrical and electronics industries, textiles and clothing, the automotive industry and paper and printing products.

The value-addition by downstream sectors is typically orders of magnitude larger than the chemicals sector itself. For example Organic Light-Emitting Diodes (OLED's) represent a relatively modest market of €350 million, but generate a market in display technology products some 10 times larger, which in turn are important components in consumer products (mobile phones, flat screens, etc.) with a retail value of nearly €50 billion. This example clearly demonstrates the enabling nature of chemistry.

Figure 1. The share of chemical domestic consumption incl. pharmaceuticals



Sources: Cefic & Eurostat
Notes: Percentage shares are calculated by taking into account the re-allocation of domestic consumption to downstream customers of chemicals self-consumption & consumption by the rubber & plastic processing industries
* EU 15

The EU is a leading global chemicals producing area, with 32% of world chemicals production. The sector contributes 2.4% to EU GDP and comprises some 25,000 enterprises in Europe. 98% of these are SMEs which account for 45% of the sector's added value. The EU(25) chemical industry currently employs 2.7 million people directly, of which 46% are in SMEs, with many times this number employed indirectly.

The EU chemical industry sells over 70% of its output within the European internal market of which almost half are intra-EU exports. The net chemical trade surplus has grown from €14 billion in 1990 to an estimated €40 billion in 2004. The chemical industry is therefore a major net contributor (some 25%) to the positive manufacturing trade balance of the European Union.

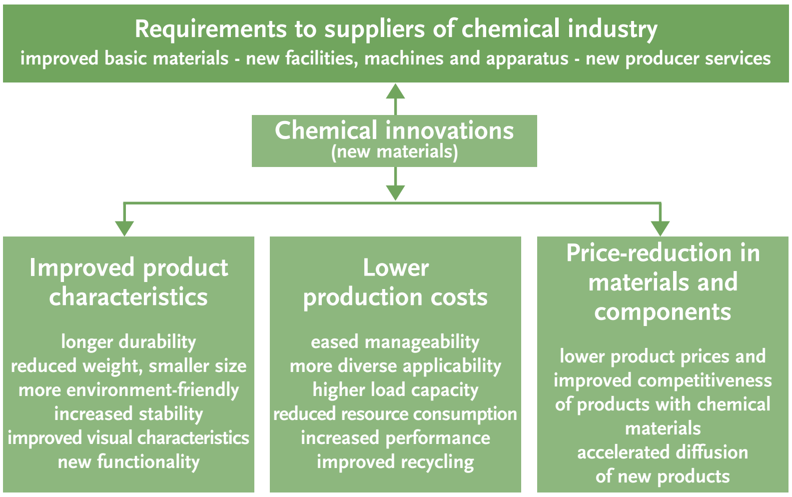
CHEMISTRY: THE ENGINE FOR INNOVATION

More than just a supplier of raw materials, the chemical industry is a major source of innovation to downstream sectors. As shown in Figure 2, this is achieved through various mechanisms including: new materials for improved and novel products, new materials for process innovations, and price reduction enabling use of chemicals in more and larger volume applications. A recent German study underlined the disproportionate impact of chemicals innovation as a driver of innovation in other sectors[3]: accounting for well over 50% of innovation in pharmaceuticals, textile and clothing, metal and petroleum processing industries. In Germany alone €19.2 billion of annual additional turnover from product innovations plus €9.4 billion cost savings (1998 data) from process innovations was generated; this translates into every Euro spent in chemical R&D yielding €0.80 additional annual turnover and €0.50 cost savings downstream, in addition to the benefits for the chemical sector itself[4].

COMPETITIVENESS AT RISK: THE CHALLENGE FOR EUROPE

Whilst the industry today appears strong and healthy, a recent study by Cefic[5] concluded that the sector's future competitiveness is in danger. Pressures on the chemicals business in Europe, such as by the growing number of regulations, have increased over the years. The industry has responded appropriately, but this has resulted in an unfortunate dilution of focus on innovation and growth.

Figure 2. Impact of chemical innovations on innovation activities in other industries[3]



The European chemical industry has reached a phase of maturity; many products have become commodities subject to strong competition particularly from Asia. Markets in Europe are stagnant, whilst strong growth occurs in China[6]. Efforts based on new products through innovations and cost reduction by economy of scale and technology excellence as well as competitive feedstock supplies appears increasingly futile.

The leading position of the EU in chemical manufacturing is already slowly eroding because of the dynamic development in Asia and the global investment pattern that goes with it; the EU(15) share of global output has declined from 32% a decade ago to 28% today. While labour productivity has steadily increased over the last ten years, employment in the EU(15) chemical industry has decreased by 16% to 1.7 million, and by 40% in Central and Eastern Europe to one million.

Further investment in chemicals is not particularly favourable in Europe, because of low returns on investment due to a combination of relatively high production costs, high costs related to regulation, the changing regional balance in manufacturing in customer sectors, and the absence of advantaged feed stocks. This, however, also depends on the development of feed stock prices on the long run. This is leading to a net outflow of investment to other regions. The EU needs innovative leadership to reduce or even reverse this trend and to beat international competition, in particular from emerging Asian economies. To do this will rely on enhanced knowledge and skills.

The Cefic competitiveness study developed four future scenarios with a 2015 time horizon. The EU share of global production was calculated to decrease to 16-23%, depending on the particular scenario. In all but the most optimistic scenarios the net trade balance falls and Europe could well become a net importer of chemicals by 2015. This would have a serious 'knock-on' effect on the future viability of customer businesses in Europe. The difference between the most optimistic scenario and the others is a chemical industry focused in innovation, thus innovation being the key driver for the future competitiveness sector and its associated supplier and customer industries.

REGULATORY ISSUES

The usefulness of chemicals derives from their reactivity and industry's skill in harnessing this. With this goes the responsibility for effective management of risk to both health and the environment. In common with many other technologies there often is public concern about the effectiveness of risk management and the extent of our knowledge of risks. This in turn has led to calls for increased regulation of chemicals and greater efforts to quantify their risk via European initiatives such as REACH and SCALE.

In terms of the broader ecological load, the industry has made good progress in decoupling production growth from emissions and energy usage. By 2002 the chemical industry had increased production by 43% compared to 1990 but its energy consumption had increased by only 1% while CO_2 emissions have fallen by 9%. These are important developments in eco-efficiency consistent with the Commission's call for more sustainable technologies contained in the Environmental Technologies Action Plan[7]. The aspiration should be for ever more sustainable production and consumption of chemicals in the future, increasing eco-efficiency (and therefore reducing waste) and restored confidence in the industry's (new) products and technologies.

Research, development and innovation

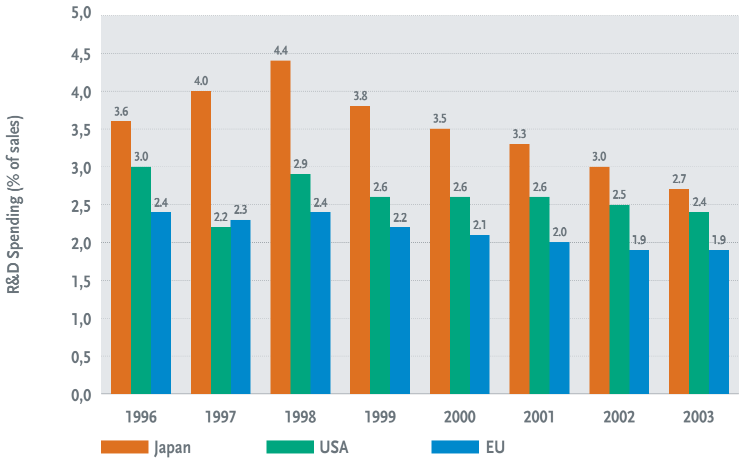
The chemical industry is particularly “knowledge intensive” and Europe's research is globally competitive. Europe is a leader in many key technology areas, as demonstrated by its high share of publications in the principal scientific journals in this field, and by the large number of patents deposited by European companies and researchers, e.g. in the US (23%). The European chemical industry has an impressive track record of turning chemistry inventions into products and process innovations. R&D, next to customer relationships, is recognised by most chemical companies and downstream users of chemicals as a key driver for innovation[3,8].

However, the current focus on financial performance, frequent restructuring programmes and increasing regulatory costs are limiting R&D spending in industry, which structurally underperforms in comparison to the USA and Japan (see Figure 3). As chemistry offers the base for many innovations in other sectors, this has wider repercussions for European manufacturing and for the provision of knowledge and skills.

Unlike Europe, both the USA[9] and Japan[10] have formulated national strategies and road-maps for key chemical technology areas to guide public-private research expenditure. In comparison European efforts are fragmented and public-private partnerships are not yet fully developed. This places Europe at a competitive disadvantage relative to its main competitors: competitors that are generally recognised to provide more supportive environments for innovation.

Traditionally there is a high degree of industry-academia collaboration in chemistry research. For example, 22% of German chemical companies are engaged with universities compared to less than 7% overall in German industry. Two major incentives for collaboration are improved access to remote expertise and shorter time-to-market. Collaboration is increasingly important, driven by the trends towards lean organisations and outsourcing of "non-core" activities. It is particularly important to SMEs, however larger companies tend to benefit most from this trend. In today's marketplace, collaboration should ultimately save time for all companies[11].

Figure 3. Trends in private R&D expenditure 1996-2003



Sources: Cefic and OECD
* EU 15, excluding pharmaceuticals

Human resources

Europe is witnessing a sharp decline in the number of students graduating in chemistry and chemical engineering. This trend is expected to continue in the foreseeable future and reflects a similar experience across all scientific disciplines. If the sector is to remain innovative and continue to grow, then this must be reversed.

Education systems within the European Research Area must be developed in order to present chemical sciences and technologies as an essential and relevant part of modern culture and in turn inspire more students to take up careers in science and technology. The demand side on human resources also needs to improve: the industry needs to communicate its longer term needs and requirements.

The image of chemistry is an important factor in attracting potential students; explicit attention to sustainable chemistry and engineering in secondary and tertiary education could contribute positively to engaging the minds of the next generation.

Additional pertinent questions are: How to ensure that academics engage with the (industrial) problems that need addressing? How to train the next generation of researchers? How to fund the required infrastructure to ensure our world-class universities have the equipment they need? And, how to provide sufficient attractive career opportunities to retain the best students?

The vision

Our vision for the European Technology Platform for Sustainable Chemistry is that:

1. The European chemical and associated industries will remain competitive based on technology leadership and innovation.
2. Mastering the molecular scale (as in nanotechnology and biotechnology) will yield new generations of products with enhanced properties leading to new applications in many industrial sectors.
3. Better use of chemistry and biotechnology will enable increased eco-efficiency of the industry.
4. The industry will have a reputation as a reliable, safe, and responsible partner in society.
5. Europe will provide an effective framework for chemical and biotechnological innovation and will strengthen its excellent skills base.

The sustainable vision

Chemistry was one of the foundations of the wealth and growth of the European economy during the 20th century based on an ever-improving understanding of interactions on a molecular level to enable increasingly sophisticated manipulation of the physical world. Chemistry will continue to be a primary driver for growth and sustainable development in the European economy and for the well-being of its citizens.

The next challenges for chemical science will be key to solving the challenges that society will face in the near future. *"Other fields sometimes take basic chemistry for granted. This is unfortunate, because it serves as both an enabling technology - it helped make high-throughput sequencing of the human genome possible, for example - and a common language that scientists in many disciplines use to communicate. Investing more in basic chemistry will advance other fields, and help the language of science evolve[12]".*

The European chemical and associated industries will remain competitive based on technology leadership and innovation

Increased investment in chemistry research and innovation, particularly in the key areas of industrial ('white') biotechnology, materials technology and reaction & process design, will lead to breakthrough chemical product and process innovations. This in turn will improve the competitiveness of the chemical industry and allow it to continue to make significant contributions to solving major societal challenges. The EU chemical industry will maintain a large global share well above 20% and, as a consequence, make a significant contribution to the net EU trade balance.

Mastering the molecular scale (as in nanotechnology and biotechnology) will yield new generations of products with enhanced properties leading to new applications in many industrial sectors.

Improved and new tailored properties will be generated by means of rational design of new materials and new formulations based on controlled transfer of the properties at the molecular level to the macroscopic one.

Continuous improvement of control at the molecular level will lead to improvements in materials efficiency, leading to new applications in e.g. energy, health, transport, communications, electronics, security, and food and feed. Examples include new materials for hydrogen storage, improved membranes for more viable water desalination plants and waterborne self-repairing coatings.

Better use of chemistry and biotechnology will enable increased eco-efficiency of the industry.

The 'Eco-efficiency'[13] of the industry's products and processes will further improve by better use of chemistry and biotechnology. The development of larger bulk production sites will make better use of integration to maximise the efficient use of resources, reduce chemical transportation and develop new technologies that will create useful co-products from today's waste streams. In parallel, for other applications, new types of chemical plants could emerge which are smaller and less obtrusive, more flexible and less capital-intensive.

Industrial biotechnology can make a significant contribution, enabling production by minimising hazardous materials, waste and emissions and operating at more benign conditions of temperatures, pressures, pH as well as using novel auxiliary materials and solvents.

The industry will have secured access to competitive feedstock. Approaches to improving the efficiency of current feedstocks will be balanced with the search for alternatives. Chemical conversions will become more efficient with the use of advanced catalysis applied in process-intensified equipment, which is flexible across a broad range of product scales and scope. Process conditions will be benign and utilise (integrated) advanced separation technologies, e.g. membrane technology. The viability of biomass as a raw material will have been demonstrated for certain specific feedstock applications.

The industry will have a reputation as a reliable, safe, and responsible partner in society.

The tendency to open communication, as facilitated by programmes such as Responsible Care, will be continued and further improved. The industry will be well organised for continuous, constructive and open dialogue with all stakeholders.

Europe will provide an effective framework for chemical and biotechnological innovation and will strengthen its excellent skills base.

Europe will foster and sustain its chemical and chemical engineering skills base and research infrastructure. Renewed approaches to education and mobility will keep our excellent skills base.

Legal and financial conditions will stimulate chemical investments in Europe. European society will celebrate entrepreneurship that stimulates new business initiatives

Boosting chemical research will lead to world leadership in chemical innovation.

Enhanced research in chemical sciences including industrial applications of biotechnology will be a priority for European, national and regional research funding programmes.

The Technology Platform will provide an effective mechanism to generate and exploit innovations in technology partnerships. This will help provide solutions in response to market needs in downstream industries, providing increasingly integrated system solutions rather than only delivering basic materials. Improved communication within the supply chain will facilitate this.

The challenges stated above require a boost in chemistry R&D across the board to sustain and strengthen the EU's leading position both in science and business. This boost will be essential to give added impetus[14] to chemistry that will underpin industrial development consistent with the main tenets of sustainable development[15].

We would like to end by quoting Professor George Whitesides from Harvard University:

"Chemistry has always been the invisible hand that builds and operates the tools, and sustains the infrastructure. It can be more. We think of ourselves as experts in quarrying blocks from granite; we have not thought it our job to build cathedrals from them[16]".

Materials technology

Material and material development are fundamental to our very culture. We even ascribe major historical periods of our society to materials such as the Stone Age, Bronze Age, Iron Age, Steel Age (the industrial revolution), Polymer Age and Silicon Age (the telecoms revolution). This reflects how important materials are to us. We have, and always will, strive to understand and modify the world around us and the material it is made of. As the 21st century unfolds, it is becoming more apparent that the next technological frontiers will be opened not through a better understanding and application of a particular material, but rather by understanding and optimising material combinations and their synergistic function, hence blurring the distinction between a material and a functional device comprised of distinct materials[17].

Discovery of new materials with tailored properties and the ability to process them are rate-limiting to new business development in many industries. The demands of tomorrow's technology translate directly into increasingly stringent demands on the chemicals and materials involved: their intrinsic properties, their cost, their processing and fabrication, benign health and environmental attributes and their recyclability with focus on eco-efficiency. This requires doing complete life cycle analysis on the new developed products and considering both the ecological as well as the economic components. Furthermore, material science will play an important role in contributing to solve some emerging societal needs and to increase the quality of life of European citizens.

Converging with the various performance demands are a suite of new technologies and approaches that offer more rapid new materials discovery, better characterisation, more direct molecular-level control of their properties and more reliable design and simulation.

There is a need for enhanced identification of opportunities, in close co-operation with partner industries down the value chain, and to co-ordinate and enhance public-private research to move beyond the limited nature of industrial research programmes to avoid fragmentation and duplication of efforts.

The confluence of market demand and innovative technology development will create many opportunities for new enterprises in the materials sector, amongst which will be new high technology leaders. Moreover, innovation in this area will drive many innovative, high-value applications in the downstream industries.

Application areas of interest include:

- Functional materials: bio-compatible and bio-degradable materials with tailored properties which include thin films and surface coatings, medical prosthetics, materials for therapeutic and diagnostic applications, formulation technologies for drugs, agrochemicals, nutrition, cosmetic

Our vision is:

1. To make Europe the world's leading supplier of advanced materials.
2. Innovation in materials technology driven by societal needs and contributing to improved quality of life for European citizens.
3. Accelerated identification of opportunities, in close co-operation with partner industries down the value chain, leading to materials with new and improved properties.
4. The ability to rationally design materials with tailored macroscopic properties based on their molecular structure.
5. Products based on integrated complex systems available by improving and combining the benefits of traditional materials and nanomaterials.
6. Convergence of market demand and technology development creating many opportunities for new enterprises in the materials sector (e.g. SMEs).

and personal care products and bio-nanocomposites using nanotechnological and biomimetic materials concepts amongst others. In this area links with the technology section industrial biotechnology are to be found and concerted activities will be necessary;

- Intelligent Materials with tailored electrical (e.g. superconducting), optical, mechanical and magnetic properties for applications in electronic devices such as displays or sensors for the development of organic electronics;
- Materials for new sustainable technologies in the areas of energy creation, storage, transport and conversion covering areas ranging from renewable energy sources such as solar and fuel cell technologies to nanoporous materials for insulation; and
- Development of new methods for the controlled synthesis of rational designed materials including novel polymerisation techniques and catalytic processes giving access to yet unknown materials.

Activities in this area will be linked with activities in the other two sections: Reaction & Process Design and Industrial Biotechnology, seeking the most eco-efficient process possible.

Nanotechnology[18] is the design, characterisation, production and application of structures, devices and systems by controlling shape and size at the nanometre scale.

This technology has the potential to make a significant impact on our world. Like chemistry it has an enabling character - it underpins technology clusters of importance to the EU such as materials and manufacturing. Application areas include construction, cosmetics, polymer additives, functional surfaces, vehicles, aerospace industry, sensors and biosensors, molecular electronics, targeted drug release and manufacturing. Design approaches are (top-down) miniaturisation and (bottom-up) molecular assembly.

Although there is nothing like a single "discipline" called "nanotechnology", nevertheless the ability to design the properties of many materials on molecular scale will be crucial for most high-value applications. The technology development will go hand-in-hand with assessing and managing the balance between benefits and risks.

Reaction & process design

Conventional plant and processes, which have served the chemical industry and society well in the past, have evolved as chemistry and chemical engineering have advanced and as new feedstocks have emerged. Chemical processes have continually improved in terms of their increased utilisation of raw materials, improved safety, and increased productivity whilst minimising waste and energy use. Step-change improvements are possible through further chemical and process intensification, including the use of catalysis, new solvents and separation techniques, and novel plant design. In our vision, the chemical industry will change significantly within the next 20 years:

Our vision is:

1. Production plants with increased productivity and efficiency, and reduced cost of manufacturing.
2. Flexible production plants equipped with appropriate process control systems and equipment that is geared for variable scale and scope.
3. Production facilities having minimal environmental impact and utilising more benign materials, while maximising recycling.
4. More inherently safe design of production facilities leading to near zero accidents in chemical manufacturing.

- The **smart design of the synthetic route itself** is a key factor for new processes with reduced waste, side products and energy consumption and which use inexpensive raw materials. High throughput experimentation accelerates product development due to rapid parameter screening (e.g. solvents, temperatures, and catalysts). Highly sophisticated, multifunctional or micro-structured mixing/reaction devices give access to intensified processes with better economics. Mature large-scale production processes serve to illustrate that process optimisation and innovation is indispensable, and feasible, even for a bulk commodity. New reaction paths (e.g. based on powerful oxidation agents such as hydrogen peroxide or breakthroughs in selective oxidations using molecular oxygen) can open the door for potentially superior processes that will differentiate Europe from other chemical producing countries.
- **Micro process technologies** have achieved major break-throughs not only in areas such as fine chemicals but also for bulk chemicals and polymers. Process integration, combining multiple steps in one device, opens up areas for improvement in bulk chemical processing. Reactive distillation, divided wall columns, separation with ionic liquids, and heat and power integration will result in significant savings in capital and operational expenses.
- More than 80% of chemical products depend on **catalytic reactions**. Due to its significant impact on process performance, catalysis is a key enabling technology. Even in mature processes such as polyolefin production, the latest catalyst developments achieve improved reaction activities orders of magnitudes greater than in earlier decades. Catalyst development is enabled by reaction engineering and vice versa; therefore catalyst and reactor should be developed simultaneously. **Integration and intensification of processes combined with new catalyst concepts** is essential for the design of competitive commodity processes. Catalysis is a decisive technology in exploiting new feedstocks, producing high performance materials and creating environment-friendly processes.
- Last but not least, by 2025 the process industry will be significantly affected by developments in ***in-silico* technologies**. Modern computer hardware and software give rise to fast modelling, simulation and data mining. Computer methods for personalised medical therapies, the search for active ingredients supported by property prediction, and improvement in the understanding of biological processes by simulation on a cellular level, will accelerate product development significantly, increase process yield/productivity and lead to new and unexpected business opportunities.

Industrial ("white") biotechnology

Industrial or white biotechnology is the application of biotechnology for the processing and production of chemicals, materials and energy. White biotechnology uses enzymes and micro-organisms to make products in sectors such as chemistry, food and feed, paper and pulp, textiles and energy. White biotechnology will have a considerable impact by providing biomass as an alternative to fossil resources for the production of biochemicals such as biofuels and biopolymers. The use of renewable raw materials as alternative feedstock will reduce consumption of the limited fossil resources and lower European dependence on imports. Consequently this could contribute significantly to meeting the Kyoto protocol targets for reductions in carbon dioxide emissions. At the same time such use may also offer an opportunity to boost the rural economy by providing new markets for agricultural crops and for the development of integrated biorefineries in rural areas.

White biotechnology processes can help make processes more environmentally friendly. They take place in a contained environment, and have the potential to produce high yields of specific products with low energy use and minimal waste. The potential for white biotechnology is very promising and it is expected that white biotechnology will be a key technology contributing to the achievement of the Lisbon strategy to make Europe the most competitive and dynamic knowledge-based economy in the world. The EU's major trading partners recognise the importance of white or industrial biotechnology for their industrial base and have already put in place well-funded long-term strategic plans. In light of this, the vision for white biotechnology has been established.

Our vision is:

1. Increasing numbers of chemicals and materials will be produced using biotechnology in one or more of the processing steps. Biotechnological processes will be used to produce chemicals and materials not accessible by conventional means or in a more efficient way.
2. Biotechnology will allow increasingly eco-efficient use of renewable resources as raw materials for industry.
3. Industrial biotechnology will enable a range of industries to manufacture products in an economically and environmentally sustainable way.
4. Biomass derived energy based on biotechnology will deliver an increasing amount of our energy needs.
5. Green biotechnology will make a substantial contribution to the efficient production of raw materials.
6. European industry will be innovative and competitive, with sustained cooperation and support between the research community, industry, agriculture and society.

The stakeholders recognise that the vision will only become reality with the appropriate enabling political and economical environment stimulating research and innovation, entrepreneurship, product approval and market development. Such a supporting environment will help industries to switch and produce eco-efficient products with less of an economic burden, and benefit from the broad potential of white biotechnology to the European industry.

The action plan necessary to achieve this vision includes:

- The development of a strategic research agenda and road map;
- The removal of technical, economic, regulatory and implementation barriers; and
- The involvement of the society in decision making via stakeholder dialogue.

In this type of activity it is of paramount importance to carry out extensive and careful life cycle analysis of new developments and to compare alternatives, since only a real eco-efficient technology can be implemented in a sustainable fashion.

Innovation framework and economic outcomes

The competitiveness of the EU chemical industry is dependent on several factors. The decisions made by industry with respect to R&D expenditure and investment are not made in a vacuum. The effectiveness of innovation (turning ideas into profitable business) in the three core areas of this vision will be defined by overall conditions in the European market. A key question is: how can Europe become the global location for chemistry and biotechnology innovation?

It is essential that all aspects of innovation in the European context are considered, ranging from society's concerns for health and the environment, to the availability of venture capital; from education to achieving a supportive regulatory environment; from efficient intellectual property protection to the ease with which industry consortia can research fertile areas of new science.

This requires that industry, regulators and other stakeholders work closely together. It is vital that there is engagement and alignment with other relevant (EU) initiatives, for example the proposed European Research Council, and with related European Action Plans and initiatives. Such action plans and initiatives include the "3%",[19] environmental technologies,[7] innovation and manufacturing technologies[21] action plans, and other European Technology Platforms for which chemistry is an essential enabling technology.

A further requirement for success is the availability of a skilled workforce. Education and training issues are critical and young peoples' interest in science (chemistry) careers needs to be raised by improving the image of chemistry and chemical engineering.

Our vision is:

1. A transparent regulatory framework based on sound science and balanced consideration of risk and benefit.
2. Europe having a regulatory, financial and legal framework conducive to innovation.
3. The added boost to innovation provided by this platform significantly raising the EU chemical and associated industries' output, thus leading to increased net trade surpluses and employment.
4. A prosperous chemical industry at the heart of a sustainable and competitive European manufacturing sector.
5. Chemical and biochemical industries contributing to revitalising European manufacturing, driving economic growth and improving quality of life.

Economic outcome

Analysis of scenarios developed by Cefic[5] suggests that growth in the European chemical sector is only probable with a revitalised industry with increased innovative capacity and a focus on customer needs. This vision also relies on a positive market situation and a favourable macro-economic and political environment. This scenario should be used as the benchmark against which the initiatives coordinated by the Technology Platform can be measured.

In the most optimistic scenario, growth in the chemical sector due to favourable macro-economic parameters is further boosted by industry's own efforts: in particular the specialty/fine chemicals sector optimises its downstream value chain and outperforms even the currently excellent competitiveness shown by the European petrochemicals/plastics sector. Predictions based on this scenario show an average annual growth of 3.3% in chemical output, which is somewhat higher than in the past decade. This would lead to an increase in the total value of EU chemical output (excl. pharmaceuticals) from €360 billion in 2002 to €550 billion in 2015. In terms of the EU's external trade balance, this translates to an annual surplus by 2015 of over €110 billion for the chemicals sector.

Enabling sustainability throughout manufacturing

As we have seen, the EU chemical production platform is an important factor in maintaining a strong EU manufacturing industry as a whole. A healthy EU chemical industry will contribute positively in terms of trade balance and innovation, enabling the sustainable development of the entire EU economy.

The role of the chemical industry in Europe's economy, and the well-being of European society, cannot be overstated. The chemical industry has direct and indirect impacts on the European economy through:

- Demanding products and services from suppliers;
- Producing products and providing services for customers; and
- Enabling innovation in sectors where further added value is generated.

How to achieve the vision

The rationale

In order to achieve the vision for a sustainable chemical industry, there is clear and pressing need for a mechanism to galvanise and focus research and innovation activities across the chemical industry and its partners in the value chain. A strategy is required that will deliver the key elements of:

- A long-term concerted effort, which is continuous and fully supported by all stakeholders;
- A comprehensive and structured approach;
- A focus on a limited number of critical technology areas; and
- A parallel dialogue to establish regulatory and economic frameworks that stimulate innovation, whilst maintaining effective public safety.

Scope and objectives

The main goal of SUSCHEM is to support the long-term success of the European chemical and associated industries' supply chain as a whole, by providing a major incentive for renewed chemical innovation in Europe, both across the supply chain and across disciplines.

The main technology platform deliverables will be:

- A long-term vision for sustainable chemical technologies in Europe that will enable a competitive and sustainable chemical industry;
- Strategic Research Agendas (SRAs) and Implementation Action Plans for the key technology areas identified that will catalyse the alignment of EU and national initiatives and boost research excellence;
- Mobilisation of financial support for R&D from public (EU, national and regional) funds, and from private sources, to provide a European dimension to chemical sciences research by increasing focus and avoiding duplication of activities;
- Identification of, and action to eliminate, barriers and constraints to chemical innovation, including enhanced skills and education initiatives, innovation transfer, regulation and societal acceptance; and
- Assessment of the socio-economic impacts of SRAs and related actions, including the expected benefits and potential adverse consequences arising from the prioritised new technologies.

SusChem will be instrumental in stimulating both the public and private sectors in Europe to commit more and better-focused funds to chemical and biotechnological R&D. It will address major specific barriers and constraints to innovation and so accelerate the pace of innovation.

The European Technology Platform

SusChem will consist of a network of strategic and intellectual alliances that bridge academia, industry and relevant additional partners, to foster the whole innovation process from initial idea to commercial application. While the Platform will be industry led, it is imperative that there is a real partnership with other key stakeholders sharing a common vision and goal. A pan-European approach will reduce fragmentation and avoid unintended duplication of research efforts.

Technical solutions to unsolved problems can only be achieved by close collaboration between academic and industrial research, therefore first-rate academic partners as well as national and international research councils, in particular through relevant ERAnets such as ERAnet Chemistry and ERAnet Acenet, will play a pivotal role in the proposed research activities.

The collaborative research that is proposed to further skills and knowledge in the prioritised areas will provide fertile ground for subsequent commercial development and deployment and must be truly innovative with a high-risk, high-reward profile. Basic and applied research has to be balanced to address medium-to long-term technology needs. Determination of the content and priorities of the research agenda will require focus and rigorous choices to be made based on anticipated impact in the context of sustainability.

Industrial partners from across the value chain will have a key role in relaying their demands for new chemistry. Links will also have to be made to other relevant European Technology Platforms, such as those on energy, pharmaceuticals, textile and clothing, transport and electronics due to the enabling nature of chemistry.

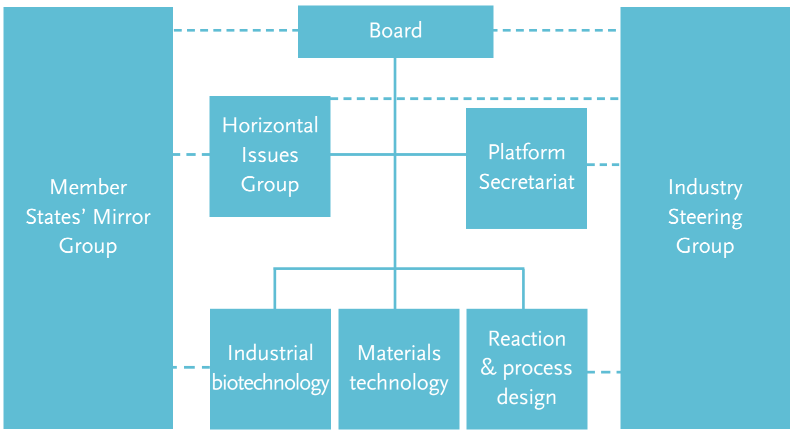
To enable a smooth transition of an invention into the market, financial institutions, such as the European Investment Bank, and venture capitalists also need to be in close contact in appropriate phases. Innovation framework matters can only be effectively addressed by close engagement with policy makers and regulatory bodies.

SusChem will operate a transparent structure and this openness will be key to achieving public trust. The composition of the partnership will grow or change as its priorities evolve. It is a long-term project. The combination of skills and infrastructure to support this initiative is already considerable in Europe.

Platform organisation

The organisation of the Platform has been outlined, as shown schematically in figure 4.

Figure 4. Proposed organisational structure for the Technology Platform



A high-level board, consisting of nominees from the main stakeholder groups and representing the three sections, will manage the Platform's overall activities. Essentially the Board has a strategic role - it should set directions, policies and strategies. As the Technology Platform progresses, the board will provide advice and guidance to the Executive Committee which is comprised of the Board's chair and the chairs of the technology sections and the Horizontal Issues Group.

The Board will ensure:

- Synergy among the technology sections and the Horizontal Issues Group;
- Provision of external representation; and
- Endorsement of proposals from external liaison groups, i.e. the Member States' Mirror Group and the Industry Steering Group.

Furthermore, the Board is responsible for:

- Budget and accounting; and
- Addition or removal of sections.

In order to maintain an efficient and flexible management, the Board will consist of around 15 high-level representatives from industry, academia and other key stakeholder organisations.

The three technology sections will coordinate their activities in the key technology areas identified: materials technology, reaction and process design and industrial biotechnology.

The task of each of the sections will be to:

- Develop innovation targets, a strategic Research Agenda and an Implementation Action Plan for their respective sections based on the detailed long-term vision;
- Form the policy interface on the issues specific to the respective sections; and
- Initiate and eventually manage projects relevant to the respective sections.

The sections are responsible for the planning and implementation of programmes and each will be guided by their respective steering groups.

A professional Platform Secretariat and a Horizontal Issues Group will support the Platform.

The Platform will have a Mirror Group consisting of representatives of member states and regions. This group will allow co-ordination with national initiatives and projects, ensure a two-way flow of information to and from the platform, and act as a discussion forum for member states and regions.

In addition, an Industry Steering Group, composed of high-level representatives from industry, was formed and has steered the establishment of SusChem; the Industry Steering Group will hand over leadership to the Platform Board, and continue to support the Board and the platform by coordinating industrial input.

Key technology priorities

The outputs from the chemical sciences have such a broad impact, including in life sciences, computational sciences, and advanced methods of process engineering and control, that research requires discovery activities and invention across the entire spectrum of the chemical sciences. This spans from fundamental, molecular-level chemistry to large-scale chemical processing technology and cross-disciplinary collaborations with biology and physics, as well as with underpinning chemical technologies such as catalysis and emerging technologies like nanotechnology[23].

Three key technology areas for the chemical industry and its partners have been identified, which are critical to achieve the vision. These areas will form the three sections in which the technology platform will explore its future technical challenges. The basic rationales and perspectives for each section have been described in Section 2 of this document and further details of each section are given in the annexes.

Each technology section will develop its own detailed Strategic Research Agenda and Implementation Action Plan, based on the views of the respective stakeholder communities involved and will include relevant existing and future European networks, such as ERAnets (e.g. ERA Chemistry) and Networks-of-Excellence.

Strategic Research Agendas describe the main research issues to be addressed in order to realise the vision. A Strategic Research Agenda is neither a specific research programme nor a work programme. It is in effect, a set of principles, issues, requirements and research areas that should inspire all stakeholders when they develop their own activities or programmes. Research effort will encompass basic research, applied research and development, demonstration and supporting research.

The horizontal issues

A strategic approach to innovation must achieve the appropriate balance between value creation, cost effectiveness and responding to critical societal concerns such as improved environmental performance. The capability to bring stakeholders together, at the start of the innovation process, to address such issues is an important advantage of SusChem.

Effective management of the potential health, safety and environmental concerns of our new technologies will be a pre-requisite for their early acceptance by society. This acceptance will in turn be crucial to ensure a supportive political environment and an effective regulatory framework for all the industries that rely heavily on chemistry for their innovations. Successful innovation must also address multiple other generic factors (beyond the technology) to ensure its long term success. Examples of these cross-cutting factors for the technology platform include:

- Defining the human resources needs for our innovation processes and thus contributing to the debate on science education, skills, training and mobility for researchers;
- Refining knowledge and technology transfer mechanisms;
- Supporting more effective research infrastructures and engagement in EU research funding programmes
- Improving involvement and alignment with other relevant EU and member state initiatives;
- Increasing access to venture capital;
- Building early confidence in our new technologies both with the general public and political leaders; and
- Developing mechanisms to facilitate access to the output of our collaborative R&D to SMEs -this is particularly relevant to chemical technologies due to their enabling role in downstream innovations.

A number of more general innovation issues, which are beyond the specific remit of this platform, have also been identified. Such issues will be monitored and contributions made to policy discussions as appropriate.

These issues include:

- Intellectual property rights exploitation and protection;
- State subsidies for R&D; and
- Technology transfer block exemption regulation.

Overall there is a need for additional supportive political and fiscal measures, as well as efforts by all stakeholders to engage in dialogue with end-users and the broader public about new chemical technologies in a more constructive fashion. This platform can therefore serve as an effective interface with these stakeholders as well as the European institutions on these matters.

The ultimate aims of our chemical technology initiatives are to “put new chemistry knowledge to work” to support the growth, competitiveness and sustainability of our manufacturing industries and the EU citizens they serve. The Horizontal Issues Group will develop common actions on the resulting priority issues with contributing stakeholders to support these aims.

Thus an interim vision of our group is to ensure early and broad societal appreciation of these new sustainable technology initiatives. This, in turn, will create an increasingly supportive environment for further technological progress in Europe.

The development of the vision and plan for the Horizontal Issues Group will be significantly influenced by both the evolution of the three technology sections and also by the output of its own working group that will tackle the prioritised horizontal issues during 2005/6. Hence the above should be seen as the starting point for our vision.

Recommendations

Chemistry has a pivotal role to play in the transition towards a sustainable, competitive and knowledge-based European society. In combination with its own downstream and supplier sectors, chemistry can provide an environmentally sensitive source of innovation that can contribute to improved economic and social welfare.

To achieve its full potential in pursuit of common European goals, maximum support for the activities of the European Technology Platform for Sustainable Chemistry is needed from stakeholders in a wide range of industrial, academic, political and public organisations. The Platform needs to consult widely and form a consensus on relevant Strategic Research Agendas.

To achieve this objective a number of actions are required. In particular, it is recommended that:

1. The three technology sections work to collate initial Strategic Research Agendas to act as feed mechanisms for the formulation process for the next European Commission's Framework Research Programme during 2005 and 2006, as well as a basis for discussions on alignment with national and international R&D programmes.
2. The Horizontal Issues Group prioritises issues and develops a coherent programme of work in support of the technology sections and industrial competitiveness in general.
3. The Member States' Mirror Group meets regularly to ensure alignment with relevant national programmes and establish inventories of relevant national initiatives, contact people and Centres of Excellence.
4. The activities of the Platform are publicised widely.

Annexes

ANNEX 1. MATERIALS TECHNOLOGY

Discovery of new materials with tailored properties and the ability to process them are the rate-limiting steps in new business development in many industries. The demands of tomorrow's technology translate directly into increasingly stringent demands on the chemicals and materials involved - their intrinsic properties, their costs, their processing and fabrication, and their recyclability.

Materials science deals with the design and manufacture of materials, an area in which chemistry plays the central role; there is also considerable overlap with the field of chemical engineering and physics. Substantial contributions include: modern plastics, paints, textiles and electronic materials; but there are greater opportunities and challenges for the future.

The materials sector of the chemical sciences is vital, both fundamentally and pragmatically, for all areas of science and technology - as well as for the needs of society in terms of energy, information and communications technology, health care, quality of life and citizen protection.

We aim to make Europe the world-leading supplier of advanced materials adding high value to full growth in the EU.

PROSPECTS

Important areas of innovation in this area are numerous. The most important future topics are:

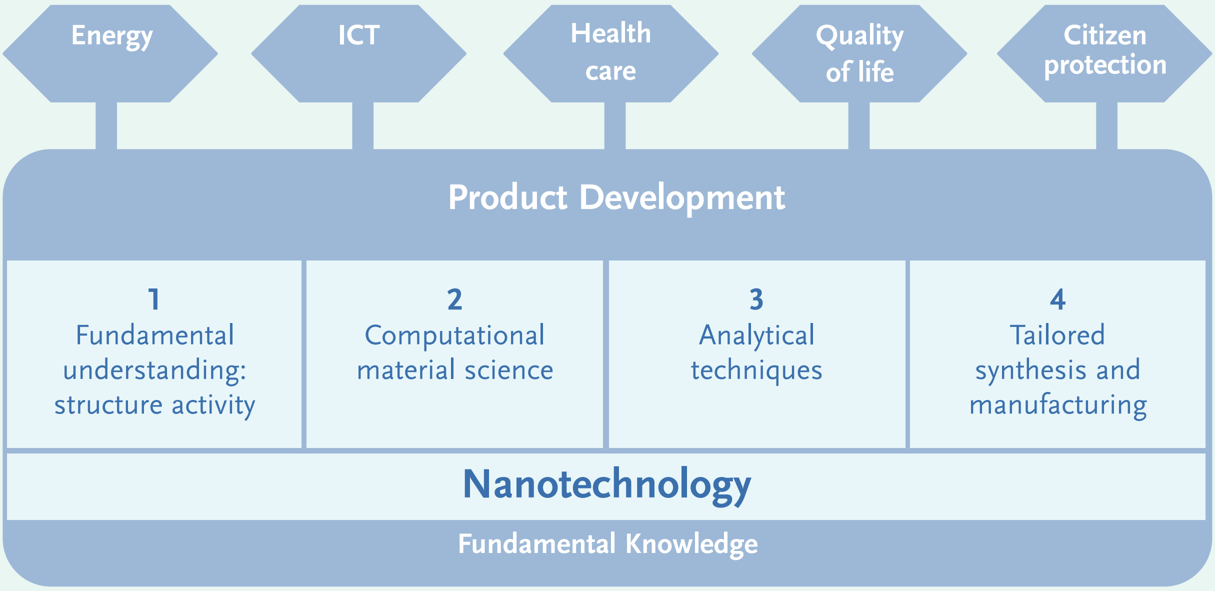
Energy

The total world consumption of energy in 2003 was 14 Terawatts with 70% originating from fossil fuels. It is predicted that the energy need for 2050 will be between 30 to 60 Terawatts. This increase presents a major challenge for the current technologies.

The energy problem can be divided into the following topics:

- Energy creation: this includes current technologies from fossil fuels, alternative technologies for renewable resources (solar, hydro, wind, geothermal, biomass for bio-refinery) and nuclear. In the case of materials technology the focus will be on fuel cell technology and photovoltaics;
- Energy transmission and distribution: this includes heat networks, electric wires and electric grids.

Figure 5. Proposed structure for the Materials Technology section



- Energy storage: batteries, superconductors, hydrogen storage etc.; and
- Energy management: insulation in buildings, more efficient lighting, lighter materials for transport, minimisation of energy losses, etc.

Without new discoveries in material science, the required breakthroughs in any of the above areas will not be possible.

In energy production and transportation, new materials with useful conducting and **superconducting** properties will have a significant impact on our society in practical systems for the transmission of large electrical currents over long distances without energy losses. New ceramic materials will play an important role in this area.

In the area of energy management and conservation, new materials with lightweight construction will greatly enhance the efficiency and environmental sustainability of surface and air transport. The most common form of surface engineering is painting. While paints prevent corrosion and water damage, they need to be renewed on a regular basis, which is costly and labour intensive. One significant contribution to modern life would be the development of **long-lasting coatings** with high scratch resistance and weatherability, smart functional packaging materials, and even self-cleaning and self-healing properties. Such **surfaces can** easily be cleaned by rain, and have a mechanism to self-repair after any surface damage.

Information and Communications Technologies (ICT)

In our modern society communication, information and entertainment is one of the largest market sectors in which the electronics industry continually seeks new materials for superconductors, polymeric conductors and semiconductors, dielectrics, capacitors, photo resists, laser materials, luminescent materials for displays as well as new adhesives, solders and packaging materials. For the world wide high speed transfer of digital information new materials in the field of optical data transfer are also indispensable: nonlinear optics materials, responsive optical materials for molecular switches, refractive materials and fibre optics materials for optical cables.

The challenge lies not only in the development of new materials with the desired properties but also in their effective incorporation into functional systems.

Quality of life

The quality of life of European citizens can be enhanced dramatically by the use of new materials for better mobility, i.e. mobile phones, portable computers, more efficient and sustainable transportation, cosmetic preparations for better appearance and protection from external environment and improved nutrition by increasing the stability and bio-availability of vitamins and food additives via innovative formulation techniques. This could mean smart internal and external coatings with self-cleaning properties and responsive to changes in the environment or surfaces with antifouling properties able to recognise and destroy pollutants and corrosion agents. Specialty polymer industries would benefit from 'intelligent' composite materials based on organic or inorganic materials and also biocompatible materials to design longer lasting batteries, smaller and more stable sensors, materials for functional clothing that is self-cleaning, adapting and protecting, prosthetics and implants, and more.

Health care

As a result of the increase in life expectancy and consequent aging profile of the population a new paradigm is required to provide optimal and personalised medical care as well as a higher demand for health prevention in order to reduce increasing medical costs. There is need for new materials for implants, drug delivery, and novel therapeutics, but also for health protection and care, diagnostics, and sensors for prevention and timely detection of serious diseases.

The path from electronics to biological function goes via chemistry. Sensor technology provides a connection between biological function and an electrical signal. Advanced sensors and new micro-analytical devices will have a substantial impact on health, environment, and individual protection strategies in the coming years. The ability to reliably link biologically active molecules to a surface will take functional integration to levels previously deemed impossible. This provides huge opportunities for improved medical devices and drug delivery strategies. Another aspiration is the design of materials that mimic the behaviour of physiological systems such as muscle.

Citizen protection

Society has been increasingly challenged by accidents, terrorist attacks, sudden climate changes and catastrophes causing extensive personal and material damage. There is a need to develop new intelligent technologies in order to protect the civil population from these extreme situations as well as to provide new ways of predicting and avoiding them. Sensors for explosives, toxic agents and biohazards at low concentration, materials for personal protection and/or buildings, e.g. hospitals, airports, and vehicles, functional textiles that recognise and destroy toxic agents or administer the right counteragents. In addition, new sensor systems could help to detect chemical or biological threats and play an important role as components of security systems.

Nanotechnology - contribution & integration

Of particular interest is **nanotechnology**, which spans many areas including: nanoparticles, nanocomposites and custom-designed nanostructures that will find applications from polymer additives to drug delivery and cosmetics. Especially nanotubes (see Table 1) are of great interest for many applications like storage, transport, separation, drug delivery, thermal isolation, photonic and electronic applications or templates.

The largest barrier to rational design and controlled synthesis of nanomaterials with predefined properties is the lack of fundamental understanding of thermodynamic, kinetic and quantum processes at the nanoscale. Today, the principles of self-assembly are not well understood nor do we have the ability to bridge length scales from nano to micro to macro. This lack of basic scientific knowledge regarding the physics and chemistry of the nanoscale significantly limits the ability to predict a priori structural properties and processing relationships. Profitable research will result in the development of kinetic and thermodynamic rules for synthesis and assembly that can be applied to the rational design of nanomaterials at commercial scales (including hierarchical nanomaterials) from first principles.

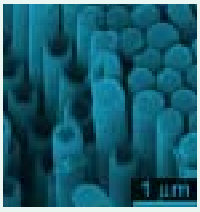
Nanomaterials will deliver new functionalities and materials options. Manufacturers will combine the benefits of traditional materials and nanomaterials to create a new generation of nanomaterial-enhanced products that can be seamlessly integrated into complex systems. In some instances, nanomaterials will serve as stand-alone devices, providing unprecedented functionality.

Table 1: Examples for applied production processes of nanotubes[24].

Nanotubes by fibre templates

Nanotubes by electron spinning with hair

Nanotubes made by wetting



Nanotechnology is an integral part of almost all areas of interest. The benefits of nanotechnology play an important role as a base for the development of new functionalised materials and products, as mentioned above. The wide range of applications known today clarifies the comprehensive character of nanotechnology, e.g. self-cleaning effect of modified surfaces, transparent sun-blocker for skin protective applications and scratch resistant coatings.

Many of the potential applications are based on exploiting effects that are part of our current understanding of science. However, producing structures and operating at the atomic level will produce novel effects that will stimulate new science and hence lead to new applications.

The market for nanomaterials has been estimated by analysts to be €700 to 1,000 billion by 2011[25]. As new materials and applications are used by the human society, the possible impact of nanomaterials on the environment and human health has to be considered.

Such impact studies have to be done by industrial, NGO or independent national scientific groups, as current knowledge is inadequate for risk assessment of nanoparticles and fibres. As materials exhibit unique properties at the nanoscale level, which affect their physical, chemical and biological behaviour, the potential hazard of each nanomaterial needs to be considered in parallel with their potential benefits on a case-by-case basis.

Strategic Research Agenda
The astonishing progress in chemical science and engineering during the 20th century make it possible to envision new goals that might previously have been considered impossible. The Technology Platform will identify the key opportunities and challenges for Material Sciences, from basic research to societal needs and from resource utilisation to environmental protection. It will look at ways in which chemists in industry and academia can work together to contribute to an improved future for our society. The focus of the activities goes well beyond the framework of industrial R&D programmes and includes the following **Research Topics**:

- Fundamental understanding of structure activity relationships for the rational design of functional materials;
- Computational material science;
- Development of analytical techniques; and
- From laboratory synthesis to tailored large scale manufacturing of materials

and **Product Areas**:

- ***Materials for energy management***
  Solutions have do be found in energy creation, transmission and distribution, storage and conservation;
- ***Materials for the electronics industry - communication, information, entertainment***
  The electronics industry continually seeks new materials for improved electrical and optical conduction, displays;
- ***Materials for medicine, agriculture, nutrition, health care***
  Topics are for example materials for diagnostics and imaging, drug and bio-active compounds delivery systems, cosmetics;
- ***Quality of life***
  Smart materials that respond to their environment, that are self-cleaning, anti-fouling and have anti-corrosion properties; and
- ***Citizen protection***
  Sensors and detectors, novel protecting clothing and more.

CONCLUSION & CONNECTIONS TO OTHER TECHNOLOGY PLATFORMS OR SECTIONS

In summary, the future of the materials technology section is driven by societal needs and the basis of success will be multidisciplinary teams with intensive cooperation among industries and academia. Furthermore, new materials form the cornerstone for many innovations in downstream industries and material science will act as an enabling technology for many of the other European technology platforms under preparation, including: hydrogen and fuel cells; nanoelectronics; nanomedicine; photovoltaics; aeronautics and textiles and clothing.

Table 2: Overlap with other Technology Platforms

Technology Platforms	Understanding of structure activity relationships	Computational material science	Analytical techniques	Synthesis & manufacturing of materials	Products
Fuel cells	High	High	Low	High	High
Nanoelectronics	High	High	High	High	High
Plant genomics	Low	Low	Low	Low	Low
Water	Medium	Medium	Medium	Medium	Medium
Photovoltaic	High	High	High	High	High
Road transport	Medium	Low	Low	Medium	Low
Rail transport	Medium	Low	Low	Medium	Low
Marine transport	Medium	Low	Low	Medium	Low
Mobile and wireless	High	Medium	High	High	High
Innovative medicine	High	Medium	High	High	High
Aeronautics	High	High	High	High	High
Space tech.	High	High	High	High	High
Steel	Medium	Low	Low	Medium	Medium
Manufacturing	High	Low	Low	Medium	High
Construction	High	Low	Low	Medium	High
Animal health	Medium	Medium	Medium	Medium	Medium
Advanced materials	High	High	High	High	High
Gas reactors	Low	Low	Low	Low	Low
Forestry	Medium	Low	Low	Medium	Low
Nanomedicine	High	High	High	High	High
Artemis/Embedded systems	High	High	High	High	High
Textiles & clothing	High	Medium	High	High	High
Materials relevance	Low		Medium		High

ANNEX 2. REACTION AND PROCESS DESIGN

Reaction and process design is of vital importance for the chemical industry. The life cycles of products are becoming shorter and specialty chemicals are transformed rapidly into commodity products. The only way to remain profitable under these high cost pressure conditions is to keep a high level of excellence in the area of reaction and process design. It is of paramount importance to have the best, i.e. the fastest, cheapest and cleanest production processes.

As reaction and process design we define a group of enabling technologies that can be applied to all areas of chemistry aiming at optimisation of production processes for basic chemicals, intermediates and fine chemicals.

Two complementary approaches are integrated in this section:

Chemical synthesis including:

- Novel synthetic routes and new reactions;
- Novel solvents and solvent-free routes; and
- Catalysis.

Process science and engineering including:

- Reactor design;
- Drying and purification methods;
- Distillation, crystallisation and separation technologies;
- Product design and formulation; and
- Process analysis and control.

Reaction and process design encompasses both reaction design and process engineering. These are well established disciplines that are the foundation for the development, scale-up and design of chemical manufacturing facilities. When effectively integrated with basic science and enabling technologies, this area offers great potential for a quantitative understanding of chemical manufacturing allowing for improved yields, reduced waste and higher capital utilisation. Our strategic priorities are to enhance Europe's capabilities in reaction design and process engineering; to promote excellence and enthuse the next generation; and to lead debate by guiding informed thinking and influencing public policy.

The **smart design of the synthesis route itself** is a key factor for processes with reduced waste, side products and energy consumption based on inexpensive raw materials. High throughput experimentation accelerates product development due to rapid parameter screening (e.g. solvents, temperatures, and catalysts). Highly sophisticated, multifunctional or micro-structured mixing/reaction devices give access to intensified processes with better economics. Mature large-scale production processes serve as an example that process optimisation and innovation is indispensable and feasible even for a bulk commodity. New reaction paths (e.g. based on smooth oxidation agents such as hydrogen peroxide or break-throughs in selective oxidations using molecular oxygen) open the window for potentially superior processes differentiating the European industry from other chemical producing regions.

Micro technologies have achieved major break-throughs not only in areas such as fine chemicals but also for bulk chemicals and polymers. Process Integration combining various steps in one apparatus opens up areas for improvement in bulk chemical processing. Reactive distillation, dividing wall columns, separation with ionic liquids, heat and power integration result in significant savings in capital and operational expenses.

More than 80% of the chemical products depend on **catalytic reactions**. Due to its significant impact on process performance, catalysis is still a key enabling technology. Even in mature processes such as polyolefin production, the latest catalyst developments achieve activities orders of magnitudes higher than in earlier decades. Catalyst development is enabled by reaction engineering and vice-versa; catalyst and reactor are developed simultaneously. **Integration and intensification of processes combined with new catalyst concepts** are essential for the design of competitive commodity processes. Catalysis is definitely a decisive technology in tapping new feedstock, producing high performance materials and creating environment-friendly processes.

In general, the manufacturing of chemicals and functional materials based on **renewable resources** is becoming more and more important. Large-scale bio-production of mass polymers and basic chemicals will be state of the art.

In contrast to large-scale biotechnological processes for commodity chemicals and polymers, synthesis of drugs, antibiotics, therapeutic proteins, etc. requires sophisticated, small-scale technologies offering a wide area for research and development.

Although fermentation and enzymatic conversion are established production techniques, within 20 years new **approaches in biotechnology will** provide an important tool for new biochemical processes (proteins, antibodies etc.) and a very attractive alternative for classical chemical processes as well. This Platform will consider computer based optimisation tools of bioprocesses, unit operations for fermentation, cell handling/separation and of course purification techniques (chromatography, crystallisation, virus inactivation and freeze-drying).

Last but not least, the process industry in 2025 will be tremendously influenced by the developments in ***in-silico* technologies**. Computer methods have developed dramatically in the last decade and will develop further by 2025. Both modern hardware and software give rise to fast modelling, simulation and data mining. The simulation tools for complex chemical processes represent an excellent know-how basis for many in-silico technologies. As an example, computer methods for individual medical therapy, the search for active ingredients supported by property prediction and the improvement of biological processes by simulation on a cellular level will accelerate product development significantly, increase process yield/ productivity and lead to new and unexpected business possibilities.

STRATEGIC RESEARCH AGENDA

The Strategic Research Agenda for reaction and process engineering must include the following areas in order to meet the challenges outlined:

Smart synthesis routes

Organic synthesis, despite being a mature science continues to develop and is learning some new tricks that will have great impact on the future of the chemical industry including.

Development of novel reaction pathways to give:

- Processes with high atom efficiency (= no or less waste);
- Reuse of wastes, closing of material loops;
- Selective oxidation using molecular oxygen;
- Processes avoiding hazardous adducts and by-products;
- Use of CO_2 as molecular building block;
- Use of biotechnology as an alternative to chemical processes; and
- Use of renewable feedstocks for industrial chemistry (biorefineries).

New synthetic methodologies could exploit renewable resources such as emission gases like CO, CO_2. These could be used as raw materials for a number of compounds and products. Development of new methodologies and catalysts for the incorporation of these cheap and readily available raw materials is required.

Use of alternative reaction media:

- Ionic liquids: Ionic liquids have been described as green solvents, as a result of their low vapour pressure, and even though BASF and Degussa have recently developed processes involving ionic liquids, a lot of research is needed to allow wider use of ionic liquids in the chemical industry. The separation of the final product from the solvent is a problem that remains to be solved, fundamental studies on the properties of ionic liquids and the kinetics and reaction parameters in ionic liquids are still lacking. The wide variety of ionic liquids available and the possibility of having a tailored synthesis of ionic liquid for given applications open significant opportunities for this topic; and
- Use of water as a solvent: Water is one of the cheapest and most environmentally friendly solvents, however, most chemical transformations take place in organic solvents. New paradigms in research have to be developed in order to use water in organic synthesis, not only dealing with the stability of reagents and catalysts, but also with the solubility problems of adducts and products.

Use of alternative reaction conditions:

- High pressure and supercritical gases (i.e. CO_2) as solvents, micro-emulsion media;
- Photochemical and electrochemical reactions; and
- Microwave- and ultrasonic induced reactions (e.g. polymerisation).

Microtechnology

Developments in this area could include:

- New apparatus for technical application (cheap, easy to clean and / or easy to change, long term stability towards reaction conditions, e.g. corrosion resistant, high tolerance of fouling and blockage);
- New plant concepts for highly intensified processes including logistic and supply chain aspects;
- Online analytical tools for microreactors; and

- Combined/integrated approaches (e.g. catalytic microreactors, high throughput experimentation including combinatorial approaches).

Catalysis[26]

Catalysis is the chemical and molecular science that focuses on accelerating and increasing the material and energy efficiency of chemical reactions. More than 80% of the processes in the chemical industry (including pharmaceuticals), worth approximately €1500 billion, depend on catalytic technologies (Source: VCI). Catalysis directly contributes 2 to 3% of the EU's GDP, and an order of magnitude larger when taking into account industries that depend on chemical raw materials (source: OECD). There is constant need for improved conversion technologies and new catalysts including enzymes, coupled with novel reactor and process technologies including:

- C-H-bond activation for the exploitation of lower alkanes such as methane and ethane as the major constituents of natural gas; direct conversion of alkanes to valuable, functionalised molecules; advanced syngas chemistry;
- Catalytic systems for the conversion of alternative feedstocks such as biomass and waste ;
- Enabling the use of hydrogen in energy systems (cheaper, catalysts in converters and fuel cells with higher lifetime, CO tolerant catalysts in fuel cells, hydrogen storage materials);
- Catalysis with respect to mobility (improved exhaust gas converters, fuels free from sulphur and aromatic hydrocarbons);
- Improved catalytic methods for the production of life science intermediates and active ingredients (such as enantioselective reactions);
- New and improved catalytic systems for high performance polymers (production of monomers, tailor-made polymeric materials by smart catalysts);
- Environment protection (catalytic exhaust gas and waste water purification);
- Integrated reactor approaches (catalytic microreactors, catalytic membrane reactors); and
- Improved methods for the understanding of catalysts (characterisation, mechanisms) for a rational catalyst design.

Reactor design, plant design and unit operations

The emphasis here should be on:

- Process intensification by integrated approaches: combination of reaction and separation, catalytic membrane reactors, catalytic microreactors;
- Reduced capital investments using cheaper units (integration of different separations in one apparatus);
- New plant concepts for reduction of investments (value engineering) and process costs including knowledge-based manufacturing concepts (e.g. batch/semi-batch, network/distributed manufacturing); and
- Adaptation of unit operations to new challenges: pre- and post processing of biomass feedstocks.

Materials properties design

The area will link with the materials technology section to investigate topics including:

- Methods for tailoring active ingredient properties with regard to specific application demands (e.g. encapsulation of reactives, drug delivery systems by coating, intercalation or encapsulation, taste mask, drug targeting, controlled and triggered release formulations, multi-emulsions).

Drying methods and purification techniques

Topics include:

- Adaptation of established techniques to new challenges: drying and processing of nanomaterials, purification of nanomaterials; and
- Purification of biotechnological products.

***In-silico* technologies**

This area will cover:

- Adaptation of established techniques to new challenges: systems biology approach in bioprocesses, metabolic engineering for the improvement of fermentations; and
- Digital manufacturing employing advanced modelling and planning tools.

ANNEX 3.
INDUSTRIAL BIOTECHNOLOGY

In the past, eco-industries have mainly been associated with end-of-pipe technologies focusing on waste treatment rather than waste prevention. Today, modern industrial biotechnologies are preventative, focusing on cleaner manufacturing processes to minimise waste at source. Industrial biotechnologies range from the use of enzymes or whole cell systems to catalyse chemical conversions of conventional or renewable resources, to thermo chemical and (catalytic) hydrothermal (sub- and supercritical water) biomass conversion processes for bulk chemical industry. Examples of the results biotechnology can produce include:

- The move to bio-processing for production of vitamin B2 resulted in a 40% cost reduction and only 5% of the previous level of waste;
- A similar change to a biological production process for antibiotics combined the original ten-stage process into a single step, giving a 65% reduction in waste, using 50% less energy and halving the cost;
- Use of enzymes for textile processing reduced energy needs by 25% and gave 60% less effluent;
- Production of bio-plastics derived from cornstarch reduced the inputs of fossil fuels by 17-55% compared to the conventional alternatives; and
- The use of bio-fuels and conversion of chemical processes to use agricultural feedstocks gives significant reductions in net carbon emissions.

PROSPECTS

Further development of industrial biotechnology will enable improvement of current chemical processes as well as allowing for the use of unconventional renewable raw materials including low value biomass.

Although a small number of industries are involved in industrial biotechnology today, its contribution will be most keenly felt in the EU's heavy industries, which will increasingly depend on it to remain competitive. Biotechnology will have an impact on a great many industries including: the chemical industry; the pharmaceutical industry; the food, drink and feed industry; the pulp and paper industry; the textile industry; the detergents industry; the energy sector; and the agricultural sector.

The development of industrial biotechnology is of great interest to the European chemical industry and agro-industry. Through the collaboration of these two industries, entirely new chemical activities can be created. Industrial biotechnology can contribute significantly to the future of European agriculture, and as such is very relevant for the sustainable development of our society.

According to a McKinsey study[27] biotechnology is expected to make significant inroads in all areas of the chemical industry by 2010, but particularly in the fine chemicals sector. McKinsey estimates that biological process will, at the end of the decade, account for between 10 and 20% of production across the whole industry, from a current level of 5%. For the polymers and bulk chemicals sector, the penetration of biotechnology is estimated at 6-12%, but for fine chemicals the figure is predicted to be between 30 and 60%. Continued growth of industrial biotechnology is expected beyond 2010.

McKinsey estimate the current value of chemical products produced using biotechnology to be at least $50 billion and believe this could rise to $160 billion by the end of this decade.

These figures are impressive, but the exact rate of growth will depend on a number of factors. The relative prices of oil and agricultural raw materials, combined with the speed of technological progress, will be major determinants. However, of equal importance will be the political will to support and develop the technology base.

Strategic Research Agenda

White biotechnology is a relatively new discipline and therefore immature: there are major areas of knowledge still to be explored. This presents a bottleneck to greater exploitation, but also offers a tremendous opportunity for further research. As a first step on the road to increased industrial use of the biological sciences, a Strategic Research Agenda covering both basic and applied science is needed. Both are essential: basic science to develop our fundamental knowledge base, and applied science to use this knowledge to introduce innovative products and processes.

Industrial biotechnology is by its nature a multi-disciplinary area, comprising biology, microbiology, biochemistry, molecular biotechnology, chemistry, engineering etc. This can be a strength, since combining knowledge from different scientific specialisms can create unexpected synergies. However, it can also be a weakness if the various disciplines remain fragmented and unconnected. Good contacts and coordination, including the formation of multi-disciplinary project teams, is therefore essential if industrial biotechnology is to be a real driver of innovation and sustainability in Europe.

The strategic research agenda should be organised within the following research areas in industrial biotechnology:

- **Novel enzymes and micro-organisms - metagenomics:** The search for novel enzymes and micro-organisms from specific or extreme environments, whether by direct isolation or mining of metagenomes will create an expanding range of biological processes for industrial use;
- **Fermentation science:** Processes will continue to be improved as knowledge of microbial physiology and nutrition is combined with better understanding of bioreactor performance and improved equipment design;
- **Metabolic engineering and modelling:** As our understanding of micro organism metabolism improves, there will be increasing opportunities to modify bacteria and yeasts to produce new products and increase yields;
- **Performance proteins and nano-composite materials:** The combination of proteins and inorganic materials, often with specific nano-scale geometry, offers new and innovative product areas such as self-cleaning, self-repairing and sensing products. This is a good example of a new and fertile scientific interface that must be explored by multi-disciplinary teams;
- **Microbial genomics and bio-informatics:** The key to understanding the activities of micro-organisms lies in a fuller knowledge of their genetics. With good genome mapping, we would be in a better position to identify desirable metabolic pathways and adapt them to manufacturing processes;
- **Biocatalyst function and optimisation:** Techniques such as protein engineering, gene shuffling and directed evolution will enable the development of enzymes better suited to industrial environments. These tools also allow the synthesis of new bio-catalysts for completely novel applications;
- **Bio-catalytic process design:** Biological processes that work well in the laboratory need careful scale-up if they are to be equally effective on an industrial level. Good process engineering knowledge and skills are essential to this;
- **Innovative down-stream processing:** Once made in a bio-reactor, products have to be efficiently recovered and purified if the product quality and economics are to be acceptable. Down-stream process design is therefore an integral part of successful innovation; and
- **Integrated bio-refineries:** At a manufacturing scale, there has to be efficient integration of the various steps from handling and processing of biomass, fermentation in bio-reactors, any necessary chemical processing and final recovery and purification of the product. The level of sophistication and control built up over many years in the chemical industry also needs to be achieved in bio-refineries.

These various aspects of industrial biotechnology have different potentials in a wide range of application areas such as fine chemicals, bulk chemicals and intermediates, performance chemicals, biofuels, food and feed ingredients, paper and pulp, textiles, pharmaceutical sectors.

ANNEX 4. HORIZONTAL ISSUES

Successful innovation is never defined solely by scientific and technological aspects. Many other factors need to be addressed including economic, regulatory, and societal issues. Where such issues are common to the three technology sections, they will be addressed within the Horizontal Issues Group. This is the starting point and first priority for the group.

In addition, the diverse range of stakeholders that contribute to the Horizontal Issues Group may raise other specific items that are synergistic to the aims of SusChem. Furthermore, advances from the technology sections themselves may yield knowledge that can be applied more generically to bring benefits to the technology platform's ultimate customers - the citizens of the EU.

The first step for the Horizontal Issues Group will be to identify and understand the impact of these generic factors. From this we will build a portfolio of issues that we believe we can influence in a significant manner using the resources of the platform and its stakeholders. Our goal will be to take concrete steps to minimise the more critical "horizontal barriers to innovation" and to initiate a few important programmes that can stimulate "a more supportive environment for innovation". The Horizontal Issues Group will thus provide a service to the technology sections and to the stakeholders of the Platform, and as such will be an integral part of SusChem.

To address its programme, the Horizontal Working Group will split its activities amongst three task forces, covering the following topics:

- HSE - Health Safety & Environmental Issues;
- Requirements for a supportive environment; and
- Financial mechanisms needed for more successful innovation within the EU.

Each of the above task forces will need to contribute to a pro-active communications and coordination programme to keep key stakeholders well informed and ensure that due account is always taken of societal concerns. Activities within the task forces will vary from defining potential research topics for eventual inclusion in the programme to capturing best practices from other countries or bodies involved in innovation. Activities on individual issues will also vary from direct actions where we manage a project, to much more limited initiatives where we simply generate a position statement on behalf of the platform.

An important element of the group's strategy will be to leverage effectively existing activities of institutions, associations and other bodies with an interest in supporting improvements in future chemistry innovations. Within this context we will be very much focused on developing new pragmatic solutions to our future issues, once we have clear consensus on what today's priority constraints are.

Examples of potential generic issues that would need to be characterised and addressed include:

- **Risk communication:** The real, rather than perceived, risk from innovative technologies needs to be effectively discussed with wider society to achieve earlier and broader societal acceptance. Past practices which had one side focusing on scare-mongering and the other side ignoring the need for dialogue, need to be replaced by an inclusive process based on a constructive and early dialogue. In addition the benefit of the technology needs to be effectively communicated to ensure adequate understanding of the risks of not making use of the new technology;

- **Global communication coordination:** New technologies that attract headlines such as nano-technology and bio-technology face an array of initiatives at country and regional level. These initiatives vary from setting standards to devising test methods to proposing use restrictions. In each of these cases there is a need for a coherent communications strategy. Whilst the individual technology sections will address their technical concerns, there may be an important coordination role for the Horizontal Issues Group to ensure a concerted European approach;

- **Skills and knowledge base:** The availability and mobility of an appropriately qualified and skilled labour force is essential to the long-term viability and innovative capacity of the European chemical industry. The ability to attract the best human resources, update training programmes and ensure adequate funding for the chemical sciences throughout an enlarged Europe is an important objective of SusChem. Activities here can be pursued in conjunction with partner organisations such as AllChemE[22];

- **Education:** Teaching activities in science and chemistry in particular must be enhanced. Laboratories must be made more available for school pupils to make chemistry more attractive. With no, or very limited, practical experience in chemistry, we lose not only potential future innovators but we also risk building a society that finds it increasingly difficult to understand the most basic aspects of the technology that they expect us to deliver. An example of a recent initiative in this area is the European Union Science Olympiad (EUSO): http://www.euso.dcu.ie;

- **Regulatory safety assessment:** New actions are being taken to work on more intelligent testing strategies. Included within this are specific plans to develop alternatives to animal testing. It is logical to explore synergies with these programmes for a number of reasons. Firstly new technologies will raise new issues and these will need to be appropriately addressed in any new testing strategy. Secondly the technologies themselves will develop new capabilities, such as advanced computational modelling, that may have applicability within these testing strategies. Potential partners in the Commission, including the Joint Research Centre (JRC), will be an instrumental factor in this area. The Horizontal Issues Group can also serve as a mediator between the Platform and initiatives on the above at ECOPA, ECVAM and ECETOC;

- **Industry-academia research collaborations:** Collaborative research is an important driver of innovation. Facilitation of cooperation with academic partners to access remote expertise and enhance time to market is an aim of SusChem;

- **More effective use of resources:** Significant societal concerns such as reducing our reliance on fossil fuels and reducing the emission of waste will be addressed from the technical perspective in all the technology sections. Within the Horizontal Issues Group the breadth of our stakeholder base could be used to facilitate the exploitation of progress made in these areas; and

- **Access to Venture Capital:** This is a potentially limiting factor in the successful adoption and implementation of innovation. In particular, this is a problem for SMEs. Improved knowledge of sources, and enhanced availability, of risk capital will therefore be a success criterion for SusChem. Roles for the European Investment Bank (EIB), the European Investment Funds (EIF) and private venture capital providers can be envisaged here.

Within the Horizontal Issues Group we have an obvious goal to support successful innovation. We are also focused both on the future and the current needs of the platform's new technologies. However, we are at the start of both the definition of these new technologies and our stakeholder dialogue processes. To take account of this our “horizontal vision” will mature with further input. In parallel, the above (and other) examples will evolve into concrete issues or be removed from our priority list. In this manner the horizontal agenda will develop into a clear and actionable support plan for SusChem.

Ultimately, our vision will yield a plan that addresses which specific items we need to change within 5, 10 and 15 years. Successful implementation of these changes will create a society with a sufficient understanding and appreciation of our innovations so that they will become a primary catalyst for further innovations.

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Representatives from the companies and organisations listed below have contributed to this document in one or more stages of its development.

Industrial companies
ATOFINA
BASF
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BP Chemicals
Degussa
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DSM
Novozymes
Oleon
Pfizer
Procter & Gamble Eurocor
Rohm and Haas

Industry Networks, Associations
AISE - International Association for Soaps, Detergents and Maintenance Products
Association of Chemical Industry of the Czech Republic
Cefic - European Chemical Industry Council
CEPI - Confederation of European Paper Industries
CIA - Chemicals Industries Association (UK)
COLIPA - European Cosmetic Toiletry and Perfumery Association
Crystal Faraday Partnership (UK)
ERRMA - European Renewable Raw Materials Association
EURATEX - European Apparel and Textile Organisation
EuropaBio - The European Association for Bioindustries
FEDERCHIMICA - Federazione Nazionale dell' Industria Chimica (Italy)
FEDICHEM - Fédération des Industries Chimiques de Belgique (Belgium)
FEIQUE - Federacion Empresarial de la Industria Quimica Española (Spain)
Finnish Chemical Industry Federation (Finland)
IMEC -InterUniversity MicroElectronics Centre, Belgium
ORGALIME - European Association of the Mechanical, Electrical, Electronic and Metalworking Industries
Polish Chamber of Chemical Industry (Poland)
Société de Chimie Industrielle (France)
UK CLC-ITF - Chemical Leadership Council, Innovation Task Force
VCI - Verband der Chemischen Industrie (Germany)
VNCI - Vereniging van de Nederlandse Chemische Industrie (Netherlands)
Academic networks, associations
CERC3 - Chairmen of the European Research Councils Chemistry Committees
COST Chemistry - European Cooperation in the field of Scientific and Technical Research
DECHEMA - Gesellschaft für Chemische Technik und Biotechnologie (Germany)
ECTN - European Chemistry Thematic Network Association
EFC - European Federation of Corrosion
EFCE - European Federation of Chemical Engineers
E-MRS - European Materials Research Society
EPF - European Polymer Federation
ESAB - European Federation of Biotechnology - Section on Applied Biocatalysis
EuCheMS -European Association for Chemical and Molecular Sciences
GDCh - Gesellschaft Deutscher Chemiker (Germany)
RSC - Royal Society of Chemistry (UK)

Unions
IG BCE - Mining, Chemical and Energy Union (Germany)

Governments and government organisations
ECRN - European Chemical Regions Network
European Commission, DG Enterprise and Industry
European Commission, DG Research
JRC Ispra - Joint Research Center
Member States Mirror Group

(Inclusion in this list does not imply formal endorsement of the document.)

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