Road Map Document for a Sustainable Chemical Industry

January 2013
**Energ-Ice Project**

Dow Italia, Afros and Crios (Cannon Group), and Federchimica are partners in the Energ-Ice Project funded by LIFE, the EU’s financial instrument supporting environmental and nature conservation projects.

The Energ-Ice Project focuses on reducing the environmental impact of energy using products, such as cold appliances, by taking action at the design stage, where the pollution caused during the product’s life cycle can be best prevented.

Additional objectives of the Energ-Ice project are the preparation of two documents:

2. “Road Map Document for a Sustainable Chemical Industry”.

The Documents goal is important to show the contribution of Chemical to the Sustainable Development and to highlight a roadmap towards the sustainability of the Chemical Industry and its contribution to the sustainable development of the planet.
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1. Sustainable manufacturing

There is no unique and common definition for sustainable manufacturing but the US Department of Commerce’s Sustainable Manufacturing Initiative describe it as: “The creation of manufactured products that use processes that minimize negative environmental impacts, conserve energy and natural resources, are safe for employees, communities, and consumers and are economically sound.”

We have to remember that sustainable manufacturing is part of a larger concept, sustainable development, which emerged in the early 1980’s in response to increased awareness and concern over the environmental impact of economic growth and global expansion of business and trade.

In 1992 during the Earth summit in Rio de Janeiro, sustainable production was introduced and adopted as one of the guiding principles for business and governments in transitioning towards and achieving sustainable development. As sustainability is becoming an expected business practice by companies, large and small, sustainable manufacturing is being defined, developed and implemented by manufacturing companies and their networks of suppliers and customers.

Today, emerging regulatory and social trends around sustainability create both pressures and opportunities for chemical companies at global and EU levels. Legislative requirements, stakeholder expectations and companies’ own business and Responsible Care strategies are driving the development of more sustainable chemical products and supply chains.

Clear trends are already surfacing:

- the introduction of REACH creates new pressures on specific substances;
- the emergence of eco-design, Green Public Procurement (GPP), Ecolabel criteria and waste prevention schemes is creating demand for more sustainable products;
- rising consumer interest in sustainable goods is giving incentives retailers to develop sustainability measures for their suppliers.

The move towards sustainable products will take many years to progress through legislative and business processes. During this time, retailers, consumers and non-governmental organizations (NGOs) will continue to call for transparency and clear statements about the constituents of the goods they purchase.

In this period, doing business with a good environmental practice is an important aspect for investors, regulators, customers and the communities. Sustainable manufacturing can bring to industry an economic profit, a good reputation and can attract investments. These benefits are not just a game
for big business, but also new firms and small businesses can also play an exciting role. Start-ups, small and medium-sized enterprises (SMEs) with their flexible business models and less reliance on established ways of working, can also benefit, evolving and innovating quickly to gain advantage over the competition. For example the green marketplace value trillions; the global market for low-carbon products is already estimated to be worth over 5 trillion USA Dollars.

1.1. Chemical industry

In May 2012 the European chemical industry published its first sustainability report, outlining the sector’s vision to play a key role in ensuring that by 2050 over nine billion people live well, within the resources of the planet. Making this vision a reality means, among other things, that our industry strives to be sustainable in terms of its operations and to be a key enabler of a sustainable society through the excellence of its employees and the benefits of its products.

It is important that sound science be used as a critical element to ensuring industry, society and governments make good choices in terms of product selection, technology options and framework conditions. Today, resource efficiency is becoming as important an element of the sustainability of products as chemicals safety. This document is an introduction to how sustainability may apply to chemicals in practice. It explains approaches that industry can use to make science-based choices in product development and assessment. It is particularly aimed at smaller companies, as part of Cefic’s programme to help deliver the chemical industry’s vision.

The chemical industry has a very important role in the global industry. On a global scale it produces an annual turnover of more than €1,700 billion, generating 9% of international trade. Chemical industry is placed upstream of various sectors such as construction, transport, food, health, personal cleanliness and home, clothing, electronics, etc.; this industry is also able to supply intermediate products for downstream industries and it contributes directly to create materials for the consumer market. Since chemical industry have a strategic position it is fully involved in the question of industrial sustainability outlined above.

Moreover it is often perceived by the public opinion as one of the biggest causes of the environmental degradation. Chemical industry has a structure very various, it includes different areas, for example: petrochemicals, chemistry for the production of industrial intermediates or products, inorganic and organic intermediates, polymers, dyes, medicines and products for agriculture.

A reality so varied obviously multiplies the problems posed by sustainability, but at the same time increases the opportunities to resolve them. The issues connected with sustainability can be summarized as follows: pollution caused by chemical processes and products, risks arising from hazardous chemicals, reduction of sources of raw materials.
Chemical Industry, due to Responsible Care Programme improved its performance in all the three issues but still need to increase the performance to contribute to the sustainable development of the planet.

In fact a significant proportion of final products of the chemical industry are outspread in the environment, not only by the chemical industry that created them but also by industries that hire them in various application areas and by the final consumers.

We must also stress the difference between the negative effects that result from polluting agents and those from dangerous products.

Highly toxic, flammable, explosive products can be the cause of the dramatic events that involve people and things but always on a local scale.

The pollutants are certainly dangerous to the environment and can also act in insidious way for their long-term effects (effects that are not so easily and unequivocally recognizable) and on a global scale.

The prevention of the effects of pollution and the protection of accidents caused by the release of chemicals must be kept distinct.

The third problem identified is related to the depletion or exhaustion of the sources of the raw materials used, whether mineral or organic fossil, even for a local area, with consequent changes in the scenario of prices and the economic balance of the production and sales. This will lead to the development and use of new or modified products and processes to enable a shift towards the use of renewable resources as raw materials.

The objectives of the industrial chemical system must stand in the face of these problems can therefore be summarized as follows:

- reducing the use and generation of polluting chemicals in chemical processes;
- reducing the use of hazardous chemicals in chemical processes;
- reducing of the harmful effects of the final products;
- reducing the use of scarce raw materials and non-renewable.

In recent year, also for a bigger awareness and sensitivity for this argument, we have an introduction of new legislations with stricter and stringent procedures for: industrial processes, characteristics of the products used and placed on the market, the quality and quantity of emissions and wastes generated.

At the same time, also some managers, as part of Responsible care policy, have adopted voluntarily some technical measures for the reduction, for the waste treatment and, where possible, for the recycling of products at the end of their use.

The introduction in Europe of REACH (Registration, Evaluation and Authorization of Chemicals) gave an important contribution to index chemical substances.
2. Life Cycle of Product

The chemical industry can help people live better, within the limits of the planet; so we need to find ways to provide the likes of housing, health and hygiene in the most resource efficient way, with minimum burdens placed on the environment. It applies not just to produce themselves, but to the whole product life cycle – from cradle-to-grave or even cradle-to-cradle. It includes the impacts of raw material sourcing, manufacture, packaging, transport and distribution, retail, use and then post-use recovery or disposal. Any sustainability assessment of products or services needs to be both integrated and based on a life cycle approach.

The business of the Industry may be the manufacture of complete products that are destined for consumers or components and intermediate products that are transported to other businesses and that may become part of the final products for sale or products used to provide services. Whatever they make, their business uses resources and services provided by the natural environment (e.g. metals, materials, fossil fuels, soil, water, biodiversity) and discharges “by-products” (e.g. wastes, emissions) into the environment. As a consequence, all this actions have an impact on the environment.

We can represent the pattern of the life cycle of a product as in figure:

<table>
<thead>
<tr>
<th>Tab. 1 - The life cycle of a product</th>
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<tbody>
<tr>
<td><img src="image" alt="Life cycle diagram" /></td>
</tr>
</tbody>
</table>

Source: CEFIC

Figure above shows an integrated life cycle; in this cycle we have to consider all three pillars of sustainability: environmental, social and economic.
Considering these aspects together helps identify how to deliver benefits in all areas, or at least to inform decisions if trade-offs between the different pillars are required.

<table>
<thead>
<tr>
<th>Tab. 2 - Pillars of Sustainable Development</th>
</tr>
</thead>
<tbody>
<tr>
<td>![Diagram of Sustainable Development]</td>
</tr>
<tr>
<td>Source: European commission; Institute for Environment and Sustainability</td>
</tr>
</tbody>
</table>

The same applies to decisions within each pillar. For example, improvement in one environmental area – such as air, water, land or biodiversity – may have trade-offs in another area.

It is important to integrate all pillars of sustainability in any decision-making process.

We can see in the next figure the basic interaction between your facility and the environment and the impact it may have on the environment throughout the lifecycle of the products that it produces. Even though the actual production processes are far more sophisticated, your environmental impacts are principally formed in the following three stages:
2.1. What is a closed loop approach?

Companies are increasingly moving from linear production models to closed-loop value chains. This means that a by-product from one process becomes the raw material for another process. Closing the loop can help to improve resource efficiency and security of supply and reduce costs for waste management and disposal. The move towards closed-loop models is thus accelerated by rising commodity prices and increasing scarcity of resources. Moving from a linear to a circular economic model is also promoted by policymakers in some regions. “Circular economy” legislation has been enacted in countries such as Germany and China.

We can see in the figure that there are different ways for closing the loop:
Tab. 4 - Ways for closing the loop

<table>
<thead>
<tr>
<th>Re-use</th>
<th>Use</th>
<th>Recycle</th>
<th>Replace</th>
</tr>
</thead>
</table>

Source: European commission; Institute for Environment and Sustainability

- the simplest closed loop is re-use, where a product is re-used without need for remanufacturing;
- when recovery and material recycling is needed, then closed loop recycling involves taking the product or material back for use in the same application;
- a wider loop occurs where used materials are recovered for subsequent use in a different application.

The priority for material use is that the loop is closed, rather than material being lost from the system and disposed to landfill. The choice between the different options will depend on an overall sustainability evaluation, which will include environmental effectiveness, economic efficiency and social acceptance. While closing, the loop makes both economic and environmental sense in many cases, it is important to take a broad view of the energy use, emissions and overall environmental impact generated by chemical products and processes. Tools such as Life Cycle Assessment (LCA) can help identify the most sustainable strategy.
3. Managing products

Sustainable products provide environmental, social and economic benefits while respecting public health, welfare, and environment over their full life cycle, from the extraction of raw materials to final disposal. Sound product and process management practices are crucial to make this happen.

3.1 Product safety management

A key aspect of sustainability is ensuring that products – existing and new – are safe for their intended uses. Product stewardship involves the active management of chemical products on site and beyond, and a dynamic engagement with downstream users and suppliers. Product characteristics and functionalities should be considered based on a life cycle approach, including:

- Risk-based analysis (including hazard and exposure) of safety, health and environmental impacts of existing and new industrial processes, activities and products throughout the life cycle;
- Reduction of actual and potential risks by several means, including product labelling, product handling precautions, product use restrictions, and substitution if needed;
- Commitment to continuous improvement in product design, assessment practices, education, communication and customer support;
- Clear commitment to provide product information and support along the whole value chain as appropriate to ensure safe handling and use;
- Partnerships with authorities, local community and NGOs to prevent accidents and answer public concerns.

3.1.1 Developing new products

There are many more reasons for a company to consider new product development rather than just improving margins. It could be, for example:

- to improve its own production efficiency with a view to reducing waste generation or limiting resource consumption;
- to increase safety for workers, customers and the environment by reducing exposure or choosing less hazardous substances;
- or simply because one of its suppliers has brought a new product onto the market, which offers novel and improved properties.

These changes can be motivated by factors including the company’s own Responsible Care product stewardship programme, customer demands or a change in legislation. Planning ahead makes good business sense. Keeping
informed of emerging legislative and social trends helps identify the substances and product ranges that are the most likely to be successful in the long term, and working with upstream and downstream supply chains can deliver true benefits in terms of meeting and pre-empting new product expectations.

When developing a new product or product range, companies will make choices based on the customers they wish to supply. For example, the issues to be considered will be different if the product is to end up in a consumer application rather than an industrial application – although some issues, such as safety, are common to both.

### 3.1.2 Evaluating alternative products

When evaluating alternative products, some key elements should be considered:

- Does the substitute substance offer the same functionality as the substance it is intended to replace, application by application?
- Is the substitute compatible with the process in which it is intended to be used?
- Is the substitute readily available? (For example, is it a rare earth?) Can its supply be easily secured?
- Is there medium or long-term experience of the use and effects of the substitute material?
- Is the substitute’s human and environmental profile available? For example, in the context of REACH, it would prove counter-productive to attempt to replace one Substance of Very High Concern (SVHC) with another known SVHC substance.
- What is the impact of the production of the substitute on resource use?
- Are there any potential socio-economic implications?

### 3.2 Process management

Companies seek to optimise their processes to reduce energy and other resource use and waste generation. In some instances, this can be achieved by completely rethinking the way the substance is manufactured by using different technologies. For example, a membrane system could be used instead of a solvent to separate two substances. Chemistry based on renewable materials might present a number of opportunities in this area. For example, a fermentation process can be used instead of a traditional petrochemical one to manufacture some alcohols such as butanol.

Similar to product safety, it is important that a life cycle approach be used when assessing process safety impacts of manufacturing changes. Improvements in one part of the chain can result in trade-offs in other parts of the chain.
Process safety risk assessments should be conducted across the supply chain to understand the full impact.

### 3.3 Product and chemical services

Sustainable management of chemicals also includes substance-by-service replacement, also known as chemical leasing. Chemical leasing is defined by the United Nations Industrial Development Organization (UNIDO) as a service-oriented business model that shifts the focus from increasing sales volume of chemicals, towards a value-added approach.

The producer mainly sells the functions performed by the chemical, and functional units are the main basis for payment. Functional units can be, for example, the number of pieces cleaned or the amount of area coated. This system is used in some applications, but it is not applicable to all chemicals and their uses due to feasibility or performance issues. Chemical leasing is an option among other substitution possibilities, but its economic, environmental and social benefits should be demonstrated in each case.
4. Evaluating product sustainability

A range of assessment tools exist to evaluate the sustainability of products and processes, focusing on different aspects (environmental, economic and social) and using different methods.

4.1 Life Cycle Assessment (LCA)

Life cycle assessment methodologies were developed in the 1970s after the energy crisis. While life cycle thinking simply involves taking a life cycle approach, Life Cycle Assessment (LCA) is a structured tool for assessing environmental burdens across the whole product life cycle, either to identify improvement areas or to make comparisons with other product or service systems.

LCA allows to assess the impact associated with all the phases of a process from cradle-to-grave, i.e. from definition till recycling. It provides tools for compiling inventories (energy, material inputs and environmental releases), evaluating the potential impacts associated with identified releases and inputs, and interpreting the results for decision making.

A Standard exists today for LCA (ISO 14040 and 14044) and this is built on by a large usage community of practitioners and solution providers. GHG (Greenhouse Gases) emission reduction can be consider as a subset or simplified LCA, as current and future regulations on GHG reduction emission are based on existing LCA methodologies and practises.

The LCA goal is to compare the full range of environmental effects assignable to products and services in order to improve processes, support policy and provide a sound basis for informed decisions.

The term Life Cycle Scientific refers to the notion that a fair, holistic assessment requires the assessment of raw-material production, manufacture, distribution, use and disposal including all intervening transportation steps necessary or caused by the product’s existence.

A Life Cycle Assessment is carried out in four distinct phases as illustrated in the figure.

<table>
<thead>
<tr>
<th>Tab. 5 - Life Cycle Assessment phases</th>
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<td>Source: European commission; Institute for Environment and Sustainability</td>
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</table>
The phases are often interdependent in that the results of one phase will inform how other phases are completed.

- **Goal and scope definition**: Defining the functional unit for the product or service, i.e. the service delivered to society and the boundaries of the system that are included. An LCA starts with an explicit statement of the goal and scope of the study, which sets out the context of the study and explains how and to who the results are to be communicated.

- **Life Cycle Inventory (LCI)**: Life Cycle Inventory (LCI) analysis involves creating an inventory of flows from and to nature for a product system. Inventory flows include inputs of water, energy, and raw materials, and releases to air, land, and water. To develop the inventory, a flow model of the technical system is constructed using data on inputs and outputs. For product LCAs at either the generic (i.e., representative industry averages) or brand-specific level, that data is typically collected through survey questionnaires.

- **Life Cycle Impact Assessment (LCIA)**: Evaluating the significance of environmental impacts using the LCI results. In general, this process involves associating inventory data with specific environmental impact categories and category indicators, thereby attempting to understand these impacts. It can include for example global warming potential, ozone depletion potential, eutrophication, and potential resource depletion. This phase of LCA is aimed at evaluating the significance of potential environmental impacts based on the LCI flow results. Classical life cycle impact assessment (LCIA) consists of the following mandatory elements:

  1. selection of impact categories, category indicators, and characterization models
  2. the classification stage, where the inventory parameters are sorted and assigned to specific impact categories
  3. impact measurement, where the categorized LCI flows are characterized, using one of many possible LCIA methodologies, into common equivalence units that are then summed to provide an overall impact category total

Optional elements of the LCIA are:

  1. normalization: calculating the magnitude of category indicator results relative to reference information;
  2. grouping: sorting and possibly ranking the impact categories;
  3. weighting: converting and possibly aggregating indicator results across impact categories using numerical factors based on value choices;
4. data quality analysis: better understanding the reliability of the collection of indicator results, the LCIA profile.

- Interpretation: In this phase, the findings from the inventory analysis and the impact assessment are considered together. The results should be consistent with the defined goal and scope. They should reach conclusions, explain limitations and provide recommendations.

- Peer review: Any LCA result that is communicated to an external audience should be subjected to a peer review, in accordance with the ISO standard.

4.1.1 Choosing the right parameters

In LCA, the functional unit is the unit of comparison between different products or services. As its name suggests, it is related to the function, or service delivered, by the product. The choice of the most appropriate functional unit is essential in any LCA, since it is the unit against which all of the life cycle impacts are normalized. For instance, in some cases it is appropriate to compare “per tonne of product produced”, but for consumer goods it is often more appropriate to consider “per consumer use”. Laundry detergents, for example, can be assessed per wash-load. It is also important that the geographical scope and the defined system boundaries of the data reflect the purpose of the study. For example, to inform decisions at an EU level, the study should reflect the product life cycle across the EU, using data with geographical relevance. Real situation data should be provided even if the production falls outside of the geographical scope of the EU.

4.1.2 LCA tools and databases

A variety of LCA software tools are commercially available to help conduct assessments. Examples include tools such as SimaPro, TEAM, Umberto, Gabi, and others.

In some cases it is necessary to collect life cycle inventory data from the system under study, but there are also a range of sector- and industry-wide databases that can be used to run LCA studies. Examples include databases by Plastics Europe, EcoInvent, the European Reference Life Cycle Database (ELCD), and others.

The type of question that is being asked will determine the type of data required, for example whether it should be industry average, best available technology or actual measured data. Using industry standard data will facilitate conducting LCA studies, but the results have to be interpreted with care. In particular, it is important to ensure that comparisons use data of comparable age, geography, quality standard and scope.
4.1.3 Data analysis

A Life Cycle Analysis is only as valid as its data; therefore, it is crucial that data used for the completion of a life cycle analysis are accurate and current. When comparing different life cycle analyses with one another, it is crucial that equivalent data are available for both products in question. If one product has a much higher availability of data, it cannot be justly compared to another product which has less detailed data. Data validity is an ongoing concern for Life Cycle Analyses. Due to globalization and the rapid steps of research and development, new materials and manufacturing methods are continually being introduced to the market. This makes it both very important and very difficult to use up-to-date information when performing an LCA. If an LCA’s conclusions are to be valid, the data must be recent.

4.2 Carbon Footprinting

Recent developments have focused on just one of the environmental impacts over the product or service life cycle – that of greenhouse gas emissions, or the “carbon footprint”. This reflects the recent focus on climate change and the need to manage and reduce carbon emissions.

A carbon footprint has historically been defined as "the total set of greenhouse gas (GHG) emissions caused by an organization, event, product or person." However, as calculating the total carbon footprint is impossible due to the large amount of data required.

Carbon footprinting can help identify where significant greenhouse gas emissions arise in a product or service life cycle and help target improvements. But to ensure an overall environmental improvement, other environmental aspects – such as water – also need to be considered, as do social and economic aspects for an overall sustainability assessment.

Standard methodologies for calculating a carbon footprint have been developed by several organizations. Examples include the British Standard BSI PAS 2050, ISO 14067 (in preparation) and WRI/WBCSD Greenhouse Gas Protocols.

4.3 EU Environmental Footprint Methodology

The EU Product Environmental Footprint is a multi-criteria measure of the environmental performance of a product or service throughout its life cycle. Product Environmental Footprint information is produced for the overarching purpose of seeking to reduce the environmental impacts of goods and services.
The methodology is being developed by the Joint Research Centre (JRC). It is intended to become an integral part of the existing regulatory framework through its introduction as a mandatory requirement into specific pieces of legislation, such as the Ecolabel.

The Product Environmental Footprint criteria take into consideration the recommendations of similar internationally recognized product environmental accounting methods and guidance documents.

Specifically, the methodology guides considered were:
- ISO 14044: Environmental management -Life cycle assessment– Requirements and guidelines
- ISO 14067: Carbon footprint of products
- ILCD: International Reference Life Cycle Data System
- Ecological Footprint
- Product and supply chain standards, Greenhouse Gas Protocol (WRI/WBCSD)
- Méthodologie d’affichage environnemental (BPX 30-323)
- Specification for the assessment of the life cycle greenhouse gas emissions of goods and services
- British Standard for Carbon Footprinting BSI PAS 2050

4.4 Environmental product declaration

An Environmental Product Declaration (EPD) is a standardized (ISO 14025/TR) and LCA based tool to communicate the environmental performance of a product or system. Environmental Product Declarations can be of three types:

- Type I: a label or mark authorized by a third party (ISO 14024). A Type I label is awarded to a product by a third party based on that product meeting certain criteria pre-established for a given product category. An example of a Type I label would be the EU Ecolabel.
- Type II: a self-declared claim involving limited environmental elements (ISO 14021). A Type II claim is made by the manufacturer based on a product’s performance against one or more limited environmental attributes. Specific ISO guidance exists for the following Type II claims: compostable, degradable, designed for disassembly, extended life product, recovered energy, recyclable, recycled content, pre-consumer material, post-consumer material, recycled material, recovered (reclaimed) material, reduced energy consumption, reduced water consumption, reduced resource use, reusable, refillable, waste reduction.
- Type III: an environmental declaration based on the entire product life cycle (ISO 14025). A Type III claim is made by the manufacturer and
presents quantified information about the net environmental impacts of a product across its entire life cycle.

4.5 Identification of hotspots

A valuable aspect of life cycle thinking is identifying where environmental hotspots occur in product life cycles, so that strategies can be devised to address them. While a full LCA can require considerable time and resources, industry now has LCAs for many existing product categories, and these can be used to guide future efforts.

4.6 Economic and Social Analysis

Companies use a range of tools to assess and manage the economic aspects of production. Analogously to LCA, Life Cycle Costing (LCC) generates cost figures related to a product using the same system boundaries as in LCA, but focuses on its monetary impacts. There is no general standard which prescribes or describes how to conduct an LCC or ensure comparability between different applications. Therefore, institutions conducting LCA and LCC simultaneously need to address the issue of system boundaries and time scales in order to ensure consistency and comparability. LCA has to be combined with LCC in order to cover both the economic and environmental dimension of a complete sustainability analysis. Companies conducting LCC and LCA have to ensure that different departments, such as accounting, finance and environmental management, work hand in hand in order to avoid inefficient, redundant work and inconsistent data.

The combination of environmental and economic values is known as Eco-efficiency, and will be covered by the upcoming ISO standard 14045. Eco-Efficiency can be understood as economic-ecological efficiency. It links environmental impacts with economic issues by measuring the environmental impacts per monetary unit earned.

Assessing the social aspects of product sustainability is not an easy task. First, the social dimension of sustainability is a complex issue. Second, in addition to questions on assessment methods, there are very practical obstacles, such as the availability of data and the consensus on the procedure by industry and the public. A basic problem is that many of the social aspects – such as ensuring safe working practices, provision of high-skill employment, or absence of child or forced labour in the supply chain – are qualitative aspects covered at the level of the company, rather than quantitative measures that can be attributed to individual products. Data on environmentally relevant inputs and outputs related to one product unit (usually 1 kg or 1 MJ) can be found in life cycle assessment databases, but so far there are no similar databases for social aspects.
5. The situation nowadays

Traditionally, the end of pipe system is the way to reduce the environmental impacts of industrial production activities. These technological solutions are not essential parts of the manufacturing process and don’t change the process itself. Unlike end-of-pipe technologies, the cleaner production (or pollution prevention) is based on precautionary principle: the focus shifts to the cause of pollution, which is the industrial process. The concept of cleaner production also includes the efficient use of resources and reduction of waste. The improvement of environmental performance in accordance with the principles of cleaner production requires changes to processes, products, organizational structures. Although the practice of cleaner production remains within the organizational boundaries of each company, it is the first step towards a more integrated approach to the environment. It is in fact central to an eco-efficient production (doing more with less) and for the transition to the closed-loop production systems. Applying the concepts of cleaner production at the macro level leads directly to the concept of industrial ecology.

In Europe, a limited number of sectors of the economy contribute significantly to environmental pressures: agriculture, industry, electricity generation, transport, construction (buildings and infrastructure) and manufacturing base (refinery products, chemicals, non-metallic minerals, basic metals).

The main eco-innovation in the chemical industry regarding waste minimization in chemical processes, replacing conventional chemicals with less toxic and less impact on the environment and the use of renewable raw materials for the production of chemicals and materials. Open fields for eco-innovation in the chemical concern heterogeneous catalysts, biocatalysis, the use of alternative solvents, the design of solvent-free chemical processes and the development of innovative technologies such as micro-reactors, reactors rotating disk, the continuous-flow reactors, reactors with micro-channels and the catalytic membrane reactors. Much work has been done on alternative techniques to provide energy to chemical processes, in particular the use of radiofrequency and microwave. The use of renewable raw materials for the production of chemicals and materials is certainly the most promising field of eco-innovation, green growth of the chemical industry. The use of biomass in the production of bio-products commercial and industrial provides considerable benefits of environmental and socio-economic development.

One of the objectives of the Working Group was the creation of "Yearbook on Industrial Research for Sustainable Chemistry". In this paper it has been made an analysis of the various activities of research and development of some Companies associated with Federchimica. In particular, we examined the activities in the field of research for both incremental and innovative products and processes. The survey also considers the research activities aimed at obtaining a saving in the use of water and a reduction of carbon dioxide emissions into the atmosphere. The table also includes actions that companies play in the field of biotechnology research, treatment of wastewater and chemistry from renewable sources.
These figures show that it is also possible to obtain the economic benefits. Here is an example to some estimates provided by companies participating in the project, in which they were obtained, thanks to the research of new products and processes, sustainable savings for water consumption (about 22% per finished product), reduction of emissions (about 25% for greenhouse gases in 7 years) and waste (about 50% of industrial sites do not send waste to landfill, thanks to research for treatment on site).

Finally, it is shown the importance of collaboration between companies and public research institutions, in fact, the exchange of information with Italian or foreign Universities optimizes the results reached in the research.

In Table below there are the areas of research and sectors most active within them.

<table>
<thead>
<tr>
<th>Tab. 6 - Database of companies in the field of sustainable chemistry</th>
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<tbody>
<tr>
<td><strong>Sectors</strong></td>
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<tr>
<td>-------------</td>
</tr>
<tr>
<td>Agrochemicals</td>
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<tr>
<td>Aerosol</td>
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<tr>
<td>Fine chemicals and specialized areas</td>
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<tr>
<td>Active ingredients and intermediates for the pharmaceutical industry</td>
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<tr>
<td>Chemistry of inorganic and organic</td>
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<tr>
<td>Detergents and specialties for industry and for the home</td>
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<tr>
<td>Technical, special and medical gases</td>
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<tr>
<td>Paints, inks, sealants and adhesives</td>
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<td>Ceramic objects and manufacturers of metal oxides</td>
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<td>Plastics</td>
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<tr>
<td>Cosmetics</td>
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<td>Services</td>
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Source: Federchimica

Moreover the Chemical Industry has an important role to play as a solution provider for other Green House Gases reduction sectors as indicated in Tab 7.
Tab. 7 - GHG savings allowed by the Chemical Industry along the Value Chain

Source: Iccca/McKinsey analysis
6. The role of the R&D of the Chemical Industry for the Sustainable development and for the resource efficiency

In 2004 was founded the European Technology Platform SusChem as a joint initiative of Cefic, EuropaBio and the European Commission (DG Research), with the main purpose to unite, at European level, companies, research institutions, the financial world and Authority to define a common research agenda which should mobilize a critical mass of public and private resources, national and European. The Italian Technology Platform for Sustainable Chemistry SusChem Italy was created in 2006. This arises from the strategic alliance between industry, public research and society, with the aim of promoting the specific Italian in the European effort for sustainable chemistry. Federchimica, ENEA, CNR, the Italian Society of Chemistry, the University of Bologna are some of the promoters of this new Italian initiative, which raised the number of media, such as companies, institutions, research institutes, consortia, universities, associations, banks and Foundations. Federchimica, with other partners has also promoted the formation of the national technology cluster of green chemistry whose objective is the promotion of bio-European low-carbon, resource-efficient, sustainable and competitive. The Activity is focused on the promotion of bio-economy with the development of bio-refineries that use biomass, biowaste and biotechnological products derived primary production and the opening of new markets through support to standardization, regulation and the activities demo / test and others, taking into account the consequences of the bio-economy on land use and changes in land use.

Several work groups composed of SusChem members (representatives from industry, research and technology organizations (RTO) and academic bodies), were brought together to compile the input for the PPP proposal on behalf of SusChem. There are many research, development and innovation opportunities to address the barriers to a more sustainable and resource efficient European economy.

The SusChem stakeholder forum opted to split the solutions specific to the chemical sector into five program components:

- Feedstock
- Process
- End-of-life waste management and recycle
- New materials and processes
- Substitution of high concern products

A list of potential solutions has been filled out for these program components. For each of these solutions an analysis was performed on the gaps and needs in all stages of development. The gap analysis also included an
estimation of the time – short, medium or long (<5 years, 5-10 years, >10 years) - needed to solve the issue. This timing has been combined with a prioritization, based on the expected impact of the solution on the ambitions defined, to create a high level strategic technology road map.

<table>
<thead>
<tr>
<th>Tab. 8 - Examples of upstream and downstream processes</th>
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<tbody>
<tr>
<td><img src="image.png" alt="Diagram" /></td>
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<td>Source: STP Position Paper</td>
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6.1 Response Efficiency Partnerships

The Resource and Energy Efficiency Partnership (REP) has launched a proposal for a Research & Innovation Public-Private Partnership (PPP) on Sustainable Process Industry (SPI). SusChem has been one of the platforms leading the effort and has made major contributions to the proposal document issued by REP.

The Resource and Energy Efficiency Partnership (REP) will implement a rolling work program, through six Key Components targeting the four building blocks of a resource and energy efficient process industry:

1. Feed: increased energy and resource efficiency through better preparation and product mix of raw materials, higher levels of alternative and renewable feedstock (including waste and waste water), as well as better managing increased quality variations in material resources.
2. Process: solutions for more efficient processing and energy systems for the process industry, including industrial symbiosis.
3. Materials: new processes to produce materials for market applications that boost energy and resource efficiency up and down the value chain.
4. End of life/Recycle: valorization and re-use of waste streams within and across sectors, including recycling of post-consumer waste streams and new business models for eco-innovation.
5. Horizontal actions: underpinning the accelerated deployment of the R&D&I opportunities through sustainability evaluation tools and skills and education programs as well as enhance the sharing of knowledge and best practices.
6. Outreach: reach out to the process industry, policy makers and citizens to support the realization of impact through awareness, stimulating societal responsible behavior.

A schematic overview of the complete value chain is shown below:

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<th>Tab. 9 - High level strategic technology roadmap</th>
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SPIRE is initiated by the Resource & Energy Efficiency Partnership (REP) which includes more than 10 major European sectors including chemical and bio-chemical industry. REP represents 20% of the total European manufacturing industry in employment and turn over.

SPIRE aims to deliver demonstrations of sustainable solutions to improve resource and energy efficiency in the process industry and along the value chain by 2020. The SPIRE PPP will be instrumental in addressing the Grand Societal Challenges defined within EU 2020 Agenda through the broad correlation it has across various flagships initiatives (Innovation Union, Resource Efficient Europe, and Industrial Policy for the Globalisation Era). SPIRE will be governed by a specific legal entity that will function as a counterpart to the European Commission.
In the latter, the Commission specifically addresses the need for public-private collaborations to ensure uptake of resource and energy efficiency innovations – “in the context of the discussion on future research Public-Private Partnerships, consider an Energy-intensive Industries Low Carbon Implementation initiative, bringing together the relevant technology platforms with EU and Member States, to ensure the appropriate R&D, financing and deployment strategies for low-carbon production”.

SPIRE addresses the whole value chain – from different types of feedstock, including renewable feedstocks, through industrial transformation into intermediate and end products.

In the Outreach component, the SPIRE proposal combines research with studies on socioeconomics, analysis and quantification of the impact of growth, employment, investment and industrial competitiveness within the framework of the projects undertaken. Therefore, studies on the social and economic impact of the different technologies available and the use of resources, as well as the feasibility and impact of investments in resources and energy, to provide a comprehensive view will be encouraged, thereby integrating science and technology into society. Due to this cross sectorial view, SPIRE can play a significant role as a key agent offering advice to organizations when preparing strategic plans and energy programs thanks to the developments and barriers overcome within this initiative. The assessments accomplished within SPIRE will offer to companies solutions
based on eco-innovation studies related to their processes and products, including economic factors, the environmental impact and social aspect of the activities they perform.

The Horizontal actions implemented by response SPIRE will facilitate the cross-sectorial potential benefits that are at the core of this PPP. The fact that SPIRE brings together different process sectors is its strength and potential. At the same time exploiting this strength requires the removal of significant important bottlenecks that have so far proven to be barriers for cross-sectorial knowledge and technology transfer and to synergetic optimization and sharing of resource streams. This horizontal component will drive cross-sectorial synergies by stimulating the identification of good resource and energy solutions and practices from one sector and promoting their transfer to another. Furthermore, cross-sectorial Life Cycle Cost assessment methodologies, tools and standards will be fostered to create a level playing field for the emerging eco-innovation market (e.g. for novel businesses based on the collection and exploitation of waste streams as a novel resource base), and also to promote novel products that have a significantly better sustainability impact performance down the value chain, based on agreed LCA and LCC standards. Also new social Life Analyses will be taken into account. Finally, skills and educational programs will be put in place that will prepare the workforce needed to deliver the development, transfer and adoption of novel resource and energy efficient solutions and practices.

6.2 Programme components

6.2.1 Feedstock

The chemical industry still relies exclusively on the use of fossil feedstock to produce its chemical intermediates and final consumer products. Recent developments based on alternative feedstock promise a gradual but accelerated reduction on fossil feedstock dependency over the next decades. However this is not likely to happen as long as there are no proven non-food competing 2nd or 3rd generation bio-based sustainable production processes commercially available. Also full life cycle cost analysis is required to consider all effects of using renewable feedstock (e.g. water usage) and to prove the sustainability advantage.

While switching to bio-based resources is feasible in areas like specialty chemicals, this is much more complicated for commodity products given the volumes needed and current uncertainty related to bio-mass availability and costs. The feedstock component of the SPI initiative therefore aims for a dual approach:

1. To develop new technologies and solutions to drastically increase the capabilities to transform bio-based feedstock and CO₂ into chemicals and fuel
2. To further increase the efficiency in fossil feedstock exploitation and transformation with consideration to minimizing the environmental impact.

This will be done through focused research, development and innovation in three subcomponents with a variety of development paths.

The primary target for the impact of the Key Component FEED in SPIRE is a reduction of 5-10% in the use of primary resources/feedstock intensity in 2030. Resource efficiency will consequently be accompanied by energy efficiency and reductions in the amount of waste and emissions to soil, air and water.

**Bio-feedstock** promises to play an ever more important part in the production of chemicals, with the SPI PPP aiming for a 10-fold increase of bio-based chemicals production over the next 20 years. To achieve this, it will be essential to ensure the sustainable availability of bio-based feedstock for bio-based chemicals, without jeopardizing bio-diversity and use for other purposes like food production. Cost competitive processes need to be developed for the chemo- and bio-catalytic production of (bio-based) chemicals. The effective integration of pathways for the production of chemical products from platform molecules is a key element for resource-efficiency in the use of bio-mass, and for the successful implementation of a bio-based economy and of agro-energy districts. The objective is to develop cost competitive processes for the chemo- and bio-catalytic production of chemicals and fuels, through processes such as fermentation of sugars or other inputs (syngas, organic compounds, etc), biological and/or chemical conversion of ligno-cellulose and of other bio-mass and bio-waste components like vegetable oils, glycerol, etc.

These objectives require the development of:

- New energy-efficient methods to pre-treat and selectively deconstruct the bio-mass/bio-waste to specific platform molecules (olefins, acids etc.) and their valorization through conversion to both (bio)chemicals and fuels

- New selective methodologies, based on chemo- and/or bio-catalytic processes including new metabolic pathways, for the integrated utilization of these bio-based platform molecules for the production of high-value chemicals. The target is to realize flexible and energy-efficient processes at the scale suited for agro-energy districts, limiting CO₂ emissions, waste production and solvent and energy consumption with respect to conventional fossil feedstock. A goal is also to produce chemicals, especially bio-based chemicals, which could be easily integrated into the existing value chain to accelerate their market introduction. It is necessary to integrate the development of these enabling technologies with demonstration units to prove their integration capability in the whole product tree, and within agro-energy districts.
This sub-component is aimed at the valorization of waste as a feedstock, concentrating on two major developments: the valorization of municipal wastes and agro-food wastes and the conversion of CO$_2$ into feedstock for the chemical/process industry.

The waste stream is an important potential source of raw materials to be optimized and exploited either through direct recycling or through waste reprocessing to produce base chemicals. Especially relevant waste streams are: sorted municipal organic waste and agro-industry bio-waste. These streams are often rich and cheap sources of a variety of valuable natural molecules that have great potential to be directly exploited in the chemical and energy industries and/or used as substrates for the biotechnological production of high added-value tailored bio-based chemicals, materials and fuels. While recycling is quite well developed in some EU countries, reprocessing of waste currently incinerated or sent to landfill requires demonstration throughout the value chain, from collection to valorization into base chemicals that could be fed into existing units. The use of waste as a secondary source of raw materials is clearly still far from being optimized. Effectively managing waste is not simple and addressing it will require the involvement of several actors, not only from the chemicals sector. It also requires the combination of complementary technologies - sorting, cleaning, recycling, reprocessing for use as raw material as well as incineration for combined heat & power, etc. This is especially true in the case of bio-waste, for which special logistic pathways associated with collection and homogenization, as well specific stabilization and pre-treatment steps are required.

This sub-component therefore aims to develop chemical and/or biological processes for the pre-treatment, integrated and multipurpose conversion of bio-waste as well as other industrial waste, like glycerol, into usable raw material and/or valuable products (waste bio-refinery concepts, relying on depolymerisation, bio-conversion, (bio-) gasification, etc.).

The SPI PPP will pursue the development of new technologies for the conversion of CO$_2$ into feedstock for the chemical/process industry. The largest sources of emissions are distant from the possible storage sites, and the construction of new pipelines for CO$_2$ transport is problematic. Therefore, there is a need to reuse carbon dioxide, avoiding the loss of this relevant carbon source to balance the depletion and environmental impact of fossil carbon sources. This objective requires developing new technologies for the conversion of CO$_2$ into feedstock for the chemical industry, and new energy-efficient technologies to recover CO$_2$ from industrial streams. The market implementation also requires securing the long-term CO$_2$ market development. In the short-term, high-added value products (CO$_2$-based polymers, formic acid and fine chemicals) are the target via reaction of CO$_2$ with high-energy molecules. In a longer-term approach it is necessary to address larger volume chemicals (methanol, higher alcohols and hydrocarbons, etc.) via chemo- and/or bio-catalytic routes of valorization, where the energy required for the process (direct or indirect, for example to produce the H$_2$ required for the reaction) derives from renewable sources.
These long-term paths of valorization of CO$_2$ have multiple benefits in terms of resource-efficiency: i) avoiding emissions of CO$_2$, ii) reducing the use of fossil carbon sources, and iii) introducing renewable energy in the chemical industry.

While switching to bio-based resources is feasible in some specific areas like specialties, this is much more complicated for commodity products given the volumes needed and current uncertainty related to biomass availability and its cost.

Increasing resource efficiency in using fossil feedstock is therefore of crucial importance for the overall SPI PPP objectives. This can be partly achieved through improved processes to do “more with less” (see the process component section), through recycling (see the recycle component) and by using fossil feedstock in developing applications that have a resource efficiency impact down the value chain (see the materials component). In addition, resource efficiency and availability can be boosted by further looking into the Identification of new sources of fossil feedstock for use in the chemical industry and new technologies to optimize the conversion of different fossil feedstock (waste, coal, gas etc.) to chemicals. Also the development of sustainable processes for conversion of light alkanes, coal, natural gas or other non-conventional sources into valuable intermediates and products needs to be investigated, as well as new catalytic pathways for integrated production of fuels and chemicals.

6.2.2 Process

It is estimated that 20-50% of the energy used in industrial processes is lost in the form of hot exhaust gases, cooling water and heat losses from equipment and products. Figure 10 show a figure present in an IEA-IETS report that compares the energy use and energy losses in industry sectors in the US to illustrate the potential that exists in utilizing waste heat streams
Recovery of energy from production processes represents the greatest single opportunity for reducing energy use, and solutions are frequently cross-sectorial. Despite the significant environmental and energy savings benefits of waste heat recovery, its implementation depends primarily on the economics and perceived technical risks. Industrial manufacturing facilities will invest in waste heat recovery only when it results in savings that yield a “reasonable” payback period (<< 3 years) and the perceived risks are low. A key objective in any R&D&I effort, therefore, should be maximizing the economic returns of waste heat recovery technologies. Another important factor is the misfit (in time) between supply and demand of recovered/reused energy. This means that reliable, cheap energy storage is as essential as recovery and energy management.

Modeling and simulation is required to show how heat recovery systems coupled with energy storage systems could be deployed in processing operations. Energy storage will be a fundamental need in a future where fluctuating renewable energy plays a major role particularly approaches for storage of low-grade energy.
In the context of resource efficiency cross-sectorial as well as sector innovative advances towards Process Intensification are required to bring dramatic improvements in processing, substantially decreasing equipment-size/production-capacity ratio, energy and resource consumption, or waste production, and ultimately resulting in cheaper, sustainable technologies as a result of process and chain efficiency and reduced capital and operating expenses.

The introduction and further penetration of process intensification technologies will achieve faster and more flexible modular and standardized production capacity within Europe. It will enable accelerated innovation towards a wider portfolio of end products due to its flexible and multipurpose operational modes. As such it is very important for the positioning of key enabling technologies and advanced manufacturing in Europe as well. Process intensification (including new catalyst development) will provide major opportunities for intrinsic improvement in safety and environmental performance as this reduces significantly the amount of in-process chemicals in manufacturing. As a result, catalysis and process intensification can offer a fundamental change in raw material efficiency as reactions can be achieved at optimal conditions with significantly less side reactions creating fewer by-products, and using less auxiliary materials such as water.

In order to drive continuous progress and innovation in process technology to enable improved resource and energy efficiency, it is a prerequisite to acquire improved process understanding. Hence, design and engineering methodologies and systems engineering methods and tools, such as process modeling, simulation and control strategy, are essential to extrapolate and catalyze the dissemination of advanced process technologies into all kinds of industrial production units. Linking process modeling capabilities with eco-efficiency and economic models is also a requirement for qualified, knowledge-based decision making for sustainable production.

It is important to realize that both systematic integration of best practice technologies into existing large and small scale plants (retro-fitting) is key for this PPP as well the development of novel enabling technologies. Opportunities for developments with regard to intensified processes include the requirement of new materials, new reaction technologies, new separation technologies, new hybrid technologies, advanced process control including auto-adaptive methods, extended use of on line analysis, improved energy integration, and new supply chain concepts etc.

Better ways to store energy are critical to become more energy efficient in end-user markets like mobility as well as for operation in the process industry. One of the keys to advances in (chemical) energy storage lies in both finding novel materials and in understanding how current and new materials function and how energy can be transformed into materials in an efficient way.

Storing energy allows balancing the supply and demand of energy. Energy storage systems in commercial use today can be broadly categorized as mechanical, electrical, chemical, biological and thermal. Energy storage became a dominant factor in economic development with the widespread introduction of electricity and refined chemical fuels, such as gasoline, kerosene and natural gas. Unlike other common energy storage in prior use,
such as wood or coal, electricity must be used as it is being generated, or converted immediately into another form of energy such as potential, kinetic or chemical. Energy storage is a key to wider deployment of renewable energy (wind, solar) to compensate for its normally intermittent availability. Although many energy storage techniques are available, they all have issues such as relative inefficiencies (transformation, capacity), cost, weight, pollution, hazards, safety etc. As such, one of the topics of this PPP could be to research and develop advanced materials with superior storage possibilities and novel chemical processes allowing for adoption of alternating or cycling energy- and feedstock fluctuations. Main requirements for future energy converters are ultra-low (near zero) emission capability with respect to locally and regionally acting pollutants (such as NOx, SOx, CO) and the long-term target of minimizing globally relevant greenhouse gas emissions. Mandatory features of future energy converters to meet these goals are high conversion efficiencies (mainly to electricity), broad fuel spectrum (with emphasis on low carbon, hydrogen-rich fuels) and other systems to reduce emissions.

Energy storage is particularly important to valorize solar or wind energies which are renewable but intermittent and therefore cannot be efficiently used. For example, batteries or fuel cells are potential solutions but they must be improved. Other possibilities are storage of energy as methane or hydrogen. The latter can take different forms; gaseous, liquid, solid or chemical. The conversion of solar energy into chemical energy carriers, that can be stored over long periods of time and transported over long distances, overcomes the principal drawbacks of solar energy, namely: being dilute, intermittent, and inconveniently distributed. One goal is to develop a technically and economically viable solar technology for producing chemical fuels for a sustainable energy supply system.

Chemical energy storage (CES) is a novel category that can be used for efficient energy storage. As an example, CES has a working principle similar to the chemical heat pump (CHP), which uses a reversible chemical reaction between a reactive salt and a refrigerant. CES could be thermally driven without mechanical work as in a vapor compression cycle. This allows the temperature level of the thermal energy to be changed by upgrading. CES is one of the potential candidates for the improvement of energy transformation technology, because CES could be employed over a wide temperature range by choosing appropriate reaction systems.

6.2.3 Materials

To be successful in developing the materials and processes according to the priorities set within Europe for across and along different value chains it will be essential to connect to already on-going public supported innovation initiatives like the current recovery plan PPPs (Factory of the Future, Energy Efficient Buildings and Green Cars) as well as potential new initiatives that may be supported under HORIZON 2020. Good examples are refractories and high efficient insulation materials/systems. Research and development in
processes to produce those new materials will be essential for new insulation designs, equipment and materials” as well as “new adiabatic systems and furnaces with 100% insulation”. Sustainability versus present technologies has to be improved. Further demonstration is needed to extend solutions and application in the process industry. Other examples are steels, super alloys, metals and ceramics for high temperature application; materials withstanding higher temperatures for ovens and furnaces: maximum temperature for cement kiln reach 1800°C, glass furnace 1600°C, reheating furnace at 1300°C. There is a lack of experience on performance and up scaling of developed new materials as well as the need to improve the ratio of performance/cost.

Specifically we also want to consider here the need to implement more means of cost efficient energy storage that are essential to provide the flexibility to adopt more use of renewable energy sources as well as benefit from harvesting of waste energy. These could be through e.g. battery technology, fuel cells, super capacitors as well as through novel thermo-chemical solutions for local storage. Generation of renewable energy through improved photovoltaic technology is also a must for success. Some of these technologies will also find application in other parts of the value chain (energy, transport and construction sector) through higher resource efficient electrification of society (smart grids, building heating/cooling, transport propulsion etc.).

Lithium ions batteries are a popular power source for portable electronic devices, but not yet sufficient for industrial or automotive goals. Other energy storage solutions (e.g. chemical storage, fluid transportation etc.), will require the development of novel materials (i.e. inorganic phase change materials (PCM) for high temperatures, high heat capacity (e.g. > 800°) and PCM materials based on organic and polymeric molecules) as well as their production processes. Chemical storage of non-standard energy fluids will require searching of solutions that while meeting the needs of high storage capacity will encompass moderate operating temperature, fast kinetics, low cost and/or excellent reversibility and low toxicity.

Regarding H₂ storage materials (HSM) research is still open in order to find materials meeting the above mentioned needs as well as routes to process them. An important contribution of the process industry will be to enable energy and/or resource efficiency down the value chain. Illustrative examples will be more sustainable processes to develop materials with a potential impact on the efficiency and durability of industrial and transport systems, such as (bio-) lubricants for industrial applications and coatings to reduce the effect of wear, erosion, corrosion and/or to improve the thermal barrier properties. Other examples could be more energy and resource efficient processes to develop inorganic light emitting diodes (LEDs) as well as organic light emitting diodes (OLEDs) with longer lifetime. Additional areas could include new sustainable processes for novel composites (biobased and non-bio-based), new thermoelectrical materials or coated materials with new functionalities as well as materials of potential future use in the construction sector (i.e. thermo-electrical roof tiles, energy storing clay blocks, ultra-high-performance concrete, lightweight construction composites etc.) as well as for example sustainable processes for materials used in the energy sector.
such as for cost-efficient windmills having superior energy conversion capacity and novel materials with applicability in energy efficient power plants.

6.2.4 End of life/Recycle

In EU approximately 2.8 billion tonnes of waste were generated in 2006/2007 from a variety of sources including construction and demolition (33%), household waste (8%) and manufacturing waste (13%, excluding recycling). A significant majority of the waste is mineral based (63%) and the rest split over much smaller categories like animal/vegetable waste (8%) and mixed household waste (7%). An estimated 38% of total waste was reused and recycled, although certain sectors achieve much higher recycle rates, for example automotive EOL achieved 82% and packaging 59%. Clearly though more than 1.7 billion tonnes of waste is currently left for incineration and landfill and this is a resource which if tapped into would significantly improve sustainability of the EU region. Increasing reuse, increasing the quantity as well as quality of recycle, developing new and improved methods to valorize waste streams all lead to reduced amounts of virgin resources having to be used in production of new goods.

Recycling of industrial waste streams and management of end of life waste streams is a very complex matter with many players involved along the value chain and many national, regional and local differences. Ownership of the waste stream can be the key determinant in how it is treated, rather than what might be concluded from performing a thorough LCC analysis. In addition, waste streams from different value chains vary considerably, requiring significantly different methods of collection, sorting, preparation and treatment (e.g. packaging versus automotive sectors).

A distinction can be made between efforts to make products recyclable, or to create raw materials by putting the end products themselves back into the processing/chemical recycling of end-of-life products. The SPI PPP proposed here addresses EOL/recycling across the full value chain, in which the process industry will play a breakthrough role by actually bringing materials from downstream (e.g. end user markets) back upstream into the feed of the process industry. This is a significant difference compared to the current state of the art with regard to recycling, where most, or even all, of the recycling takes place at the end of the value chain (end-users). This partnership commits to integrate this type of recycling into the process industry, which will require rethinking the architecture of the recycling loop of products/materials.

Different technologies, tools, methods and business models at different levels of maturity are being developed and have already been implemented in the market. An extra impulse however will be needed to valorize the more than 50% of waste that is currently unused. Some examples of technologies in the development stages are new sensors and automatic identification units integrated into the sorting processes for paper waste handling or magnetic sorting and ultrasound technologies for plastic waste sorting. Hydrocracking
and gasification technology to break plastics down back to raw materials that can be used for polymerizing new materials are examples of projects that are mainly in the research stages of development. This can only be successful if in the design phase of applications the need to recycle and, therefore for efficient dismantling and subsequent sorting etc. is taken into account. Several other initiatives are piloting new technologies and business models to re-use and valorize waste from one sector to another, such as the re-use of spent acid from the steel industry as feedstock for innovative fertilizer production processes. New business models down the value chain need to be stimulated in combination with, and based on, the development of waste decomposition and re-utilization.

The SPI PPP aims to significantly increase the reuse and recycle of industrial and EOL waste by developing the value chain partnerships that are needed to create an effective exchange of information for data based decision making, as well as to organize the exchange of material streams between various value chain players and different sectors. Incentives should be developed to stimulate new businesses based on the valorization of waste streams between value chains. Creation of “new ideas, concepts and consumer perception” of materials and manufacturing of products so that their recyclability – second life value chain– can constitute a competitive advantage versus present materials and manufacturing technologies.

The technology required to allow increased quantity and quality levels for waste-based feedstreams are to be brought forward through both research and demonstration projects.

Recycling constitutes a fundamental key element in a holistic LCA approach and therefore it will be necessary to involve different stakeholders across the value chain (i.e. process Industry, product designers and manufacturers, end users, etc) to be able to fit-for-the-purpose the most efficient recycling existing or novel technologies.

The value proposition posed in this component is therefore the transformation of waste into a Resource, so that what is considered waste in one context can be transformed into a resource in a different context.

In order to contribute to realizing the vision 4 Key Actions have been developed:

- Systems approach: understanding the value of waste streams
- Technologies for separation, extraction, sorting and harvesting
- Technologies for (pre)treatment of process and waste streams
- (Cross-sector) Value chain collection, re-use and recycle schemes and business models

In figure, we can see the different steps involved in this key component waste & resource; first we employ a systems approach in order to increase the understanding of the value within the waste streams; second, separation and capture of the valuable elements; third, treatment of the valuable elements to increase the reuse and recycle potential of the elements; fourth, value chain collection reuse and recycle schemes and business models as a step
towards increasing the eco-innovation potential and creating economically attractive business opportunities.

Tab. 12 - The four steps involved in Key Component End of life/recycle

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<thead>
<tr>
<th>Sorting</th>
<th>Treatment</th>
<th>Design</th>
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<tr>
<td>Value Chain collection, reuse and recycle schemes and business models</td>
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Source: Sustainable Process Industry through resource and energy efficiency

6.2.5 Horizontal actions

The various thematic components within SPIRE will be underpinned by an important Horizontal Key Component that will be targeted at facilitating the cross-sectorial potential benefits that are at the core of this PPP. The fact that SPIRE brings together different process sectors is its strength and potential. At the same time exploiting this strength requires overcoming important bottlenecks that hitherto have proven to be barriers for cross-sectorial knowledge and technology transfer as well as for synergistic optimization and sharing of resource streams, which would boost resource efficiency in Europe. The horizontal component will drive the cross-sectorial synergies by stimulating the identification of good resource and energy solutions and practices from one sector and their transfer to another. Furthermore, cross-sectorial Life Cycle Cost (LCC) assessment methodologies, tools and standards will be fostered to create a level playing field for the emerging eco-innovation market (e.g. for novel businesses based on the collection and exploitation of waste streams as a novel resource base), but also to promote novel products that have a significantly better environmental impact performance down the value chain, based on the agreed LCA and LCC standards. Also new Social Life Cycle Analysis will be taken into account. Finally, skills and educational programs targeted at the development, transfer and adoption of novel resource efficient solutions and
practices, will be put in place to accelerate the impact of SPIRE where required.
The overarching objective is to better understand and develop the role of the process industry in resource and energy efficiency, to meet sustainable development needs. Sustainable development, as we have already told, has been defined as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs”. We consider sustainability around three main elements: economy, environment and society; only when these three points overlap, it is possible to have a sustainable product or service.

The detailed objectives are:

- to address competitiveness, i.e. a strong and competitive value chain of production, with at the core the process industries;
- to develop, via research, innovation and knowledge exchange in the value chain, new solutions to improve resource and energy efficiency in industry;
- to develop and deploy solutions enabling to reduce the carbon footprint of fabricated mass products such as cement, ceramics or glass;
- to develop solutions that demonstrate the advantages of industrial co-operation, and help regulators optimize the regulatory, financial and organizational framework for industry;
- to explain and promote the current and future potential role of industry and associated value chain in addressing the current challenges of employment creation, sustainability and energy policy;
- to provide a channel for a broad coalition of industry interests to dialogue with the EU institutions on methods of improving resource and energy performance;
- to include the trade dimension, that is develop solutions taking into consideration the global context, including the effectiveness of policies and impact on the three elements of sustainable development;
- to raise understanding and awareness among all actors (including industry and policy makers) about the actual and future role of the modern process industry, to crucially achieve declared aims via optimized framework conditions.
7. Conclusion – to do list

- **Encourage life cycle thinking.** Conducting a full Life Cycle Assessment (LCA) can be a timeconsuming and expensive business, but taking a life cycle approach by considering all stages of your product or service’s life cycle can lead to new insights. There are many LCA studies available in the public domain that can help you get started in life cycle thinking.

- **Engage with your customers and suppliers.** Understand your customers’ needs and what your suppliers can offer in terms of innovative products.

- **Understand exactly where your product or service adds value.** How can you maximize this value? Is there a way you could deliver that benefit in a different way, using fewer materials or less energy?

- **Know where the environmental hotspots are** for your company, your products or your services. Do the major impacts arise from your operations, your supply chain or from the use of your products? Knowing where the hotspots are will help you identify strategies to reduce them.

- **Measure, monitor and manage.** Do you currently measure your energy, and water consumption and emissions of CO2 and waste? Having the data allows you to identify where you can target efforts and reductions, and in many cases this will lead to cost savings.

- **Turn a waste into a resource** Identify all of the materials that leave your operations as waste, and look to see which of them may be of value in another process. Taking a systematic approach may identify materials that can be sold as a secondary raw material, turning a waste into a resource, and a cost into a revenue stream.

- **Keep up to date with upcoming policy and regulatory requirements** Cefic and national associations can help you anticipate new policies and regulations, to shape your future business strategy.

- **Use sound science** in your business decisions and in your advocacy efforts.

- **Ensure transparency** by providing credible information on data used to estimate the life cycle of your product, you will gain confidence from your stakeholders.
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