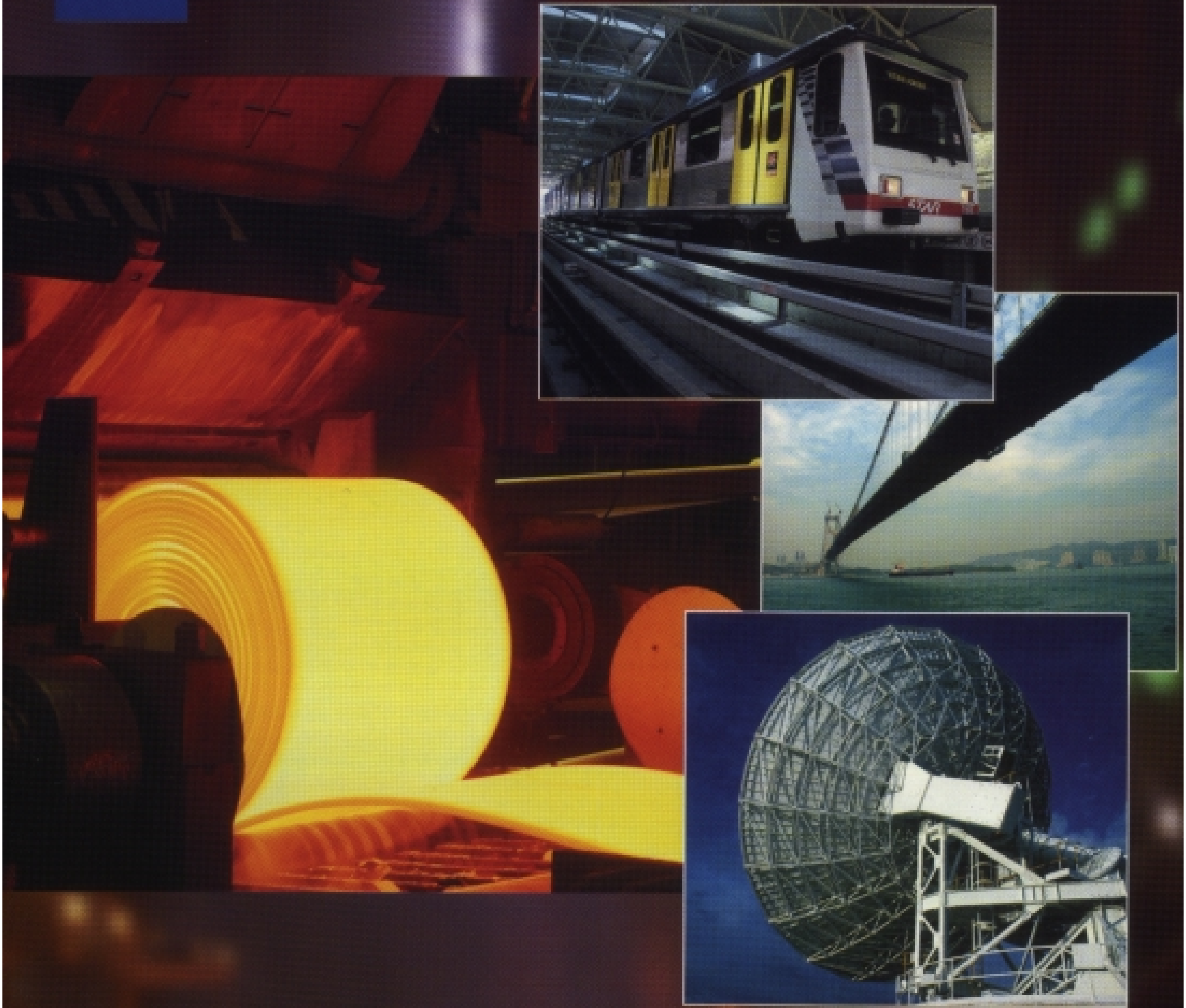
Technology Road Map to Determine the Research Priorities of the European Steel Industry



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Contents

Executive Summary

This document is based on the premise that steel will remain the most important metallic material in the economic development of the next century. It describes the challenges that the European steel industry will have to face in order to keep its leading position in the global economy. The 21st century will belong to those producers who are best at innovation and who are able to contribute to the satisfaction of society's needs. As during the past decades, new technologies will have to be developed for producing the steel qualities requested by the customers that are compatible with sustainable growth.

This Technology Road map discusses in particular the different Research and Technology Development (RTD) needs that are required for reaching this goal. These RTD needs are best achieved through collaborative research.

The European Steel Industry has a proven record of successful collaborative research, due to the experience gained from participating in the "Steel Research and Pilot/Demonstration Programme" within the European Coal and Steel Community (ECSC). The ECSC treaty will expires in 2002. Therefore this document is also considered to be a contribution to the ongoing discussions with the European Commission concerning the partial 'phasing-in' of the successful ECSC research into the Fifth and subsequent Framework Programmes.

1. Technical Vision

Steel production and products made from steel are a major source of employment and wealth in the European Union (EU). New technologies are being developed to ensure the growth of steel applications to meet the future needs of EU citizens. Sustainable growth, including the efficient management of resources, will be a major concern when developing these new technologies.

There is still considerable scope for improvements and development of steelmaking and finishing technologies as well as product properties; in particular:

- Cost reduction to combat pressures from competitive materials.
- Conservation and most efficient use of raw materials and energy to minimise resource consumption.
- New production control technologies to improve performance, yield, quality, and working conditions and to increase work safety.
- Recycling of end-of-life products to minimise environmental impact.
- New and higher quality steel grades to make the sector more responsive to market changes.

There is no apparent threat to world-wide steel consumption and it can be assumed that steel demand and production in the European Union will remain fairly constant during the coming years.

To increase market share and margins, steel companies must devote even more attention and resources to product development to regain markets from competitive materials to take advantage of the superior ecological characteristics of steel.

The steel industry will continue to increase its co-operation with customers and end-user product manufacturing companies to overcome current barriers between designers and consumers and achieve full integration of "product/service combinations", using new product design, fabrication and assembly technologies, together with ease of recycling at "end of service life".

The parallel developments of RTD for more efficient production processes, new steel grades and new steel applications will enable the development of sustainable manufacturing and technologies for steel based products in the following sectors:

- Construction.
- Transport.
- Packaging and Distribution.
- Energy.
- Mechanical, Manufacturing and Chemical Engineering.
- Domestic Leisure and Health Equipment.
- Tele-Communication Infrastructure.

2. Technologies for steel production

During the next two decades, it is anticipated that at least 50 to 60 percent of crude steel will be produced in the EU via the Blast Furnace – Basic Oxygen Furnace (BF-BOF) route, while the rest will be obtained from the Electric Arc Furnace (EAF) route. Steel production will be concentrated to the best performing installations.

Due to the high production levels using these two alternative production routes, very small changes and improvements in the technologies used can already result in substantial advances in primary materials and energy savings, productivity improvements and cost reduction. The ongoing development of existing process lines will continue to be of great importance.

Reduction of production costs, improvement of product quality, minimisation of environmental impact and minimisation of resource consumption can only be achieved by optimum design of all automatic control facilities. For this purpose, new sensors, linked to the application of artificial intelligence techniques, in production planning and integrated quality assurance are indispensable measures.

Both in the hot metal-BOF route and in the EAF route, new steelmaking and finishing techniques will be developed. Priority themes are:

- New cokemaking technologies.
- New reduction processes.
- Improved scrap preparation processes.
- High speed near net shape casting with integrated hot rolling.
- New engineering technologies for continuous operations within the "cold rolling plant" (pickling, cold rolling, annealing, temper rolling, coating lines).

Environmental improvements will be obtained by the minimisation of resource consumption and emissions. The reduction of energy consumption and the upgrading and recovery of waste materials generated inside the steelworks will be further developed.

3. Steel applications

The European steel industry is distinguished by the high standard of its products. The objectives for the future are to speed up the development of new products and new systems. The value added to the customer by new steel products and steel based composite materials will be the increased flexibility possible in new product or structure design in addition to its superior intrinsic properties.

New design rules and the increased use of industrially prefabricated products will raise the steel building practice to a higher quality level than is currently normal in the building industry.

The current systems for transport of goods by sea, truck and rail must be redesigned. Steel has a major role in developing vehicle technologies suitable for sustainable mobility of people and goods, in particular in urban environments.

Steel will continue to have an important role in the further development of high-speed rail systems to provide more environmentally friendly long distance transport systems.

New steel products, e.g. special steel sections, need to be developed to meet the design requirements of a new generation of marine vessels.

Special steel grades will be needed for the future aircraft engines and spacecraft for components and sub-assemblies operating in extreme service conditions.

In the energy field, steels are required that combine high mechanical strength and stability with high corrosion/oxidation resistance at elevated temperatures.

Europe is the world's major market and production area for packaging and it appears now as a technical leader as well. Steel is an environmentally friendly packaging material that can be easily recycled.

In mechanical and chemical engineering high-alloy steels are required which combine excellent geometrical tolerances with outstanding mechanical and corrosion resistance at high temperatures.

In all these fields the European steel industry will develop the knowledge, the technologies and the quality assurance systems which are necessary. It will collaborate with its customers who also face similar challenges.

4. Research requirements

The steel industry must be able to easily change configuration to respond the rapidly changing customer-driven market requirements, which have just been described and will develop a proactive new product development policy. The present document presents an extensive list of Research and Development needs that result from this vision and these challenges. They include:

- New technologies for streamlining existing facilities.
- Innovative steelmaking and finishing routes.
- The protection of the environment.
- Information technology, measurements, non-destructive testing and automation for more reliable and safer process control and product quality assurance.
- Steel grades for demanding applications in construction, transport, energy, manufacturing and packaging.

It is obvious that these research and development needs of the European steel industry fit well with the objectives of the Fifth Framework Programme of the European Union and are in line with the Guidelines for ECSC Steel Research Programme 1996-2002.

1. Technical Vision

1.1 The role of steel in the life of EU citizens

Steel is at the heart of the EU economy, making a major contribution to quality of the citizen's lifestyle in the home and work. EU citizens use products made of steel every day. Even products not containing steel require steel to make and transport them to the final customer. Steel plays an essential role in providing citizens with energy, transport, manufacturing, infrastructure, construction, home appliances, and many other products and services. Steel's unique range of chemical and physical attributes provides the combination of properties that can be tailored to demanding user applications at a lower cost compared to other manufacturing materials, which makes it the material of choice for all these sectors.

Steel scrap is easily collected and recycled without deterioration of the steel quality.

Steel production, and products made from steel, are a major source of employment and wealth creation in the EU. More than 120 million tonnes of steel are used per year in Western Europe alone, compared with 30 million tonnes of plastics, around 8 million tonnes of aluminium, and less than 8 million tonnes of other non-ferrous metals.

More than 2000 different steel grades have been registered which demonstrates the versatility of the material known as "steel". Within the last five years about the half of these steel grades have been further developed by changes to the production process or have been newly developed to meet latest application requirements.

1.2 The drivers for new technologies

New technologies are being developed to ensure the sustainable growth of steel applications to meet the future needs of EU citizens. These new technologies are required to achieve competitive and sustainable growth in the EU economy to provide the employment, goods and services needed to improve the quality of life of EU citizens, including improved homes, cities, and transport. The driving forces for the development of these new technologies will be influenced by:

- The need to provide and keep sustainable employment within the framework of the global market.
- The need to refurbish and upgrade the quality, comfort and energy efficiency of domestic accommodation in low rise and high rise multi-storey buildings.
- The demand for improved transport systems providing better protection of people and goods with minimum pollution of the environment.
- The impact of new developments in information technologies on future life styles, e.g. location of people's homes in relation to their place of work, patterns of employment, travel and distribution of goods and services.
- The demand for new products and support systems to improve quality of life for the ageing EU population.
- The need to reduce the cost of the production and distribution of current energy sources (coal, oil, gas, and electricity) and develop sustainable energy sources with minimum pollution of the environment for the future.
- The need to achieve sustainable recovery of mineral resources.

- The need to improve water distribution, treatment and recycling technologies.
- The need to increase the recycling and re-use of materials from the end-of-life disposal of goods or dismantling of buildings and infrastructure.

1.3 The utilisation of materials and related process technologies

The main raw materials for steel production are iron ore, coal, recycled steel scrap, and water; with small amounts of oil, natural gas, dolomite and limestone, and various alloying element ores. No future shortages are foreseen for iron ore, coal and water. The amount of recycled steel scrap is continually increasing. Nevertheless, there is still considerable scope for improved raw material utilisation by improvements to steel production and finishing process technologies and the development of new technologies for the treatment, recycling and utilisation of by-products, with a corresponding reduction in outflows to the environment per unit of finished product. In particular:

- Scrap will continue to be an important raw material in the EU and new technologies for scrap quality upgrading and recycling must be developed. Closed material circuits between "steel producer-product manufacturer-final customer" are being developed to enable improved quality control of an increasing quantity of recycled material from the disposal of ‘end-of-life’ goods and demolished buildings. Recycled steel scrap is a very flexible raw material because steel scrap from any source can be re-cycled to make around 80 percent of the total range of steel products produced.
- New process route technologies will be required to improve the quality of existing steel grades and products, achieve effective and sustainable material, energy and water usage, and increase manufacturing flexibility to respond to specific market and customer needs. These technologies in turn will require investments, which will provide sustainable employment and justify future capital investment by customers of the EU steel industry.

Also, the development of these new technologies will enable EU plant builders and equipment suppliers to retain world leadership in equipment for the production and use of steel. In addition there will be opportunities for exports of steel and equipment for making and processing steel to the rest of the world, particularly for the developing economies of China, the Indian sub-continent, South East Asia, South America and Africa.

1.4 The market

Provisional figures and estimates indicate that total 1997 world crude steel production reached 794.5 Mt, 6.2 percent more than the global production in 1996.

Despite the economic and financial crises in South East Asia in the second half of 1997, world production reached levels well above production in recent years. The increase reflects growing steel-making capacities and strong global market conditions in most regions.

In 1997 in **Western Europe** continued industry cost cutting and raised productivity led to a record production of 176.3 Mt. **This includes 159.3 Mt produced in the 15 European Union countries**. The region increased its exports and its domestic market share.

Growing steel demand and continued rationalisation and modernisation of facilities in **Eastern Europe in 1997** (79.0 Mt in the former USSR) reflected positively on its annual output which reached 33.2 Mt.

1997 was also a peak year for **North America** production and imports. The region's output reached 130.1 Mt. The NAFTA countries, namely Canada, the United States and Mexico, have continuously improved their production over six consecutive years.

In **South America**, privatisation as well as investments in modernisation and capacity increased crude steel production to 36.9 Mt.

Total 1997 production **in Africa** rose to 12.7 Mt (8.2 Mt in South Africa).

In 1997 **Asia** remained the world's largest steel producing region, with a record production of 306.9 Mt, despite severe economic and financial crises in the second half of the year.

China remains the world's largest steel producing nation with total production at a level of 107.3 Mt (13.5% of the world total).

Japan ranks second with a record 104.5 Mt. Weak domestic demand was offset by strong vehicle exports and steel shipments favoured by the weakening of the yen against the dollar.

Strong vehicle exports were beneficial also to producers in the **Republic of Korea**, with crude steel production of 42.5 Mt.

It is estimated that there are 95 countries producing steel. In 1996, 5 countries accounted for 50% of world production, 24 countries accounted for 90% and 43 countries accounted for 98%.

The challenge for the steel industry is the pressures from structural changes within the industry itself and the closure of non-competitive facilities. This arises from the shift in consumption and capacity towards Asia-Pacific, with continuing over capacity productivity improvements and technological changes in the developed economies of Western Europe and North America.

Two additional features of the international steel industry are the roles of China and the former Soviet Union. In the case of China, wide fluctuations in net imports have created turbulence on world markets. In the former Soviet economies, low consumption levels have led to growing exports of low priced steel as these countries struggle to earn foreign exchange.

Despite extensive privatisation in the EU, government intervention remains common in the industry in many countries world-wide. For many developing countries, the development of a steel industry is seen as a type of industry to be developed regardless of economics. However, government intervention is not limited to developing countries as the governments of some western economies struggle with the political and social consequences of structural change.

Although the figures quoted above show that the steel production capacity in the world continues to grow at a healthy rate, a quick review of the earnings reported by steel companies shows that most of them are not reaping the financial rewards that were expected.

The need for steel companies to focus much more on **return-on-capital** as a benchmark for making capital-investment decisions has become imperative. Although cost reductions and increasing market share are worthy objectives, they can be offset by decreased margins. Profit margins suffer when steel producers fight one another for markets within the same geographic areas and win *"increased"* market share through price discounting.

Steel companies need to rethink their strategies for *"increasing market share"*.

The last decades have seen substantial growth in "steel alternative" products, which have all proven suitable substitutes for steel in certain product lines. Substantial RTD has been carried out to improve products' suitability for steel's markets as well as to promote their use. However, too often, the steel industry has ignored the serious threat posed by these alternative materials. To increase market share and margins, steel companies must devote even more attention and resources to product development to regain markets from competitive materials. This is vital to reverse the decreasing market for steel that will occur if the substitution of other materials in traditional steel markets continues at recent rates.

To ensure the prospects for the steel industry will be improved, there is a need to look for new approaches; i.e. a new ***technical vision***.

1.5 The end user products

The steel industry will continue to increase co-operation with customers and end-user product manufacturing companies to respond to new product design, fabrication, assembly and delivery technologies and anticipate their needs. Part of the production chain will shift upstream, towards the materials producer. Examples: precoated steel, tailor made blanks, prefabrication of components.

Recycling-friendly design, manufacturing, and assembly technologies will be developed with steel customers to open new markets and find new applications for steel and steel-based composite materials, mainly in the following sectors:

Construction: Domestic, commercial and civil buildings; transport infrastructure e.g. bridges and tunnels, crash barriers, acoustic barriers for rail track and roadways; lighting and power support systems; supply, treatment and distribution of water and effluents; protection of waterways and coastlines from erosion.

Transport: Aeronautics; automotive and commercial; rail, marine and inland waterway; mechanised pedestrian walkways and elevators.

Packaging and Distribution: Food, beverage and aerosol containers; tanks and drums; casing for electronic goods; shelving and racking systems; automated storage and recovery systems; mini-container systems for urban distribution.

Mechanical, Manufacturing and Chemical Engineering: Machine tools; pressure vessels, mineral extraction and earth moving equipment, cranes, pumps, process equipment e.g. petro-chemical industry; heat exchangers, furnaces; storage tanks; pulp & paper equipment; textile machinery, etc.

Domestic Leisure and Health Equipment: Kitchen and household appliances; sports arenas and equipment; food preparation and catering equipment; hospital fittings and equipment, surgical instruments and implants.

Energy: Coal, oil, and gas fired power stations with associated emission control equipment, heat exchangers; Distribution and supply of electricity, oil and gas; coal, gas and oil extraction and processing facilities; off-shore structures for energy recovery systems; renewable energy systems.

Tele-Communication infrastructure: Utility poles, transmission towers; pipework for service distribution, e.g. fibre optic links.

2. Technologies for Steel Production and Application

2.1 Steelmaking and finishing processes

2.1.1 Asset life extension/Streamlining of existing facilities

2.1.1.1 Improved performance from existing production plant

The EU steel industry has major capital investments in a limited number of large integrated mills, located on the coast or along major internal waterways. These integrated mills produce steel via the BF-BOF route from imported ores and coal, together with a large number of smaller steel mills, located nearer to customers producing steel via the EAF route from recycled scrap. Steel production will continue to be concentrated to the best performing installations.

During the next two decades, it is anticipated that at least 50-60 percent of the crude steel will be produced in the EU via the BF-BOF route. These large integrated mills will continue to produce semi-finished coil, plate and long steel products from imported ores and coal. In order to ensure these existing assets will continue to produce semi-finished coil, plate and long steel products with improved through yield from raw materials; further reductions in energy utilisation and environmental emissions, new technologies are required. Similar technologies will be developed for the smaller steel works and mini mills based on scrap and DRI producing special and alloy steels in the form of coils, sections, bars and rods.

These developments will go into the following directions:

- Developments to upgrade the quality of raw materials fed to the furnaces producing liquid iron and steel.
- Developments in process instrumentation, control, and engineering to improve existing asset management, safe working conditions, plant security and environmental performance, return on capital employed.
- Applications of information technology to allow better process control linkage between process operations and plant logistics to give production flexibility and guarantee product quality.
- Decreasing the number of process steps (e.g. near-net-shape casting, direct rolling, etc.) to reduce delivered product cost, save energy and minimise emissions.
- Development of new technologies to reduce the capital cost of current technologies for recycling and energy saving during processing.

Future needs of customers and future market opportunities will require both the optimisation of the process parameters of currently produced products and the development of new products using existing production facilities and the development of new production processes. Present cold rolling, annealing and coating lines will be optimised to improve flexibility of supply from existing lines and develop new high quality products from existing investments for demanding applications delivered in time.

2.1.1.2 Supporting technologies for improved understanding of process technology and its influence on product quality

Minimisation of production costs, improvement of product quality and reduction of environmental pollution in iron and steel production can only be achieved by optimum design of all plant components and automatic control facilities on each plant. Mathematical process modelling is an important tool to achieve this aim. It requires a description of the relevant physical and chemical process phenomena in the form of mathematical equation systems, which are then solved by computer software. Considerable success has already been achieved in the development and application of this technique in the European steel industry. In the future, numerical modelling techniques need to be further developed and refined, to exploit the on-going developments in computing power. More process features will be included in these numerical process models to improve the level of realism and the predictive value.

Whenever possible, all mathematical models should be based on physical and chemical fundamentals. Where this is not possible, the analytical models will be combined with artificial intelligence methods (including rule-based systems, e.g. expert systems, artificial neural nets, fuzzy-logic processes, machine learning and genetic algorithms) to provide more efficient, more robust and less costly solutions for both on-line and off-line application.

Further development of advanced sensors and actuators will be required to validate and calibrate these developments in process modelling and artificial intelligence. These new sensors and actuators, in combination with improved process models and artificial intelligence systems, will enable immediate feedback control to allow the prediction of the final quality of products from process operating conditions during processing. This approach will enable out-of-specification products to be recognised early in the process route, and allow control systems to restore operating conditions to those that will produce final products within specification.

Further developments of refractories and hollow-ware with improved thermo-mechanical properties and corrosion resistance will be required. The use of multi-layer systems could provide interesting solutions. Further work will be required to develop non-toxic refractory materials to improve working conditions and prevent problems during manufacture, installation, recycling and disposal.

In addition, new technologies to ensure efficient and operator friendly interfaces with the new generation of process control systems will be required e.g. new data display technologies, as well as simulation and visualisation of process environments.

2.1.1.3 Production planning and control with integrated quality assurance

Optimised logistic sequences in production processes combined with integrated quality assurance are essential components of measures to safeguard the European steel industry in the future. Viable standard software systems are available today from various companies to support commercial and administration functions such as purchasing, sales, financial accounting, asset accounting, costing and personnel management. These systems are being increasingly used in steel companies. The use of these systems for production planning and control, quality assurance and production cost control falls a long way short of the currently available possibilities.

Adaptation of the systems during changes in the organisation (e.g. mergers), production plants, production processes and products are extraordinarily laborious, tedious and expensive. The development of a modular standard software system covering all the functions in technical order scheduling for all stages in iron and steel production for the purpose of reducing costs, increasing logistic efficiency and improving quality assurance would, therefore, make an important contribution to maintaining the competitiveness of companies.

2.1.2 New steelmaking and finishing routes

2.1.2.1 Raw materials input and processing

New ore-reduction processes

In the EU, coal is the only reductant available that is likely to provide a competitive route to produce virgin iron by a coke-free reduction process, compared to the hot metal produced by the blast furnace. It is important for Europe to develop a coal-based direct reduction process that is competitive with sponge iron (DRI) imported from those countries where natural gas-based direct reduction is economic. Coal based reduction technologies are being developed in Europe based on fine ore reduction using rotary hearth processes (e.g. the Comet process) and circulating fluidised bed processes (e.g. the Circofer process). Smelting reduction of fine ore in one or two stages is a major challenge. A promising process for use in the EU is the Cyclone Converter Furnace (CCF) process.

Work to date has shown the potential of these new process routes to virgin iron. The next step of development requires the building of larger scale units to demonstrate the feasibility of these processes as a long-term alternative for the BF route. Furthermore, it seems that two-stage processes with combination of direct reduction of fine ore and subsequent melting of the fully reduced material without gas connection of the two process stages will also have a good chance for future application.

The need to achieve low energy consumption for melting of sponge iron by post-combustion with hot blast enriched with oxygen should be taken into account also.

BF hot metal - BOF steelmaking route

For the future of the "BF hot metal - BOF steelmaking route" it is essential to overcome the environmental problems linked to cokemaking and to lower the specific investment costs of new cokemaking installations. Currently there are developments going on world-wide to achieve further advances with new coke making systems. These new technologies have to include:

- Convincing progress towards environmentally friendly coke production conditions.
- Continuous processing for higher productivity.
- Elimination of by-products other than gases to be converted into steam and electricity or for iron ore reduction use.
- An increase in the ratio of non-coking coals in blends.

Conventional cokemaking plants based on the modern multi-chamber system that fulfils all regulations for environmental protection have been built over the last few years in Europe. The multi-chamber cokemaking concept has reached the peak of its development.

The new cokemaking system 'single coking reactor' has been tested on a demonstration scale. The process operates based on independent single chambers, and one of the remarkable features is a greater flexibility in raw materials, which means the process can use a major portion of non-coking, low-cost coals. Further advantages are: better coke quality, less consumption of under firing media, improved compatibility with pollution control demands, improved flexibility from the module technique, individual performance rate adapted to coke demand and coke quality. The industrial application of this system has to be undertaken in the near future.

The feasibility of cracking the coke-oven gas produced in a coking plant to produce a reducing gas with over 60 % hydrogen and 30 % carbon monoxide, and avoiding coal by-products, needs further RTD. It could lead to the two-product coking plant system. The use of this 'new coke oven gas' for heating purposes as well as a reducing agent for iron ore reduction processes will improve the carbon dioxide balance in steel production and may create new structures in integrated iron and steel works. Its use as a raw material (synthesis gas) in the chemical industry is also possible.

Other developments already ongoing outside Europe concentrate on new environmental friendly systems with direct use of heat for providing steam for turbine generators (e.g. the non-recovery coke plant of SunCoke) or seek to produce metallurgical coal blends in a new continuous working process (e.g. the Calderon Coking Reactor). Considerable efforts will be necessary to develop productivity and environment enhancements to build up more economical and clean coke plants to replace existing facilities.

For integrated steel plants, the blast furnace will maintain its dominating role in hot metal production also. New blast furnace technologies related to the reduction of its reliance on coke through increased use of coal are required. In future, the trends will be:

- Replacing coke by injected coal or other reducing agents including injection of reducing gas or recycled process gas as well as utilising higher oxygen contents in the blast.
- Injecting fine ore or metallised materials depending on the economic situation.

The refining of hot metal in the BOF for crude steel production is a mature technology; but new developments could go into the direction of:

- Continuous steelmaking and continuous vacuum treatment.
- New vessel designs to achieve higher throughput of metal and gases as well as lower final contents of accompanying elements.

<u>Electric Arc Furnace (EAF) steelmaking route</u>

To enable a higher percentage of scrap-based steelmaking of about 40-50 percent in the EU, virgin iron for diluting the recycled scrap must be made available for the EAF and improved recycled scrap upgrading technologies must be developed. The ultimate objective will be to develop a coal-based process that produces liquid iron directly from coal and ore fines or concentrate. Liquid iron is preferred to solid DRI because there is no gangue and it retains sensible heat. The tasks for process development consequently have to be concentrated on:

- Advanced shredding and scrap treatment technologies for producing a sustainable high-quality charge material for steels for demanding applications, e.g. by new shredding, sorting and classification technologies.
- New technologies for continuous charging, charge pre-heating, air-tight operation, arc voltage and electrode control.
- Developments of coal-based direct reduction or smelting reduction processes for fine ore reduction.
- Development of alternative technologies for extracting iron from ore fines and concentrates, e.g. technologies based on hydrogen reduction, or extraction from ores or recovered scrap with chemical or biological leaching followed by electrolysis.
- Development of continuous melting processes, together with scrap and DRI, based on primary energy input.
- New refining technologies and ladle treatment technologies to enable the

EAF route to produce steels for demanding applications that are currently produced by the BF-BOF route.

2.1.2.2 Direct steelmaking

Direct steelmaking is defined as a total continuous line for the production of crude steel by means of continuous reactors via hot metal refining in iron ore based routes or via scrap melting and refining in scrap based routes including continuous steelmaking.

The technology for using direct steelmaking is still to be developed, but is feasible from a technical point of view. The main problem of direct steelmaking in both the iron ore and scrap-based routes is not only the continuous operation of reactors but also the linkage between them.

In the iron ore based route one possible configuration of direct steelmaking consists of a continuous line with three reactors where the liquid metal flows from one reactor to another, i.e. from the smelting reduction reactor to a desulphurisation unit and then to a continuous steelmaking reactor. From new developments achieved on refractory linings of reactors, sensors and electromagnetic transportation, it appears that such a direct steelmaking line could be feasible.

In the scrap-based route, one possible configuration consists of a continuous line with two reactors where the liquid metal flows from the first to the second by gravity. Either an electric arc furnace, or a scrap melting converter type furnace with coal injection and post-combustion with hot air, where only melting takes place, has to be combined with a reactor for the final dephosphorisation and decarburisation. A channel reactor with counter-current flow of slag and metal would achieve a very high metallurgical efficiency. Upstream a closed-system scrap preheater installation continuously feeding the melter would assist the overall economy of such a process line.

2.1.2.3 Casting and hot rolling

<u>Flat Products</u>

Today flat strip products are cast in continuous slab casters with a strand thickness around 200 mm. This material is hot rolled to hot band with around 3 mm thickness. Sheet is then produced by cold rolling and annealing. This process route could be drastically reduced by near net shape casting. During the last few years, medium thickness slab casting (thickness around 150 mm) and thin slab casting (thickness around 50 mm.) have become established technologies. Thin slab casting has the potential for casting some plate grades, although it is unlikely the more demanding plate qualities will be produced via this route. Direct strip casting (thickness around 10 mm.) following by direct rolling can produce materials properties suitable for some sheet grades. Twin roller casting can produce 3 mm thick strip directly, and eliminate the need for hot rolling entirely.

From these new processes routes, combining near net shape casting and rolling, lower investment requirements, lower energy consumption, low emissions and improved material properties are expected. Considerable further RTD work will be needed to develop these technologies. This will include improved technologies for:

- Thin slab casting and rolling to improve productivity and quality and accommodate a variety of steel grades.
- Direct strip casting with direct rolling with high performance and productivity.
- Thin strip casting by twin-roll process for stainless steel strip production, as well as further developments for casting of silicon and carbon steel grades.

- Improvement of rolling schedules to achieve greater rolling efficiency, more accurate product dimensions and enhanced product surface quality and material properties.

The use of hot-rolled coil instead of cold-rolled coil in some market sectors offers another way to reduce drastically the production costs. Present hot rolling technologies and hot rolled coil finishing technologies will have to be adapted for this purpose. These developments will be assisted by further developments in microstructural models and applying these on-line to a wide range of products to enable the required end use metallurgical and surface properties, e.g. formability, and high-quality surface without physical or chemical defects, to be achieved from the hot rolled material.

Long products

The development of technologies for the production of long products via bloom and billet casting has to go towards higher casting speeds in combination with direct rolling. Further developments will be needed to achieve:

- Uniform as-cast structures without, or having drastically reduced, core segregation using special means (stirring, rapid cooling, liquid core reduction).
- Cleanliness sufficient for high performance applications.
- Hot charging of 'as cast' defect free blooms and billets.
- Reduction of surface decarburisation.
- Improved dimensional tolerances, straightness and consistency of properties.

2.1.2.4 Cold rolling and finishing processes

Cold rolling and finishing processes start after hot rolling and include pickling, cold rolling, annealing, temper rolling and coating.

Steelmakers building new cold mill plants are choosing between continuous and uncoupled operations. Several mills have continuous lines for pickling and cold reduction. The continuous lines improve yield (up to 95%) because of decreased re-coiling damage, less off-gauge rolling at the front and back end of coils, and lower inventory levels. In a continuous line, delays at either end affect production levels, but yield and quality factors outweigh that disadvantage. However, in a continuous line the problems of the process uniformity, particularly when the sequential processing of different steel gauges and grades remains to be solved.

There is a need to improve surface qualities at process velocities compatible with prior processes and to develop integrated coating systems with fewer process steps.

During the past 20 years new **pickling processes** e.g. Hydrochloric acid instead of Sulphuric acid Pickling, Turbulence-tank Pickling, Push-pull Pickling have made it possible to achieve a high degree of strip cleanliness in the shortest time and permitted control of pickling efficiency in accordance with the strip speed. However there are still needs to reduce pickling time, minimise evaporation, limit gas emissions, reduce spent pickle liquors and improve working conditions. The use of ultrasonic energy to improve acid pickling, dry pickling methods (blasting methods) and water jet pickling, are promising emerging technologies. Further developments are needed to ensure higher productivity from pickle lines, full recycling of metal oxides from pickling and efficient regeneration of scale removal materials.

The **cold rolling** mills of the EU steel works have been modernising over the past 20 years thanks to improvements such as hydraulic gauge control, hydraulic roll-force cylinders, supported by on-line shapemeters and X-ray gauge monitors. However, additional progress is still required in different stages of cold rolling. These include:

- The linking of different process stages through the matching of the processing capabilities of the several plants.
- Improved control of the strip crown.
- Reduction of the scrap deriving from the off-gauge steel at the temper mill through the holding of standard gauge tolerances throughout most of the strip length.

Concerning **continuous annealing**, different technologies have been developed over the past 20 years and the classical batch annealing technology has been improved by the use of hydrogen. However further progress in terms of heating and efficient cooling solutions for carbon, silicon and stainless steels is still required to assure homogeneous materials properties, strip cleanliness, freedom from internal stresses and high flexibility with widest possible range of products.

The main evolution expected in terms of speed and thickness in cold mill processes are as follows:

- **Evolution of speed**. For carbon steels, a few lines are operating with higher speeds than conventional lines, e.g. 2500 m/min for tinplate tandem mills and 1000 m/min for tinplate continuous annealing lines. For stainless steels, speed of bright annealing lines is usually between 50 m/min. and 80 m/min. A technical breakthrough could enable higher line speeds and change the productivity of all cold mill processes.
- **Evolution of thickness**. The market demands for steel sheets are for thinner material (down to less than 0.2 mm), while the efficiency of high-speed forming and deep-drawing operations downstream demands an increasing accuracy and uniformity of the gauge and shape.
  1. *For existing products*: The general trend for decreasing the average thickness of sheet requires further progress in order to keep the same entry thickness before cold rolling (which determines hot rolling and pickling productivity) and also to keep or, if attainable, increase productivity and quality associated with cold rolling.
  2. *For new products:* The wider use of sandwich steel sheets to obtain both a reduction of sound transmission and weight, (in which the thickness of each sheet in the sandwich is less than half the overall thickness) will create the need to roll steel coils with very high width/thickness ratios and to process them on continuous annealing lines. This can not be achieved today while keeping a satisfactory cost efficiency.

The new products will require adaptation of production processes to the new metallurgical routes. For example, very high strength grades (dual phase) will need a higher cold reduction ratio to obtain extra deep drawing properties. Continuous operations with a range of alloyed grades will only be possible if current problems with welding different grades together in process lines can be overcome. New grades will often require changes to pickling process parameters.

A diversification of temper rolling technologies will be required for improving shape, flatness, hardness and formability, and providing the proper range of surface roughness for different applications particularly for deep drawing steels. In particular, new technologies will be required to enable changes in surface finish of the final delivered sheet steel to be achieved without the need to replace work rolls in cold rolling and temper rolling mills.

The demand for better control over residual stress will require improvements in cold flattening and levelling processes. As near net shape casting and rolling technologies are developed, finishing processes will need to be adapted for this alternative feed stock.

The increase of metallic coating lines devoted to automotive industry has been the most evident evolution over the past 20 years and the zinc consumption has more than doubled since 1974. This trend will continue beyond the year 2000 and thinner and higher quality products will be required (with improved cosmetic appearance, corrosion resistance, forming and welding ability, etc.).

New technologies are required to replace the galvanising bath (no immersed material, small liquid bath, etc.) and for a faster galvanising response.

New organic coatings and the improvement of existing technologies will be required for many applications: automotive, constructions, packaging and home appliances (sandwich panels, sound barriers, hard-coated laminates, Poly Vinyl Chloride (PVC) free laminates, etc.).

In summary, further areas for process improvements include:

- Increases in line operating speeds in pickling, rolling, annealing and coating processes.
- Development of improved thermal efficiency and thermal cycle control during annealing.
- Extension of continuous annealing line operations to process strip with a very high width/thickness ratio.
- Improved technologies for continuous metallic and organic coating.
- Improved automatic surface inspection techniques with on-line feed back of defect detection and location during rolling, annealing and on final inspection lines.
- Development of improved automated systems for coil and sheet packaging, warehousing and distribution.

2.1.2.5 New process lines for new products

Due to the increasing sophistication of the demand of customers (e.g. automotive, packaging, building industry, home appliances, etc.) coated steel products must be designed for specific applications. Advances in coating technology for many markets are constrained by a number of factors, including cost, quality and environmental regulations.

Environmental constraints will require alternative coating processes. Beside the general constraint of cost, environmental regulations play an increasing role in the field of surface treatments and coating processes. Costs of recycling or neutralisation treatments for electrolytes have also to be considered. Alternative surface pre-treatments avoiding chromium, other heavy metals, and organic solvents must be developed.

New high-speed surface engineering technologies are required for continuous coating lines, e.g. dry coating technologies such as Physical Vapour Deposition (PVD) capable of a new generation of coated materials and the development of solvent free coatings that last for the life time of the end use application.

Similarly new surface engineering technologies need to be developed to improve adhesion of coatings and surface hardness of long products e.g. to reduce rates of wear in rails for high speed trains.

The development of new process lines for the continuous production of laminated steel sheets are required e.g. for applications where sound or heat insulation is required.

2.1.3 New technologies for efficient design and production

The most significant sources of competitive pressures on European steel manufacturing are related to the volume and structure of demand in Europe. There are two sides of this issue. First, the steel products are under constant threat of substitution by alternative materials, which means a competition for intermediate markets, possibly against non-European producers. Second, as a locally produced intermediate material, the level of demand for steel products depends on the level of demand in steel using sectors such as canning, automobiles, construction etc. The steel sector, therefore, is directly affected by the competitive performance of its purchasing industries. In turn, the competitiveness of these major steel-using industries depends to a significant degree upon the ability of the steel industry to meet international standards of performance, product quality and price.

The competitive response of the European producers to the volume of semi-finished alloy steel which have been available from non-European producers has been to develop markets in areas where these producers cannot meet the quality thresholds, such as in high alloy specialised steel and components, and to design and market them in collaboration with downstream customers.

A considerable effort has been expended by the steel industry to improve competitiveness through products of higher added value, reduced time-to-market and strengthening of its linkages with the downstream customers, rather than through cost competition.

Steelmakers are now more and more involved in close partnership with customers in major steel-using manufacturing sectors. As an example, the move of the automotive industry to become an assembler of purchased semi-finished components has stimulated the steel industry to consider the development of component product fabrication lines using new forming and joining techniques in its steel service centres or in its distribution subsidiary companies.

The new technologies in support of this change in role by the automotive industry include tailor-welded blanks, and rapid prototyping technologies for hot, warm and cold-formed components to speed up time-to-market of new models. These technologies require steel to be made with increasingly accurate composition, to closer tolerances, with improved control over consistency of mechanical properties and residual stress in order to fully exploit the benefits of laser cutting and welding in the fabrication of tailor welded blanks. Similar market pressures could develop in other manufacturing sectors, e.g. domestic equipment and electronics goods.

Further opportunities for improvement and development:

- New steel grades such as (ultra) high strength steels for light weight constructions, new dual phase steels for dent resistance, steels for hydroforming, tailored blanks for light weight and materials saving; new tools have to be developed for the forming and joining and surface treatment of these grades.
- CAD/CAM technologies and concurrent engineering with steel.
- Rapid prototyping.

- 3-D measurement of formed products.
- New technologies to shorten the time to start of production in the automotive industry (FEM, CAD/CAM, CE, virtual reality).

2.1.4 Environmental improvements by minimisation of resource consumption and emissions and by increasing safety

2.1.4.1 Environmental engineering to reduce emissions

All measures for the direct curtailment of consumption, the enhancement of efficiency and the use of more efficient process stages are important to reduce emissions. It must, of course, be acknowledged that, in view of the already sophisticated and integrated energy management systems running in modern integrated iron and steel works, no further major reductions in carbon dioxide emissions per tonne of liquid steel produced by this route are likely. In the longer term, it will be necessary to concentrate on new process technologies, elimination of process steps, and progress in recycling techniques.

One initial approach is the improvement of scrap preparation for the production of high-grade flat products via the steel scrap EAF route. Finally, the steel industry makes a substantial indirect contribution to reducing carbon dioxide emissions through materials development (higher-strength steels for lightweight construction, high-temperature steels for improving power-plant efficiency and improved corrosion-resistant steels with longer lives in chemical process technology).

A long-term objective is the development of clean technologies for zero wastes and emissions. However, carbon-free ore reduction and steel production by hydrogen metallurgy will only be possible if an economical way of hydrogen production is made available. Ore reduction using hydrogen is a well-developed technique, but hydrogen production from fossil sources does not solve the problem of carbon dioxide emissions.

2.1.4.2 Use of off-gases

Reduction and refining processes produce off-gases, mainly containing carbon monoxide and hydrogen. The enthalpy of these gases has to be used, preferably within the steelworks processes by heat recovery, e.g. for pre-heating of input materials like ore or scrap. The chemical energy can be used by post-combustion, which has the potential to minimise the overall energy consumption through heat transfer within the process (see comments on energy costs v. capital costs of current technologies).

2.1.4.3 Reduction of energy consumption

The EU steel industry is a major consumer of electricity. Energy costs account for 15 to 20 percent of the total manufacturing cost of producing steel. Electricity on average represents only about 7 percent of the total energy consumed by the industry, but at some steel plants over half of purchased energy is in the form of electricity. Costs of electrical energy are disproportionately higher than of other forms of energy. New electric-arc furnace technologies are required to reduce energy consumption and to make more efficient use of energy in the process. Direct use of fossil energy will continue to have a high priority in efforts to reduce overall energy consumption.

2.1.4.4 Finishing process improvements

Continuing research for the development of metallic alloy and organic coatings to improve the corrosion performance of steel is required but changes in environmental regulations relating to processes for surface treatments and coating of steel will require the development of alternative coating processes. The engineering of steel surfaces needs to be developed with new concepts of surface conditioning and coatings. Preliminary results related to chromium-free surface pre-treatments prior to organic coating obtained recently have indicated several new promising possibilities.

Costs of electrolyte regeneration for recycling or neutralisation treatments prior to disposal have also to be considered. The aim of further RTD will be to eliminate the use of electrolytes when possible. Dry coating technologies are attractive for their environmental working conditions and for the wide range of products that can be manufactured. Development of new curing technologies (by electron or radiation) and/or new products (for example paint in powder) will be required in order to avoid any organic compound solvent emissions. However safety conditions and production cost have to be considered as well.

2.1.4.5 Upgrading and recovery of waste materials generated inside the steelworks

In iron and steel production, valuable by-products (slag, sludge, pickling liquors, scrap, water, and oils) are normally generated which can be recycled into the materials circuit or used for the production of new products. The main objective in this context is to complete the entire materials recycling circuit from initial raw material to final end user whilst, at the same time, considering recycling behaviour when designing this circuit. In the steel industry, the production chain consists of a large number of individual stages. The utilisation and disposal techniques for effluents, sludge, dusts and slag, although requiring further improvement, make a valuable contribution to closing up material circuits. Therefore, integrated processing of steelworks wastes has to be further developed. There are needs for improved cleaning systems as well as for new process technologies for converting dusts, sludge and slag to secondary raw materials. A special need is seen for developments to process zinc-containing BOF dusts, achieving a high enrichment of zinc. Pickling liquors have to be processed to retain the oxides that can then be treated to produce new products.

Regarding scrap as an important raw material source for steelmaking of flat high quality products, every effort has to be made to develop effective scrap sorting and processing techniques. Special efforts have to be undertaken to control the copper, molybdenum and tin contents of scrap. New technologies are needed for extracting non-ferrous metals and materials from low-grade scrap arising from both within the steelworks and outside for recycling.

Within process control systems, considerable use is made of hydraulic actuators, mostly using mineral oil fluids. Any leakage of oil from these hydraulic systems presents a hazard, particularly when operating near hot or glowing steel surfaces, due to the risk of fire. The leakage can also cause environmental problems and increase the risks to mill operatives and maintenance personnel. New hydraulic system design concepts have to be developed to prevent accidents due to leakage, and to replace mineral oils with less hazardous hydraulic fluids.

2.1.4.6 Upgrading and recovery of waste materials generated outside the steelworks

Steel is the most recycled material in commerce. More tonnes of steel are recycled than all other materials combined. The total amount of recycled steel saves the equivalent energy to power 18 million homes per year. Steel has superb recycling properties. High-grade products can be produced again from prepared and sorted steel scrap. For steel-based products, scrap generated during product manufacture, product usage and recycling can be recycled into the materials circuit and used for the production of new steel products, particularly with scrap arising from the automotive, packaging and construction sectors. Steel's unique magnetic properties facilitate its separation from other materials. A closed shaft furnace, like a cupola, is well suited to melt scrap contaminated by organic materials. Developments are going on for an "oxygen cupola" with off-gas recycling for melting obsolete scrap. The liquid metal produced can be mixed with hot metal from the blast furnace.

Beyond scrap, the recycling of other materials generated outside steelworks within steel plants is also possible. Steelmaking is an inherent recycling process. Sinter plants are employed to re-process iron-bearing dusts and sludge to produce an alternative to iron ore suitable for charging into blast furnace. Coke ovens are used to recycle by-product cokemaking process materials that would otherwise require disposal.

Other potential new technologies include injection of waste materials containing carbon into blast furnaces: e.g. pre-sorted and agglomerated halogen-free plastics freed from foreign substances can be injected into the blast furnace. At the processing temperature (2100°C) the gas evolved from the injected plastics is used to reduce iron ore to iron. The process is a viable method for using plastics as a raw material, at the same time reducing waste plastics otherwise requiring disposal by land filling.

2.2 Steel grades for demanding applications

2.2.1 Construction and renovation of buildings

European industry is distinguished by the high standard of its products, which enables it to successfully compete in world markets even from high wage-rate locations. The increased use of industrially prefabricated products produced under modern quality assurance systems will raise both national and international building practice to a higher quality level than is currently normal in the building industry. Steel-building components are more suitable for off-site fabrication of sub-assemblies, improving the safety and working conditions of construction workers, as well as facilitating rapid erection.

New production concepts need to be developed for modularised ecological and cost-productive domestic dwellings to suit individual tastes. The production of domestic dwellings, e.g. using steel housing modules of hybrid construction, is being shifted away from the imponderable external influences on building sites to the highly technical environment of modern industrial manufacturing plants. The finished domestic dwelling will be produced at 25 percent lower cost, enabling new groups of buyers to become house owners. This will enable the building industry to open up new markets and hereby increase production. The time required to build a house will be reduced by 50 percent or more compared to current normal building times.

Finally, the quality of the work will be raised to a higher level. The "imported cheap labour" currently used on building sites will be replaced by the technical expertise of specialist workers. This will raise the quality of the work to the same level as that performed by highly skilled industrial workers. The modularised construction of domestic dwellings will create the high-tech jobs desired at high-wage locations in Europe.

High strength steel and weathering steels (i.e. non-rusting steels) are the structural steels suitable for commercial and industrial buildings. The increased use of steel in the construction and renovation of domestic and commercial buildings offers outstanding advantages for the following applications:

- Construction of buildings with fewer columns and longer spans for increased floor area.
- Construction and renovation of buildings able to withstand seismic loads, particularly in EU member states bordering the Mediterranean.
- Preservation and refurbishment of the architectural heritage by using steel to enhance structural stability.
- Construction and renovation of buildings able to withstand wind loads (hurricanes) and fire.
- Construction and renovation of buildings with increased thermal and acoustic insulation, particularly for high-rise domestic accommodation in cities.
- Increased architectural options with lighter and stronger elements and frames, offering improved aesthetics, durability and functionality.
- Development of new automated construction methods, especially for temporary and mobile homes; modular building components for offices, hotels, and retail outlets.
- The structural stability against humidity, heat and cold make the steel constructions more safe and in the long-term less expensive.

Steel constructions are more environment-friendly because they can be designed to enable easy dismantling and recycling of the steel-based components. They are more resistant to infestation from external agents, such as termites and fungi, compared to other building materials.

2.2.2 Construction of infrastructure

Interfaces between transport systems: Both from the global competition and environmental point of view, the intermodal mobility of goods and people is a primary target in Europe. Much progress has already been made in the use of steel containers for transport of goods by sea, linking to land transport systems by truck and rail. The current systems have been developed for bulk transport of goods and are not always suitable for use in goods distribution in an urban environment. A new modular mini-container concept needs to be developed that would be integrated with the current bulk container standards, and suitable for urban goods distribution by smaller capacity, more environmentally friendly vehicles. This will require a new design of interports or logistic platforms, with an organic framework, capable of offering different services dedicated to efficient and environmentally friendly goods exchange and distribution, effectively integrating transport systems on and through roads and railway towards highways, airports, and inland waterway and marine harbours.

Bridges and tunnels: Steels with high mechanical and corrosion resistance are required for short-, medium-, and long-span bridges and tunnel linings. Outside cities, the construction of bridges with fewer columns and longer spans reduces the environmental impact of the structure in regions of scenic beauty.

Water distribution with leakage-free and safe systems: Stainless steels for water distribution in buildings with improved joint systems to avoid costly and time-consuming conventional welding processes are required. For water treatment, long distance distribution and storage, coated steels have several advantages compared with concrete and plastic. It has a high strength-to-weight ratio, it is easy to handle, and can be fabricated at the work site.

Water drainage and retention systems: For corrugated drainage pipes, coated steel has similar advantages compared with concrete and plastic. Among competing materials, large concrete pipes and components require a crane at the work site as well as more precise back filling to ensure proper load distribution. Plastic materials resist corrosion but have structural integrity questions about how well they withstand freezing and thawing.

Utility poles for telephone and power lines: Utility poles made of cold-rolled and galvanised steel can compete with wood, fibreglass and concrete. Steel has an environmental advantage over wood, since wooden poles are treated for preservation with benzene or other hazardous substances. Fibreglass is more expensive than steel and concrete is heavier.

Steel as a component of composite materials: Although the application of steel in this sector will continue to expand, it will also be used in combination with other materials, including concrete, to provide increased flexibility in design and optimum 'system' solutions.

2.2.3 Transport systems

Automotive Sector: Steel has a major future role in developing vehicle technologies suitable for sustainable mobility of people and goods in urban environments. New design concepts are being developed in the Ultra Light Steel Auto Body (ULSAB) project and related projects concerned with closures (bonnets, doors and boot lids), drive and suspension systems, all sponsored by the International Iron and Steel Institute. Particular areas for the further development and application of new steel products are:

Complex car body parts: The mix of stiffness, strength and formability that only modern steel can provide is vital for cars and lightweight commercial vehicles of the future: safe, lower-emission, energy efficient, recyclable vehicles. Lightness, stiffness and strength are being increased by advanced forming technology, e.g. hydroforming and joining technology and by (steel for) laser welding and cutting to realise complex body parts. This results in safer components of a more complex shape suitable for improving aerodynamics and aesthetic appearance.

Tailored blanks and formed panels are good examples of new products that can be developed and provided by the steel industry.

Steel inherently provides a vital security margin in case of a crash because of its remarkable ability to deform and harden simultaneously. At higher impact velocities, the strength of steel increases enabling more energy to be absorbed. In addition, low weight allows fuel saving with corresponding reduction of polluting emissions, while new advanced multi-layer coating systems in specific critical points in the vehicle structure will provide guarantees for more than 12 years against major types of corrosion and an extended durability. These new designs will be conceived in terms of improved end-of-life dismantling and recycling:

- *Forging parts and different steel components*: high mechanical resistance/weight ratio and in particular wear resistance and fatigue resistance is required for many forged parts (pinions, conrods, crankshaft, etc.). However, other steel components (springs, bearings, steels cords) used in automotive construction require high mechanical properties, namely tensile and yield strength, fatigue, hardness and wear resistance.
- *Hydroformed parts for space-frame and car-body components*: Tubular hydroforming produces high dimensional stability of whatever profiles and complex shaped components are required by the new design concepts. They feature high strength/weight ratio required for increasing passive safety of the body and reducing fuel consumption, together with improved stiffness due to a reduction in the number of joints in components.
- *Development of safe structures* (active and passive) for automotive applications.
- *Development of steels with good "crash performance"*.

Steel-based composite components: Reduction of noise and vibration in vehicle can be achieved by combining steel with other metallic or non-metallic materials. This, in turn, will require the development of reliable joining techniques, e.g. mechanical joining, clinching, adhesive joints, etc. Steel composite sandwich panels will also increase the stiffness of the auto body and other sub assemblies.

Tanks for "clean" fuel: The viability of vehicles running on alternative clean fuels, e.g. liquefied petroleum gas (LPG), compressed natural gas (CNG), or liquefied hydrogen, in order to reduce emissions is still under debate. This is mainly because the fuel tank must be stronger and larger, which presently limits the annual size of the market to about one million vehicles. Steel could offer a solution in reducing the weight of the tank. In addition, new legislation to control the emission of hydrocarbons via permeation through the walls of tanks will favour steel-based designs.

Improved suspension and drive systems: New forming technologies like contour forging, hydroforming, semi-hot forming and squeeze casting will be developed and introduced to produce light weight suspension components with higher strength and toughness, optimum cleanliness and good weldability.

Improved steel-wheel bearings: Further developments are required to extend the use of Automatic Braking Systems (ABS) to the full range of smaller vehicles for use in urban environments to provide safer vehicles in avoiding skidding.

<u>Rail Sector</u>: Steel will continue to have an important role in the further development of high-speed rail systems to provide more environmentally friendly long-distance transport systems between cities as an alternative to multi-lane highways and air transport. Particular areas for the further development and application of new steel products are:

Traction equipment in high-speed trains: The big challenge lies with satisfying a very large power and traction effort requirement, within drastic axle-load constraints. Asynchronous 3-phase AC induction motors featuring very high power/weight ratio (around 1 kW/kg) will need to be developed.

High-speed train brakes: Adhesion at high speeds is insufficient to enable a quick stop in emergencies. A new brake system is needed. Magnetic induction brakes, which need supplemental thermal capacity to dissipate kinetic energy of the train as heat, can be achieved through the use of new energy dissipating steel based systems.

Carriages, wagons and trailers: One of the biggest challenges for the design of high-speed tilting trains is the keeping down the weight of carriages and trailers. The first approach to cut weight is by using the least possible material to fulfil structural requirements. The second way is new materials including new steel grades and new steel based composites. The research efforts will be mainly devoted to explore new materials that can yield a weight reduction of at least 20% over conventional materials and in addition exhibit a high resistance to the wear and tear encountered over 30 years of high-speed operation.

Similarly, there is considerable scope for improvement in design of wagons for bulk transport of solids, liquids and gases, using enhanced steel properties to reduce the overall weight, while retaining extended in-service performance on the future high speed rail networks.

Crashworthiness of high-speed trains: Following recent trends in the auto industry, there is significant effort going into the design of passive security concepts for high-speed trains. As it stands, the present high-speed train architecture shows some weaknesses. It has been found that only 10 percent of the crash energy can be absorbed in deformations of the first trailer, with the result of serious injury to the passengers. Railroad crash simulations by super computer have proved the need for trailers to have extremely rigid bodies with deformable, energy-absorbing crush zones at the ends. In order to achieve this, new designs of coupling between the power units and trailers are needed. In addition, the energy-absorbing ram shield already mounted in the nose of all high-speed train power units to protect the cab cubicle needs to be improved. This in turn calls for a new generation of steel for use in rolling stock able to deform and harden simultaneously to absorb the energy of high-speed impacts.

Rails: Development of new steel grades for rail tracks is required to give improved ride on high speed rail links, with improved fracture toughness and in-service performance.

System Optimisation: Optimisation for ride comfort, minimum maintenance and total cost will be achieved by designing carriage, bogie, wheel, rail, sleeper and ballast as an integrated system.

Sound barrier design: New designs for efficient sound barriers are needed to reduce the noise reaching surrounding inhabited areas manufactured from sandwich steel sheets, once the strengths of the noise sources are known. An interactive engineering tool for the simulation of compressible flows with moving bodies has been employed to better understand the physics of tunnel entry problems of trains and predict the level of discomfort to passengers, as well as to design the next generation of high-speed trains and tunnels. Also another important unsteady aerodynamics problem of high-speed trains, the crossing of two trains, appears to be solvable by designing new steel-based sound shielding systems.

<u>Marine Sector</u>: New steel products, e.g. special steel sections, need to be developed to meet the design requirements of a new generation of marine vessels that are safe, environmentally friendly, and efficient at minimum cost. Installations for obtaining future supplies of oil and gas from deeper offshore fields, particularly in Arctic or Antarctic regions will depend on new steel grades to be developed. Particular areas for the further development and application of these new steel products are:

Fast ferries for medium-range transport services: Several new or improved steels and advanced joining technologies are identified as priority RTD areas to support new design concepts for ferries. Light-weight, noise and vibration-insulating steel sandwich panels for load-carrying ship components, manufactured by low-distortion joining techniques such as laser stake-welding; fire and corrosion resistant steels, anti-fouling coatings and fast-joining systems for ship piping and tubing circuits; ultra-high strength steels for structural and propulsion (water jet) components. Low-cost, high-productivity joining techniques (e.g. adhesive and/or mechanical bonding) are some examples.

Spill-safe tanker, chemical tankers or containers: In ocean highways, steel technology provides ships to deliver oil or hazardous cargoes safely and cleanly. It also provides new steels to transport hard-to-handle but more environment-friendly fuels like natural gas and even hydrogen.

Sub-zero gas carrier and storage containers: Advanced stainless steel alloys, which defy temperature changes down to -160°C, make possible safe, large-scale ocean transport of Liquid Natural Gas (LNG). New high-strength/high-toughness cryogenic steels are needed, able to reduce the normal expansion and contraction of the metal and limit the amount of gas evaporating. Thicker cryogenic steels are also required for high-volume liquid gas tanks in sea terminals.

Cost-effective exploitation of offshore marginal fields: High-strength steels for light-weight floating units, including mooring and riser systems; medium-diameter dynamic load resistant, clad steel pipes for sub-sea transport of ultra-aggressive fluid; high-quality line pipes and coatings suitable for reliable laying technologies of deep-sea pipe lines. In addition the use of equipment made from stainless steel installed on offshore rigs increases safety and reduces the use of corrosion inhibitors with the corresponding risk of transfer to the environment.

Aerospace Sector: Special steel grades will be needed for the next generation of aircraft engines and space craft for components and sub-assemblies operating in extreme service conditions. In order to obtain the required performance, highly sophisticated manufacturing technologies will need to be developed. Examples include:

Parts of aircraft engines: The middle compressor section, where heat and pressure build, needs steels that remain hard and wear-resistant at temperatures as high as 900°C. In the rear turbine section, where the heat and pressure are the greatest, coated steel grades are required with high thermal shock resistance, wear resistance and structural stability.

Landing-gear support systems, engine mounts, flap and slat tracks: For safety reasons, weight saving aspects and environmental conditions, the forged and machined components require higher strength, toughness, improved fatigue properties, wear and corrosion resistance. New grades of maraging steels and precipitation hardening steels will be required.

Fasteners and bolts: Wear, creep and corrosion resistant, ultra-high alloyed steel will be required to withstand very severe temperature and climate service conditions encountered along the vast distances of space.

2.2.4 Advanced energy systems and services

2.2.4.1 Competitive and clean production of fossil fuels

Coal-fired power plants: In order to restore, stabilise, protect, and enhance the environment, a new generation of coal-fired power plants needs to be developed to promote clean efficient energy technologies and enhance energy security. The performance requirements are to progressively reduce carbon dioxide emissions by 30 to 50 percent, achieve 96 percent or greater removal of sulphur dioxide, and nitrogen oxide reductions of at least 90 percent, and produce electricity at costs 10 to 20 percent below those of today's conventional plants.

Pressurised Fluidised Bed Combustion, Integrated Gasification Combined Cycle, and Low Emission Boiler Systems are among the most advanced approaches for substantially improving the efficiency (over 52 percent) of coal-fired power systems, while significantly reducing emissions. However, to realise their full potential, advanced research is necessary - in particular in areas like gasifier systems, hot-gas desulphurisation, hot-gas particulate removal, and turbine systems.

These new design concepts will require suitably alloyed and super-alloyed steels (super-stainless steels) with high creep resistance at high pressure, excellent fatigue strength and resistance to corrosive acids and condensates.

Oil and gas technology: The European Union still has large oil and gas resources. However, these are locked in complex geological structures and bypassed by conventional technologies, so most of these resources remain elusive. With a better understanding of the "architecture" of an oil reservoir - its geology, the way oil moves through the pores and fractures of the reservoir rock and its underground pressures - exploration and production could become effective through drilling between existing wells or opening existing wells at different levels. Once penetrated by production wells, the oil flows freely to the surface, pushed by the natural pressure of the reservoir. When this *"primary production"* declines, operators often inject water or gases to maintain the underground pressures. These *"secondary recovery"* techniques, even though in use currently, need to be improved to increase their effectiveness and predictability. Several chemical, thermal or simply mechanical approaches are under investigation aimed at reducing the tendency of the oil to cling to surrounding rock, making it thinner for increasing its intrinsic mobility through a reservoir or easier to be moved.

All these approaches require steels that combine high mechanical strength and stability, high corrosion/oxidation resistance at elevated temperature and a suitable stability against the attack of bacteria that can survive the harsh environment of an oil reservoir.

In general, crude oil supplies are getting heavier and their sulphur content is increasing. This creates new challenges for refiners who need to produce light-end motor fuels and other products and at the same time reduce the amount of heavy residual oil left unprocessed. In this respect processes that produce higher quality products efficiently and economically are the downstream research priorities. New refinery catalysts have the potential to generate breakthroughs in process economics. New steel-based catalysis support systems will allow the development of new catalysts that enable better thermal efficiencies to minimise refinery heat losses, and reduce fuel consumption and reduce costs. It may also be possible to develop new separation processes - using new steel support systems for membranes, for example, that are more efficient than traditional distillation. Pressure vessels with improved hydrogen, creep and high temperature resistance will improve the yield of finished products from lower quality crude oil supplies.

2.2.4.2 New and renewable sources of energy

Fuel cells: Fuel cells convert chemical energy (e.g. in the form of hydrogen or natural gas) directly into electrical current. Cells for mobile use as well as for stationary use are currently under development. A typical fuel cell is 65 percent steel. To reduce costs and make possible fuel cells in the megawatt range (up to 50 MW) and with an efficiency up to 70 percent, mass production of thin nickel-clad stainless steel sheets are required, able to withstand the elevated operating temperatures inside the cell.

Refuse-Derived Fuel (RDF): While the productive use of municipal solid waste (MSW) to generate energy is proven, the full potential of converting combustible components in the MSW stream to energy has not been fulfilled. Pelletised binder-enhanced, refuse-derived fuel has been burned in coal-based systems, but only in quantities of less than three percent in large utility systems. A target would be the use of binder-enhanced, refuse-derived fuel in quantities up to 20 percent, to quantify the pollutants released during combustion, measure combustion performance and develop operating, technical, and financial data for the use of RDF as an alternative fuel in cyclone, suspension-fired combustion systems.

In order to develop new combustion systems to generate steam a temperature of up to around 700°C, existing materials (stainless steels and nickel-based alloys) will have to be modified, both in terms of mechanical properties, geometrical design and corrosion resistance.

2.2.5 Packaging and distribution networks

2.2.5.1 Packaging

The European packaging steel production amounts roughly to 5 million tonnes per year, which is equivalent to 30% of the world production. Europe accounts for 24% of the world consumption, the USA also for 24%, Japan 11%. The UK, Germany, France and Italy provide the major European markets. Both in Europe and Japan, offer of packaging steels exceeds demand (25%). The current breakdown of sales of packaging steels in Europe is:

- 46% food industry
- 25% other cans
- 13% beverage cans

Europe is the world's major market and producing area and appears now as a technical leader as well. The economical prospects for Western Europe are good; a period of solid growth is expected for the coming years. Packaging materials are essential to protect and preserve the package contents. Steel is an environmentally friendly packaging material that can easily be recycled. Activities are continuously going on to reduce the weight of steel packaging and to increase recycling rates.

Packaging companies have restructured, concentrating on their core business and putting emphasis on lean and efficient production processes. Mergers and acquisitions have reduced the number of big producers of metal packaging significantly (since 1986 around 20% of the European production of steel based packaging has been restructured via mergers and acquisition). Many companies act on a global basis. Most of them not only produce metal packaging but also products from other materials (e.g. glass or plastics). The basic requirement for the future is an international outlook, with the capacity of delivering the same technical solutions, the same quality of products, wherever in the world the packaging is required. The fillers are indeed in a position to choose the technical solutions.

The annual steel consumption for packaging in terms of number of square meters has been growing constantly over the last few years. In the future competition with other materials will become more severe. Steel not only has to fight substantial substitution competition, but also has to succeed in introducing new and improved metal packaging concepts into the market place. It is the challenge for the steel industry to exploit fully the excellent properties of steel packaging materials (e.g. low weight, high strength, impermeability to light or air, unbreakable, with good recyclability). This demands a new approach in which market oriented product innovations and entrepeneurship play an important role. For this purpose, strategic networks for further RTD have to be created between the steelmakers, their customers and other partners in the packaging chain.

Food Cans: Many fresh foods are picked before they are ripe and transported many kilometres to the market. Fruit and vegetables for canning are grown near processing plants and canned within hours of harvest to preserve natural flavour and freshness. Food in steel cans is preservative free because the canning process preserves the food naturally. In addition, since the food is heat sterilised after being vacuum-sealed in the steel can, it is protected from contamination. Higher quality steels which are stronger and more dent-resistant, able to absorb more abuse in handling, filling, closing and more suitable for mass storage and long distance shipping will be developed. Also the average thickness of tinplate for food cans will be reduced from 0.25 mm to 0.20 mm and the density of the tin coating will be reduced to 2.7 g/kg of steel to avoid the need for de-tinning processes before recycling. The further development of easy-open steel can ends will enable the manufacture of all steel cans, with improved recovery and recycling potential. In addition, food can design developments will need to take advantage of emerging developments in downstream filling and processing technologies, such as new sterilising technologies.

Beverage cans: The packaging steel used for beverage cans represents only 7% of the world wide packaging steel shipments. The typical weight of steel beverage cans is 25 g with some cans weighing less than 20 g. Further reductions in the thickness of tinplate for beverage cans from 0.14 mm to 0.12 mm without loss of stiffness are required.

2.2.5.2 Distribution Networks

As changes are introduced in wholesale and retail distribution networks, particularly in urban environments, in response to pressures for more environmentally friendly transport systems, there will be opportunities to develop new steel based products to ensure goods are distributed with minimum handling and damage in automated systems. In particular, there is scope for improving exchange of goods between long distance transport systems and urban distribution systems. Steel’s properties of strength, endurance and ease of recycling, combined with innovative lightweight designs will provide new solutions.

2.2.6 Communication infrastructure

The communications industry trends for a new generation of services may be identified in three main targets:

- A fast call set-up (data transfer rates near to 30 000 bit per second, against the present 9600 bit per second).
- The move from analogue to digital data transmission.
- The elevation to some 75 metres of the communication poles in order to avoid housing of Radio Frequency equipment in free-standing building or enclosure near the base of the pole.

Dominant for these applications are materials with high permeability at low magnetic field. However possible niche-markets for electrical steels with improved initial permeability might be identified.

Shielding for electric and electronic systems: There is some concern about the health implications of exposure to electromagnetic radiation. Some research with human cells and laboratory animals, plus epidemiological studies, has suggested that the electromagnetic radiation around power lines, electric motors and household appliances might have biological effects. A possible mechanism for the way in which electromagnetic radiation might affect the human body is related to the possibility of resonance with cells occurring when there is a match between the wavelength of the radiation and the physical size of the cell. This resonance might assist in the transfer of some energy into the cell, which can result in observable biological effects that may be harmful, when high-energy radiation is involved. The extremely low (50 Hz) and very low frequency (15 to 85 kHz) electromagnetic radiation from power lines, home wiring, etc. is in the wavelength range which might induce harmful resonance. If further work shows a significant risk to health does exist in close proximity to high energy radiation sources, specially conceived electrical steels for electromagnetic shielding that can reduce the background level to less than 1 milliGauss will need to be developed.

2.2.7 Mechanical, manufacturing and chemical engineering

In manufacturing industry, a huge number of gear drives are in operation, transmitting power to processing equipment. Rolling mill drives in the metals and paper-processing industries are a particular example. In order to prevent friction and wear, the gear components are continuously bathed in oil lubricants. The circulation of lubricating oils can require considerable energy, and problems can occur when changing the oil and in the disposal of waste oil. The development of steel alloys for gear drives that could be operated in a dry manner, without the need for lubrication and without shortening their life in service would give considerable benefits.

In the field of mechanical engineering, shaft and shaft seal covers, inlet valves (e.g. butterfly valves for geothermal power plant which should withstand coarse sands, pointed fragments of rocks and other hard debris) and various pressure, vacuum and compound gauges are recognised as the most critical parts, especially in terms of material performances. This is due to ever-larger sizes of the required components, as well as to the more severe service conditions of their operation. High-alloy steels (very often stainless steels) are required which due to the sophisticated geometry of the components should combine high machinability to excellent mechanical and corrosion resistance at high temperatures and pressures.

In the field of chemical engineering, gasification and liquefaction of high energy density biofuels (high energy density means that on-board fuel storage is minimised and a vehicle can travel long distances between refuelling) for a new generation of clean internal combustion engines, heterogeneous catalysis and catalytic processes for sound environmental industrial applications (e.g. catalytic combustion, catalytic conversion, catalytic abatement of VOC, NO_x) do appear as chemical processes whose success is strongly related to the engineering of the relevant reactors and materials.

The high operating temperature (up to 1100°C) and pressure (approx. 5 MPa) and the reactivity of different biofuels, also at the ionic level, require special steels featuring high mechanical and at the same time excellent chemical properties. Improved control of product tolerances and properties, particularly toughness and fatigue resistance will enable the development of more efficient mineral extraction and earth moving equipment. The increased use of in-service monitoring of machine structures, e.g. via strain gauges, will enable the prolongation of machine life.

Machine Tools

Further development is needed for high-speed steel grades; cold-work tool steel grades; hot-work tool steel grades and plastic-mould steels.

The application of modern technologies, new alloys and optimised production routes will have to be very important for minimising costs and withstand the world-wide competition.

Pressure vessels and process equipment

Production without waste and effluents, achieved by closed cycle processes are the conditions to reduce the impact of chemical and process industries on the environment. But this means higher pressures, higher temperatures, and more concentrated reagents to increase yield and reduce by-product generation. The development of higher strength, high temperature, high corrosion resistant stainless steels is one of the conditions for clean production. Closed loop systems generally tend to concentrate corrosive products (sulphides, chlorides, etc.) in process waters, which become more corrosive and must be purified before release to the environment.

In non-corrosive applications, the challenge is the reduction of wall thickness using higher strength steels and the design of vessels with higher operations pressures.

The steel industry should co-operate with fabricators and end users to improve the fabrication properties of existing and new materials (welding, forming, surface finishing, etc.) without loss of performance in service and without sacrificing (or even improving) the safety of the workers and population.

Earth moving equipment, cranes

The use of materials with higher abrasion resistance will help to reduce downtime and maintenance in quarrying earth moving and mining equipment.

1300 MPa steels will help to reduce weight at the top of cranes and other lifting equipment, improving performance, stability and safety of such equipment.

3. Research Requirements

3.1 Introduction

Competitiveness of the steel industry is more and more determined by the ability to reduce time-to-market, lower production costs, increase performances of products, and minimise environmental impacts. The steel industry must be able to easily change configuration to respond rapidly to changing customer-driven market requirements. Cost-effective, and faster production equipment and processes taking advantage of new technologies for improved accuracy and repeatability, reduced energy consumption and generation of waste, and more flexible production schedules will need to be integrated into future production systems.

In this chapter, the research requirements to enable the vision outlined in Chapter 1 to be achieved, and the challenges outlined in Chapter 2 to be met, are presented. These research topics will require collaboration between steel companies and other organisations primarily involved in the development and application of the new technologies required. Time scales and possible partners outside the steel industry for the RTD topics are indicated.

In the context of this chapter the definitions of ‘Time Scale’ are as follows:

- ‘Short term’ means practical application of RTD results will be achieved within five years.
- ‘Medium term’ means practical application of RTD results will be achieved within six to ten years.
- ‘Long term’ means practical application of RTD results will be achieved within ten to fifteen years.

Similarly, the alternative ‘Possible Partners’ are indicated as ‘Horizontal’ and ‘Vertical’. The term ‘Horizontal’ means partners are expected to be other steel companies, research centres and universities with expertise in steel process and product technologies, or from other sectors whose technology can be further developed for application in the steel industry, i.e. technology transfer partners.

The term ‘Vertical’ means partners are expected to be from sectors in the supply chain outside the steel industry. These could be ‘upstream’ organisations involved in supply of materials and equipment to the steel industry, or ‘downstream’ customers for steel products.

In both cases these possible partner organisations will include:

- Universities, technical institutes and research centres carrying out basic research.
- Specialist SMEs that convert basic research results into practical prototype applications relating to engineering design, sensors and actuators, application software, components and sub-assemblies, etc.
- Engineering and software design houses.
- Fabricators and assemblers of sub assemblies using the new technologies.
- Manufacturers of commercial products and equipment needed to implement the new technologies, who could be supplying other sectors in addition to the steel industry.
- Suppliers of services to these organisations involved in the exploitation of new technologies.

The research topics for process improvements and protection of the environment are presented in section 3.2 and the research topics for product improvements and new steel applications are presented in section 3.3.

3.2 New and efficient steelmaking and finishing technologies. Protection of the environment

3.2.1 Asset life extension/Streamlining of existing facilities

3.2.1.1 New technologies for process improvements

Project proposals for improved blast furnace operations

Topic	Time Scale	Possible Partners
Optimisation of raw materials handling/treatment for consistent high production rates in blast furnaces.	Short term	Horizontal
Optimisation of blast furnace operations to give flexibility in raw materials usage.	Short term	Horizontal
Coke properties for high rates of coal injection.	Short term	Horizontal
On-line assessment of the internal state of the blast furnace.	Short term	Horizontal
Further development of artificial intelligence techniques for real time adaptive control.	Short term	Horizontal
Measures for the prolongation of the blast furnace life.	Short term	Horizontal
Improved in-service repair techniques for hearth, bosh and stack refractories.	Short term	Vertical and horizontal
Development of replaceable taphole systems.	Short term	Horizontal
Improved damage detection, and in-service repair and construction techniques for blast furnace, cast house and ancillary services.	Short term	Horizontal
Advanced studies of ceramic/water cooling systems.	Medium term	Vertical and horizontal
Improved plant condition monitoring, maintenance and engineering systems.	Medium term	Horizontal

Project proposals for improved steelmaking operations

BOF steelmaking

Topic	Time Scale	Possible Partners
More accurate and rapid gas analysis techniques for control both of the metallurgical process and of gas cleaning plant.	Short term	Horizontal
More efficient prevention of slag carryover on tapping.	Short term	Horizontal
Use of new charge materials (e.g. DRI) and fluxes.	Short term	Horizontal
Improved consistency of metallurgical performance over long campaigns, bath agitation, etc.	Short term	Horizontal
Increasing application of IT, expert systems, soft computing technologies for process and engineering control, monitoring and diagnostics.	Short term	Horizontal
Extension of life of converter vessels, improved cooling systems to prevent cone distortion.	Medium term	Horizontal and vertical

Topic	Time Scale	Possible Partners
Extension of life of ancillary and waste gas cleaning equipment.	Medium term	Horizontal
Improved shell support systems and trunnion bearings.	Medium term	Horizontal and vertical
Improvement to oxygen delivery systems including new nozzle designs to give longer coherent jets, secondary lance improvements.	Medium term	Horizontal
Reduced energy consumption, e.g. post-combustion, reduced energy losses, improved gas collection efficiency.	Medium term	Horizontal and vertical
Improved monitoring of refining and slag development (e.g. by means of Radio Wave Interferometry).	Medium term	Horizontal

EAF steelmaking

Topic	Time Scale	Possible Partners
Increased productivity and reduced energy consumption, e.g. post-combustion, chemical energy, oxy-fuel burners, oxygen/carbon injection, scrap pre-heating.	Short term	Horizontal and vertical
Power input control systems for more efficient electricity usage.	Short term	Horizontal
Use of higher voltages on EAF.	Short term	Horizontal and vertical
Improved techniques for charging/injecting of low residual Fe unit materials, e.g. DRI, HBI, hot and cold BF iron, Corex iron, charcoal BF iron.	Short term	Horizontal
Extensions of steel grade capability through EAF route, low residuals, low N_2.	Short term	Horizontal
Increasing application of IT, expert systems, soft computing technologies for process and engineering control, monitoring and diagnostics.	Short term	Horizontal
New EAF technologies, e.g. shaft, twin shaft, central shaft, twin shell, AC/DC, electrode number and design.	Medium term	Horizontal and vertical
Direct feed systems.	Medium term	Horizontal and vertical
Improved dust collection and re-use.	Medium term	Horizontal and vertical

Secondary steelmaking

Topic	Time Scale	Possible Partners
Improved ladle slag conditioning.	Short term	Horizontal
Further development of inclusion engineering techniques to assist in removal and eliminate non-ductile residual inclusions.	Short term	Horizontal
Improved and novel analytical techniques for liquid and solid steels, and ladle slags.	Short term	Horizontal
Increasing application of IT, expert systems, soft computing technologies for process and engineering control, monitoring and diagnostics.	Short term	Horizontal

Topic	Time Scale	Possible Partners
New technologies for secondary steelmaking for high quality and cleaner steels.	Short term	Horizontal
Improved availability of secondary steelmaking units.	Short term	Horizontal and vertical
Improved scheduling and logistic systems to extend flexibility of feeding downstream casters.	Short term	Horizontal
Development of process routes for wider ranges of high added value steel grades.	Medium term	Horizontal
Extended service life of secondary steelmaking equipment and ladles.	Medium term	Horizontal and vertical
Multi-functional plant combining various process stages (e.g. alloying, reheating, desulphurisation, degassing, cleaning, stirring, injection) at a single station.	Medium term	Horizontal and vertical
Improved technologies for removal and control of residual levels of tramp elements (Cu, Sn, Ti, etc.) in liquid steel.	Medium term	Horizontal
Improved Vacuum Melting and Remelting, and Electro-slag Remelting technologies for ultra-clean ingots that weigh up to 12-13 tonnes for manufacturing aircraft engine components and large power plant components.	Medium term	Horizontal and vertical

Project proposals for improved casting operations

Topic	Time Scale	Possible Partners
Further development of tundish technologies to ensure consistency of composition, temperature and flow of liquid steel and flexibility of scheduling of different grades in sequence casts.	Short term	Horizontal
Improved systems for robotic tundish changes.	Short term	Horizontal and vertical
Use of enhanced computing power to improve quality by precise control of casting speed and soft reduction and provide flexibility of scheduling of different grades in sequence casts.	Short term	Horizontal
Development of real time prediction of stresses, strains and final point of solidification for product quality prediction.	Short term	Horizontal
Development of powders for higher speed casting.	Short term	Horizontal and vertical
New operating practices, sensors and devices to avoid core segregation.	Short term	Horizontal
Technologies to achieve internal cleanness (freedom from non-metallic inclusions) in slabs and blooms required for high performance applications.	Short term	Horizontal
New developments for submerged entry nozzles.	Medium term	Horizontal
New sensors for direct flow control and direct cleanness measurement in the melt.	Medium term	Horizontal
Electromagnetic devices to influence fluid flow and solidification.	Medium term	Horizontal

Topic	Time Scale	Possible Partners
Development of an intelligent mould with flow pattern measurement and electromagnetic control.	Medium term	Horizontal
Re-design of below mould cooling section.	Medium term	Horizontal and vertical
Improved secondary cooling support roll systems to improve reliability and extend life cycle.	Medium term	Horizontal and vertical

Project proposals for improved reheating and rolling operations

Reheat Furnaces

Topic	Time Scale	Possible Partners
Improved feedback and feed forward control of reheating furnaces supplying hot rolling mills.	Short term	Horizontal
Increased performance and productivity for heat-treatment and reheating by improved heating and control technologies, e.g. further developments in sequential firing, regenerative air preheat, oxy-fuel technology, flame radiation increases.	Short term	Horizontal
Improved instrumentation and control systems for heating and process gas utilisation, e.g. rapid detection of changes in gas quality.	Short term	Horizontal
Development of detailed process models for heat-treatment.	Short term	Horizontal
Radical skid system designs.	Medium term	Horizontal and vertical
Development of variable shape furnaces to deal with different production rates.	Medium term	Horizontal and vertical

Hot rolling - General

Topic	Time Scale	Possible Partners
Through yield optimisation to reduce raw material per delivered product, e.g. optimisation of intermediate transfer slab/bar dimensions, particularly for plates and sections.	Short term	Horizontal
New techniques for rolling schedule development, linked to order acceptance criteria to maximise just in time delivery and earnings per order.	Short term	Horizontal

Hot rolling -Sections and long products

Topic	Time Scale	Possible Partners
Improved understanding of section rolling processes, e.g. contact region between roll and product, effect of lubrication, cooling.	Short term	Horizontal
Use of FEM supported by simpler models for control algorithms.	Short term	Horizontal
Achieving required final properties from beam blanks with reduced rolling reductions.	Short term	Horizontal

Topic	Time Scale	Possible Partners
Reduction of surface decarburisation during rolling.	Short term	Horizontal
Improved technologies for rolling of rails and special sections – improved roll design and rolling schedules.	Short term	Horizontal
New rolling and treatment techniques for high strength and wear resistant rails with good roll contact fatigue properties.	Short term	Horizontal
Improved technologies for rolling of tubes, rods and wires.	Short term	Horizontal
Improved control of ancillary processes: - pre-rolling: descaling, scarfing, and related fume control - post rolling: cooling, cutting (sawing, shearing, and burning).	Short term	Horizontal and vertical

Rolling - Flat Products

Strip - wide and narrow

Topic	Time Scale	Possible Partners
Improved control of coil head end and tail end shape and properties - by application of improved off-line and on-line control models including hybrid modelling - linking off-line model results with on-line control models.	Short term	Horizontal
Improved ROT control to increase flexibility of range of end user properties achieved from limited compositions.	Short term	Horizontal
Techniques for temporary surface protection to prevent oxidation.	Short term	Horizontal
Further development of rolling practices for production of high-strength steels (dual-phase, TRIP, etc.).	Short term	Horizontal
Optimise appropriate hot-strip mill control technologies (geometry and shape) and appropriate surface conditioning (surface roughness and finish) for flexible rolling schedules.	Medium term	Horizontal
Define and model new metallurgical/thermal routes to manufacture high-strength steels (up to 1000 MPa).	Medium term	Horizontal
Develop new grades of plate steels for structural, marine and pipeline applications, e.g. with X100 and X150 properties.	Medium term	Horizontal
Further development of rolling technologies for rolling, cooling and coiling of hot rolled coil below 1 mm thickness.	Medium term	Horizontal and vertical

Plate

Topic	Time Scale	Possible Partners
Shearing and cutting, optimisation of mother/daughter plate cutting schedules.	Short term	Horizontal
Plate normalisation, improved equipment for quenching rate vs. time optimisation.	Short term	Horizontal and vertical
Improved technologies for control of hydrogen.	Medium term	Horizontal

Topic	Time Scale	Possible Partners
Hot levelling and cold levelling of plate free of internal stress distribution after processing.	Medium term	Horizontal and vertical

Stainless

Topic	Time Scale	Possible Partners
Steckel mill technology development to overcome problems with roll life, surface quality, coil box operation.	Medium term	Horizontal and vertical
Development of new integrated lines (rolling, annealing, tempering and levelling).	Medium term	Horizontal and vertical

<u>Project proposals for improved finishing and coating operations</u>

Long products

Topic	Time Scale	Possible Partners
Reduction in cooling bank space by improved cooling technologies.	Short term	Horizontal
Improved handling after rolling, including noise reduction.	Medium term	Horizontal
New technologies for coating of sections and beams.	Medium term	Horizontal
Restrained cooling to prevent distortion.	Medium term	Horizontal

Flat products

Topic	Time Scale	Possible Partners
Improved hot sheet finishing technologies for shape, residual stress and surface quality control, particularly for hot rolled coil below 1.2 mm in thickness.	Short term	Horizontal
Improved cold rolling lubrication for increasing the productivity and surface quality of products.	Short term	Horizontal
Reduction of waste oil by optimising rolling oils and increasing the ratio of regenerated oil.	Short term	Horizontal
Develop finishing processes to improve surface characteristics for adhesive bonding.	Short term	Horizontal
Optimisation of parameters of conventional lines of hot-dip coating (galvanised and aluminised) for obtaining products with better properties (cosmetic appearance, weldability, forming, corrosion resistance, etc.) and sizing regularity (thickness, flatness) at the same or even at lower production cost.	Short term	Horizontal
Optimisation of parameters of conventional electro-coating lines (zinc, tin and ECCS) for obtaining products with better properties (cosmetic appearance, weldability, forming, corrosion resistance, etc.) and sizing regularity (thickness, flatness) at the same or even at lower production cost.	Short term	Horizontal
Increase efficiency of both heating and cooling processes of annealing by appropriate technology.	Medium term	Horizontal and vertical

Topic	Time Scale	Possible Partners
Adaptation of production processes to the new metallurgical routes required for new products.	Medium term	Horizontal

3.2.1.2 Supporting technologies for improved understanding of process technology and its influence on product quality

Project proposals for information technology

Developments in information technology are required to enable through-process integration of order receipt, production scheduling, manufacturing, logistics and distribution to meet end user customer requirements for 'just-in-time' full order delivery.

Topic	Time Scale	Possible Partners
Support for process operators using artificial intelligence (knowledge-based systems, fuzzy-logic control, hybrid systems).	Short term	Horizontal
Further developments in self-learning control systems (neural networks).	Short term	Horizontal
Optimisation of material flow and optimisation of assignments through the use of constraint programming technologies.	Short term	Horizontal
Integration of simulation technologies for process routes.	Medium term	Horizontal
Exploitation of process data in order to improve on-line product quality control: data visualisation, interpretation tools using virtual reality, data-mining technologies and advanced network services.	Medium term	Horizontal
Improvement of worker skills by knowledge management: development of methods and tools for the systematisation of knowledge engineering, use of Intranet technologies to share knowledge, etc.	Medium term	Horizontal
Effective use of expert systems to capture process knowledge and experience as steel producers continue to de-layer and down-size their organisations.	Medium term	Horizontal
Object-oriented technologies and new user-interface technologies assistance in customer relations using multimedia and INTERNET technologies to present information on products, intelligent agents, and data mining technologies.	Medium term	Horizontal

Project proposals for generic tools for process development

Topic	Time Scale	Possible Partners
Physical modelling of fluid multi-phase systems assisted by automated measurements for transient flows e.g. Laser-Doppler technologies, image analysis.	Short term	Horizontal

Topic	Time Scale	Possible Partners
Numerical modelling of heat transfer and fluid flow in multi-phase systems for stationary and non-stationary conditions supported by much faster computing processing e.g. parallel computing and other CPU developments.	Short term	Horizontal
Developments for combining mass transfer, heat transfer, thermodynamics and fluid flow in multi-phase multi-component systems at high temperatures.	Medium term	Horizontal
Further developments in obtaining reliable thermodynamic equilibrium data for complex systems arising in steelmaking processing, finishing and coating.	Medium term	Horizontal

Project proposals for measurement, non-destructive testing, and automation

Topic	Time Scale	Possible Partners
Drastic improvement in the sensitivity of NDT sensors for the characterisation of steel cleanliness as well as the detection of surface and subcutaneous defects (on-line inspection).	Medium term	Horizontal
Development of measurement and NDT to check on-line the homogeneity of characteristics of manufactured products as regards metallurgical and surface properties.	Medium term	Horizontal
Calibration and measurements and NDT systems corresponding to more and more severe quality-assurance requirements.	Medium term	Horizontal
Development of data processing methods integrating simultaneously process knowledge, the physics of sensors and a priori interaction models, allowing the process control system to adapt to real-time constraints.	Medium term	Horizontal
Implementation all along the steel production route of a relevant net of methods and sensors dedicated to process control and product-quality evaluation, particularly analysis of trace elements, detection of NMIs below 15 micrometres, and residual stress distribution in rolled products.	Medium term	Horizontal
Development of new sensors and sensor systems suited to the determination of global dimensions and shape measurements of large-dimension products as plates, flat and long products, particularly re-entrant surfaces in long product cross sections, etc.	Medium term	Horizontal
New technologies for high-speed data transmission from sensors over long distances in noisy (electromagnetic and physical) environments at high temperatures.	Medium term	Horizontal and vertical
On-line process simulation using sensor outputs for quality prediction during processing.	Medium term	Horizontal

3.2.1.3 Supporting technologies for improved condition and availability of process equipment and its influence on product quality

Project proposals for improved engineering procedures

Topic	**Time Scale**	**Possible Partners**
Application of Fault Detection and Isolation (FDI) techniques to indicate early warning of failure of components i.e. intelligent plant condition monitoring linked to advanced communications system, e.g. field bus technology.	Short term	Horizontal
Use of virtual reality tools for design, construction and training to ensure rapid introduction of new steel works facilities.	Short term	Horizontal and vertical
Modelling of existing plant to identify where modifications will give significant life extension, also to identify and minimise risk of possible environmental problems.	Medium term	Horizontal
Application of 'Failure Mode and Effects Analysis (FMEA): Involves further extension of risk analysis techniques linked with process simulation to identify weak links and critical components, based on maintenance history, failure mode analysis and stress analysis, i.e. specialised form of data mining.	Medium term	Horizontal
Industrial plants diagnosis using related Artificial Intelligence (AI) technologies e.g. expert systems, neural networks, case-based reasoning, process data visualisation and interpretation tools.	Medium term	Horizontal
Further development of hydraulic system fluids and components to minimise environmental impact of leaks and spillage.	Medium term	Horizontal
Development of hydraulic fluids based on water instead of oils, including solution of the problems caused by cavitation corrosion and differences in damping coefficients.	Medium term	Horizontal and vertical
Improved tribology for heavily loaded bearings.	Medium term	Horizontal and vertical
Improved drive systems for work rolls and stock transfer rolls.	Medium term	Horizontal and vertical
The robotisation of hazardous/unpleasant/awkward steelmaking and rolling operations to improve operator working conditions.	Medium term	Horizontal and vertical
Computer aided design to reduce equipment supplier lead times.	Medium term	Horizontal and vertical
Use of advanced engineering tools to improve commissioning of new facilities.	Long term	Horizontal and vertical

Project proposals for improved refractories

Topic	Time Scale	Possible Partners
Renewable surface treatments for preventing skulling by liquid metal on reaction vessels and transport systems, e.g. lances, BOF vessel cones, and ladles.	Short term	Horizontal
Development of refractories for new hot metal production routes based on DRI processing.	Short term	Horizontal and vertical
Further developments in refractories to extend vessel and furnace service life and minimise environmental impact.	Medium term	Horizontal and vertical
Development of new refractory design concepts based on new refractory material developments.	Medium term	Horizontal and vertical
Further developments in refractory hollow-ware to extend service life and minimise environmental impact, including multi-layer systems to prevent crack propagation, reduce wear rates and improve thermal shock resistance.	Medium term	Horizontal and vertical
Use of non-toxic materials in refractories – further development of materials to replace chromium oxide, and alternative fibre insulating materials, particularly for large reheating furnaces and continuous annealing lines.	Medium term	Horizontal and vertical

3.2.1.4 Improved technologies for production planning and control with integrated quality assurance

Project proposals

Topic	Time Scale	Possible Partners
Use of advanced statistical techniques for PCM linked to improved control systems to define and monitor changes over time of plant capability for making particular qualities of products and to optimise production schedules to maximise plant life and availability.	Short term	Horizontal
Design of interfaces with neighbouring systems, especially for quality assurance.	Short term	Horizontal
New and efficient methods for process and labour organisation, with particular attention to safe working procedures.	Short term	Horizontal
Development of standardised solutions for modular standard software embracing all the functions of technical order scheduling.	Medium term	Horizontal
Cost-optimising the scheduling of multiple steelmaking stations.	Medium term	Horizontal
Development of multi-use semi-finished grades of steel to reduce stocks of work-in-hand.	Medium term	Horizontal
Development of new technologies for product tracking and attachment of quality data to delivered product.	Medium term	Horizontal
Further development of direct electronic communications with suppliers and customers for orders and invoicing.	Medium term	Horizontal and vertical

Topic	Time Scale	Possible Partners
Development of technologies to convert an enquiry/order/specification from a customer into a detailed steelmaking, rolling, finishing and heat treatment process route linked electronically to process control systems to ensure the required micro-structure and end user properties are achieved.	Long term	Horizontal and vertical

3.2.2 Efficient production facilities, new steelmaking routes

3.2.2.1 Project proposals for improved raw materials input and processing

Project proposals for new ore-reduction processes

The priority is the development of alternative ore reduction process based on coal. In the longer term, it will be necessary to make further developments in alternative technologies for extracting iron from ore fines, concentrates and low grade iron bearing materials.

Topic	Time Scale	Possible Partners
Further development of coal-based smelting reduction processes.	Medium term	Horizontal and vertical
Further development of coal-based direct-reduction processes.	Medium term	Horizontal and vertical
Development of coal-based melting processes for DRI and scrap.	Medium term	Horizontal and vertical
Technologies to produce virgin iron units from ores based on hydrogen reduction.	Long term	Horizontal and vertical
Chemical leaching of iron from ore and recycled scrap followed by electrolysis to generate thin iron foils.	Long term	Horizontal and vertical
Biological leaching of iron from low-grade ore deposits followed by electrolysis to generate thin iron foils.	Long term	Horizontal and vertical

Project proposals for the blast furnace hot metal route

The main emphasis will be on new technologies to reduce the environmental impact of blast furnace operation, including replacing coke with injected coal and other reducing agents, replacing sinter with injected fine ore or metallised materials, and reducing slag and off gas volumes. In the longer term, alternative coke making technologies will be required.

Topic	Time Scale	Possible Partners
New technologies for environmentally friendly by-products management e.g. slag granulation and water cleaning.	Short term	Horizontal and vertical
Faster coking rates.	Medium term	Horizontal and vertical
Recirculation of blast furnace top gas.	Medium term	Horizontal and vertical

Topic	Time Scale	Possible Partners
New methods to increase the usage of process gases, e.g. gas cleaning, gas separation.	Medium term	Horizontal and vertical
Coal gasification for production of reduction gas.	Medium term	Horizontal and vertical
Further development of technologies for injecting fine ores or metallised materials.	Medium term	Horizontal and vertical
Two-product coke making (coke and gas).	Long term	Horizontal and vertical
Continuous working coke making facilities.	Long term	Horizontal and vertical
Blast furnace operation without nitrogen.	Long term	Horizontal and vertical

Project proposals for improving electric arc furnace operations

Topic	Time Scale	Possible Partners
Advanced shredding and scrap treatment technologies for producing a sustainable high-quality charge material for steels for demanding applications e.g. by new shredding, sorting and classification technologies.	Medium term	Horizontal and vertical
New technologies for continuous charging, charge preheating, airtight operation, arc voltage and electrode control in the EAF.	Medium term	Horizontal and vertical
New ladle refining technologies for the EAF to produce steels for demanding applications, e.g. deep drawing, surface-quality critical grades and tool steels.	Medium term	Horizontal and vertical

3.2.2.2 Project proposals for new steelmaking processes

Topic	Time Scale	Possible Partners
Development of continuous steelmaking technology for refining liquid hot metal from iron ore based route.	Long term	Horizontal and vertical
Development of continuous steelmaking technology based on recycled scrap melting.	Long term	Horizontal and vertical

3.2.2.3 Project proposals for casting and hot rolling

Project proposals for Flat Products

Topic	Time Scale	Possible Partners
Further development of thin-slab casting and direct rolling to improve productivity and quality and to accommodate a variety of steel grades.	Medium term	Horizontal and vertical
Further development of direct strip casting and rolling to produce strip grades for demanding applications at high productivity.	Medium term	Horizontal and vertical

Topic	Time Scale	Possible Partners
Further development of thin strip casting by the twin-roll process for stainless steel strip production as well as for the casting of silicon and medium carbon steel grades for direct application.	Medium term	Horizontal and vertical
Further development of hot rolling technologies and hot rolled coil finishing technologies for thin-gauge strip steels (less than 1 mm), suitable for replacing lower quality cold rolled grades.	Medium term	Horizontal and vertical
Further development of ferritic rolling technologies.	Medium term	Horizontal
Direct rolling of thin slab to retain surface and metallurgical properties for direct application of coiled plate products - optimisation of thin cast slab thickness.	Medium term	Horizontal and vertical
Direct finishing and coating (e.g. hot dip galvanising/aluminising) of near net shape cast and direct rolled strip.	Medium term	Horizontal and vertical

<u>Project proposals for Long Products</u>

Topic	Time Scale	Possible Partners
Hot charging of as cast blooms and billets for direct rolling of long products with defect free surface.	Short term	Horizontal and vertical
Further development of technologies for casting of near net shape long products.	Short term	Horizontal
High speed casting of semi-finished products with satisfactory product properties.	Short term	Horizontal and vertical
High speed continuous casting of small diameter bars.	Short term	Horizontal and vertical
Reduction of core segregation level by special means (stirring, rapid cooling, liquid core reduction).	Short term	Horizontal
Improved control surface properties (oxide layers for corrosion resistance, surface roughness and finish).	Short term	Horizontal
Improved control of cross-sectional dimensions and straightness, particularly for direct rolled products.	Short term	Horizontal
Development of rolling practices to achieve extra strength by ultra-fine (sub- micron) grain size.	Medium term	Horizontal
Elimination of intermediate cold processing steps (e.g. heat treatment, quenching and tempering process on wire rods for cold heading).	Medium term	Horizontal and vertical
Development of direct coating technologies (galvanising and aluminising) for direct application of cast long products.	Medium term	Horizontal and vertical

<u>Project proposals for improved heating and cooling technologies</u>

The need for high productivity, space saving, rational use of energy will require more and more new technologies for efficient heating and cooling technologies.

Topic	Time Scale	Possible Partners
Development of cooling technologies: modelling of the cooling capability, development of new cooling systems, particularly for rapid cooling after hot rolling.	Short term	Horizontal
Development of flexible heating technologies: contactless heating by high-power density, e.g. induction and infrared heating.	Medium term	Horizontal and vertical
Development of adapted technologies for high-power density contact heating, e.g. contact resistance, new power sources (i.e. high-current density/low voltage), non-oxidising atmospheres, etc.	Medium term	Horizontal and vertical

3.2.2.4 Cold rolling and finishing

As increasingly sophisticated surface properties are demanded by the market for both carbon and stainless steels, surface cleaning and conditioning at different steps of the production process is of great importance. New technologies are needed for the elimination of surface defects, improved adhesion of subsequent conversion treatments and surface coatings. These will require new methods for the removal of oxide scales by gas reactions or by pickling, and for degreasing and surface conditioning before any subsequent treatment.

Project proposals

Topic	Time Scale	Possible Partners
Develop environmentally friendly electrolytes for pickling and cleaning treatments.	Short term	Horizontal
Development of high-strength grades (dual phase) having extra deep drawing quality by higher cold reduction ratio.	Short term	Horizontal
Development of new grades of more alloyed weldable steels compatible with coupled or continuous lines.	Short term	Horizontal
Development of new grades of high strength galvanised steels.	Short term	Horizontal
Cost reduction of electrolytic coating (tinplating, tin-free).	Short term	Horizontal
Further development of high-current density cells; use of pulsed current.	Short term	Horizontal and vertical
Developments of finishing treatments, pre-phosphating treatments, dry films, thin organic coatings, etc.	Short term	Horizontal and vertical
Development of new thin organic coating for packaging to substitute for lacquers coatings.	Short term	Horizontal
Further development of rolling and forming processes for complex shaped sections.	Short term	Horizontal
Further development of finishing processes to ensure delivered products are free from residual stresses to meet requirements of subsequent fabrication using laser cutting and new precision forming and machining technologies.	Short term	Horizontal

Topic	Time Scale	Possible Partners
Develop new integrated routes combining surface conditioning and surface coating (metallic as well as organic).	Medium term	Horizontal and vertical
Direct application of near net shape cast long products.	Medium term	Horizontal
Increase the range of coated materials by appropriate technologies.	Medium term	Horizontal and vertical
Suppression of cleaning line before batch annealing in tinplate processing.	Medium term	Horizontal and vertical
New self-regulating surface treatment liquor systems for best surface quality without by-products, e.g. continuous biological degreasing and electro-dialysis pickling systems.	Medium/long term	Horizontal
Development of environmentally friendly flexible and shorter routes for surface treatments and coatings.	Medium/long term	Horizontal and vertical
Develop mechanical (ultrasonic) or physical (plasmas) treatments for scale removal and surface cleaning instead of chemical processes.	Medium/long term	Horizontal and vertical
Development of versatile annealing technologies and conception of high-temperature reactors adapted for obtaining both mechanical and surface properties for stainless and carbon steels.	Medium/long term	Horizontal and vertical

3.2.2.5 Development of component-product fabrication technologies

Steelmakers are more and more involved in close partnership with many manufacturing sectors, to develop new technologies for reducing time-to-market and fabrication costs for existing and new products.

Project proposals

Topic	Time Scale	Possible Partners
Pilot project to shorten time to start of production passenger car (concurrent engineering project of joint research between OEM, tool manufacturer and material supplier) and to make the introduction of new models more flexible.	Medium term	Horizontal
Development and application of numerical techniques for optimising product engineering and design low-cost tooling.	Short term	Horizontal
Development of low-cost, low-weight forming and assembling technologies (e.g. hydroforming technology, laser-welded blanks, etc.).	Short term	Horizontal
Development of numerical modelling of forming, forging, welding and machining processes, modelling of in-service performance, implementation of computer technical numerical simulations, implementation of forming technologies (surface characteristics and lubrication conditions).	Short term	Horizontal

Topic	Time Scale	Possible Partners
Rapid prototyping for formed and forged components.	Short term	Horizontal
Development of rheo-casting for steel components e.g. nodes for hydroformed space frames.	Medium term	Horizontal

3.2.3 Protection of the environment – Increasing safety

3.2.3.1 Proposals for process improvements to reduce emissions

Topic	Time Scale	Possible Partners
Improved methods for comparing the environmental impact of different process options.	Short term	Horizontal
Measures to prevent fugitive emissions during coal/coke storage and handling and coal preparation.	Short term	Horizontal and vertical
Improved methods for coke-oven gas cleaning.	Short term	Horizontal and vertical
Process-integrated or end of pipe measures to reduce NO_x emissions due to coke-oven firing.	Short term	Horizontal and vertical
Investigation into the reliability of and reasons for failure of biological treatment of coke-oven effluents.	Short term	Horizontal
Reduction of NO_x and other air pollutants during sintering and reheating.	Short term	Horizontal and vertical
Investigation into the best overall solution for control and minimisation of sinter-plant emissions.	Short term	Horizontal
Reduction of air emissions during tapping from blast furnaces, steelmaking furnaces, ladle treatment stations, and during casting.	Short term	Horizontal and vertical
Further development of highly efficient bag filters for dust collection.	Short term	Horizontal and vertical
Post-combustion or adsorptive technologies to prevent the emission of organic compounds.	Medium term	Horizontal and vertical
Measures for preventing emissions of dioxins, furans, and polycyclic hydrocarbons, preferably by preventing their formation.	Medium term	Horizontal
Elimination of total loss lubrication systems, particularly grease lubrication, with improved environmental consequences by replacement with different bearing designs - dry lubrication designs at end of current bearing lives.	Medium term	Horizontal and vertical
New technologies to reduce noise for use in buildings and with auxiliary equipment to keep the noise level as low as 45 dB (A) in the plant vicinity.	Medium term	Horizontal and vertical
Development of new technologies for in process dedusting.	Medium term	Horizontal and vertical

3.2.3.2 Project proposals for improved utilisation of off-gases

Topic	**Time Scale**	**Possible Partners**
Heat recovery by using off-gas (CO and H_2) post-combustion to pre-heat scrap for electric arc furnaces.	Short term	Horizontal and vertical
Development of improved technologies to reduce energy consumption and emissions, e.g. by regenerative air preheating or oxygen-fuel technology.	Short term	Horizontal and vertical
Improved electricity generation by BF and BOF gas recuperation and BF top-gas pressure recuperation.	Medium term	Horizontal and vertical

3.2.3.3 Project proposals for reduction of energy consumption

Topic	**Time Scale**	**Possible Partners**
New technologies to reduce energy consumption (kWh per liquid tonne steel and kWh per delivered tonne steel).	Short term	Horizontal
New technologies to increase productivity i.e. to reduce energy consumption per hour.	Short term	Horizontal
New technologies to reduce radiation losses from furnaces, e.g. by surrounding the electric arc furnace with columns of scrap.	Short term	Horizontal
New technologies to extend the partial replacement of electric energy with fossil fuel in electric arc furnaces.	Short term	Horizontal
New technologies to increase the charge of high-quality molten iron (pig iron and direct-reduced iron) into the furnace, in order to reduce electricity consumption, increase productivity and improve quality.	Short term	Horizontal
Developments for reduced energy consumption in electrolytic strip galvanising by modified electrode processes.	Medium term	Horizontal and vertical

3.2.3.4 Project proposals for finishing process improvements

Topic	**Time Scale**	**Possible Partners**
Substitute new electrolytes for coating (e.g. phenol-free electrolyte for tin-plating).	Short term	Horizontal
Develop chromium-free (hexavalent chromium must be avoided) electrolytes for surface passivation treatments, development of primers and tin-free plating.	Short term	Horizontal
Reduction of emission in the cold rolling and finishing processes.	Short term	Horizontal
Eliminate the use of volatile organic compounds (VOCs) in cold rolling and finishing processes by:		
Development of new curing technologies (by electron or radiation) to avoid any organic compound solvent emissions.	Short term	Horizontal and vertical
Development of new organic coating products (for example paint in powder form) in order to avoid any organic compound solvent emissions.	Short term	Horizontal and vertical

Topic	Time Scale	Possible Partners
Development of dry coating technologies for a wide range of coated product applications.	Medium term	Horizontal and vertical
New metallic alloy coating technologies to eliminate the use of electrolytes.	Medium term	Horizontal and vertical
Selective extraction of environmentally damaging components in electrolytes and finishing liquors prior to recycling.	Medium term	Horizontal and vertical

3.2.3.5 Project proposals for upgrading and recovery of waste materials generated inside the steelworks

Topic	Time Scale	Possible Partners
Minimise slag production in ironmaking and steelmaking.	Short term	Horizontal
Properties and potential uses of BOF and EAF slags.	Short term	Horizontal
Reduction in quantity and greater utilisation of EAF slags.	Short term	Horizontal
Further development of slag for various uses.	Short term	Horizontal
Use of XRF and microwave measurement technologies at hot end (improved blowing practices, recovery of Zn) and cold end (monitoring of residual emissions) of BOF fume collection systems.	Short term	Horizontal
Cost-effective methods for recovery/recycling of EAF dust.	Short term	Horizontal and vertical
Recycling of dusts, low grade scraps, organically and Zn coated steels.	Short term	Horizontal
Recycling waste from steelmaking processes into other steelmaking processes.	Short term	Horizontal
Extending the opportunities for by-product recycling and re-use.	Short term	Horizontal
New technologies for refractory recycling.	Short term	Horizontal and vertical
New technologies for conversion of dusts, sludge, pickling liquors and oils for recycling and re-use.	Medium term	Horizontal and vertical
Pyrometallurgical methods to smelt dust and sludge.	Medium term	Horizontal and vertical
Hydrometallurgical recovery of zinc, lead and iron from BOF and EAF dust.	Medium term	Horizontal and vertical
Reduction of water and oil in sludges from rolling mill cooling and lubrication systems.	Medium term	Horizontal
Improved technologies for injecting treated rolling mill sludges into blast furnaces.	Medium term	Horizontal and vertical
Upgrading of pickling liquors for re-cycling and re-utilisation.	Medium term	Horizontal
Recycling of electrolytes from electro-plating lines.	Medium term	Horizontal

3.2.3.6 Project proposals for upgrading and recovery of waste materials generated outside the steelworks

Topic	Time Scale	Possible Partners
Improved technologies for separation of non-ferrous materials from scrap and removal of metallic alloy coatings and organic coatings from scrap.	Short term	Horizontal and vertical
New technologies to control the copper, molybdenum and tin contents of scrap.	Medium term	Horizontal and vertical
Investigation of the environmental effects of the use of plastics as a BF injectant.	Medium term	Horizontal and vertical

3.3 Steel grades for demanding applications

3.3.1 Introduction

Efforts to conserve resources, save energy and protect the environment naturally lead to demands for light structures for structural components and finished products. The material steel with its, as yet, unexhausted potential for further development of its properties (e.g. improved strength and toughness) and its versatility when used in joined assemblies offers plenty of scope for particularly cost-effective solutions in light-weight construction. The excellent recyclability of steel must be utilised already at the design stage. Vehicle manufacture, high-rise steel structures, and pressure vessels are examples of the application of lightweight construction technologies.

As in the previous section, these research topics will require collaboration between steel companies and other organisations primarily involved in the development and application of the new technologies required. Time scales and possible partners outside the steel industry for the RTD topics are indicated. The definitions of these are given in the introduction to this chapter - section 3.1.

3.3.2 Construction and renovation of buildings

Project proposals

Topic	**Time Scale**	**Possible Partners**
Solutions for new designs of buildings for individual domestic dwellings and multi-storey domestic housing, particularly flexible modular pre-fabricated designs.	Short term	Horizontal and vertical
New fire-protection concepts and new solutions for fire safety in multi-storey domestic housing blocks.	Short term	Horizontal
New technologies to improve the performance of steel-sheet panels and composite sandwich panels for external cladding and internal partitioning.	Short term	Horizontal
Derivation of characteristic material parameters for forming higher strength carbon steel and stainless steel sheets as a basis for material and design simulations.	Short term	Horizontal
Development of special cables with high fatigue resistance for service lifts and innovative design concepts in high rise structures.	Short term	Horizontal
Development of novel section shapes for optimised structural efficiency.	Short term	Horizontal
New methods for joining steel for new housing construction, e.g. plug-and-socket joining, mechanical joining, adhesives, forming and/or lock-seaming.	Short term	Horizontal and vertical
New technologies to improve the corrosion resistance, ease of fabrication, joining and assembly, while reducing the end-use cost, for steels for building applications.	Short term	Horizontal
New technologies for the integration of services into the design and construction of steel intensive buildings, particularly commercial and industrial buildings.	Medium term	Horizontal and vertical

Topic	Time Scale	Possible Partners
New design concepts involving steel, and steel based composites, to enable commercial and industrial buildings to be re-used for different applications during their total life span, together with ease of recycling at final dismantling.	Medium term	Horizontal and vertical
A new technological system for industrial fabrication of domestic dwelling modules from steel in hybrid construction.	Medium term	Horizontal and vertical
Resource-conserving and cost-saving replacement of conventional building materials by new energy-saving use of steel in selected areas of house building.	Medium term	Horizontal and vertical
Further incorporation of 'smart materials' into steel intensive construction e.g. photovoltaic surfaces and moisture indicators.	Medium term	Horizontal and vertical
New technologies for exploiting steel as part of composite solutions for industrial buildings and civil projects.	Medium term	Horizontal and vertical
New applications of steel in foundations and building sub-structures including prevention of corrosion from soil interactions and biologically induced corrosion mechanisms.	Medium term	Horizontal and vertical
Life cycle assessment of buildings.	Medium term	Horizontal and vertical
New technologies for dismantling of buildings, and recovery of demolition wastes.	Long term	Horizontal and vertical

3.3.3 Construction of infrastructure

It will be necessary to develop steels with new or improved end use properties, to be applied in a new transport infrastructure with logistic interports, tunnels, harbours, etc. These new intermodality concepts will facilitate the exchange of goods between the different transport means like rail wagons, city trolleys, trucks, barges and ships.

Project proposals

Topic	Time Scale	Possible Partners
Improved grades of high-strength steel (500-2000 MPa) and weathering steels suitable for short-, medium-, and long-span bridges and tunnel linings.	Short term	Horizontal
Stainless steels with improved joint systems for water distribution systems and trouble free water treatment and storage equipment.	Short term	Horizontal
New applications of steel in foundations of civil engineering structures.	Short term	Horizontal
New technologies for prevention of corrosion from soil and marine interactions and biologically induced corrosion mechanisms for land, coastal and off shore structures.	Short term	Horizontal

3.3.4 Transport systems

Project proposals for the automotive sector

Steel has a major future role in developing vehicle technologies suitable for sustainable mobility of people and goods in urban environments.

Topic	Time Scale	Possible Partners
Development of new steels for lightweight construction.	Short term	Horizontal and vertical
Modelling of forming and prediction of in-use performance.	Short term	Horizontal and vertical
New technologies for large-scale flexible production of tailor welded steel blanks for lightweight car design concepts.	Short term	Horizontal and vertical
New techniques for joining new combinations of materials, hydroforming and lightweight chassis components.	Short term	Horizontal and vertical
Multi-layer steel sheet assemblies for new vehicle down weighting concepts.	Short term	Horizontal and vertical
Combined use of improved steel grades and advanced forming technology for the manufacture of complex car-body parts characterised by lightness and strength.	Short term	Horizontal and vertical
Development of tubular hydroforming for space frame and car-body components for increasing passive safety of the body and reducing fuel consumption.	Short term	Horizontal and vertical
Reduction of fabrication costs for forged components (near net shape, deformation ability, etc.) for transmission systems.	Short term	Horizontal and vertical
New technologies for large-scale flexible production of lightweight steel components for suspension and braking systems.	Short term	Horizontal and vertical
Application of steel-based composite components for noise and vibration reduction in vehicle and development of relevant joining techniques.	Short term	Horizontal and vertical
Development of new steel grades for ‘clean fuel’ tanks.	Medium term	Horizontal

Project proposals for the rail sector

New steel grades are required for new lightweight design concepts for future high-speed inter-city rail transport systems, with improved crash resistance, ride comfort and high resistance to wear over 30 years of high-speed operation.

Topic	Time Scale	Possible Partners
Development of new steel grades for lightweight carriage, wagon and trailer design concepts.	Short term	Horizontal
Development of new steel grades for rail tracks for improved high-speed rail links with high fatigue resistance, high strength and limited thermal expansion.	Short term	Horizontal and vertical
Development of new steel grades for wheels and suspension systems for high-speed trains.	Short term	Horizontal and vertical
New designs for efficient sound barriers to reduce the noise reaching surrounding inhabited areas, manufactured from sandwich steel sheets, once the strengths of the noise source are known.	Short term	Horizontal and vertical
Development of new steel grades for traction equipment in high-speed trains exhibiting very high power to weight ratio (around 1 kW/kg).	Medium term	Horizontal and vertical
Design and development of a new generation of ‘rail steel’ able to deform and harden simultaneously to absorb the energy of high-speed impacts (crashworthiness for high-speed trains), with high fatigue resistance, high strength and limited thermal expansion.	Medium term	Horizontal and vertical
Development of new steel based magnetic induction braking systems for high-speed trains.	Medium term	Horizontal and vertical
New design concepts exploiting steel properties for optimisation of ride comfort, integrating all factors from carriage design to ballast.	Medium term	Horizontal and vertical

Project proposals for the marine sector

Topic	Time Scale	Possible Partners
New or improved steels and advanced joining technologies to support new design concepts for fast ferries for medium-range transport services.	Short term	Horizontal and vertical
Development of advanced stainless alloys with high strength/toughness ratio, which defy temperature changes down to -160°C, for sub-zero gas carriers.	Short term	Horizontal
Development of high-quality line pipes and coatings suitable for reliable laying technologies of deep-sea pipe lines.	Short term	Horizontal and vertical
Improved high-strength steels for lightweight floating units to be used for cost-effective exploitation of offshore marginal fields.	Medium term	Horizontal and vertical

Project proposals for the aerospace sector:

The development of new special steel grades is required for the next generation of aircraft and spacecraft for components and sub-assemblies operating in extreme service conditions.

Topic	Time Scale	Possible Partners
Development of new steel grades for aircraft engines e.g. steels that remain hard and wear resistant at temperatures as high as 900°C and coated steel grades with high thermal shock resistance, wear resistance and structural stability.	Short term	Horizontal
Development of improved steel grades for extreme load-carrying components, e.g. landing gear supports, engine mountings, etc.	Short term	Horizontal
Development of improved steel grades for fasteners and bolts, particularly for space vehicles.	Short term	Horizontal

3.3.5 Advanced energy systems and services

Project proposals for competitive and clean production of energy from fossil fuels

The development of new special steel grades is required for the new technologies for clean production of energy from fossil fuels, capable of operating in extreme service conditions.

Topic	Time Scale	Possible Partners
Coal and gas fired power plants:		
Development of alloyed and super-alloyed steels (super-stainless steels) with 100 000-hour rupture strength of around 200 MPa at the operating temperature of 700°C to 750°C and steam pressure of around 400 bar; with excellent high and low cycle fatigue strength.	Medium term	Horizontal and vertical
Development of new solid solution strengthened alloys that do not suffer from embrittlement with high temperature exposure.	Medium term	Horizontal
Development of advanced ferritic steels for service at 650°C.	Medium term	Horizontal
Improvements to the long-term structural stability of power generation steels.	Medium term	Horizontal
New steel grades for turbine and generator shafts.	Medium term	Horizontal
Oil and gas technology:		
New steel grades for new refinery technologies.	Short term	Horizontal
New designs of new steel-based support systems for new catalysts that enable better thermal efficiencies and for membranes, which can be more efficient than traditional distillation.	Medium term	Horizontal
New designs of pressure vessels with improved hydrogen, creep and high temperature resistance.	Medium term	Horizontal
Oil and gas drilling and mining industries:		
New steel grades for new oil and gas extraction technologies.	Short term	Horizontal

Topic	Time Scale	Possible Partners
New techniques for prediction of in-use properties of different equipment (drill collars, drill pipe, kelly, flexible risers, etc.).	Short term	Horizontal and vertical

Project proposals for new and renewable sources of energy

Topic	Time Scale	Possible Partners
Fuel cells: Development of thin nickel clad stainless steel sheets able to withstand the 650°C operating temperatures inside the fuel cell.	Short term	Horizontal
Refuse-Derived Fuel (RDF): Existing materials (stainless steels and nickel-based alloys) will have to be modified, both in terms of mechanical properties and geometrical design in order to develop new combustion systems for steam temperatures of up to around 700°C.	Short term	Horizontal
Refuse-Derived Fuel (RDF): The generation of corrosive (sulphuric, high chloride or sulphide condensates) requires the development of steels with improve corrosion and oxidation resistance.	Short term	Horizontal

Project proposals for improved equipment for control of emissions

Topic	Time Scale	Possible Partners
Scrubbers: Development of new stainless steels for scrubbing sulphur-containing waste gases from coal, oil and gas burned in electric power plants.	Short term	Horizontal and vertical
Dust removal equipment: Development of steels with improved strength and electrical properties for more efficient electrostatic precipitators in removing dust from flue gases.	Short term	Horizontal and vertical
Biological treatment tower: Development of steels for biological treatment of wastewater containing cyanide, ammonia, or hydrocarbons. In a biological tower, the use of steel implies an extremely efficient utilisation of O_2 supplied with microbes and other substances to help the digestion of bacteria.	Medium term	Horizontal and vertical

3.3.6 Packaging and distribution networks

Project proposals for beverage cans

Topic	Time Scale	Possible Partners
Development of shaped cans: forming and durability of two pieces shaped cans.	Short term	Horizontal
Development of flexible and formable organic coatings.	Short term	Horizontal
Development of methods to obtain the surface aspect expected by the client for classical and shaped cans.	Short term	Horizontal and vertical

Project proposals for food cans

Topic	Time Scale	Possible Partners
Development of light-weight higher-quality steels, stronger and more dent-resistant, able to absorb more abuse in handling, shaping, filling, closing and more suitable for mass storage and long-distance shipping.	Short term	Horizontal
Development easy-to-open steel can ends with improved recovery and recycling potential.	Short term	Horizontal
New design concepts for weight reduction of easy-to-open cans.	Short term	Horizontal and vertical
New can designs to take advantage of developments in food sterilisation technologies.	Short term	Horizontal and vertical

3.3.7 Mechanical, manufacturing and chemical engineering

Project proposals

Topic	Time Scale	Possible Partners
Development of steel grades for power beam cutting and welding for all applications in this sector.	Short term	Horizontal
Development and use of high-strength steels for tank and pressure vessel construction.	Short term	Horizontal and vertical
Development of high-strength and high corrosion resistance stainless steels for storage and distribution of concentrated chemicals at high pressures and temperatures.	Short term	Horizontal
Development of low cost stainless steels for closed loop process water treatment plants.	Short term	Horizontal
Co-operation with constructors and welding material suppliers to develop more efficient and safer fabrication procedures and improve the weldability of new steels (high performance stainless steels and high strength steels).	Short term	Horizontal and vertical
Development of steels for high temperature applications in presence of gases (oxygen, hydrogen, nitrogen, sulphur, etc.) in furnaces, incinerators, process vessels and furnaces at high temperatures.	Short term	Horizontal and vertical
Development of steels with abrasion resistance and slide ability while maintaining weldability and ease of fabrication.	Short term	Horizontal
High speed steels: New alloys with no segregation will be developed to close the gap between HSS and cemented carbides without loosing the advantage of good toughness properties.	Short term	Horizontal
Cold-work tool steels: New grades with best combination of toughness, wear resistance and compression strength.	Short term	Horizontal

Topic	Time Scale	Possible Partners
Hot-work tool steels: New grades with improved toughness and strength for higher processing temperatures also combined with optimised heat conductivity.	Short term	Horizontal
Plastic-mould steels: Development of new grades with higher corrosion and wear resistance, best homogeneity and cleanliness for the processing of advanced and also more aggressive plastics.	Short term	Horizontal
High alloy carbon steel tools: Development and optimisation of cost effective spray casting technologies to ensure homogeneity and cleanliness.	Short term	Horizontal
Development of steels for high duty wear stresses under unlubricated conditions with high heat resistance for use in gear drives.	Medium term	Horizontal and vertical
Development of metallic coatings which are wear resistant or which enable low friction by phase transformation surface boundaries.	Medium term	Horizontal and vertical

3.3.8 Communication Infrastructure

Project proposals

Topic	Time Scale	Possible Partners
New ultra high strength steels for transmitter/receiver support towers.	Short term	Horizontal
New ultra long life pipe grades for cable and optic fibre distribution systems.	Short term	Horizontal
Development of specially conceived electrical steels for electromagnetic shielding able to reduce the background level to less than 1 milliGauss.	Short term	Horizontal
Improvement of the soft magnetic properties and continuous casting of ribbons of metallic glasses based on (Fe, Ni, Co) 75-80/(Bi, Si, P) 20-25 alloys.	Short term	Horizontal

3.3.9 Quantitative modelling of material behaviour

Evaluation of the effects of process stages on the properties and behaviour of materials can be carried out with increasing success with models based on a physical and chemical description of the microstructural processes. The confidence in the results of simulation models is mainly dependent on knowledge of the relationships between influencing parameters, which require substantial effort to determine experimentally. Only current developments in computers have made it possible to undertake the large volume of modelling required for simulation of material behaviour. This will include prediction not only of strength and ductility, but also toughness, fatigue, creep and wear. With the aid of models designed for a complete description of material behaviour, it is possible to optimise the production and use of a given material and develop innovative design solutions. Experimental and testing times can be reduced and the material can be more fully utilised as a result of improvements in through yields.

Project Proposals

Topic	Time Scale	Possible Partners
Determination of the relationships between process parameters and product properties in order to achieve an optimised material structure.	Short term	Horizontal
Influence of thermo-mechanical treatment on structural transformation and transformation induced stress.	Short term	Horizontal
Simulation of deformation in advanced/improved deep drawing, forging, welding and machining.	Short term	Horizontal
Simulation of internal high-pressure forming of steels.	Short term	Horizontal
Influence of innovative internal high-pressure forming on changes in material properties.	Short term	Horizontal
Simulation of superplastic forming of steels (die forging, deep drawing, stretch forming and blow forming operations).	Short term	Horizontal

4. Final Remarks

In a global economy in which the various sectors of activity are interdependent, the European steel industry has recognised the need for reconsideration of the conventional forms of production and innovation and of methods of management employed by companies. The reason is the pressure generated by the twin imperatives to increase competitiveness and continue to support sustainable growth.

Sustainable growth is a growth that lasts. A specific concern is that those who enjoy the fruits of economic development today may be making future generations worse off by excessively degrading the earth's resources. To ensure a sustainable growth, the current generations should meet their needs without compromising the ability of future generations to meet their own needs. Sustainable growth is a complex subject that involves not only environmental protection but also the efficient management of resources, including issues such economic prosperity, population growth and health.

Also the process of increasing the competitiveness is a very complex process. It relies on the capacity of businesses, industries, and regions exposed and remaining exposed to international competition to secure a relatively high return on the factors of production: capital and labour. It also depends on the ability of the industry to improve the way it responds to customer demands and expectations.

4.1 Steel and sustainable growth

Steel as a material has made and continues to make a major contribution to sustainable growth, the development of environmental protection, infrastructure and energy conservation systems. Steel products are environmentally friendly and are not only compatible with, but also critical to, the success of sustainable growth.

As a matter of fact, the following principles:

- Incorporation of risk assessment and cost/benefit analysis to identify the most cost-effective application of resources.
- Incorporation of innovative and progressive environmental management systems to minimise environmental impact.
- Incorporation of the fundamentals of efficient resource conservation and waste reduction, by recycling, recovery and re-use, into all elements of operations and products (scrap recycling, slag and oxide reuse, material conservation through yield improvements).
- Conservation and most efficient use of energy.

have led to the excellence in the operation of the steel industry, within the framework of sustainable growth.

In addition to growing recognition of the need to recycle a much higher fraction of materials, the ability of different materials to be returned to use began to be studied intensively. Among the material producers, steel producers have recognised explicitly the need to be able to separate components easily after use when designing products. Also thanks to its advantage in recycling, steel currently is and will remain in the future the material of choice for various applications.

4.2 Steel and competition among materials

The world production of steel has been substantially constant for the last 20 years. This means a growing steel consumption due to the success of yield management within steelmaking and steel application, and only a small share of replacement by other competitive materials. This is in agreement with the concept of intensity of use (defined as the amount or monetary value of a product per capita) going through a maximum. The rising world population means that the average use per capita world-wide has been going down during this period. Nevertheless, about 795 million annual tonnes of crude steel were produced in 1997 and world-wide capacity is much more than this.

By far the most widespread use of steel is for structural purposes, where the mechanical properties are of primary concern even though in some cases other properties also are essential, such as resistance to various forms of environmental attack.

Nevertheless, there are well-known methods to protect steel from deterioration in almost all environments, methods which include coating, galvanic protection, alloying, and chemical control of the steel's environment. By contrast, the more critical failures involving local structural collapse, which can be from mechanical as well as environmental causes, do not seem to reflect on the steel itself.

In many cases, the properties of a material per se cannot handle all the performance requirements. Materials with a low elastic modulus can be stiffened, strengthened, or toughened by inserting a modest amount of a strong material, e.g. steel reinforced concrete. For many years, companies have chosen these combinations entirely with regard to their effect on service performance. But the difficulties of recycling these composite materials recently have taken on more importance; much thought, not yet complete, has gone into this aspect. The relative competitiveness of materials will depend increasingly on their ability to perform in a system life cycle.

There has been some substitution of steel in parts of autos (by aluminium and plastics), containers (by aluminium, paper, and glass), and appliances (by plastics). The total volume of steel replaced is a small percentage, although the loss largely has been in the higher-priced grades. The volumes of hot- and cold-rolled steels produced and sold in the EU during the era spanning the period from the late 1970s to today either have remained substantially constant or have shown growth.

The competition to steel from other materials is reducing due to the trend away from simple substitution in a single part towards using the properties in new design concepts to facilitate the manufacture of the product by reducing the number of components. Each reduction in the number of components becomes more complex to achieve. To do this, steel suppliers will have to work very closely with product designers from the earliest stages to offer solutions that will ensure that their material will obtain maximum use.

The metallic materials often discussed as possible replacements for steel based on weight savings are aluminium, magnesium, and titanium. Their total annual production in the EU is nearly 4 million tonnes, less than 5 percent that of steel. Hence, if all the production of these three metals were used to replace steel, less than 5 percent of the steel market by weight would be lost.

But most of the production of these metals and alloys is dedicated already to specific applications in selected markets. Only a small portion would be available as a substitute for steel at a competitive price, in a wide range of other markets.

Companies producing these alternative metals will need to make huge investments to substantially increase the production. These investments are unlikely because of the high cost of capital equipment and energy needed to produce these alternative materials.

There is no apparent major threat to current annual world-wide steel consumption greater than a few percent fluctuations around a long-term upward trend, but there are no massive new or expanded markets to be expected in the short term. In the developing economies around the world, there is the potential for a dramatic increase in the demand for steel to improve the quality of life and to meet significant infrastructure needs. However the slow growth of per capita income and the lack of resources to commit enough public funds to make a big difference probably will delay a significant increase in the world wide demand for steel.

4.3 Steel and competition among manufacturing methods

Important to steel's future competitiveness also is the competition among manufacturing methods in the steel industry itself.

Today's highly developed blast furnaces/basic oxygen furnace (BF/BOF) route still account for 60% of world liquid steel production, by producing much more iron and consuming much less coke than they did even a few years ago. However, the impending environmental standards on cokemaking could constrain blast furnace output and offset the recent improvements in productivity (+25%) achieved thanks to the injection of more supplemental reducing agents, primarily pulverised coal and oil.

The Electric Arc Furnace (EAF) is increasingly being adopted world-wide and now accounts for around 33% of world steelmaking. The advent of thin slab casting technology compatible with the EAF and the emergence of mini-mills have begun to seriously challenge conventional BF/BOF steelmaking for carbon steels. Except for heavy sections such as rotor forgings and heavy beams, most, if not all, shapes currently used can be made by mini-mills. Near net shape casting closer to size is growing, with the emergence of 30 mm to 50 mm thick slabs. Producers are beginning to cast stainless steel strip at around 1 mm to 5 mm thickness; strip casting could extend to carbon sheet, even though this appears more difficult. The fraction of steel produced by these casters should grow as the technology and experience develops.

However, the mini-mills are limited by the availability and cost of high-quality, low-residual scrap and purchased electricity as well as by restrictions on the types and qualities of steel it can produce without access to virgin iron units at an acceptable cost. For these reasons, steelmakers are investigating new, direct methods of producing iron, both in solid form as a high-quality complement to scrap and in molten form as an alternative to iron from BF.

Thus, the choice of which technology to use for new capacity is not an easy one. The EAF route fed by scrap is favoured where scrap is cheap and readily available in quantity, cost and quality desired. In addition, the scale and range of products to be produced are also relevant considerations. The EAF route fed by direct reduced iron and hot briquetted iron (DRI/HBI) or iron carbide is favoured where scrap is not readily available, or at least not at the right price or quality, and iron ore and low price gas for DRI production are readily available. Low power costs are also an advantage as an EAF using DRI/HBI consumes more power compared to one using scrap. As a result, this route is mainly found in gas-rich developing countries. But new coal-based direct reduction and smelting reduction processes are emerging which can play an important role in the EU.

On the other hand, despite the high capital costs, the BF/BOF route can still be the route of choice where the demand is large, scrap is not available, iron ore and coal are available and electric power is not cheap.

An intra-industry competition still in its early stages is taking place between hot-rolled sheet and strip, where it is not easy to go much below 2 mm, and cold-rolled material that in many cases is less than 1 mm. Hot-rolled material can replace cold-rolled in some applications if the hot-rolled is 1 mm to 1.5 mm thick. This process is technically challenging, but it could lead to savings in materials costs that users would welcome for some applications.

Another factor important in intra-industry competition is the quality of the surface and the dimensional control of steel products offered to the customer. The relative importance of these clearly depends on the application. The surface appearance of an exposed automotive body panel is much more important than the appearance of an unexposed bracket holding a component beneath the hood. The uniformity in thickness across a sheet to be used in making blanks for high-speed production of containers is much more critical than that for the external shell of an appliance.

4.4 Steel as the material of choice in the future

Much of the progress made in the past could not have been possible without the crucial support of steel. The natural processes of further sustainable development of society (promoting the quality of life and health, creating new jobs, preserving the environment, satisfying the expectations of the citizens), and the prospects of creating new opportunities for the European industry as a whole to remain competitive word-wide, assign to the steel industry a special mission. The road map outlined in this document shows that this mission can be fulfilled thanks to the intrinsic properties of the material as well as to the innumerable properties steel can be given depending on the requirements.

Success in such a mission requires adequate resources and investments in R&D activities.