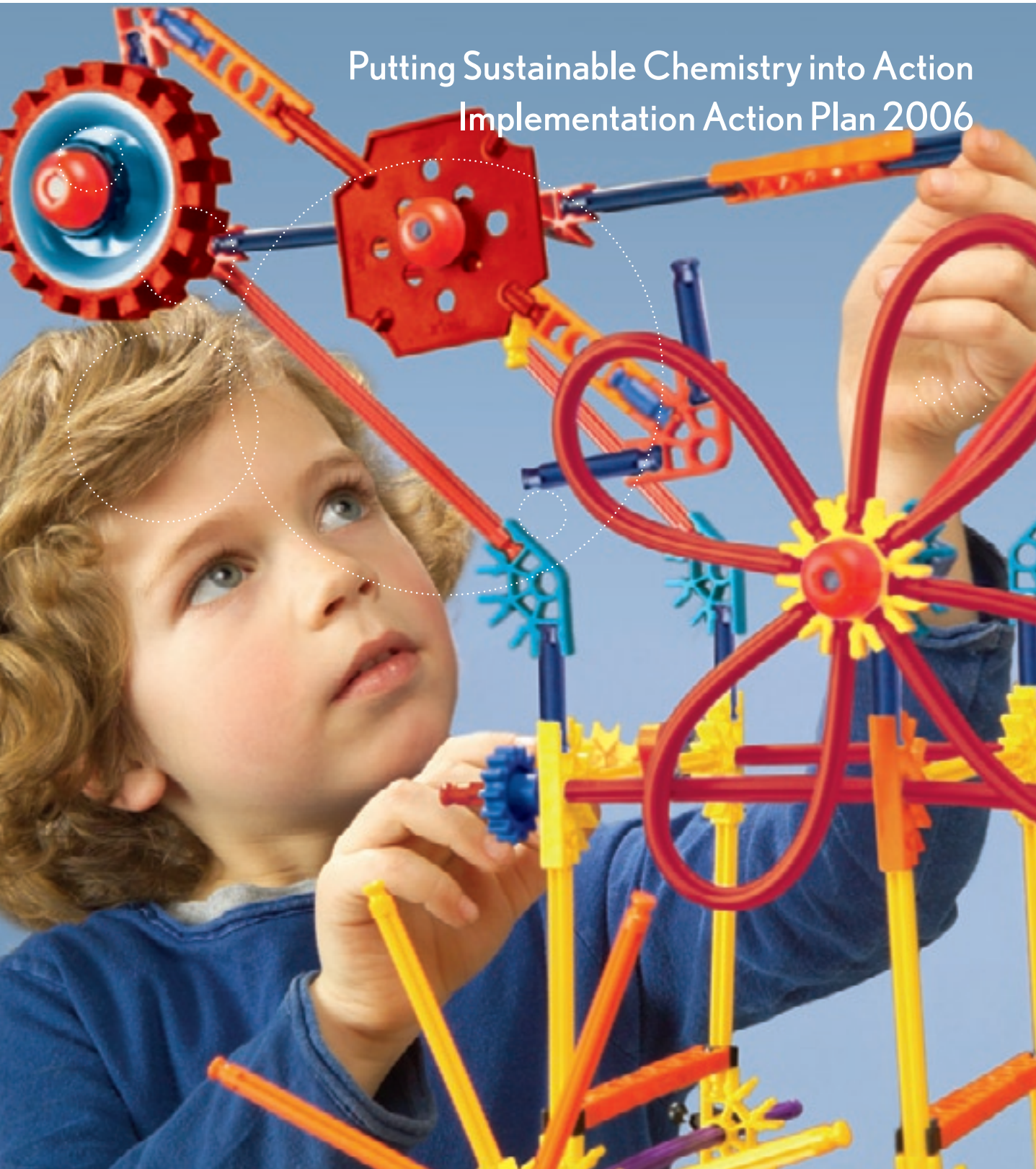
SusChem
European Technology Platform For
SUSTAINABLE CHEMISTRY

Innovating for a Better Future

Executive Summary



Putting Sustainable Chemistry into Action
Implementation Action Plan 2006

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Overview

Chemistry and biotechnology have a clear role in providing technological solutions to the challenges facing society. Building on Europe's strengths, sustainable chemistry will be a major factor in stimulating the European economy by providing new opportunities that will benefit all citizens.

Sustainable chemistry has strong cross-sector importance beyond the chemical industry. It contributes greatly to the pillars of the Lisbon Strategy.

Sustainable chemistry is a key contributor to the competitiveness of many of Europe's industries and hence is particularly important for economic growth in Europe. At the same time, it creates a highly qualified workforce and attractive employment opportunities. The chemical industry in Europe employs around two million workers in the EU(25) Member States and had 30 % of worldwide chemical sales in 2005. In addition, it contributes to sustainable development and the protection of the environment.

The European Technology Platform for Sustainable Chemistry (SusChem) seeks to foster and focus on European research in the areas of chemistry, chemical engineering and industrial biotechnology. After establishing a *Vision for 2025*, SusChem prepared a *Strategic Research Agenda* (SRA), which outlined the future priorities for European research efforts.

The *Implementation Action Plan* (IAP) outlines the next steps that are necessary to realise the proposals and the potential described in the SRA. Key activities are defined for each of the most immediate priorities of the SRA. The IAP defines eight themes of major importance for sustainable chemistry and also explains the priorities and activities organised around them:

1. Bio-based economy.
2. Energy.
3. Healthcare.
4. Information and communication technologies.
5. Nanotechnology.
6. Sustainable quality of life.
7. Sustainable product and process design.
8. Transport.

SusChem offers a unique opportunity to focus European spending in chemical R&D on the most promising areas in respect of their impact on the overall goal of sustainability and competitiveness. The collaborative activities for the most immediate priorities necessary to pave the way towards achieving the SusChem vision require funding in the order of €1.5 billion annually in the forthcoming years – approximately 50 % of this should come from public sources (both European and national). This figure clearly demonstrates the expectations of SusChem's stakeholders in terms of public contributions. At the same time it gives an estimate of the amount the private sector is willing to spend on SusChem R&D priorities provided that public co-financing is secured.

Creating a supportive environment for innovation in sustainable chemistry in Europe is essential for the implementation of the research agenda and for realising the potential of the activities highlighted in the IAP. The European Union and Member States have begun to realise this, and are looking at several national initiatives to promote research and innovation in more detail.

There are extensive structural, social and political factors that significantly impact the chemical industry's ability to innovate successfully as an industry. Project activities are envisaged to further develop the required "innovation infrastructure" required. The first activity is to develop the information needed to initiate a SusChem innovation service to support SMEs, the aim of which would be to speed up the adoption of better practices by smaller companies operating at the local level.

The introduction of emerging technologies also requires a reconsideration of the overall approach to risk assessment and management in the early stages of development. SusChem proposes a number of initiatives in areas such as intelligent risk management strategies, safety assessment of new technologies, and also proposes to evaluate how the gap between risk and perceived risk can be closed for new technologies.

SusChem proposes open dialogue between stakeholders and also public upstream engagement regarding the introduction of new products and technologies to engage stakeholders and engage with the public.

Furthermore, the IAP describes a number of activities with the objective of stimulating new education; training programmes and courses relevant to SusChem; and programmes aimed at building up an appropriately skilled work force.

SusChem future

In the future, SusChem's key goal will remain that of fostering chemistry and biotechnology research and innovation in Europe. The Platform intends to provide a service that clearly differentiates itself from other networks so that it is seen as the preferred point of entry into all SusChem-related technologies.

Monitoring the implementation of the SusChem SRA is essential to ensure a smooth process and continuous alignment of activities and requirements. The IAP will need adjusting depending on the results of current and future projects, as well as on the developments in Europe and in other parts of the world.

To promote sustainable chemistry in Europe, with its strong cross-sectional importance, SusChem will continue to work with policy makers, authorities, consumers and the public at large, also via its extensive and broad stakeholder network. It will also continue to facilitate interactions and communication between researchers and manufacturers, including downstream industries and SMEs, funders, governmental bodies and academic institutions, as well as national and European programmes.

SusChem has been successful in creating a multi-stakeholder forum and will continue to welcome other stakeholders who are interested in actively participating in the platform. The SusChem Board and partners invite all stakeholders to remain actively involved in all SusChem activities to continue its success story. As an open stakeholder forum, it is the SusChem stakeholders themselves and their ideas and actions that will drive SusChem now and in the future.

The eight themes of major importance for sustainable chemistry

1. Bio-based economy

Industrial biotechnology is a key technology to realise the knowledge-based bioeconomy by transforming the knowledge of life sciences into new, sustainable, eco-efficient and competitive products. This includes an optimised combination of the biotechnology processes with classical and new biochemical processes – especially in the chemical, materials and biofuels sectors.

The following three topics have been identified as being of major importance to facilitate the harmonious development of industrial biotechnology in Europe:

- Biocatalysis – novel and improved enzymes and processes.
- Developing the next generation of high efficiency fermentation processes, including novel and improved production of microorganisms/hosts.
- Process eco-efficiency and integration: the biorefinery concept.

SusChem early priority topic: Biocatalysis (p. 14)

Biocatalysis focuses on two aspects: the discovery and improvement of novel selective biocatalysts suitable for industrial use; and the development of systematic process design technology for a quick and reliable selection of new and clean high-performance manufacturing process configurations.

The aim of research in biocatalysis is to:

- Employ nature's toolkit to enable cleaner, safer and more cost-efficient processes.
- Address the increasing need for selectivity, stability and efficiency using enzymes as catalysts.
- Enable novel chemo-enzymatic processes through the discovery, evolution and/or design of enzymes.
- Solve reaction and process problems through the search for novel biocatalytic functions and the selection of new high-performance process configurations.

SusChem early priority topic: Fermentation (p. 18)

Fermentation processes are commonly used today to manufacture numerous products, however major technological improvements need to be achieved to increase competitiveness. Current bottlenecks include low volumetric productivity and low yield of the microorganisms under non optimal fermentation conditions in bioreactors. Another setback is the limited understanding of cellular behaviour in bioreactor surroundings.

Therefore, the major aims are to:

- Enhance existing or new microorganisms to reach optimum production capacities under industrial conditions.
- Develop analytical tools for monitoring the events in the bioreactor and mathematical models to control processes better and to improve their understanding for strain optimisation.
- Improve fermentation process engineering through better bioreactors and downstream processing.

Since it produces multiple products a biorefinery maximises the value derived from the complex biomass feedstock. It relies on the best use and valorisation of feedstock, optimisation and integration of processes for a better efficiency, optimisation of inputs (water, energy, etc.) and waste recycling/treatment.

The main focus points of research are:

- Improving biorefining technologies;
- Integrating the products into existing value chains; and
- Establishing strategies and business models for sustainability and competitiveness.

Synergies with other European technology platforms such as Plants for the Future, Sustainable Forestry and Biofuels exist and will be leveraged.

2. Energy

A sustainable, safe and efficient energy supply is crucial for every country's economy. There is a critical need to rethink energy supply and usage, since existing energy resources are limited both in volume and geographical distribution in the light of exploding global energy requirements.

SusChem concentrates therefore on three aspects:

- Developing alternative energy sources;
- Saving energy by reducing energy loss through the smart application of materials and technologies; and
- Ensuring the safer and better storage of energy through innovative ways of using and transporting it. These themes find resonance in the SusChem visionary project, the Smart Energy Home.

The diversification of energy sources tailored to the requirements and resources of each country using nature's renewable resources such as the sun (photovoltaics), wind power, geothermal energy and biomass is a definite requirement. For example, in the transportation sector, several technologies present great potential: biomass conversion to biofuels; hydrogen fuel cells; hybrid engines; and the exploration of metal nanoparticles as a fuel source.

More efficient usage and conservation of energy is possible, for example, by using OLEDs for lighting or novel nanofoams for insulation. Portable technologies require novel materials for the storage of energy, such as supercapacitors or new batteries. Synergies between several other technology platforms such as Photovoltaics, Hydrogen & Fuel Cells, Biofuels, and SusChem are expected and will be exploited.

SusChem early priority topic:
Photovoltaic (p. 27)

If solar cells are to provide an alternative to fossil fuels, significant research work is needed:

- To develop new routes for the production of crystalline silicon;
- In the development of amorphous silicon hybrid materials that could result in enhanced efficiencies;
- For further development of thin layer technology;
- In concerted efforts for cheaper and more stable dyes;
- In improving the efficiency of the dye sensitised cells; and
- In process development to deliver enhanced device performances, ensure sustainability and reduce production costs on an industrial scale.

SusChem early priority topic:
Fuels from biomass (p. 28)

To be competitive, the production of liquid fuels needs cheap and reliable sources of renewable raw material and efficient production processes. The attention is on organic fuels such as methanol, ethanol, butanol, and their derivatives, ETBE, MTBE, which can be produced by fermentation or gas to liquid technologies. Other points of attention are biodiesel and biogas, which can provide interesting biomass-based alternatives to diesel and LPG.

Currently, sugar prices in Europe are too high to allow competitive production and only part of the crops is being used. Therefore, new technologies need to be developed to efficiently convert cellulosic, fibre or wood-based, waste biomass into fermentable sugars.

Similarly, for biodiesel to be competitive as a transport fuel in Europe efforts have to be made to diversify the use of raw materials and to improve the processes while making them more economic by developing added-value uses for by-products such as glycerol.

SusChem early priority topic:
Energy storage (p. 41)

Higher specific energy, shorter charging times and long cycle life batteries need to be attained to keep pace with the increasingly demanding needs of personal electronic equipment. Lithium ion technology is currently the most promising for rechargeable batteries. Here, safety is key for the development of new systems (e.g. hybrid vehicles, energy networks, electronic devices).

Nanomaterials are expected to have a huge impact on active material design, due in part to their better resistance to structural strains and improved kinetics whatever the electrochemical system used (lead-acid, Li-ion or Ni-MH).

The envisaged hydrogen economy requires an efficient and safe hydrogen storage system. Hybrid organic-inorganic materials are a promising family of materials which includes dispersions of inorganic nanoparticles in organic (polymer) matrices; the converse, porous metal organic framework materials; pure nanoporous polymers; and organic macromolecules into mesoporous oxides such as silicas.

Supercapacitors containing electronically conducting polymer electrodes are of great interest, in particular for hybrid and electric vehicles due to their potential for storing large amounts of energy in a small volume. The largest hurdles towards marketable products are material development, production scale up and quality control.

3. Healthcare

The challenges for the next century in healthcare are:

- An ever increasing number of patients with allergic, inheritable or contagious diseases and cancers;
- Demographic trends; and
- The exploding costs of healthcare.

Nanotechnology has the potential to revolutionise medical technologies and therapies, by providing the tools to cope with these challenges. The health sector will greatly benefit from the new products and technologies provided by materials science: treatments, medical devices and delivery systems.

Exploiting nanoparticulate formulations with nanoscale functionalities for new applications will have an immense impact on healthcare and quality of life. This will be achieved through effective drug applications, faster and non-invasive medical diagnostics, and through treatments. An important task will be to establish appropriate safety standards for these new products and formulations.

SusChem primarily focuses on the use of novel materials to achieve a targeted drug delivery or therapy and to provide new insights into medical conditions through materials for diagnostic purposes. Though just as important, the identification and design of new active pharmaceutical ingredients is dealt with elsewhere.

SusChem early priority topic:
Targeted and smart drug delivery (pp. 45 & 47)

Drug delivery, whether targeted or smart, may be achieved through the novel design of materials, in the form of coatings or formulations. These materials enhance the binding of the active ingredient/pharmaceutical to receptor sites or delivery/entry into specific cell types (e.g. cancer).

Functionalised (magnetic) metal nanoparticles with suitable polyfunctional organic groups or polymer chains are able to link to specific biomolecules or receptor sites. Different nanostructured inorganic matrices are suitable as bone tissue substitutes and, furthermore, have the potential for controlled drug delivery, specific to bone pathologies.

Currently, there are several problems with the application of nanoparticles in delivery systems, e.g. their tendency to aggregate during storage or under physiological conditions. Understanding and preventing aggregation is thus extremely important.

Time is of essence in healthcare, and therefore a key research theme is the development of technologies that enable a quick identification (e.g. lab on a chip or sensors) of a threatening medical condition or that can provide online data (e.g. implantable biomedical devices) to the physician. Furthermore, materials that enable physicians to see diseases clearly using currently available imaging methods need to be explored.

Many of these actions require extensive research in order to be realised, particularly in the understanding of how structure-property relationships affect the interactions between biological cells/organs and pharmaceuticals; how sensors work in the body; and how to interface biological systems with signal transporting materials/devices.

Synergies are expected with the ETPs Nanomedicine and Innovative Medicines.

4. Information and communication technologies

Information and communication technologies (ICT) is a fast-moving consumer sector with a strong need for new materials and products to meet demands. Existing competencies in material science will lead to improved competitiveness of European industry, enabling Europe to master and shape future developments and thus ensure its global leadership in ICT.

The adoption of newly developed architectures and materials will lead to fundamental changes in the concepts and design paradigms of integrated circuits. Early success in such a field will provide a leading edge for European industry compared to the US and Japan, which are presently dominant in the fields of standard complementary metal-oxide-semiconductor (CMOS) technology. To go beyond CMOS in the coming decade, the industry will have to move to logic devices based on alternatives to charge state variables (e.g. spin, mechanical, etc.). Already, the semiconductor industry is investigating some very interesting areas such as spintronics, quantum computing, and optical computing.

SusChem priorities in this area, as essential contributions to the ICT sector, are:

- The application and introduction of new materials (polymers, nanomaterials, etc.);
- The control, production and integration of these new materials into devices with respect to cost; and
- Energy consumption.

Important facets are the understanding of interfaces between various materials, whether organic or inorganic; the use of self-assembly and patterning techniques in production; and the identification of new semiconductors, e.g. carbon nanotubes. Furthermore, materials for information storage are also addressed, such as holographics or new forms of switches (e.g. DNA, picosecond).

Nanotechnology is a basis for many of the key areas, and synergies are expected with the ETPs ARTEMIS and ENIAC.

5. Nanotechnology

Nanotechnology is enabling new developments in material science, while providing innovations for industries such as construction, information and communications, healthcare, energy, transportation and security. The sustainable development of nanomaterials, including their potential for environmental protection and the appropriate assessment of possible risks, will contribute to sustainable economic growth.

The discovery of new materials with tailored properties and developed processing are the rate-limiting steps in new business development for many industries.

Nanotechnology, nanosciences and the associated materials play an important role in many of the activities identified in the SusChem Implementation Action Plan. The nanotechnology chapter contains a detailed description of the actions necessary for the development of novel nanomaterials, their synthesis and production, their analysis and their design by computer modelling. Synergies are expected with the many other technology platforms: ENIAC, Manufuture, Hydrogen & Fuel Cells, Innovative Medicines, Nanomedicine, Photovoltaics, Construction and EuMaT.

SusChem early priority topic:
Integration of nanostructures in device materials (p. 53)

A number of new nanostructured materials including carbon nanotubes, and silicon and germanium nanowires are of potential interest for future device applications. However, the mechanisms to control nanostructure, composition and size are not yet understood or controlled.

The role of catalyst composition and structure, in conjunction with temperature and gas composition (and other factors), in the production of, for example, carbon nanotubes is not understood in determining the structure. Understanding the mechanisms of how to control growth, structure, composition and orientation on predefined templates will be vital.

SusChem early priority topic:
Understanding of interfaces (p. 63)

The need to fully characterise interfaces between nanomaterials integrated in an IC chip is of critical importance for their controlled production. Here, novel metrology techniques will be required to characterise the electronic and structural interactions at nanometre scale interfaces.

Studying the interaction forces between molecules and interfaces by means of atomic force microscopy and fluorescence-based technologies on the nanometre scale will provide valuable information on interfaces. Investigating surface functionalisation processes with organic and biomolecular moieties, as well as self assembly at surfaces, will enable insights into the basic properties of the interfaces.

SusChem early priority topic:
Synthesis, surface chemistry and processing (pp. 76-77)

Innovations in materials technology and the design of advanced materials with tailored macroscopic properties based on their molecular structure is a prerequisite for innovations in many industries. Interesting applications are nanostructured biosensors, smart packaging with enhanced barrier properties, and functional surfaces.

The demands of tomorrow's technology translate directly into increasingly stringent demands on the chemicals and materials involved, for instance their intrinsic properties, costs, processing and fabrication; their benign health and environmental attributes; and their recyclability focusing on eco-efficiency. There is a pressing industrial need to better understand complex physical, chemical and biological phenomena relevant to the mastering and processing of multifunctional and eco-efficient materials.

SusChem early priority topic: Understanding structure property relationship (pp. 85 & 89)

To understand the phenomena that arise at the nanometre scale and to gain the ability to control structure, and integrate new properties that are related to a reduction of the material size, it is necessary to understand the structure-property relationship including the control of materials' shape and size. There a need to be able to analyse individual components, but also to analyse the properties of the whole system at the macroscopic level.

Computational modelling will lead the way in providing insights into nanophenomena and thus assist in the design of new materials. SusChem focuses on:

- Mapping the whole range of technologically relevant processes – from chemical synthesis, experimental characterisation of materials properties, through to industrial processing onto suitable models;
- Developing efficient algorithms for their simulation;
- Bridging the length and time scale; and
- Developing user friendly software.

Environment, Health and Safety (EH&S) factors also need further investigation and appropriate targeted actions, including the analysis of nanomaterials in biological tissues and in the atmosphere; exposure levels; and issues surrounding the end of their lifecycle.

6. Sustainable quality of life

This SusChem priority aims to improve the quality of life of citizens by applying SusChem technologies. At the same time, it aims to make citizens' lifestyles more sustainable, by achieving a lower environmental impact by consuming less energy, using fewer resources, and reducing emissions. All this can be done either directly in citizens' own homes or indirectly through the products they buy.

This section bundles activities together in a package that can directly influence the lives of European citizens. The focus revolves in and around the home – from energy collection via photovoltaic cells, novel insulation and lighting technologies, through to eco-efficient processes. Particular attention is paid to the actions for waste treatment, e.g. water purification. All actions play a vital role in the implementation of the SusChem visionary project, the Smart Energy Home.

Energy conservation and home owner comfort, health and convenience are all integral parts of the concept of a Smart Energy Home. Europe is already a world leader in new energy-efficient construction materials, smart appliances, alternative energy systems in the home environment, insulation and sustainable consumer products. These strengths, together with the available knowledge, need to be further developed. Some of the technologies required to achieve the vision of an eco-efficient energy-generating house are already available but many other technologies are yet to be developed.

Synergies exist with the ETPs Construction, Manufuture, Networked & Electronic Media, Photovoltaics, Hydrogen & Fuel Cells, and Water Supply & Sanitation.

7. Sustainable product and process design

Sustainable product and process design primarily builds on the research priorities described in the *Reaction & Process Design* chapter of the SRA. The overall goal of the research activities suggested is to build on existing European strengths in process design, engineering, catalysis and chemical synthesis to achieve intensified, more eco-efficient, environmentally benign and competitive processes and production technologies.

The five subchapters – *Diversification of the feedstock base, Innovative eco-efficient processes and synthetic pathways, Knowledge-based manufacturing concepts for targeted and tailored products, Implementation and integration of intensified process technologies* and *Lifecycle analysis* – aim at widely implementing innovative process technologies and knowledge-based design as well as plant operation methodologies in chemical, pharmaceutical and biotechnological production. This will provide opportunities for new business models, utilising a variety of feedstock and directly targeting specific product end-use properties. A holistic approach is depicted to rationally integrate innovative chemistry and engineering developments and to develop the most viable option regarding the whole process.

The following research activities specifically aim at innovative processes and chemical/pharmaceutical manufacturing excellence in Europe:

SusChem early priority topic: Innovative eco-efficient processes and synthetic pathways (p. 108)

This activity aims to achieve more eco-efficient chemical syntheses and corresponding processes with high resource efficiency and reduced amounts of waste. Some examples addressed are:

- Specific transformations of functional groups;
- The utilisation of highly selective multifunctional catalysts;
- The increased use of benign and easy-to-handle oxidants; and
- Alternative solvents.

Targeted process technologies are the development of integrated reactive and hybrid separations and the utilisation of non-conventional forms and sources of energy.

SusChem early priority topic: Knowledge-based manufacturing concepts for targeted and tailored products (p. 112)

This activity comprises an ambitious research programme to master a product's end use properties through process design. Intensified product engineering requires extending the capabilities of continuous processing, in particular those of highly viscous and/or solid-containing process fluids with the ultimate goal of intelligent, self-adapting process devices. Other requirements are advanced formulation technologies, high-throughput tools for formulation engineering and process systems engineering techniques, as well as reliable scale-up methods for microencapsulation and the production of fine particles and nanoformulations.

Specific synergies are expected with the Manufuture technology platform.

8. Transport

This section concentrates on the development of materials and technologies for the construction of vehicles that benefit the environment (eco-efficiency and recycling) and that assist in increasing the safety and mobility of citizens. It also concentrates on exploring systems that secure the sustainable supply of energy required to power the vehicles.

Proposed actions are:

- The sustainable management of materials, including the development of elastomeric products and materials to catalyse the decomposition of CO_x, NO_x, and SO_x;
- The development of new assembly technologies;
- Onboard H_2 production; and
- Production of low sulfur and aromatic component containing fuels.

The creation of a European Transportation Materials Development Centre is proposed to pave the way for the development of materials and technologies for such purposes as traffic management sensors (collision avoidance, night vision), instant diagnostics, constant repairing materials (coatings), and silent cars and roads.

SusChem early priority topic:
Sustainable materials management (p. 123)

Lightweight, but strong materials, combining high performance with reduced environmental impact are increasingly required. Reducing weight can be accomplished by developing innovative thermoplastic products for structural parts leading to lower fuel consumption:

- Tough thermoplastic foams;
- Organic fillers-based thermoplastic composites; and
- Polymers with improved thermal resistance for further metal replacement (body panels).

More efficient airbag systems need to be developed to bring the best degree of protection together with weight reduction. Fibres offering a better cost-performance compromise could replace metal chords in tyres resulting in a significant weight reduction, thus producing less rolling resistance and reducing fuel consumption.

Alternative body assembly technologies – gluing versus welding and reversible assembly – need to be pursued to complement the move away from rigid assembly processes. Using adhesives in the assembly process also gives the potential to reverse the process cheaply and efficiently. This can easily be done by dissolving the glue, particularly at the end of the lifecycle. Research should focus on high throughput formulation and testing techniques as well as on the development of non-destructive analytical tools.

Visionary projects

The three visionary projects proposed in the SRA described the benefits and impact on our daily life when the technologies derived from the proposed research are applied. Now SusChem intends to take the necessary steps to actually realise some of these projects and thus demonstrate the full potential of the SusChem SRA.

In particular, SusChem describes the key activities and partners for defining the concepts and planning the construction of a Smart Energy Home, an Integrated Biorefinery pilot facility for collaborative research, and an F^3 Factory. Since all visionary projects will have a high societal impact it is important that they all include stakeholder dialogue and public engagement as an integral part of their development and realisation.

1. The Smart Energy Home

The Smart Energy Home (SEH) is a visionary project that will have major impact on society in Europe and its energy consumption. The vision is to put together a collection of technologies in the Smart Energy Home that will eliminate the net use of energy in the home. In doing so, it will prove the feasibility of the technologies employed and showcase the importance of chemistry and material development for a sustainable future in Europe.

Reducing European energy consumption significantly would be possible if such products were used in new and existing homes, as well as in public buildings such as schools, hospitals, administrative centres, etc. This will be combined with the increased convenience and healthiness of the home and would serve the private needs of the individual consumer, thus leading to a natural uptake of such new products.

To build the Smart Energy Home a consortium of European technology platforms and industry needs to be established. Synergies exist with the ETPs Construction, Photovoltaics, Hydrogen & Fuel Cells, Forestry, Steel, and Water Supply & Sanitation.

With the right incentives considerable market uptake could be achieved within 3 to 5 years rather than 10 to 15 years.

In summary, the Smart Energy Home will provide:

- A partner platform to facilitate testing and scaling up;
- A demonstration platform to showcase the importance of chemistry and material development for a sustainable future in Europe;
- Direct feedback from end users ("living innovation"); and
- The implemention of the results of leading FP projects in real life solutions for consumers.

2. The Integrated Biorefinery

The integrated, zero-waste and diversified biorefinery is an integrated cluster of bioindustries using a variety of different technologies to produce a wide range of valuable commodities and end products from biomass raw materials. This is a key concept in the realisation of the knowledge-based bioeconomy, and has the potential to revolutionise the way chemicals and energy are produced.

In order to turn research into products, a crucial step is to establish a proof of concept and test it under industrial conditions. Because full scale manufacturing facilities or even pilot plants are often not accessible to researchers, the concepts developed in R&D are not immediately applicable nor necessarily economically feasible on a larger scale. Therefore, the focus of the Integrated Biorefinery visionary project lies on developing adequate industrial facilities to have access to scale-up and pilot infrastructures during the research and development stage. This will serve to develop and test industrial processes, thus reducing lead time and investment.

The integrated and diversified biorefinery will allow large scale research, testing, and optimising production processes of a wide range of products with the dual aims of using fractions of biomass and exploiting their potential to produce the highest value possible in an eco-efficient way.

3. The F³ Factory

To meet the challenges laid down by the market, and to combine product development with new manufacturing techniques, the implementation of an integrated technology initiative is needed, a technology and research spanning initiative for holistic product and process development: the F³ Factory (fast, flexible, future).

The F³ initiative will radically push new and upcoming technologies and allow product development and manufacturing with higher added value compared to current technologies. Flexible demonstration plants will be built where existing scientific concepts will be bundled and implemented. Integrated process units and combined unit operations will be linked with process modelling tools, inline monitoring, model-based process management and advanced process control. This will form a centre of gravity for fast process development. This highly integrated technology platform will generate new opportunities; lead to future factory concepts; and bring production assets together in European F³ Factories.

The F³ technology initiative will address four different focus areas, targeting aspects of product and process development, plant design and logistics:

- Value chemicals, intermediates and active ingredients;
- Specialised customised polymers by modular plants;
- New functional (nano- and microstructured) materials by multipurpose plants; and
- Life science products by new production technologies.

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The European Technology Platform for Sustainable Chemistry is supported by the Sixth Framework Programme of the European Community for Research.
http://cordis.europa.eu

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