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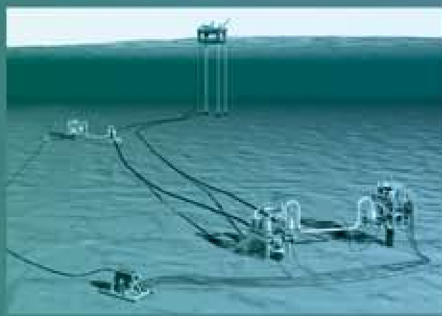

European Steel Technology Platform

From a Strategic Research Agenda to Implementation

ESTEP

A vision for the future of the steel sector

March 2006

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Directorate-General for Research
Directorate Industrial Technologies
Unit G/05 Research Fund for Coal and Steel

E-mail: rtd-steel@cec.eu.int
http://www.cordis.lu/coal-steel-rtd/home.html

This brochure has been produced thanks to the contribution of the European Confederation
of Iron and Steel Industries (www.eurofer.org)

European Steel Technology Platform

From a Strategic Research Agenda to implementation

Endorsed by the Steering Committee on 21st December 2005

A vision for the future of the steel sector

March 2006

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ISBN 92-79-01283-5

Printed in Belgium

PRINTED ON WHITE CHLORINE-FREE PAPER

On 15 of December 2004 the Strategic Research Agenda (SRA) of the European Steel Technology Platform (ESTEP) was endorsed by the Steering Committee. This document established by the Support group of ESTEP describes a way to implement the R&D programme of the SRA.

Priorities have been given within the different themes and R&D areas to the three industrial programmes of the platform with large societal impact:

- Safe, clean, cost-effective and low capital intensive technologies
- Rational use of energy resources and residues management
- Appealing steel solutions for end users

to which a transversal activity regarding human resources has been added:

- Attracting and securing qualified people to help meeting the steel sector's ambition

Private funding by the stakeholders and funding from different European, national and regional institutions is foreseen. However, the launch of a Joint Technology Initiative is envisaged and together with possible loans from the European Investment Bank, it will cover, where appropriate, both the pilot and demonstration and the industrialisation phase of the ULCOS (Ultra Low CO_2 Steelmaking) project.

The total budget for the first priorities amounts to around € 0.8 billion and their implementation should take place from 2007 to 2013 for the Research Fund for Coal and Steel (RFCS), the Seventh Framework Programme (FP7) and other programmes. On an annual basis, approximately 25% of the Research Fund for Coal and Steel programme should be devoted to programmes leading to the implementation of sectoral consensus-based R&D activities. The remaining part should be funded through the different relevant thematic sub-programmes of the next FP7 and national or regional R&D programmes.

The estimated total budget corresponding to the SRA activities amounts to around € 1.7 billion over 15 years.

The way to implement the SRA has been officially endorsed by the steering committee of the steel technology platform in December 2005

Governing bodies of the EU Steel Technology Platform

Two committees steer the Platform: a Steering Committee and a Support Group.

- **The Steering Committee.** Its missions are to:
- Define long-term priorities for R&D within the steel sector;
- Decide strategic R&D actions to support innovation;
- Approve a Strategic Research Agenda;
- Monitor and coordinate long-term actions.

In order to create an efficient and flexible body, as recommended both by the European Commission and the decision-makers of the steel industry, this Steering Committee comprises a limited number of high-level personalities (18), appropriately balanced.

- **The Support Group.** The size and composition of this body is also defined according to the technical priorities of the Platform. Its mission is to prepare a Strategic Research Agenda, to facilitate its implementation and the relevant follow-up. The support group constitutes the management level and the working body of the platform. Its participants are representatives of the main stakeholders.

Both lists of committee members are given in annexes.

Glossary

Acronyms	Meaning
AISI	American Iron and Steel Institute
APC	Advanced Process Control
BOF	Basic Oxygen Furnace
CC	Continuous Casting
CCVD	Combustion Chemical Vapour Deposition
CNG	Compressed natural Gas
CRA	Corrosion Resistant Alloy
CVD	Chemical Vapour Deposition
CSP	Compact Strip Production
DRI	Direct Reduced Iron
DSP	Direct Strip Production
EAF	Electric Arc Furnace
ESTEP	European Steel Technology Platform
FP 7	7th Framework Programme
GHG	Greenhouse Gases

GWP	Global Warming Potential
HBI	Hot Briquetted Iron
HRM	Human Resources Management
HSLA	High Strength Low Alloyed Steels
HSS	High Strength Steels
HTHP	High Temperature High Pressure
IGCC	Integrated Gas and Coal Combustion
IISI	International Iron and Steel Institute
IPTS	Institute for Prospective Technological Studies
ISE	In Situ Expansion
ISP	In line Strip Production
JRC	Joint Research Centre
LCA	Life Cycle Assessment
LCIA	Life Cycle Impact Assessment
LNG	Liquid Natural Gas
MFA	Material Flow Analysis
OCTG	Oil Country Tubular Goods
OPC	Open Process Communication
PVD	Physical Vapor Deposition
RFCS	Research Fund for Coal and Steel
SME	Small and Medium Enterprises
SRA	Strategic Research Agenda
TCO	Total Cost of Ownership
TIME	Top Industrial Manager for Europe
Thermo Calc	Thermodynamic Calculation
TMR	Total Material Requirement
TPM	Total Productive Maintenance
TQM	Total Quality Management
TRIP	Transformation Induced Plasticity
TTR	Top-Tension-Riser
TWIP	Twinning induced Plasticity
ULCOS	Ultra Low CO_2 Steel Making

Abstract

This document describes the way to implement the updated version of the R&D programmes of the ESTEP's Strategic Research Agenda (Vision 2030), which was officially launched on 12 of March 2004. It offers a global vision on the innovation and R&D initiatives which will lead to the achievement of the objectives identified in the frame of a sustainable leadership of the steel sector in the coming decades.

This updated version endorsed by the Steering Committee on 7 of July 2005 includes a detailed description on how the steel sector intends to implement its Strategic Research Agenda which was adopted by the Steering Committee of ESTEP on 15 of December 2004 as well as a new chapter on how to promote steel solutions for end users in the energy sector which was announced in the former version.

The ambition of the European steel industry is to maintain and reinforce a global leadership, which is both sustainable and competitive, given the rapid development of this industry in other parts of the world, notably Asia.

To meet the strategic objectives of the European Steel Technology Platform, in March 2004, the Group of Personalities decided to launch a determined, long-term and structured R&D action.

Six working groups involving around 110 people and corresponding to the 4 pillars of the sustainable development framework of the Platform have been set up (profit, partners involving both automotive, construction and energy sectors, planet and people) and have developed three large and complementary R&D industrial programmes which will have a large societal impact, each of them encompassing several R&D themes and research areas.

Three industrial programmes with large societal impact are proposed:

- Safe, clean, cost-effective and low capital intensive technologies
- Rational use of energy resources and residues management
- Appealing steel solutions for end users

Together they aim to play a major role in boosting competitiveness, economic growth and, as a result, future employment in Europe. The corresponding R&D themes and areas that have been identified in these programmes are making an important contribution to the sustainable development approach.

The European steel sector constantly addresses the challenge of meeting customers' demands for a broad variety of ever more sophisticated high-performance materials. To meet these needs, direct partnerships between steel producers and their immediate customers are a vital requirement. Such collaboration is a major feature of new product development in the steel industry and an essential element in the promotion of steel use. In the framework of this Strategic Research Agenda, the automotive, construction and energy sectors are regarded as priorities.

Protecting the environment (greenhouse gas emissions and more particularly CO_2 emissions) and increasing energy efficiency both constitute major transversal issues in the sphere of the R&D programmes that are proposed. Security and safety represent the third very important objective to be addressed, not only in the relevant industries but also in customers' every day lives as users of steel solutions (cars, buildings, energy production and transport, etc.) by developing new intelligent and safer steel solutions.

A major transversal theme regarding the human resources aspects has also been taken into consideration (attracting and securing qualified people to help meet the steel sector ambition). In this respect:

- A large European network (T.I.M.E, 47 universities), involved in education, training, communication and dissemination activities has been identified among the stakeholders of the EU steel technology platform. This network should play a leading role in analysing how the education system could meet the future requirements for qualified people in the European steel industry, and in devising effective approaches to address its anticipated shortcomings.
- Human resources, as the holders of a company's core competencies, represent a key asset that should be fully optimised. A survey of the steps taken by European steel producers in terms of change management and progression towards "knowledge organisations", leading to exchanges of best practices, should significantly contribute to such optimisation process.

The European steel industry has already met the challenge of lowering CO_2 emissions by creating a consortium of industries and research organisations that has taken up the mission of developing breakthrough processes, the ULCOS (Ultra Low CO_2 Steelmaking) consortium.

This large-scale consortium (48 European participants), which was set up in the spirit of a joint initiative in 2004, plans to develop a breakthrough steelmaking process that has the potential of meeting the target of drastically reducing greenhouse gas emissions beyond 2020. The full development of the process, from basic concept to fully-fledged industrial implementation, would cover both the medium and long term and consist of a number of consecutive projects.

Breakthrough technologies must be developed to achieve the technological advances of the three large industrial programmes of the platform. A critical mass of both skills and financial resources is necessary to meet the challenges of this long term ambition.

ESTEP will further integrate and broaden the scope of the European R&D partnership built in the framework of the ECSC Treaty (more than 8,000 researchers) and the Framework Programmes. Indeed it will constitute broad partnerships involving the whole European steel industry, its suppliers and customers (automotive industry and construction sector and the energy sector), SMEs, private and public research organisations, public authorities and representatives of trade unions.

Private funding by the stakeholders and funding from different European, national and regional institutions is foreseen. However, the launch of a Joint Technology Initiative is envisaged and together with possible loans from the European Investment Bank, it will cover, where appropriate both the pilot and demonstration and the industrialisation phase of the ULCOS project.

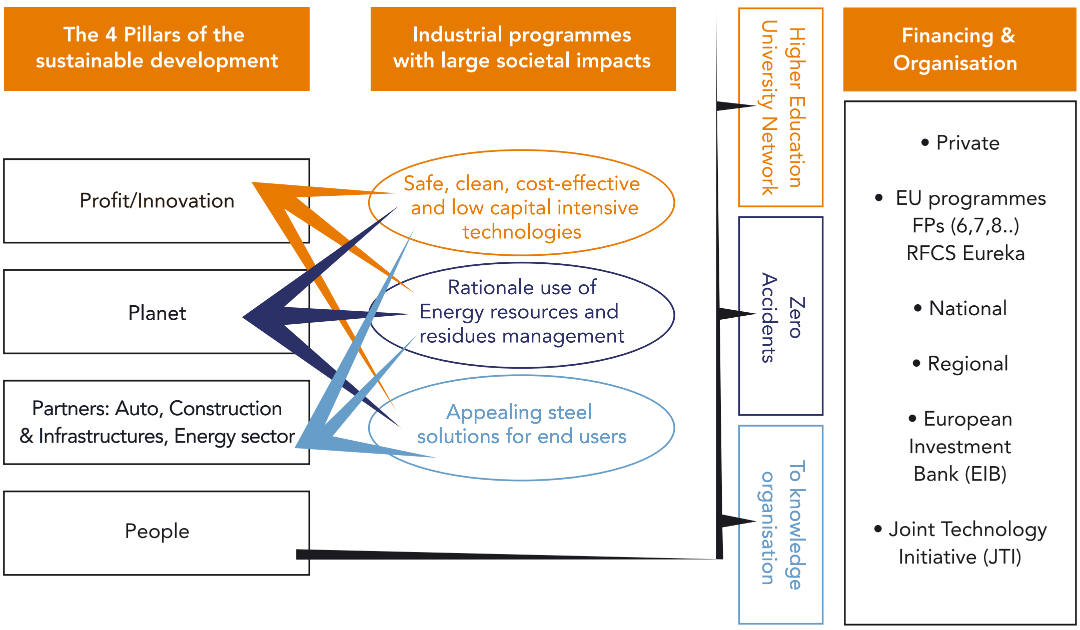
The total budget for the first priorities amounts to around € 0.8 billion.

On an annual basis, approximately 25% of the Research Fund for Coal and Steel programme should be devoted to programmes leading to the implementation of sectoral consensus-based R&D activities.

This implementation should take place from 2007 to 2013 for both RFCS and FP7 actions.

The estimated total budget corresponding to the SRA activities amounts to around € 1.7 billion over 15 years.

Implementation of the SRA



Implementation of the SRA: need for a critical mass of means

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to assume a sustainable and global leadership
in the coming 30 years

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- Changing EU regulation
- Strengthening the EU 25 partnership

Strategic objectives

- Profit trough innovation
- Meet society's needs in close partnership with its customers
- Meet environmental requirements
- Attract and secure qualified people

Recommendations

Creation of a European Steel Technology Platform
to boost innovation, to develop new breakthrough
technologies and new steel solutions

Creation of a steering committee
to select priorities and monitor progress

Development of a strategic research agenda to
implement new breakthrough technologies
and new steel solutions

Fig. 1: Ambition
(from the March 2004 GOP document – European Steel Technology Platform Vision 2030)

Background and current key features of the steel sector

Steel is a key sector for Europe's economy and competitiveness. The EU-25 steel industry has a total annual production of approximately 184 million tonnes and generates more than € 100 bn in annual turnover. It provides direct employment for around 350 000 European Union citizens, and several times this number is employed indirectly in its processing, in the user and in the recycling industries. In addition, steel is a worldwide commodity and world crude steel production exceeded 1 billion tonnes for the first time in 2004.

The steel industry is the source of millions of other jobs, in many industrial activities, as steel is a key material for many of them (road, rail, maritime and air transportation, construction, energy, chemical industry, household appliances, etc.). For example, the European construction steel industry and the automotive sector represent more than 1 300 000 jobs (EU-15). It is vital for the future of Europe and its citizens to maintain an active and competitive steel industry.

Ambition and long-term vision of the steel sector

The ambition of the European steel industry is to maintain and reinforce a global leadership, which is both sustainable and competitive, given the strong development in other parts of the world, notably Asia.

Main challenges to sustainable global competitiveness

1. The growing impact of globalisation

The globalisation of steel customers results in increased market power, stricter product requirements, and standardisation.

Collaboration with its traditional customers is so deeply rooted that the European steel industry has taken the necessary measures to continue to satisfy their needs in terms of services, quality and prices wherever they are located. Thus, many of the European steel companies have established facilities in other regions of the world or developed strategic alliances worldwide.

However, the steel industry remains much less concentrated than its major supplier or client industries. Thus it is hard pressed to accelerate its concentration and rationalisation on a global scale, which would give it increased negotiating power with its main clients and suppliers, and would boost its capacity to serve its customers, worldwide with the same quality of products and services they already enjoy, locally.

Moreover, the trend towards further liberalisation of international steel trade, and thus increased international competition, has manifested itself clearly. The steel industry, faced with this growing impact of globalisation, and to respond to the pressures on its markets, requires that the rules of fair trade be applied and respected worldwide.

2. Matching steel supply and demand

Past experience shows that crises in the steel industry usually have their roots in imbalances caused by rapid fluctuations in demand combined with somewhat rigid supply structures and global overcapacity. Fluctuations in demand are related to business cycles but also have structural backgrounds. Economic cycles influence steel demand to a large extent, bearing in mind that steel is used for both consumer and capital goods. In terms of volume, global steel demand is expected to increase more in the future than it did in the past, owing to the increased growth of developing countries like China and India. Accordingly, the stronger market growth will take place outside mature steel markets like the EU, Japan and the US, and particularly in favour of Asian and Latin American countries. Indeed, the situation worldwide is very heterogeneous: in 2004, per capita steel consumption was 197 kg for China, 364 kg for Europe (EU-25) and 601 kg for Japan. This presupposes a huge potential for growth in China and a potential change in the centre of gravity for steel from Europe to Asia. The main reason for this is the potential demand for steel products, particularly for infrastructure upgrading. In terms of quality, however, the industry expects an important potential for increased demand of high added value steel products in highly developed countries (durable consumer products, capital goods) as a result of further product development. It is expected that European steel exports will focus increasingly on higher value-added products.

3. New EU environmental regulations

As far as environmental policies are concerned, various instruments are being introduced or considered, nationally and at EU level. For the steel industry, initiatives with a potentially significant impact include: integrated pollution prevention and control permits, air quality standards and the Clean Air For Europe programme, new product and waste legislation (such as the end-of-life vehicles directive) and the thematic strategies on natural resources and waste prevention and recycling, as well as new EU legislation on chemicals ('REACH').

Another new piece of EU legislation that is important for the EU steel industry is the greenhouse gas emissions trading scheme, which is being introduced in order to implement commitments made by EU Member States in the Kyoto Protocol. Across the whole EU economy the costs for implementing these commitments could be considerable. The risk that European steel producers could see a loss of business to non-EU competitors, which are not subject to any CO_2 emissions limitations, cannot be neglected.

4. Strengthening the EU-25 enlargement

Steel companies in the new member states and in the candidate countries exhibit several characteristics, such as relatively low labour costs and a good level of technical qualification. However, production units would benefit from the implementation of modern production techniques, along with higher energy efficiency, better organisation, and improved quality and services. This would result in higher productivity levels, better product standards, and much needed environmental improvement.

Strategic Objectives

The strategic objectives are developed around the concepts based on the principles of sustainable growth: Profit, Partners, Planet and People.

1. Profit

Ensuring profit through innovation and new technologies

- Innovation and new production technologies
- Strengthening intelligent manufacturing
- Innovative products
- Reducing time to market and implementing the supply chain concept

2. Partners

Respond to society's needs with the partners of the steel sector

- The automotive sector
- The construction sector
- The energy sector

3. Planet

Develop breakthrough technologies to meet the environmental requirements

4. People

Attract and secure human resources and skills

- Become a worldwide reference for health and safety at work
- Dynamically attract and secure human resources skill
- Optimisation of deployment of human resources is key to the successful implementation of the steel industry's competitive strategies
- External concerns (clever and safer steel products)

The R&D approach: towards 3 industrial programmes with large societal impacts

To face such important challenges and to meet the objectives of the European Steel Technology Platform, it was decided by the Group of Personalities in March 2004 to launch resolute and structured long term R&D actions.

Six working groups corresponding to the 4 pillars of the sustainable development framework of the Platform were set up (figure n°2) and have developed 3 industrial programmes with large societal impacts each of them encompassing several R&D themes and research areas (figures n°3 and 4).

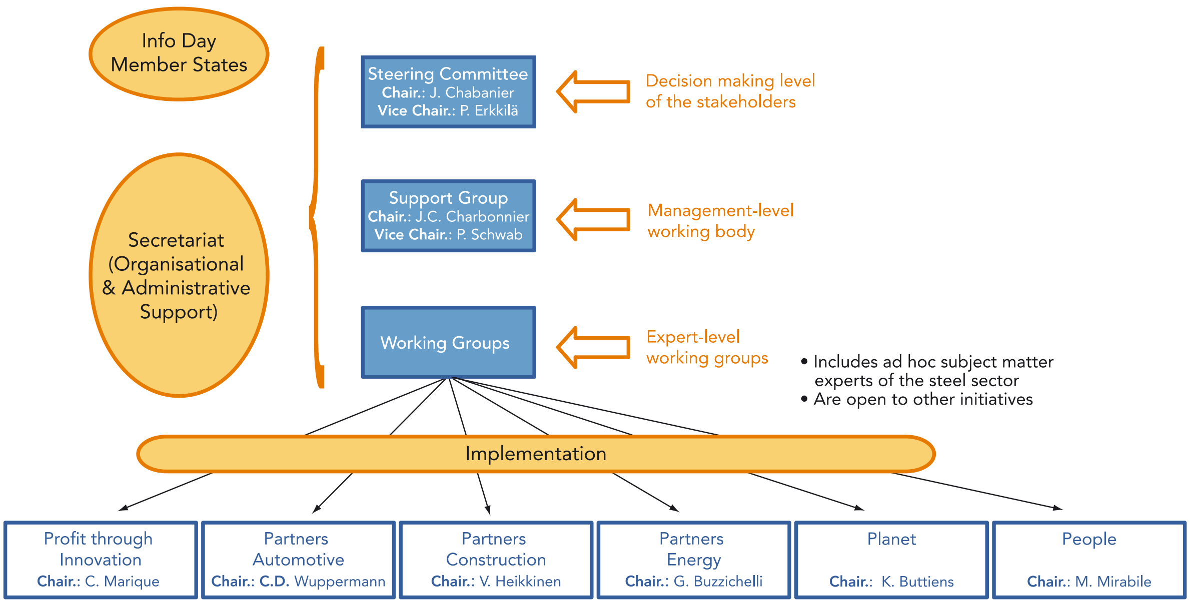


Fig. 2: The Steel Technology Platform

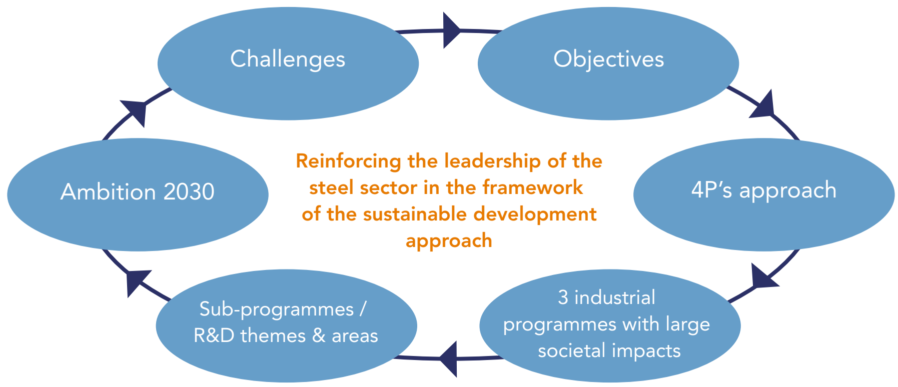


Fig. 3: The way to achieve the long term ambition through innovation and R&D

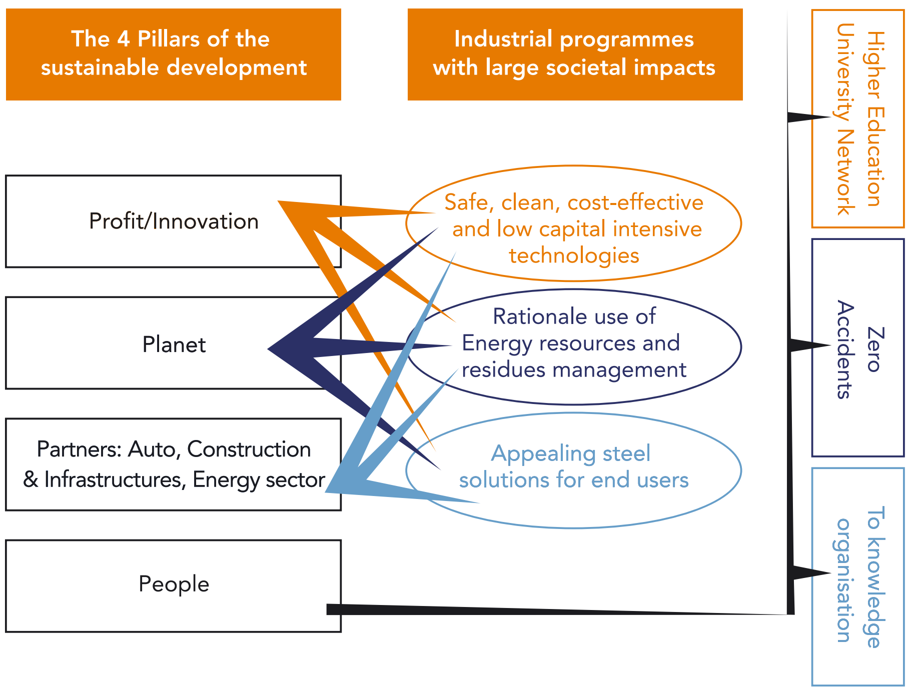


Fig. 4: Three industrial programmes with large societal impacts based on sustainable approach

The 3 industrial programmes with large societal impacts are the following:

- Safe, clean, cost-effective and low capital intensive technologies
- Rational use of energy resources and residues management
- Appealing steel solutions for end users

to which a transversal activity regarding human resources has been added

- Attracting and securing qualified people to help meeting the steel sector's ambition

A. Safe, clean, cost-effective and low capital technologies

Introduction

Strengthening its competitiveness is a major issue for the European Steel Sector.

To fulfil this global ambition in the long term, innovation is required in the production processes and manufacturing technologies in order to meet essential key challenges:

- To achieve highest standards of quality with highly productive, safe and efficient processes
- To renew continuously steel products on offer
- To ensure a short time to market
- To favour sustainable development and clean operations of the steel industry

The promotion of cost-effective processing solutions while preserving the natural resources constitutes a mandatory and permanent target for the steel sector.

Driven by the continuous quest for improved competitiveness, the steel industry, together with the downstream primary processing sector, has recently made large investments in the reduction of production costs and improvement of quality (advanced computer systems, extensive use of measurement sensors, artificial intelligence and modelling, etc.). Subsequently, significant benefits have been obtained with regard to the reliability and robustness of facilities, leading to higher production rates, greater yields and better consistency of products delivered to the customers.

The most recent industrial development is the so-called "thin slab casting". Here, a semi-finished product is cast with reduced thickness and sent directly to the hot rolling mill. However, further innovation is required to achieve the development of much more integrated and flexible process, to go further in reducing the successive steps of heating and cooling quite often associated with rolling/shaping operations or specific thermo-mechanical treatments. During many of these operations, a large portion of the product surface is exposed to oxidising conditions that results in the formation of scale, a major cause of iron loss and a potential source of defects.

Following the successful industrial development of thin slab casting, the research work led to the development of a more integrated process, the "thin strip casting" process which operates in a few industrial pilot plants for producing stainless steel. However, many problems remain to be solved before thin strip casting can be applied to the mass production of high quality grades such as those used in automobile manufacturing and to other complex steels. Furthermore, very costly developments must still be performed prior to the construction of industrial pilot plants and final implementation of new solutions for production lines.

Great flexibility is needed in the whole steel industry production chain to cope with the expanding range of products that will have to be supplied at low cost. Much more compact lines with very short response times and extended ranges of capability would be of benefit to the steel sector.

On the other hand, where conventional technologies are mature and robust enough to guarantee stable performance, intelligent manufacturing technology should contribute to developing the more flexible processes.

New production paradigms, such as intelligent manufacturing processes, efficient production organisation, need to be designed and developed, based on breakthrough concepts to ensure the evolution of new processes, products and services.

To meet these challenges, ambitious R&D efforts must be launched during the coming decades. Three major themes have been identified in this respect:

- Novel integrated routes for a "scale free" and energy efficient processing
- Flexible and multifunction production chain
- Intelligent manufacturing

Novel integrated routes for a "scale free" and energy efficient processing

1. Background

The present configuration of almost all steel processing routes is characterised by successive steps of heating and cooling, quite often associated with rolling/shaping operations or specific thermo-mechanical treatments. During many of these operations, a large portion of the product surface is exposed to oxidising conditions that result in the formation of scale, which is a major cause of iron loss and a potential source of defects. The scale, mainly formed during hot processing, must be removed, generally by an acid treatment (pickling), before any cold processing is performed, The pickling process quite often creates a bottleneck between the hot and cold rolling plants and represents an important source of pollution.

Other associated drawbacks of the current plant configuration are uncontrolled energy losses owing to radiation phenomena and a low utilisation of the heat contained in the hot products.

A major target of the steel industry is hence to promote a "scale free" and more energy efficient production route, characterised by a larger integration of continuous processing operations.

The actions to be taken to avoid scale formation, to control the oxidation mechanisms and to utilise the heat present in the products concern the existing process as well as new concepts yet to be developed, notably in the follow-up of the ULCOS programme (see 4.2.2.). This challenge has to be met whatever steelmaking route is selected. It represents an important issue for the manufacture of high quality products (carbon, stainless, and special steel grades). The effort engaged in the near-net-shape casting of flat products already constitutes an important contribution to this objective but needs to be drastically improved from the viewpoints of surface quality and oxide control.

The objective is to develop new technological concepts aimed at better control of the steel product surface quality and avoidance of oxide formation during the hot and cold processing steps. In the medium term, it would lead to the elimination of the pickling operation with evident benefits in terms of production costs, productivity and environmental impact. It also represents a unique way to reach a fully integrated connection between the hot and cold processing steps favouring the development of shorter and more direct production routes from steel casting stage up to the finishing lines.

In the future, hot production processes will also change in the direction of near-net-shape production, the implementation of more continuous processes and the introduction of more direct links between processes and plants inside the steel mill. These processes will be leaner in energy and raw materials (yield, especially), but will also provide a template for implementing the oxide-free production concept much more easily. For example, the concept of on-line casting and rolling associated with the evolution of in-line strip (ISP) technology makes it technologically easier to implement oxygen-free high temperature handling of materials, both at the casting and at the hot-rolling steps.

2. Ways and means - research areas

To reach these objectives, interdisciplinary teams should work to develop new technological concepts to control and to avoid the oxide formation during the hot and cold processing steps of carbon and high alloyed steel grades. All the operations from the solidification stage up to the final products are concerned, including the reheating furnaces. Measures must be designed to allow carefully controlled oxidation mechanisms and the removal, when required, of the oxide formed during the process without use of chemical treatments.

As main subjects of research, one must consider the development of:

- reducing and controlling scale formation (composition, thickness, homogeneity)
- avoiding scale formation - Full application aimed at novel routes (strip casting, ...)
- recovering thermal energy

3. Implementation

R&D areas	Priority	Frame	Term (S = Short, M = Medium, L = Long)	Budget (Mio Eur) 1st priority	2nd priority
1) To reduce and control scale formation (composition, thickness, homogeneity, surface quality)				**17 100 % RFCS**	
• Application of developped know-how and optimisation of the operating conditions in conventional routes:					
Casting stage, Hot rolling stage and Pickling stage	1	RFCS	S - M		
• New surface conditioning methods for hot and cold materials	1	RFCS	S - M		
• Partial application of protective coatings	1	RFCS	S - M		
2) To avoid scale formation - Full application aimed at for novel routes (strip casting, ...)				**18 100% FP 7**	**32 100% FP 7**
• Total surface protection from oxidation all along the processing lines	1	FP 7	M		
• Heating and rolling under protective atmosphere	2	FP 7	M - L		
• Removal of protective coating and scale without acid use	2	FP 7	M		
3) To recover thermal energy					**4 100% FP 7**
• New hot material flow for special steels	2	FP 7	M		

Fig. 5: Safe, clean, cost-effective and low capital technologies - Novel integrated routes for a "scale free" and energy efficient processing: implementation (time frame)

Flexible and multifunction production chain

1. Background

There is today a growing conflict between the target of the steel producers for large scale uniform and low production cost and the demands of customers for tailored products exhibiting a wide range of different properties. Indeed, the demands of society are becoming wider, encompassing very diverse applications.

Resolution of this conflict requires greater flexibility in the steel production chain. In particular, a limited range of composition is to be aimed at in the up-stream processing while greater versatility is required downstream of the manufacturing process, where the final diverse properties are imparted to the products prior to delivery to customers.

Breakthrough concepts must be investigated to fulfil this objective, which notably implies developments in the fields of casting, thermal and mechanical treatments, finishing and coating.

The objective is to design new processing lines having a multipurpose functional and flexible character. Based on adapted metallurgical concepts and proper tuning of operating conditions, the objectives are:

- To enlarge the product mix to be processed from a similar basic composition in the same line
- To accommodate changes in chemical composition while keeping the final properties of the product within a narrow range
- To propose new types of coated products with new and additional functionalities
- To shorten drastically production line dimensions

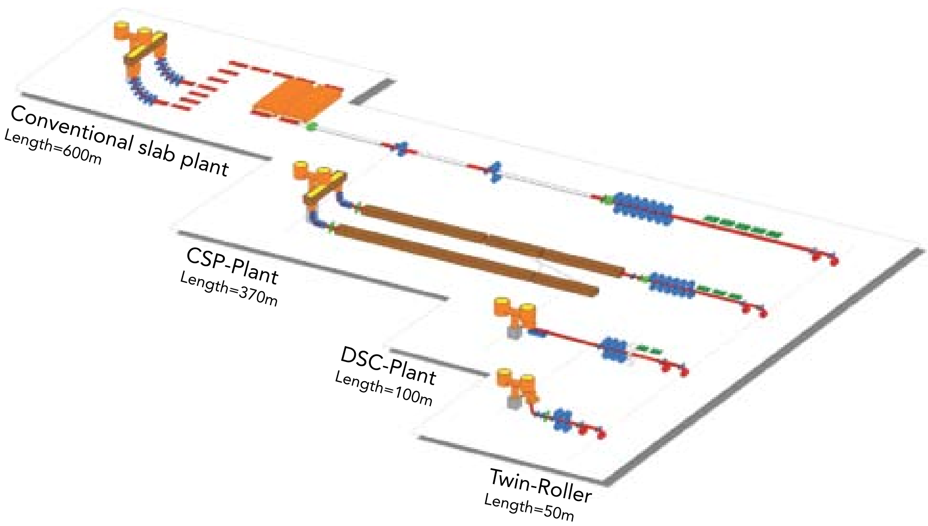


Fig. 6: Potentials of Shortening the Production Chain in Steel Manufacturing Using New Processes

2. Ways and means – research areas

Several axes of development have been identified as priority items as summarised below.

Ultimate near net shape casting and rolling/ shaping

Based on experience gained during the development of thin slab and strip casting, the targets are twofold:

- To extend the application of similar concepts to a larger range of applications. Both flat (strip, plate) and long (bar, wire, rod, sections, beam) products are concerned with the aim of integrating the solidification and shaping/rolling operations in a continuous process
- To expand the steel grade capability of near-net-shape processes to additional or new materials and alloys (high strength, high formability, etc.). High quality steels often exhibit surface problems and low throughput in the casting stage that need to be solved notably through enhanced micro-structural control.

Specific efforts must be devoted to design new casting modes and mould types to comply with the solidification of more complex shapes. Alternative cooling strategies and mould lubrication methods are other subjects to be addressed.

Tailored products can be produced by flexible casting and rolling technologies. The technology of flexible casting, i.e. casting directly with changing thickness over the length, is connected with the development of strip casting. Flexible rolling is another possible way. High strength seamless tubes are of interest for steel space frames and can be manufactured by thermo-mechanical rolling.

Multipurpose compact finishing

Different ambitious R&D objectives are aimed at:

- The production of several qualities from a single base steel composition or the enlargement of the mixed products may be envisaged by applying either a thermo-chemical treatment or suitable thermo-mechanical treatments.
- The accommodation of changes in the chemical composition while keeping constant the final properties. These first two objectives notably imply the design of new technologies allowing more efficient and faster heating and cooling systems.

Development of downstream processes

Another field of development relies on new types of lines where several and different coating layers, giving extra functions to the steel products (corrosion and scratch resistance, adhesion, aesthetic appearance…), could be deposited in a continuous and compact way.

3. Implementation

R&D areas	Priority	Frame	Term S = Short M = Medium L = Long	Budget (Mio Eur) 1st priority	 2nd priority
1) Ultimate near net shape casting and rolling					**70 100% FP 7**
• Strip casting					
To build a very large project based on a European demonstration pilot plant (Global competition) applicable to carbon steels	2	FP 7 EIB ?	M		
• Complex shape					
Study of new casting concept, Thixoforming, …	2	FP 7	M		

R&D areas	Priority	Frame	Term (S = Short, M = Medium, L = Long)	Budget (Mio Eur) 1st priority	2nd priority
2) Multipurpose compact finishing and compact lines				**9 (30 % RFCS 70 % FP 7)**	
• Properties given in the downstream process	1		M to L		
• Use of optimised simulation tool	1		L		
• Cheaper alloying concepts	1		L		
• Basic metallurgical study	1	RFCS	S to M		
• Development of adapted technologies	1	FP 7	M		
3) Development of downstream processes					**8 100% FP 7**
• Surface treatments and coatings	2	FP 7	M		

Fig. 7: Safe, clean, cost-effective and low capital technologies: Flexible and multifunction production chain - implementation

Intelligent manufacturing

1. Background

New technologies are among the most important ways of covering the technological gap required in process optimisation and increased competitiveness. Where conventional techniques are mature and robust enough to guarantee stable performance, intelligent manufacturing technology should contribute to developing more flexible production processes

The tendencies in the management of the steel industry are the creation of global programmes of development in many fields of activities. Thus, one can talk of TPM (total productive maintenance) as an example of the implication that all services and hierarchical levels of the company are devoted to achieving the best results in all production activities, by seeking to achieve the best optimum working point of facilities. Another global programme, TQM (total quality management), is aimed at involving the whole company in quality activities. Also, there are concepts of management, such as TCO (total cost of ownership), which aim to make investment decisions easier, that are actually based mostly on the basis of first investment cost. Another important topic is the automation of the processing chain to gain notable improvements in accuracy and reliability.

All these activities require great amounts of data and imply major efforts in terms of time-consuming data analysis.

Nowadays, there are many software tools to aid data handling and analysis. For example, tools are available for implementing rules and expert knowledge to processes, and for creating models and prototypes to assist in managing decisions. Nevertheless, all existing new software packages clearly need to be improved, with new tools and packages to enhance their versatility and wider applicability in order to avoid the need continually to invent new tools.

Another important weakness of current systems is the fact that it is not always easy to make the direct measurements of the required parameters. Currently, several trials are being performed in order to measure parameters through a model based on different unknowns, for example, the advanced process control programme (APC) of the American Iron and Steel Institute (AISI), in which 15 companies are involved in the development of systems of on-line measurement.

New and significant progresses are thus required to acquire an enhanced control of the process with

three different fields of development:

- A highly automated production chain
- The total control of the process
- The use of optimised simulation tools for developing and producing new steel grades

2. Ways and means – research areas

A highly automated production chain

Among the different R&D and innovation topics covered by this subject, the following are particularly highlighted:

- The customisation (hard- and software) of industrial robots for use in the steel plants. An important objective is to withdraw human beings from dangerous zones (e.g. liquid steel)
- The application to the rough steel plant environment of Web-based and mobile automation solutions allowing easy and complete access to the control and database systems within the whole plant. Besides having a positive impact on the reliability of control systems, it would also help to speed up production and maintenance actions.
- The development of self-learning automated production chains, through the introduction of expert systems, neural networks continuously trained by new data mining techniques during the on-going production. The target here is to optimise continuously product quality, production cost and delivery time.
- The introduction of various standardised interfaces to allow the exchange of information between various automation systems. As an example of such an increased functionality of automation systems, one can mention the OPC standard (open process communication) applicable to levels 1 and 2.

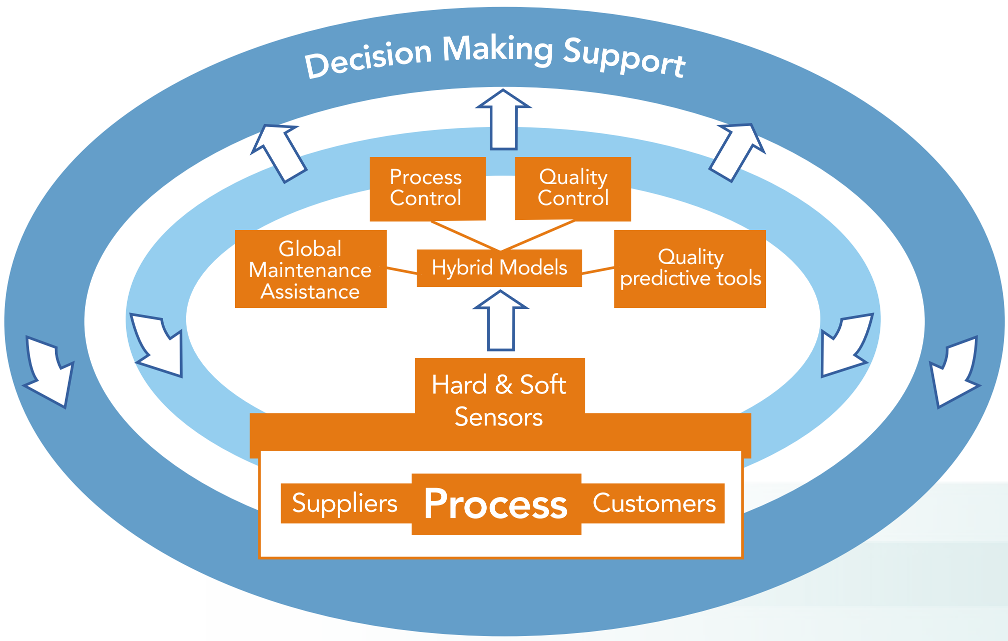


Fig. 8: The Total Control Concept starts by extracting useful information from the whole process by means of hard and soft sensors. With this heterogeneous data, both analytical and artificial intelligent models should be developed as they will provide, in a first stage of knowledge, the ability to control the process and its quality as well as to assist to the global maintenance activities. In a higher level, all this knowledge will be aggregated to build decision support systems and it will return to the process again in order to improve its performance

Reliable, fast, accurate, non-contact measurement technology has also to be developed to secure the automation systems.

The total control of the process

The main topics of interest as illustrated on figure n°8 are the following:

- The complete integrated modelling of production lines by research on new and accurate mathematical models will lead to large improvements by consideration of the non-linearities of processes. Two approaches should be followed: analytical and artificial intelligence modelling. Also, it is possible to combine both approaches to obtain hybrid models. These hybrid models can interpolate the errors between the measured values and computational results of models. This new approach will allow the development and use of the currently most advanced control techniques that require plant models to be as accurate as possible. However, life cycle analysis (LCA)-type steel mill global modelling will lead to eco-design of the steel process route. Research work will be focused on minimising human effort and on direct process supervision. The modelling should be extended to all levels of automation, including scheduling and management systems. On the other hand, new models under development will enhance the application of novel project management approaches. Global solutions in terms of customer-supplier relationship management, evaluation of cost derived from managing and aiding decision-making processes will also be targets of this research.
- The steel industry has clear demands for improving the use of sophisticated and advanced on-line measurement and testing methods. Soft sensors, based on artificial intelligence (AI) will be dedicated to estimate variables that cannot be measured directly, or for which instruments are prohibitively expensive.
- Also, new and sophisticated hard sensors (on-line contact-free measurement, on-line determination of material properties or surface structure of coated/uncoated products) must be developed to deal with parameters for which, so far, methods are either unsuitable or non-existent. As an example including shape, on-line assessments of the surface structure of coated/uncoated products constitute attractive developments. Both kinds of sensors constitute the 'eyes' of the control and automation system and are crucial for the development of the new emerging and powerful global intelligent systems.
- Important for steel industry is the development of quality predictive tools with respect to different customer demands. The aforementioned new sensors, in combination with improved process models and expert systems, will enable immediate feedback control to allow the on-line prediction of the final quality of products from process operating conditions. 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 customer specifications.
- Implementation of integrated quality control systems allowing the incorporation of factory-wide systems to control the evolution and influences in terms of quality through the different stages of the processes. This implies the application of information technology to allow better linking of process operations and plant logistics to give production flexibility, guarantee product quality and meet end user/customer requirements for 'just-in-time' order delivery. The full implementation of these systems is closely linked to the previously mentioned development of models and sensors.

The use of optimised simulation tools for developing and producing new steel grades

The aim is the dedication of new or advanced simulation tools based on atomistic modelling to allow a better understanding and prediction of the microstructure development and mechanical properties of new steel grades.

Today, simulation of material properties is undergoing a fundamental change. The combination of currently used statistical software systems, like ThermoCalc, with computational quantum mechanics offers new and efficient ways of modelling.

Existing design processes for alloys need numerous intermediate steps and trials that

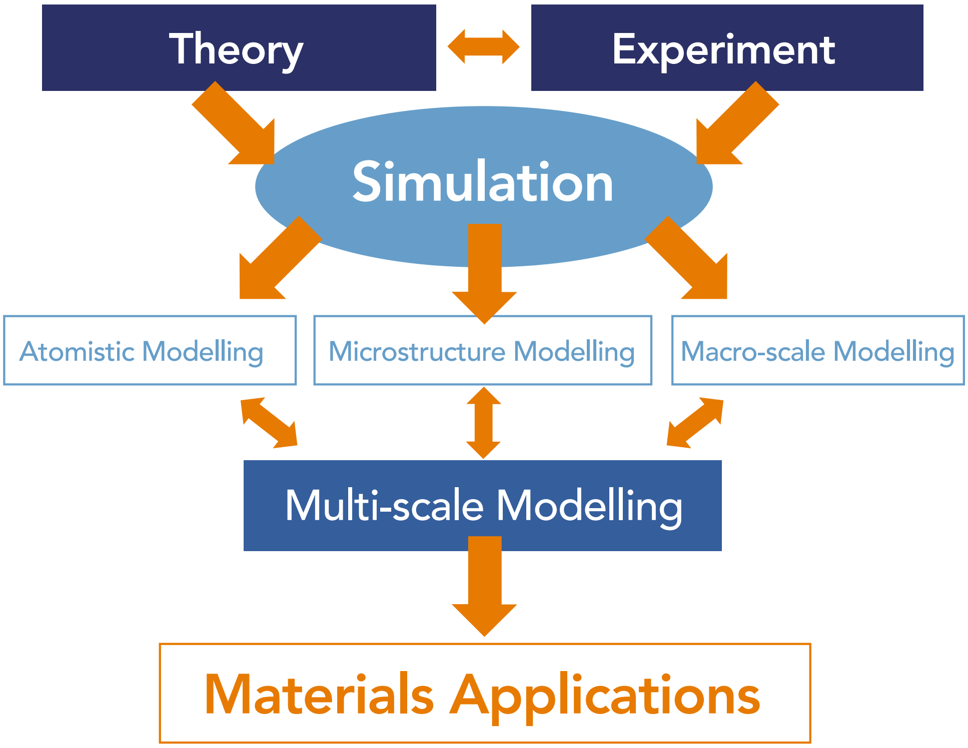


Fig. 9: Optimised simulation tools for developing and producing new steel grades

require considerable R&D capacity and finances. Furthermore, many unknown complications, covering the real problem, have to be handled during trials. This negative effect could be avoided by strengthening the dedication of computational modelling.

At the moment, promising software tools, mostly developed by universities or other research facilities, are being tested. These tools have to be enhanced and adapted to the needs of the steel industry, and is one of the most important challenges under this topic. To ensure the successful further development of such tools, the European steel industry needs to develop close partnerships with universities and to forge strong links between the leading research facilities.

Another attractive and related subject is the improvement of the existing database for alloy development together with the further development of simulation tools for new alloys. Indeed, the shortage of raw materials owing to the booming steel industry will notably force the steelmakers to use a greater blend of cheaper alloying elements. Aspects linked to the presence of undesired elements or elements difficult to remove during processing such as nitrogen or copper have to be better handled than today.

The main expected result should be the fast realisation of virtually designed new steel grades.

3. Implementation

R&D areas	Priority	Frame	Term (S = Short, M = Medium, L = Long)	Budget (Mio Eur) 1st priority	2nd priority
1) Highly automated production chain				**14 100% FP 7 / EURÊKA**	
• Total integrated predictive control including quality control	1	FP 7	S to M		
• Robot systems for steelwork	1	FP 7, EURÊKA	S to M		
2) Total control of the process				**23 100% FP 7 / EURÊKA**	
• Development of sensors (Contact free measurement systems)	1	FP 7, EURÊKA	S to M		
• Applied image analysis	1	FP 7, EURÊKA	S to M		
• Specific modules control (Integration of simulation models)	1	FP 7	S to M		
3) Optimised simulation Tools				**14 100% FP 7**	
• CFD model database and transient modelling	1	FP 7	S to M		
• Modelling of material properties and processing (welding, forming, …)	1	FP 7	S to M		
• Through process modelling of total production chain	1	FP 7	M		

Fig. 10: Safe, clean, cost-effective and low capital technologies: Intelligent manufacturing - implementation

Socio-economics aspects

In the shorter term, enhanced control of product oxidation and minimisation of the scale thickness, combined with mechanical de-scaling methods would allow a dramatic reduction in demand on pickling units and of acid consumption.

Reducing scale formation in a first step and suppressing it in a final application would lead to very interesting results:

- The iron yield would be drastically improved with a potential saving of 3 to 3.5 kg of iron per tonne of product when the scale formation is avoided.
- Considering that the operating costs of a pickling unit amounts between € 15 to 20/ tonne of treated product at least for carbon steel, a potential saving of about € 1 bn could be expected for the European steel production of pickled products.

- Protection of the environment by avoiding the generation of pickling liquors and their subsequent treatments (associated economic gain).

However, these new developments offer a unique opportunity to enhance markedly the quality of the products and services offered to the customers in a very short time-to-market while reaching a high processing efficiency and productivity.

The beneficial impact of a highly automated and totally controlled manufacturing may be evaluated from the maintenance and quality cost aspects. The average maintenance costs can be estimated at about € 45/tonne and the quality costs at about € 40/tonne of total production. Considering only the current production of 184 million tonnes of steel in Europe and anticipating an improvement, owing to the implementation of techniques outlined above, of 15 and 20% respectively, a total saving of about € 2.7 bn could be achieved.

Another expected benefit resulting from the use of a totally controlled process and advanced simulation tools is the shortening of the development time, which represents a very important advantage. This would make the steel industry more flexible and permit faster reaction to customers' requests.

Owing to the use of computational materials science, it will also be possible to decrease the number of practical trials, which leads to lower the development costs.

Stakeholders

- Steel industry
- Equipment manufacturers
- Coating suppliers
- Research institutes
- Universities
- Other metals producers
- Small & Medium Enterprises

B. Rational use of energy, resources and residues management

Introduction

Driven by mass production, quality control and cost reduction, technical progress has led to large energy savings and to the systematic use of lean and clean processes. As a result, energy consumption and CO_2 generation in the European steel industry have decreased by 50% and 60%, respectively, over the past 40 years. Furthermore, this does not result simply from recession in the sector, as the trends in specific values show. Behind these seemingly simple figures there exists a complex set of circumstances where change and modernisation have been carried out in various ways, including the movement from integrated mills to electric arc furnace mills for the manufacture of various types of long products.

This continuous trend has resulted in very significant progress. Since the beginning of the 1990s, blast furnace processes have approached their physical upper limits with respect to energy efficiency.

The EU integrated steel industry is based on intensive material and energy utilisation. It relies on overseas suppliers for a large part of its raw materials (e.g. iron ore and coking coal). Today, the three largest producers of iron ore worldwide account for 70% of all shipments.

Ferrous scrap is the principal raw material for electric arc steelmaking and, in order to obtain better quality scrap, initiatives are being taken to improve its collection and recycling. The latter is not only an environmental priority, but is also intrinsically profitable owing to energy savings and economies in materials.

In order to extend their raw materials base, and following the drive towards higher-value-added products, electric arc steel producers increasingly combine scrap with sponge iron, hot 'briquetted' iron and/or cold or hot metal from the blast furnace.

A further group of raw materials, essential for the production of special steels, is that of ferroalloys. These materials are largely imported and constitute an important and increasing part of production costs. Long-term supplies must be secured through facilitating market access and increased competition between suppliers.

Electricity and natural gas supplies make up a significant part of steel production costs. Within the EU, electricity and natural gas prices exhibit marked differences, in part because of taxation but also because of different pricing structures and regulation of the supply industries. There may still be scope for improvement in that respect.

As far as environmental policies are concerned, various legal instruments are being introduced or considered, nationally and at EU level. For the steel industry, initiatives with a potentially significant impact include: integrated pollution prevention and control permits, air quality standards and the Clean Air for Europe programme, new product and waste legislation (such as the end-of-life vehicles directive) and the thematic strategies on natural resources and waste prevention and recycling, as well as new EU legislation on chemicals ('REACH').

Another new piece of EU legislation that is important for the EU steel industry is the greenhouse gas emissions trading scheme which is being introduced in order to implement commitments made by EU Member States in the Kyoto Protocol. Across the whole EU economy the costs for implementing these commitments could be considerable. The risk that European steel producers could see a loss of business to non-EU competitors which are not subject to any CO_2 emissions limitations cannot be neglected.

A sustainable approach towards by-products and residues is a must. Conservation of resources and waste prevention are now common goals which can generate opportunities and profit while minimising environmental nuisance.

To achieve its sustainability, the European steel industry will have to meet the challenging combined targets of environmental friendliness and profitable growth.

Three major themes have been identified

- The greenhouse gases challenge
- Energy effectiveness and resources savings
- Advantages of steel: the social impact of materials

The greenhouse gases challenge

1. Background

Presently over 1 000 million tonnes of steel produced worldwide, of which 18-19 % is currently produced in the EU-25. The iron demand is met by hot metal produced in blast furnaces and smelting reduction units, whereas the cold metal is supplied as recycled steel and sponge iron/HBI manufactured in DRI plants. This current practice uses fossil fuels (e.g., coke, coal, oil, and natural gas) as sources of chemical reductants and thermal energy. About 95% of an integrated works' energy input comes from solid fuel, primarily coal, 3-4% from gaseous fuels, and 1-2% from liquid fuels. However, approximately three quarters of the carbon content of coal is consumed in the reduction reaction wherein iron ore is converted to iron in the blast furnace. The remaining carbon provides heat in the sinter and coking plants and, in the form of by-product gases, to the various downstream process stages. The quantities of liquid and gaseous fuels used, alongside the by-product gases in the downstream process stages, depend on the overall works' energy balance. Thus, by-product gases from the coke ovens, blast furnace and steelmaking typically contribute 40% of total energy consumption and are used either as a direct fuel substitute or for the internal generation of electricity.

The steel industry is in a special situation with regard to the GHG challenge. Over the last 50 years, there has been important and systematic progress in steelmaking, resulting in the halving of the CO2 emissions per tonne of steel produced. This has been achieved largely through the reduction of coke consumption in blast furnaces and the increased availability of scrap to be recycled, either in basic oxygen converters or mainly in electric arc furnaces. The steel industry still represents an important contribution to European anthropogenic CO2 emissions (6%), and therefore remains a sector of specific importance.

Further major improvements in integrated steelmaking (blast furnace) cannot be expected. In the integrated steelmaking route, coke and coal are reducing agents that cannot currently be replaced under economically viable conditions. Today, about 1.8 tonnes of CO2 are emitted per tonne of steel, which represents almost the theoretical limit for the process.

Therefore, to make meaningful progress in the reduction of CO2 emissions a new approach and breakthrough technologies for reduction of iron ore are required. The development of such a process is essential to keep the performance of the sector in line with the environmental needs of our society.

The steelmaking sector is capital intensive. New processes may replace existing production facilities only at the end of their economic lifecycle. So it is necessary to optimise the utilisation of carbon resources in existing facilities in the meantime

On a short term basis, an improvement of the carbon consumption of at least 5% should be achievable, by raising the operational performances of all European ironmaking plants up to the level of the current European benchmark.

2. Ways and means – research areas

Alternate carbon sources

Alternative carbon sources, such as wood char and/or waste plastics, used in the blast furnace have been demonstrated to replace fossil carbon in a positive way. Waste plastics can also be used to replace part of coal in the coke oven. Research should be dedicated to optimise the input of carbon according to LCA principles.

Efficient use of generated energy

Although improvement in the blast furnace process is a major target, it should not be forgotten that there are possibilities for the efficient utilisation of internally generated energy sources (adapting the energy quality to the internal or external consumers). These internal energy streams are critical to the overall energy efficiency of an integrated steel works. The complex relationships between the different energy generating and consuming facilities need to be better understood, especially with regard to quality and purification issues, to support choices for improvement. This involves large through-process modelling of all energy streams.

Direct input of energy in the Electrical Arc Furnace

Approximately 40% of steel is produced via the electric arc furnace (EAF). The EAF uses electricity as its main energy source to produce new steel from recycled steel. However, electricity in many cases is produced in coal fired power plants with efficiencies of up to 40%. The direct input of energy in the EAF can improve the efficiency of utilisation of carbon resources far above the 40%. Optimisation of carbon sources can also be achieved by using other raw materials than recycled steel: pre-reduced iron as DRI, iron carbide and HBI, which are produced with lower energy consumption in newly designed production facilities. The EAF route also has the advantage to be able to produce higher quality steel grades.

In the medium term, emphasis should be placed on the possibilities for improving the process towards production of low C, N steels that may open the production of EAF to the flat carbon steel market.

Breakthrough technology: Ultra Low CO_2 Steelmaking (ULCOS)

To respond to the challenge of lowering CO2 emissions in the steel industry, breakthrough technologies are going to be developed.

The European Steel Industry has measured up to this challenge by creating a consortium of industries and of research organisations that has taken up the mission of developing such breakthrough processes, the ULCOS (Ultra Low CO_2 Steelmaking) consortium.

The consortium plans to develop a breakthrough steelmaking process that has the potential of meeting the target of markedly reducing GHG emissions. The full development of the process, from basic concept to fully-fledged industrial implementation would cover the medium and long terms and consist of a number of consecutive projects.

- The present ULCOS project, already launched in answer to a joint call by the 6th framework and the RFCS programmes, is the first step in this series of projects. Its scope and magnitude include the selection of two main routes for steelmaking that would demonstrate the technical and economical feasibility of the chosen concepts. It will last for 5 years (2004-2009), involve 48 partners and run with a budget of € 44 million. It will test coal-based, natural-gas-based, electricity-based and biomass-based steelmaking routes, which all have the potential for meeting the reduction target for complementary reasons.
- The outcome of the first stage of this project will be a set of one or two processes, which will have been demonstrated at a sufficiently large scale to be credible but that will still need significant scale-up before the first industrial line can be installed. The steel industry, because of its size and the nature of its production investments, needs to go through these structured development steps to advance successfully and safely towards the goal of developing a breakthrough core-production process. A second-step ULCOS project is thus foreseen (2009-2015), with the objective of building and operating two industrial size pilot plants, based on the outcome of the first project, for a sufficient period of time (at least 1 year) to address all the technological problems that will inevitably occur, and to develop a reliable estimate of its operating and maintenance costs. The pilot unit would, insofar as possible, be based on existing facilities, which would be transformed into a pilot unit.
- The ULCOS process, which should emerge from this second step (beyond 2015) fully justified from a technological and economical standpoint, would then need to be implemented into a first industrial line. This step goes beyond traditional R&D, but is a significant entrepreneurial step that will need to be assumed boldly and will require further cooperation of the ULCOS partners and would greatly benefit from financial support from the European Union. The new instrument that the Commission is promoting, according to Treaty article 171 (Joint Technology Initiative) would be particularly well suited to accommodate such a programme.

Figures n°11, 12 and 13 present a diagram of the total programme, with its 3 successive steps.

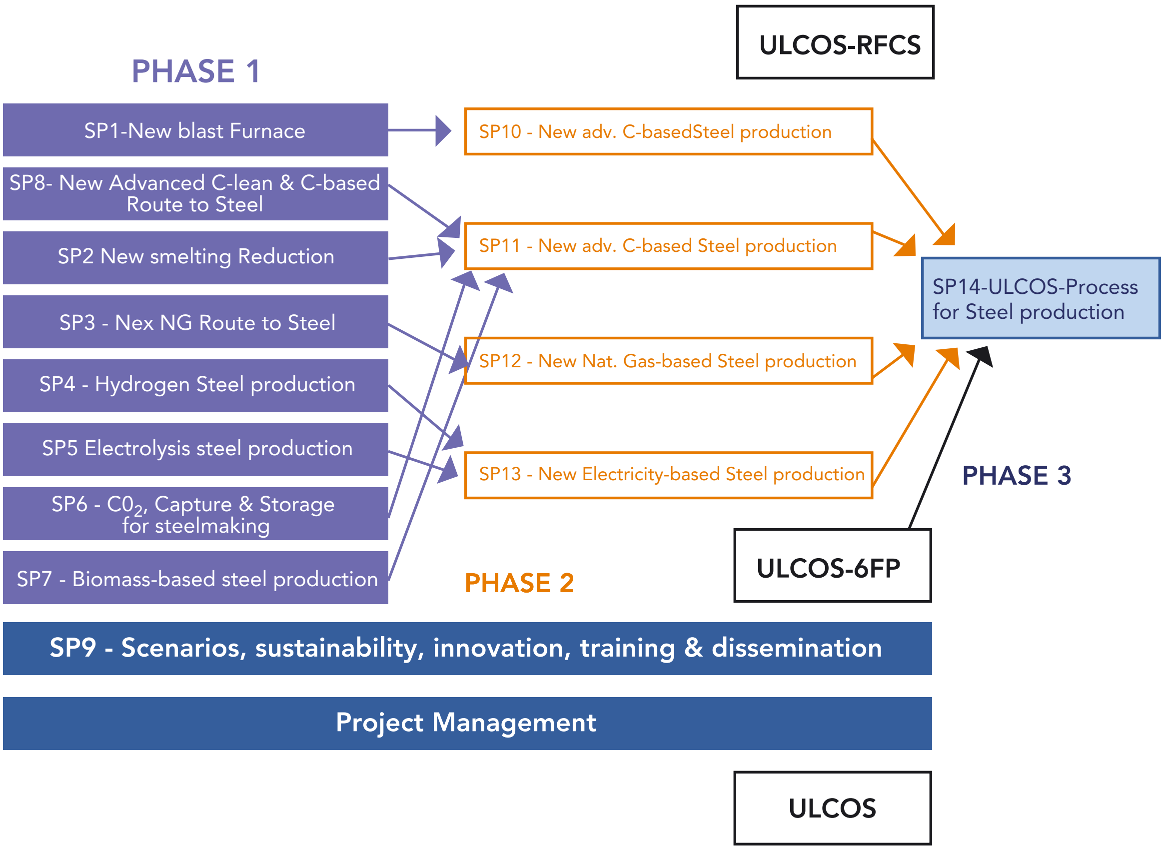


Fig. 11: Technology development - 5 years (2004-2009)

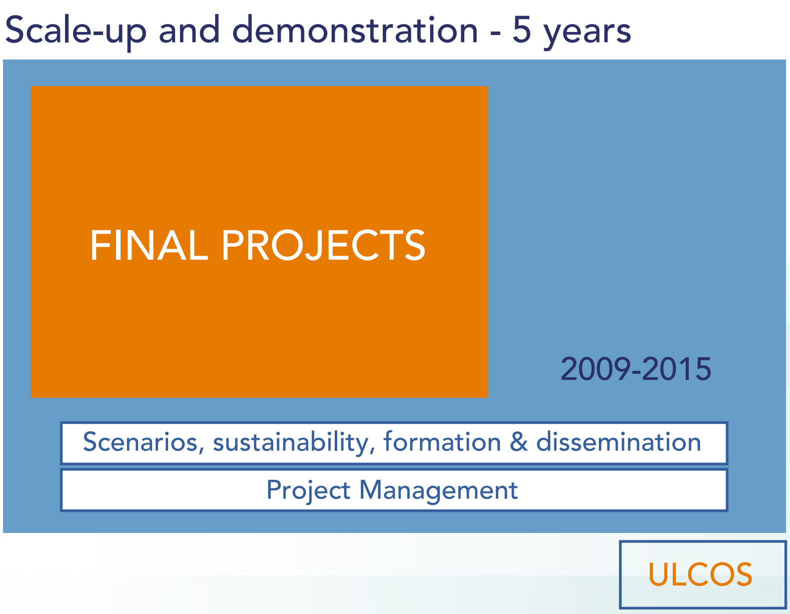


Fig. 12: Scale-up and demonstration – 5 years (2010-2015)

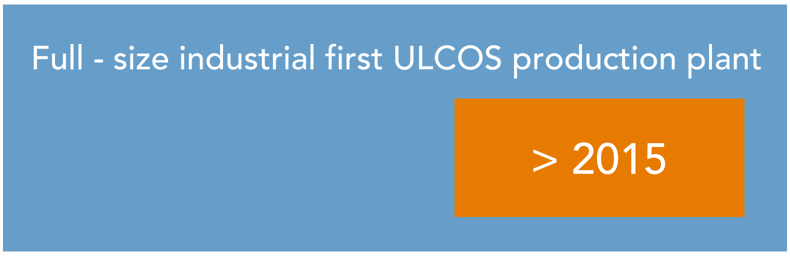


Fig. 13: Full-size industrial production plant (beyond 2015)

3. Implementation

R&D areas	Priority	Frame	Term (S = Short, M = Medium, L = Long)	Budget (Mio Eur) 1st priority	Budget (Mio Eur) 2nd priority
1) Alternate Carbon sources				**3 100% RFCS**	
• Optimise the input of carbon according to LCA principles	1	RFCS	S to M		
2) Efficient use of generated energy					**10 100% FP 7**
• Modelling of all energy streams	2	FP7	M - L		
• Intelligent use of process off-gases	2	FP 7	M - L		
3) Direct and alternative input of energy in the Electrical Arc Furnace (Optimisation of the Carbon resources)				**9 100% RFCS**	
• improvement of the EAF performances (Use of DRI in EAF)	1	RFCS	S to M		
• Feeding of carbonaceous materials in EAF	1	RFCS	S to M		
• Production of low C, N steels (extension product range EAF)	1	RFCS	S to M		
4) Breakthrough technology: Ultra Low CO2 Mitigation ULCOS)				**200 100 % FP 7**	**500 100 % FP 8**
• ULCOS (ongoing phase 1)	1	FP 6	L		
• ULCOS pilote phase 2 (process to be selected and the end of phase 1)	1	FP 7	L		
• ULCOS Industrial phase 3	1	FP 8	L		

Fig. 14: Rational use of energy, resources and residues management: The greenhouse gases challenge - implementation

Energy effectiveness and Resources savings

1. General background

Even though the European steel industry has drastically decreased its specific CO2 emission over recent decades, breakthrough technologies are needed in the long term. Progress already made is mainly due to improved energy efficiency in the steelmaking process. Indeed, the development of continuous casting, increased recycling of scrap, development of R&D activities on the optimisation of the processes, and the development of computer-controlled systems, have all contributed to reduced energy consumption in some energy-intensive stages.

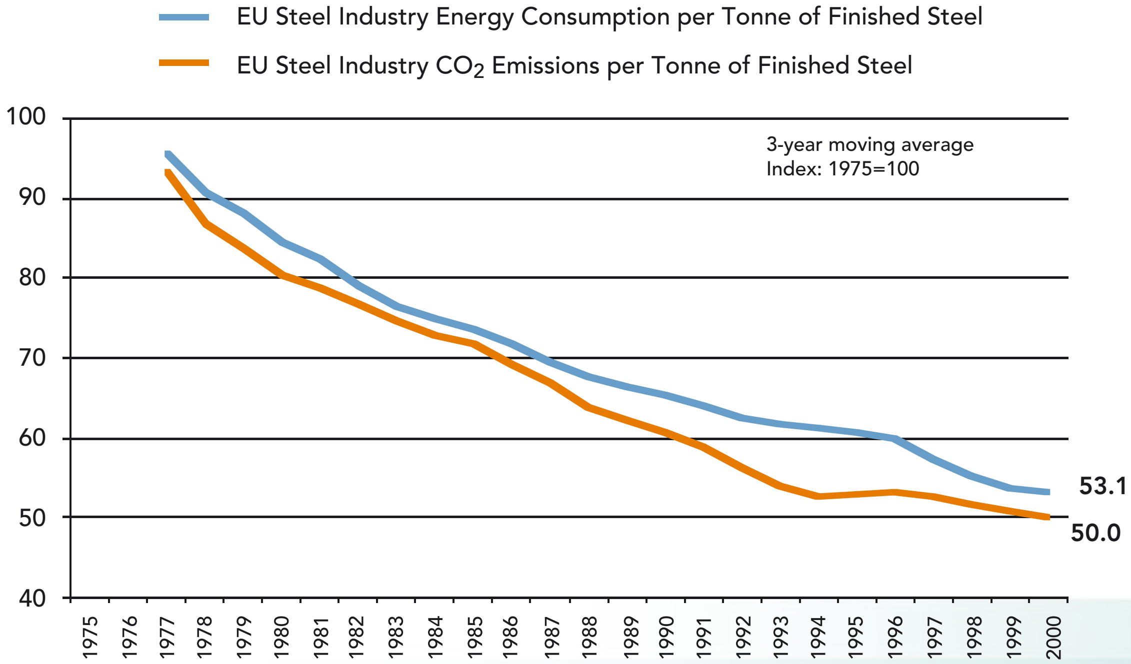


Fig. 15: Specific energy consumption and CO2 emissions during the last 30 years

The current status of steelmaking processes in Europe is that they are rather close to their optimum, taking into account techno-economic conditions.

The continuous improvement of productivity is an additional way contributing to the energy effectiveness and resources savings. An important and significant improvement could be reached at the continuous casting level: indeed in several cases the actual casting speed, especially for high strength steels (HSS), is well below the nominal casting speed, as the reduction of casting speed allows quality requirements to be met. Casting all grades at the nominal casting speed, while maintaining quality, is an ambitious short-to-medium term target contributing to overall reduction of energy consumption and conservation of resources.

However, the steelmaking process involves a number of heating and cooling operations that generate low-grade heat. Optimal energy recovery from these processes would require the development of new techniques adapted to low-temperature and continuous operation. Such techniques, when developed, would be useful for other processes as well as steelmaking (e.g. cooling of sintered products, combustion fumes, steel foundry products, continuous castings products, etc.).

2. Ways and means – research areas

Integrating new energy and steel productions

Background

This longer-term programme addresses a context that will be prevalent at the successful outcome of the ULCOS program.

To meet its energy needs, beyond the reduction of iron ore, the future ULCOS steel mill will need to import outside energy and will have to select it from carbon-lean energy in order to keep its GHG potential low. This is a proper answer to the global warming challenge, but this also narrows down the role of the steel industry to its core business of making steel.

The present project aims at redeploying the role of the future ULCOS-based steel industry beyond its steelmaking business and to integrate it more effectively into the economic, industrial and social fabric of modern society, by recreating the kind of synergies with energy generation around which the present mainstream integrated steel mill has been built. This present synergic relationship is shown in the next figure.

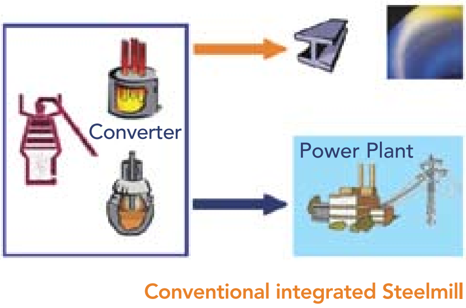


Fig. 16: Conventional mainstream integrated mill with its positive energy generation for electricity production in a dedicated power plant

Ways and means- research areas

To meet this ambition, different solutions are available, all based on using carbon-free energy in the steel mill, or with carbon but deeply intermeshed with CO_2 capture and sequestration.

One solution consists in going through the mediation of energy carriers, such as electricity or hydrogen. This means that rather than using conventional energy sources, with their carbon and CO_2 burden, new carbon-lean energy is preferred and imported into the mill as clean energy. This concept is shown in figure n°17. It is the solution, which is implicit in the present stage of the ULCOS projects.

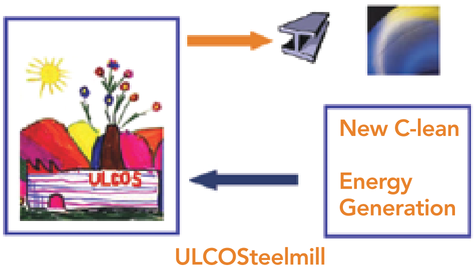


Fig. 17: ULCOS Steel Mill - Its energy needs are provided by electricity generated outside the Mill by carbon-lean routes

A more innovative approach consists in looking for a different kind of integration with carbon-free energy production. Indeed, energy generation is marred by low-yield processes that produce electricity and heat according to the Carnot principle: a fossil-fuel-based power plant or a nuclear power plant all have an electrical energy yield of typically 30%, the rest of the energy being transformed into heat.

This heat is usually produced at low-temperature, which restricts its recovery and use to steam generators and to city heating networks. More intelligent systems, that eliminate nitrogen and use pure oxygen rather than air have also been proposed, which, beyond providing a significant increase in yield, also produce rather pure CO_2, which is easier to capture and sequester [e.g., integrated gas and coal concept (IGCC)].

Such an approach, however, optimises the power plant structure independently of the process of its large customers.

A more ambitious target consists in developing higher temperature electric generation processes, which increase the ex-energy output and therefore

make higher total yield, both electrical and thermal, easier to achieve.

Fig. 18: ULCOS Steel Mill integrated with a carbon-lean electricity generation providing high temperature for the steelmaking process

Moreover, such processes could be integrated with processes from their industrial customers that would make use of high-temperature heat directly in their own process. The optimisation would be focused on a wider system and would necessarily lead to a better solution in terms of energy efficiency, at the expense of the complexity of mixing two processes synergistically into a single one (cf. figure n°18).

An evaluation, by process integration techniques, of material and energy balances including steel mills, pulp and paper mills, cement kilns, chemical industry, transportation sector and community sector is also be envisaged.

The New Energy programme presented here would target such an ambition. It would more specifically explore technologies where energy generation from carbon-lean sources would be integrated within a single process in order to design a higher yield process system, whereby electricity, steel and possibly also hydrogen could be generated at the same time. This would thus take advantage of the synergies offered by this process integration. The power plant yield would leap from 30% to at least 60%, the extra energy being used in industrial processes rather than dissipated, which is still the most common case, or used in low-temperature applications (the so-called cogeneration technologies).

The concept needs to be worked out in greater detail, but the following solution paths are already available:

- The nuclear power industry is developing 4th generation plants that would operate at higher temperature and be based on gas-cooling technologies. Temperatures of the order of 900-1000°C would be available, under which ore reduction is possible by using thermodynamic paths, which were explored in great depth in the 1950s and 1960s, before the PWR (pressurised water reactor) technology became prevalent.
- The solar scientific community has been developing concepts for solar metallurgy, which have remained outside of mainstream technology thinking, but which provide a rich basis of proposals that could be usefully revived in such a context. These explore the possibility of reaching very high temperatures, where reduction by thermal cracking becomes possible, as well as more conventional paths making use of reducing agents. Metals can also be used as energy carriers and energy storage media, in the solar community's conceptual library, which adds a further dimension to the total picture.
- Based on the IGCC concept, it is possible to imagine solutions for generating hydrogen that would be partly used for electricity generation and partly for ore reduction. They would provide easy CO_2 capture and sequestration and would therefore open the use of fossil fuel by turning them into "carbon-lean" sources.
- High temperature nuclear reactors, open up interesting paths for direct generation of hydrogen, which can further be used for transportation, ore reduction or as an energy carrier for replacing electricity.
- Given the long timescale of the technological platform (2004-2030), it would also be interesting to extend the analysis to longer-term proposals for energy generation, such as fission energy, solar towers, geothermal energy and space-based solar power plants.
- Lastly, the use of bacteria, with the complexity of the bioreactors that would be needed to grow them, should also be explored as a solution for ore reduction by bioleaching of ore heaps, for example.

New technologies for the cold plant of the post-ULCOS steel mill

The cold mill in this new steelmaking context, which we call the post-ULCOS steel mill, will call for radical technological innovations in order to accommodate the new energy context.

The simplest scenario is that the cold mill will perform the same functions by then as it does today in terms of means for achieving target product properties. It will therefore continue to include cold forming, annealing, coating, levelling and final tempering.

To minimise energy consumption, work without any excess gas in the integrated mill and offer the necessary flexibility, the new process will need to be continuous, compact and to encompass rapid heating, most probably based on electrical technologies, and rapid cooling on the basis of the minimum use of water.

The sustainable use of natural resources

Background

The steel industry has been one of the leaders in recycling of materials. Steel can be easily recovered and reprocessed for reuse. In fact, for 38% of the new steel products this is the base raw material.

There are many more materials, which are recycled within the confines of the steel plant: the non-steel by-products such as oxide dusts, sludges, scales, slag, and spent refractories. They amount to 150-450 kg/tonne of produced steel depending on the site. Many of these by-products have been reused or reprocessed inside the steel plant (e.g. via the sinter plant or steel plant) or found an application outside the steel industry (cement and construction industry, road construction, fertiliser, artificial rock). On the other hand many of the remaining valuable by-products cannot easily be reused and are classified as "residues". These end up in landfills at significantly increasing costs. In reality these materials offer significant potential for cost savings or profit.

Recirculation and reuse of water, gases and residues in, and between, the different parts of the production chain are key factors of progress. Achievements already made in water conservation and reuse should be extended to residues having an iron value. The steel industry must also embrace the philosophy of the future recycling-oriented society and contribute to the recycling of external industrial and urban residues in its processes.

Ways and means – research areas

Transforming residues into valuable raw materials

In this programme the whole processing and pre-processing of by-products should be reviewed and put in the context of (pre-) processing the whole stream of by-products. At the same time it can be advantageous and profitable to take into consideration the processing of residue streams of producers from outside the steel sector to make the whole business more profitable. To demonstrate the principles and optimise the processes for profit there should first be a review of all existing technologies, the limitations to processing and the typical costs of processing.

In the programme there should be in parallel an awareness programme to make people and workers sensitive to a new sustainable approach towards by-products: resource conservation and waste prevention are common goals and can generate opportunities and profit by minimising environmental nuisance.

Developing processes that allow a broader scope feed of raw material (ore, coke, etc).

The booming Chinese steel industry exhausts the raw material markets. High performing steel plants in western Europe are faced with shortages in availability of raw materials and in particular high quality raw materials, as they are necessary for their high productivity and cost competitiveness. The price for metallurgical coke with low ash contents and for high quality ore and scrap has exploded owing to price/demand elasticity.

In the future, steel companies will therefore need a higher degree of flexibility in processing of different materials. Utilisation of processed low quality raw materials could play an important role in optimisation of the cost mix with existing plants. Indeed, the quality of raw materials should be tuned, according to the level of required productivity of

the upstream units; in periods of lower production rates within the cycle lower quality raw materials could be processed, as long as the conditions have been well secured. The savings potential for western European plants can be estimated at around 10% of the raw material cost.

The future work has to elaborate the following actions:

- Processing low quality materials, in particular scrap, to improve the quality (in high performance aggregates)
- Improved process control on changing boundary conditions
- Definition of the most favourable process window in terms of performance, productivity and cost

3. Implementation

R&D areas	Priority	Frame	Term S = Short M = Medium L = Long	Budget (Mio Eur) 1st priority	2nd priority
1) Integrating new energy and steel productions				**56 100% FP 7, 8**	
• Integration of high temperature steel making & electricity generation & hydrogen	1	FP 7	L		
• New technologies to recover radiation thermal energy	1	FP 7	L		
• Use of low-value thermal energy	1	FP 7	S to M		
2) The sustainable use of resources				**53 20 % RFCS 80 % FP 7**	
• Turning residues into valuable raw materials or new products:					
Promoting existing technologies to recover residues from steel and other industries	**1**	**FP 7 EIB ?**	**M**		
• Increased recovery of scrap (Preheating, cleaning and use of poor quality scrap)	1	RFCS	M		
• Processing of low quality materials (broader scope feed of raw materials)	1	RFCS	S		
• Sustainable use of water and other resources	1	FP7	M		

Fig. 19: Rational use of energy, resources and residues management: Energy effectiveness & Resources savings - implementation

Advantages of steel: the societal impact of materials

1. Background

Comprehensive policies with respect to materials must take account of all relevant aspects of the social impact of materials, such as the environmental burden from the production, use and end-of-life of materials, but also the management of natural resources, the effects on health and safety of the population, on biodiversity, on employment and economic growth.

The objective of the proposed integrated project is to develop an efficient overall model that combines dynamic eco-design tools with global economic models (natural resources management, materials flow analysis and macro-economic modelling) to assess precisely all the advantages and disadvantages of competing materials for specific applications and thus help in "policy design", both at the level of product design of material-intensive goods and at the level of societal choices

2. Ways and means - research areas

Today, economic analysis related to the use of materials is being carried out more or less independently at macro- and micro-economic levels:

- at the macro-economic level, where mainly pure economists work, the objective is to describe the economic system in a global framework, with a focus on energy or raw material economy. Materials flow analysis (MFA) also provides the information necessary to deliver the quantitative data that the models need.
- at the micro-economic level, the life cycle community works on the relationship between materials, the goods they are incorporated in and the impact that their total life cycle incurs on the economy, society and the environment. Health, both in the public domain and in the workplace, and safety issues are also tackled in these approaches.

  It is necessary to assist these complementary approaches to converge as rapidly as possible, because today, with only a very loose coordination and a lack of extensive exchanges between two very different and equally complex fields, the work produced on the macroscopic level on the basis of data collected at the micro-economical level is of dubious value in terms of what it can produce, especially to assist with policy making.

  At the macro-economic level, it will be necessary to refine the methodology both on the global economical tools, several variants of which exist today (e.g. Markal and Poles) based on complementary approaches, and on MFA tools and the extensive data collection that they will induce to describe, in enough detail, the material flows in the European economy with a worldwide view. This not only describes raw materials and tackles the issue of their availability but also the recycling loop and the end-of-line, material-by-material with proper consideration of the intermediate goods.

- Redefine methodology

  Another important improvement in existing tools is to redefine methodology for LCIA (life cycle impact analysis) that broadens the scope of analysis to a complete cradle-to-grave approach, including all end-of-life aspects, multi-recycling possibilities and the end-of-life of the non-recycled fraction of the material flow. The integration of health parameters (risk assessment) and the complex matter of impact assessment using midpoint and endpoint indicators has also to be investigated further, in order to develop a range of complementary tools, each with its own target and scope, rather than competing indicators.

- Data collection

  In addition, some necessary developments focused on the steel industry will be to carry-out an intensive wide-ranging collection and verification of data, which involves the entire production chain and the recycling industry. The creation of data repositories, open and available to all users as a kind of public service, is also an important objective in this work.

- Dynamic material assessment model

- Create dynamic models that can be parameterised / modified to take into account technological improvements and new production routes (when information from new

R&D programmes is available it can be fed into the model and allow for predictive results in terms of social impacts);

- Develop specific models for recycling efficiency;
- Integrate eco-design scenarios and sensitivity analyses.

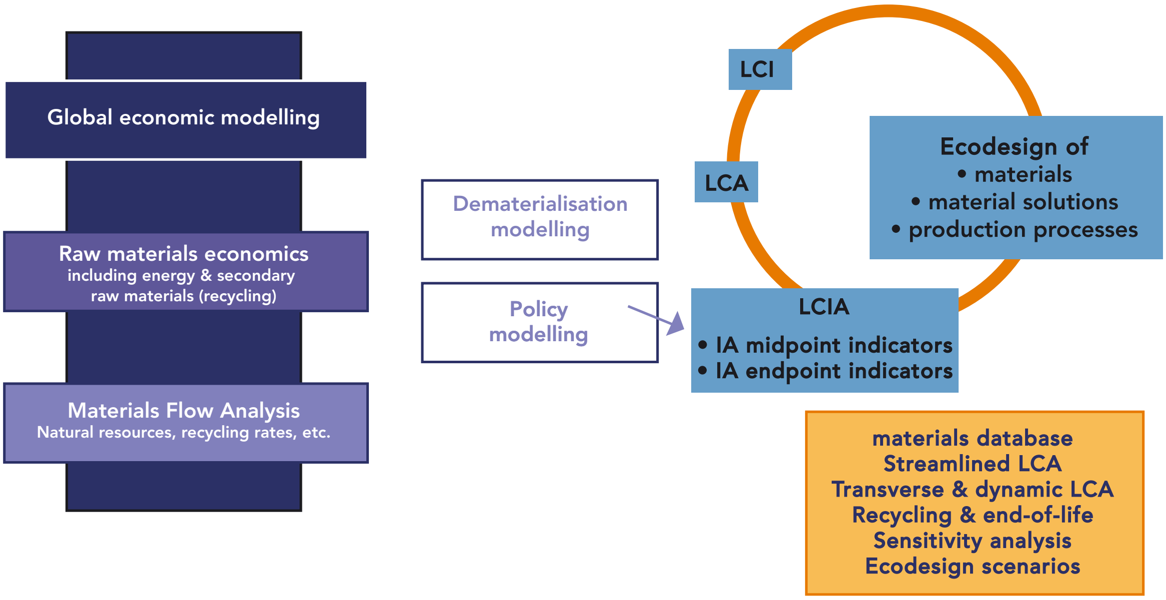


Fig. 20: Overall model that combines dynamic eco-design tools with global economic models

3. Implementation

R&D areas	Priority	Frame	Term (S = Short, M = Medium, L = Long)	Budget (Mio Eur) 1st priority	2nd priority
				30 100% FP 7	
1) Macro-economic level		**FP 7**	**S to M**		
• Energy & raw material modelling : Refine methodologies	1				
• Material Flow Analysis	1				
2) Micro-economic level		**FP 7**	**S to M**		
• Impact assessments on economy	1				
• Impact assessments on society	1				
• Impact assessments on environment	1				
• Impact assessments on health	1				
3) Redefine methodology for Life Cycle Impact assesment		**FP 7**	**S to M**		
• End of Life Assesment : Multi-Recycling	1				
4) Data collection & verification		**FP 7**	**S to M**		
• Recycling efficiency model	1				
• Scenario-design & sensitivity analysis	1				
5) Dynamic material assesment model		**FP 7**	**S to M**		

Fig. 21: Rational use of energy, resources and residues management: Advantages of steel: the societal impact of materials - implementation

Socio-economic aspects

This programme will contribute to the global climate change challenge. Transitory benefits are already expected in the medium term.

The ULCOS project should lead to a huge contribution to reducing greenhouse gas emissions reductions: it is aimed at achieving a 50% CO_2 reduction in the long term. These carbon resources should be managed in an LCA way and deliver a completely new process.

Optimising energy effectiveness and conservation of natural resources (fuels) will also bring a significant contribution to the sustainability of the steelmaking activities. Not only is there an opportunity to enhance greatly the environmental performances but at the same time strengthen the viability and economic of steelmaking.

An overall global modelling tool concerning the social impact of materials would bring a very valuable contribution to the two main long-term objectives of the steel sector by decreasing the dependability of energy and raw materials.

- It would allow strengthening the competitive position of steel products, because current materials assessment tools / dematerialisation studies do not effectively take into account the main advantages of steel applications;
- It would improve the sustainability of steel production processes and steel solutions.

In addition, the aforementioned redefinition of the methodology for LCIA will contribute to an improvement in the social acceptance of the steelmaking industry and of the steel products as well as the position of the stakeholders towards such industry. Nowadays, there are many LCA and LCI methodologies, but not all of them are suitable to assess the real impact of steel primary and secondary products and by-products on the environment.

Stakeholders

- Steel research centres
- Suppliers of gas and energy
- Suppliers of iron ores and coals
- Equipment suppliers
- Steel industry
- IISI
- Non ferrous metals producers
- Other energy intensive industries (cement, pulp & paper, chemicals, glass, etc.)
- Transportation and Community sectors
- Electricity producers
- Nuclear plant designers
- Public authorities
- Recycling industry
- Downstream users of by-products (Cement & construction sectors, road construction sector, non ferrous metals producers)
- Modelling laboratories for Eco-design and LCIA studies
- Modelling laboratories for global economic modelling (i.e. JRC/IPTS Seville)
- Specialised universities for dematerialization, for policy modelling
- Accrediting companies

C. Appealing steel solutions for end-users

Introduction

Partnerships developed by the steel industry cover a vast range of industrial sectors, such as raw materials, energy and equipment suppliers, transport sectors, manufacturers, customers and recyclers, standardisation bodies, national and international authorities and financial institutions.

Almost all European manufacturing sectors are largely based on the utilisation of steel in various forms. In addition to the automotive and construction sectors, important application areas including marine technology, packaging and engineering can all benefit from the development of new steel grades and manufacturing technologies. Shipbuilding, offshore construction as well as oil and gas transport via pipelines in Arctic or deep sea areas need collaboration from suitable partners to develop and process the necessary steel grades. The development of steel plate for use in long-distance, large diameter, sour –gas-resistant pipelines is being performed in partnership with pipe manufacturers, the oil and gas industry, and testing authorities. The work in this area is aimed at developing the production of high-strength steels, with high toughness and good weldability, suitable for use in low-temperature and high-pressure conditions.

Equipment manufacturers work in close co-operation with special steel producers. Stainless steel is very often the best value option over the total life of a project or product. Corrosion resistance, cryogenic properties, easy cleaning ability and aesthetic appearance, strength-to-weight advantage, and fire and heat resistance are unique properties afforded by more than 60 different grades of stainless steel.

The European steel sector constantly addresses the challenge of meeting customers' demands for a broad variety of ever more sophisticated high-performance materials. To meet these needs, direct partnerships between steel producers and their immediate customers are a strong requirement. Such collaborations are major features of new product development in the steel industry and an essential element in the promotion of steel use. In the framework of this Strategic Research Agenda, the automotive, construction and energy sectors are regarded as priorities.

Optimal processing of the steel products of the future is a challenge that must be addressed by improving existing production technologies or by developing new processes or technologies.

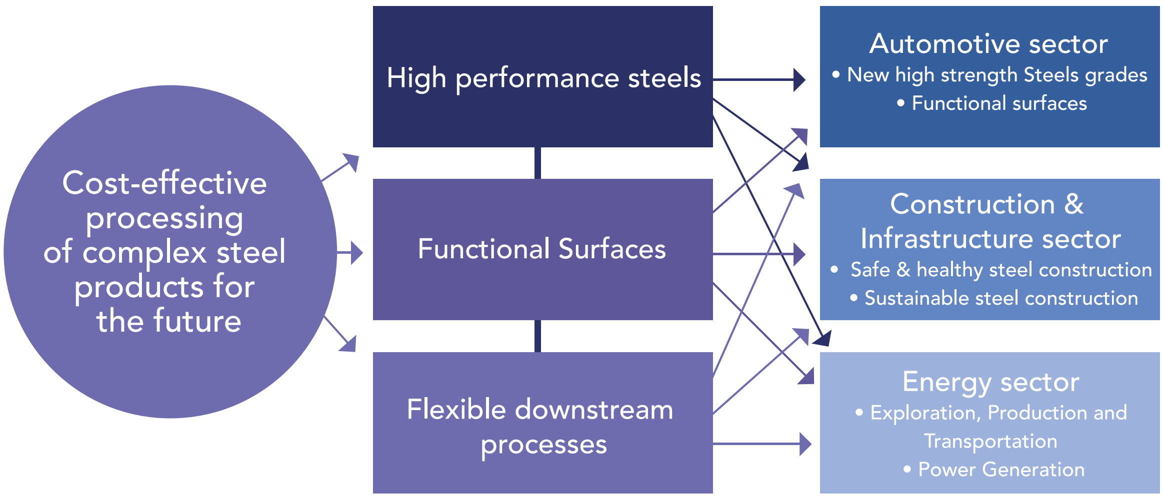


Fig. 22: Appealing steel solutions for end users: cost-effective processing of complex steel products to meet societies

C1. Sub-societal Programme: Automotive industry

Background

Mobility is a basic requirement for people in modern industrial and knowledge-based societies. In the EU freedom of movement for both persons and goods is also a prerequisite of the European integration. Value creation and economic prosperity have only been made possible by the spatial mobility of people and goods.

Energy consumption in the traffic and transport sector is dominated by road (73%) and air transport (12%). Worldwide, the transport sector is responsible for about 20% of greenhouse gas (GHG) emissions. The decrease in the specific fuel consumption of cars has been counterbalanced by trends towards bigger cars, high-power engines, and the increasing number of cars and lower passenger occupancy of cars. In addition to new fuel technologies, new transport concepts and construction methods are required in order to be able to reduce greenhouse gas emissions despite increasing passenger and goods traffic.

Every year some tens of thousands of people are killed in Europe in traffic accidents and more than 1.7 million people are injured. Road deaths are still the prime cause of mortality among the young. New strategies for maintaining mobility and for mitigating the consequences of accidents will therefore be necessary in the future. In this context, safety of passengers and drivers is increasingly becoming an important priority, as recommended by the EU Commission (a decrease by a factor two).

Challenges of the Automotive Sector

The automotive industry is dedicated to respond to the mobility needs of individuals and those of society as a whole. The targets to be derived from these challenges are

- Environmental sustainability owing to energy consumption, CO_2 emissions, resource efficiency, dismantling and recycling behaviour
- Safety
- Reliability
- Cost effectiveness
- Comfort

Further needs for the car of the future are

- Modular and flexible production
- Individual design.

Those challenges will be addressed collectively by working in close co-operation with all relevant stakeholders.

Common challenges to Steel and Automotive Sectors

The steel industry and the automotive industry in the EU have to maintain their leadership in the world market. Simultaneous engineering and concurrent engineering are tools to meet the challenges of the world market for the targeted manufacturing of vehicles. The steel industry, with its competence in production processes and tailoring of material properties, and the automotive sector, with its vision for the future development of vehicles, are well prepared for an EU joint action to achieve a quantitative leap in the construction of the car of the future, which would not be attainable through the partnership of individual steel and automotive companies.

The automotive industry stimulates light construction innovations. It is essential for the steel industry to exploit its material expertise through material development and component design for use in mass production and, in co-operation with the automotive sector, to achieve further improvements or totally new solutions for vehicle concepts. Future developments within the steel industry will also have to take into account the future needs of the automotive sector regarding modular and flexible production and individual design of new car models.

The targeted development of a production and manufacturing chain using new high performance steels for lightweight constructions including new forming and joining techniques and new coating processes will be a very ambitious R&D aim.

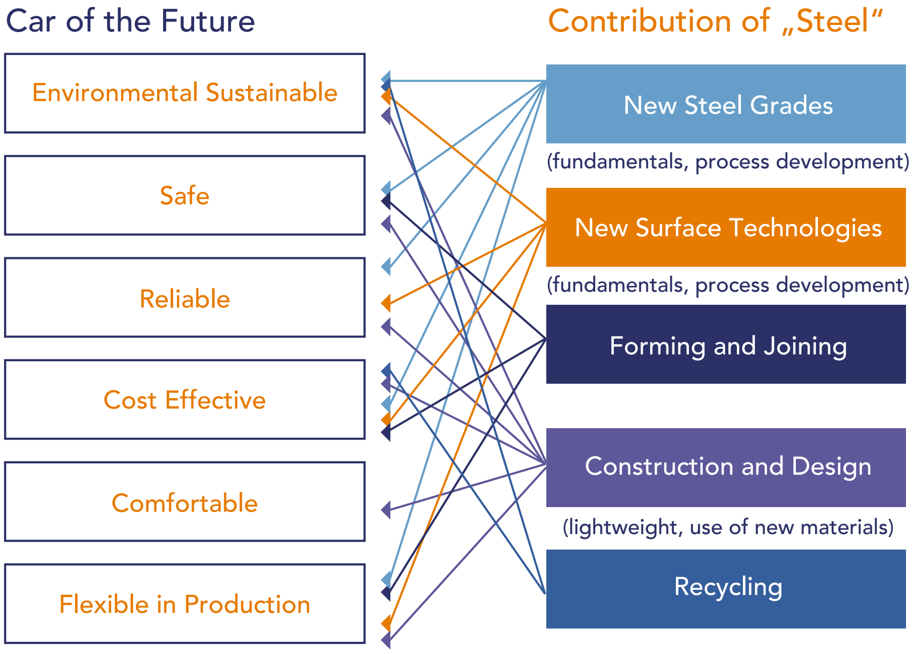


Fig. 23: Challenges of the automotive and steel sectors

Ways and means – research areas

At present, two main R&D themes and research areas have been derived from these challenges and are proposed up to the medium and long term:

- New steel grades and innovative manufacturing methods for complex components
- Development of new functional surfaces

1. New steel grades and innovative manufacturing methods for complex components

Background

New design concepts for the construction of advanced lightweight ground transportation systems, such as automotive vehicles, are basically driven by economical and ecological requirements. These requirements always evolve quickly becoming harder, thus influencing the car product and process conception and pushing innovative solutions, such as new materials. The steel industry responds to this challenge by the development of new steels with improved properties and the relevant technologies and new design concepts for the body in white.

New steel types show excellent combination of strength, ductility and crash behaviour by a tailored combination of metallurgical characteristics (i.e, fine grain size, soft and hard phases). A further improvement of automotive relevant properties would be reached by new "superductile" steels. Their extreme high energy absorption at high strain rates leads to significantly improved passive safety. Another possibility for advanced materials for the future is the development of steels containing high contents of light metals and austenitic steels.

Owing to the extreme formability of these "superductile" steels, high strength car components with completely new design will become possible. The new steel grades will offer a unique chance for cost-efficient construction with a high degree of passive safety but the suitability of the materials has to be demonstrated by pilot production and testing (e.g. crash tests) of parts.

Beneath advanced steel types new design concepts for the body in white can lead to enhanced weight and/or performance. Space-frame or mixed shell/space-frame allows significant improvements

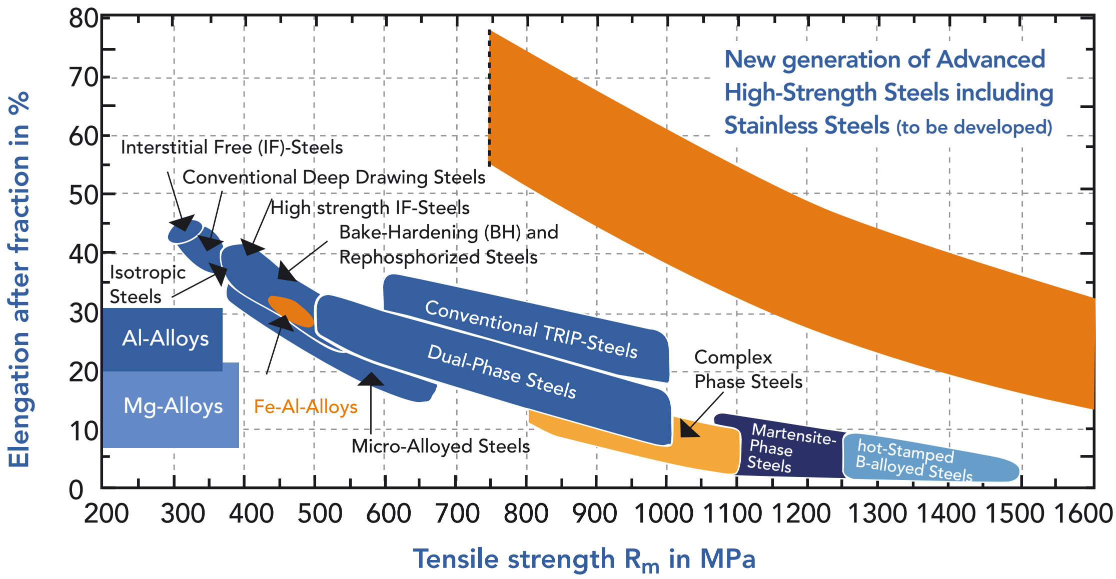


Fig. 24: New Generation of High Strength Steels for Light-Weight Construction

compared to conventional shell design. Mixed shell/space-frame concepts scale down the weight of the body in white by 25% compared to a successful large-scale series production car, while keeping performance levels in place and only slightly increasing production costs. An important aspect for the use of new design concepts is an extensive analysis of the production feasibility.

Important aspects for the use of new steels are environmental issues and recycling. The environmental impact of new steel grades and manufacturing technologies will be determined. Compared to alternative materials, steel offers the best opportunities for recycling. Important future aspects are the increasing of the recycling of scrap metal, an optimising of the use of alloys in the steel eco-cycle and an improved scrap quality by new sorting and cleaning technologies. Life-cycle and cost analysis will be performed with appropriate tools and models (societal impact of materials) but the easy dismantling conception will be undertaken in close collaboration between both the steel industry and the automotive sector.

Ways & means – Research areas

Body solutions for lightweight and improved safety. The construction techniques employed in modern automobiles are basically divided into shell design, space-frame design and mixed shell/space-frame design. New steel grades and more intelligent use of the materials, together with new types of production technologies, are imperative if the car of the future is to combine mobility with sustainability. The eminent advantage of the material is best shown by aiming at its use in complex parts (e.g. parts with high deformation degrees) and production with innovative manufacturing methods (joining by laser welding, hydro-forming, roll-forming, etc.).

Power train solutions for improved efficiency. New steels for connecting rods, gear teeth, roller bearings, drive shafts and also new tube steels need to be developed. The applicability of new forming, preparation and processing techniques (including near-net-shape forming and thixo-forming) must be tested. New steels for injection systems (raised temperatures and pressures) and for smaller component sizes can be expected to provide improved performance and savings in fuel consumption. New steels require the development of new working methods (particularly drilling).

Chassis solutions for improved drive dynamics. New steels with improved fatigue properties for smaller component size (including spring steels) and new forming and processing techniques are at the forefront of future developments.

Dismantling and recycling of cars with complex components from new steels. The environmental impact of new steel grades and new joining techniques has to be taken into account. With regard to resource efficiency, increasing scrap recycling and optimising the use of materials in the steel eco-cycle will be assisted by improving the scrap quality by new sorting and cleaning technologies.

Steels solutions for new car concepts. The automotive industry is an innovator in the field of most cutting edge technologies. At the same time production is carried out on a large scale. Therefore, the launch of new steel grades in the automotive sector offers the potential of rapid success and spread of new steel solutions. Especially new modular concepts for car body, new motor and suspension concepts using new material applications will answer the challenges concerning societal and economical needs of future generations of cars.

Design methods and simulations tools will accelerate the proposed developments regarding body solution for "Power train solutions for improved efficiency", "Power train solutions for improved efficiency" and "Chassis solutions for improved drive dynamics".

Implementation

The automotive sector is of major importance for the European production industry. Steel plays an important transversal role in enabling new technologies in order to meet the future demands, e.g. lightweight car bodies, high efficiency powertrain, safe and high performance chassis, cost-competitiveness, easy and flexible manufacturing. The work programme "Innovative steel grades, manufacturing methods and design" aims to provide a holistic approach to find the solutions for these technology frontiers in a partner-oriented research.

The project schedule with the 1st priority comprises the R&D areas "body solutions for lightweight and improved safety" and "power train solutions for improved efficiency". The 2nd priority projects include "chassis solutions for improved drive dynamics", "dismantling and recycling of cars with complex components from new steels" and "steel solutions for new car concepts".

The research programme will include projects of 7th FP, of RFCS research, of national funding and of industry funding. Within 7th FP the focus will be in the theme "Nanosciences, Nanotechnologies, Materials and New Production Technologies", but some topics will also address the themes "Information and Communication Technologies" and "Transport". Objectives are to strengthen the competitiveness of the industry by high-added-value products with improved performance and tailored properties as well as by new production technologies to meet customers requirements. Application research within the theme "ICT" may assist intelligent controls for high-precision manufacturing and low-resource utilisation. Within the theme "Transport" the research work will ensure sustainable urban mobility and improved safety to protect drivers, passenger and pedestrians. The research activities will be mainly carried out as Collaborative Projects and – to a smaller extent - as Individual Projects. The interaction between the universities and research centres might be carried out by means of Networks of Excellence while the overall managing of the programme can be supported by "Coordination and Support Action".

An overall budget of 42 M€ for the 1st priority and of 25 M€ for 2nd priority projects is planned. The projects will start in 2007. The time frame for the 1st priority projects is 2007 till 2013. A strong collaboration between steel industry, automotive industry, suppliers to steel and automotive sector, steel research centres and universities is foreseen on a European level to achieve the objectives.

R&D areas	Priority	Frame	Term S = Short M = Medium L = Long	Budget (Mio Eur) 1st priority	 2nd priority
1) Body solutions for lightweight and improved safety				**37 (50 % RFCS 50 % FP 7)**	
• Advanced high strength steels for inner, outer and structural parts (metallurgical development of HSS for visible parts)	1	RFCS	M to L		
• Steel matrix composites	1		L		
• Development of laminates, functionalisation of steel			S to M		
• Manufacturing technologies for part production in optimised biw	1	RFCS	M to L		
• Multi-material solutions	1	FP 7	M to L		
• Design methods and simulation tools	1	FP 7	M to L		
2) Power train solutions for improved efficiency				**5 (60 % RFCS 40 % FP 7)**	
• New high strength steels for high-performance engines	1	RFCS	M to L		
• High-temperature and corrosion-resistant steels	1	RFCS	M to L		
• New advanced high strength tubes	1	RFCS			
• Design methods and simulation tools	1	FP 7	M to L		
3) Chassis solutions for improved drive dynamics					**5 100 % FP 7**
• High fatigue resistant steels	2	FP 7	M		
• Fatigue-orientated design and manufacturing	2	FP 7	M		
• Design methods and simulation tools	2	FP 7	M		
4) Dismantling and recycling of cars with complex components from new steels					**5 (50 % RFCS 50 % FP 7)**
• Reuse of alloying elements and improving the scrap quality	2	RFCS	L		
• New process technologies for recycling of scrap	2	FP 7	L		
5) Steel solutions for new car concepts					**15 100 % FP 7**
• Modular concepts and/or space frame design	2	FP 7	L		
• Steel in new motor and new suspension concepts	2	FP 7	L		

**Fig. 25: Appealing steel solution for end users -
New steel grades and innovative manufacturing methods for complex components implementation**

2. Surface technology on steel sheets for automotive applications

Background

The demand for new surface layers and new coating technologies for structural materials with improved functional properties is driven by new technological, economical and ecological requirements of the automotive industry and promoted by scientific progress in the understanding and a tremendous progress of new advanced surface technologies.

To give some examples based on the application of coil-coated steel for the automotive industry:

- The car manufacturing industry has an increasing demand for pre-fabricated modules such as roofs or doors. Currently, such parts cannot be fabricated with existing coil-coating materials owing to conflicting demands such as high flexibility of surface coatings for forming and increased hardness for high scratch resistance. Furthermore, joining technology and edge corrosion of pre-primed and/or pre-finished steel have to be regarded as being yet unsolved and challenging problems.
- Some surface treatments with rather singular properties – such as release and repair systems – are based on hazardous chemicals that have to be replaced.
- Research has recently demonstrated which basic mechanisms are responsible for the loss of adhesion of organic coatings and durability can be improved significantly by means of tailored surface modification and smart film deposition.
- New Zn-alloy coatings (e.g. ZnMg+X-alloy coatings) show superior corrosion protection and manufacturability (e.g. laser weldability) but the alloy design has not been finished yet and process technologies such as physical vapour deposition need have still to be implemented in the production routes of the steel industry.

Surface technology nowadays allows the design of surfaces with unsurpassed properties. However these techniques, which are based for example on vacuum processes, radiation curing, CVD, self-assembly or nano-composite organic coatings, have not yet been applied to mass produced steel sheets. These dedicated surface technologies have to be developed and evaluated for their application in the production of automotive steel sheets.

These advanced surface coatings for automotive applications should provide functional properties such as

- Extreme long-term stability
- Tailored surface anchor groups for adhesive bonding or paint adhesion
- Tailored surface hardness and wear resistance
- Self-healing properties
- Inherent protection of cut-edges and forming induced defects which are caused during the manufacturing process

A better understanding of the structure-property relationships and further optimisation of the tailoring of the respective surface technologies for bulk steel production is crucial to enable the required technological breakthroughs.

However, the surface treated metals will always undergo further processing such as forming or joining. In particular, the forming and bonding of surface treated metals will be of great scientific interest. This requires among others the experimental and theoretical understanding of mechanical properties of thin metallic and polymeric films, the simulation of mechanical deformation processes and the adhesion between dissimilar materials on a molecular level.

Ways and means – Research areas

Improved corrosion resistance and manufacturability based on new zinc alloy coatings and thin functional films. Novel zinc alloy coatings are of increasing interest for the automotive industry since they may combine a number of new beneficial effects, such as markedly improved durability, improved manufacturability (e.g. laser welding and formability) with the already known advantages of conventional zinc coatings. However, special preparation techniques result now in surface structures not obtainable by classical methods. This offers the possibility to engineer totally new surfaces with unprecedented surface properties (i.e gradient or nano-composite zinc which show superior durability, welding and forming properties). This should also allow the use of thinner coatings to achieve increased durability and

adhesion performance together with improvements in application properties such as formability and weldability. As the method is not limited to thermodynamically stable phases, surfaces with completely new and hitherto unknown properties may be obtained by dry coating technologies (development of flexible downstream processes), creating opportunities for an unprecedented wide range of diversified applications, including those for the automotive industry. For instance, as surface compositions and oxidation state are adjustable in a wide range, coatings with pronounced depth profiles could be produced.

The long term objective is then to extend the range of current zinc-alloys-based coatings to more sophisticated coatings combining appealing advanced properties (aesthetics, self-cleaning, scratch resistance, dirt-resistance, antimicrobial properties, etc.). Research must to be carried out in combination with theoretical modelling to predict the properties of these advanced coated products and steel solutions. Developing more ecologically friendly processes, e.g., reduction of cleaning processes and avoidance of heavy metal containing conversion layers represents today an important industrial challenge. Different solutions are open and possible through the development of new coating technologies. New functional thin films have to be developed for improved tribological properties of steel sheets for the automotive industry. This kind of new thin films should on the one hand combine temporary corrosion protection, improved formability but on the other hand should be provide a basis for adhesive joining and should not disturb the further painting process in the automotive manufacturing process.

Vertical integration of automotive pre-treatment and painting. Today several surface finishing treatments are applied to the coils supplied by the steel manufacturers, i.e degreasing, phosphatation treatments, chromate post-treatments, primer deposition and final painting of the car structures. The aim is both to simplify these treatments and to make them more environmentally friendly. The development of new coating technologies for organically pre-primed/pre-fillered steels as semi-

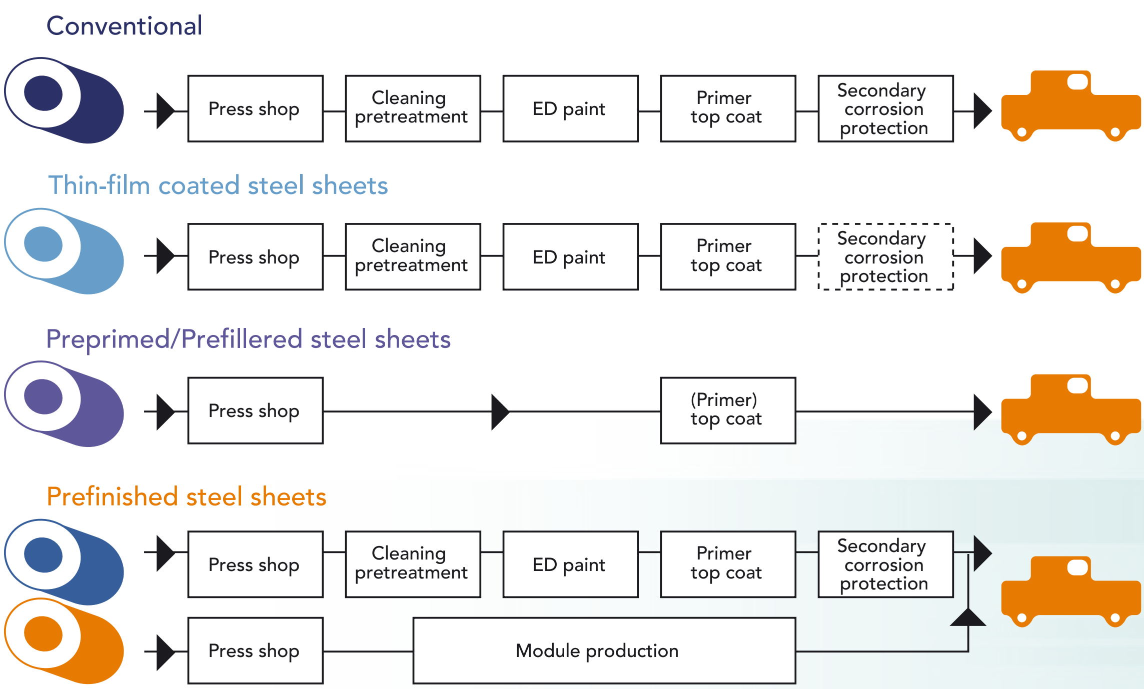


Fig. 26: Illustration of the Possibilities to Shorten the Production Chain in the Automotive Industry by Using Advanced Pre-primed Steels

finished products with advanced tailored properties offers great potential for this application, especially for the improvement of the manufacturability and performance of automotive parts. However, these products help to shorten considerably the length of the production chain in the automotive industry as seen in figure n°26, as an example. This type of primed/pre-fillered steel technology will increase sustainability by avoiding the formation of any waste. The waste-free production of pre-primed steel is, besides the addition of functional layers to the coating systems one of the major goals for the future of the coil coating industry.

These kinds of advanced coatings can be applied either at the end of galvanising lines or in coil-coating lines. To provide the customer with additional functionality new curing methods such as radiation curing (UV-curing or electron beam curing) are of high interest. Highly cross-linked films based on 100% systems (no VOCs) are formed by radiation curing.

Predictable adhesion forces in joint materials based on simulation tools. The production and use of coated steel products has to integrate simulation tools in the future to enable the prediction of product properties such as corrosion resistance and adhesion. Especially, the prediction of the long-term adhesion of joined materials, which are again composed of multi-layers, can only be done by combining advanced interface analysis techniques with simulation tools. Since adhesion between different layers is influenced by the mechanical properties of the films and substrate as well as the very interface chemistry, multiscale simulation tools will have to be developed which bridge the gap between atomistic understanding of molecular adhesion forces (application of e.g. Density Functional Theory) and the simulation thin film and interface mechanics based on continuum mechanics (Finite Element Simulation).

Long-term stability of multi-material automotive constructions in joint areas. There is an increasing demand for multi-material constructions in the automotive industry. This leads to the use of new joining technologies (e.g. adhesive joining) and the combination of steel with other metals and metal alloys or even plastic components. New pre-finished steel products with tailored surface properties will be needed for these multi-material concepts. Especially, the long-term stability of the joint areas will have to be addressed both by new surface technologies and by the simulation of the long-term stabilities in these areas.

Implementation

A strong demand exists for new surface coating technologies for steel sheets which is driven by new technological, economical and ecological requirements of the automotive industry and promoted by the development of new knowledge based thin film processes and simulation tools. The objective of this work programme is the development of knowledge based surface technologies with the implementation and combination of chemical, electrochemical and metallurgical nanotechnologies for thin film deposition and tailored hybrid materials in combination with advanced multiscale simulation tools.

Based on the combination of new nanotechnology, multiscale simulation tools and advanced production technologies it will become possible to achieve predictable unsurpassed product properties of surface finished steel sheets for automotive constructions. The newly developed knowledge based surface finished metal sheets will then be integrated in automotive construction processes.

The research programme will include projects of 7th FP, of RFCS research, of national funding and of industry funding. Within 7th FP the focus will be in the theme "Nanosciences, Nanotechnologies, Materials and New Production Technologies".

An overall budget of 30 M€ for the 1st priority is planned. The projects will start in 2007. The time frame for the 1st priority projects is 2007 till 2013. A strong collaboration between steel, automotive and chemical industry as well as a strong involvement of research institutes and universities is foreseen on a European level to achieve the objectives.

R&D areas	Priority	Frame	Term S = Short M = Medium L = Long	Budget (Mio Eur) 1st priority	 2nd priority
1) New Zn-alloys for superior corrosion resistance				**8 (50 % RFCS 50 % FP 7)**	
• Design of new ZnMg+X alloys	1	RFCS	M		
• Design of new binary and ternary Zn alloys	1	RFCS	M		
• Process development simulation and implementation	1	FP 7	M		
2) New combined surface technologies for highly functional materials				**6 (33 % RFCS 67 % FP 7)**	
• Pre-painted steel sheets for automotive applications					
• Development of new functional surface coatings based on new materials chemistry and curing technologies	1	RFCS	S to L		
• Surface aspects characterisation after painting					
• New combined smart and sustainable process routes in surface finishing of steel sheets	1	FP 7	M to L		
• Integration of functional materials into automotive production	1	FP 7	M to L		
3) Predictable interface engineering based on simulation tools					**2 100% FP 7**
• Predictable coating engineering based on multi-scale simulation Tools	2	FP 7	L		
• Interface engineering	2	FP 7	L		
4) Long-term stability of multi-material automotive constructions in joint areas				**14 100% FP 7**	
• Simulation tools for the prediction of long-term stability	1	FP 7	M to L		
• Adaptation of coatings to new joining technologies	1	FP 7	M to L		
• Corrosion protection in hems and flanges	1	RFCS	M to L		

Fig. 27: Appealing steel solution for end users - Surface technology on steel sheets for automotive applications - implementation

Socio-economic aspects

The importance of the automotive sector for the EU economy is characterised by the following figures:

- There are more than 14 million new car registration units per year in EU (15) and more than 17 million new vehicle registration units per year (including commercial vehicles, coaches and buses);
- The passenger car share represent an estimated turnover of about € 300 bn/year in the EU (15);
- The European vehicle park reached nearly 220 million units in 2003 of which passenger cars account for about 87%;
- 23% of cars in use in the EU are diesel powered against 16 % in Japan and nil in the US;
- The number of directly employed persons in the production of motor vehicles is about 1 050 000 and the total number including indirect employment is about 1 900 000.
- Taxes associated with the purchase and use of motor vehicles contribute over € 350 bn/year to the revenues of the EU Member States Governments

Steel has an important transversal role to play in enabling the technologies necessary to achieve the challenges faced by the automotive industry. The automotive sector programme would facilitate the integrated approach – design, materials and processes – needed for further innovation and value addition in the automotive industry. Several aspects are covered:

- Ecological aspects. In an ecological comparison of the products, taking life cycles and the recycling ability of steel into account car bodies, made with high-tensile steels and tailored blanks with more than 20% saving in weight, can be far less detrimental to the environment than today's conventional bodies regarding the resource efficiency indicator "total material requirement" (TMR), and the "global warming potential" (GWP). Improving the drive train efficiency would bring a strong contribution to decrease CO2 emissions.
- The implementation of innovative technologies has in the past contributed to reducing the impact of motor vehicles on the environment. To give a few examples: 100 of today's cars produce the same amount of emissions as an average car built in the 1970s, the amount of local pollutants has been reduced 20-fold in the last 20 years, while vehicle noise levels have been reduced by 90% since 1970. Such progress should be pursued in the coming decades.
- Steel is a material easy to recycle (more than 400 million tonnes per year)
- Societal aspect of increasing the integrated safety for all road users

Stakeholders

- Steel industry
- Steel research centres
- Automotive sector
- Suppliers (surface treatments and chemical industry)
- Suppliers to the automotive industry
- Universities

C2. Sub-Societal Programme: Construction and infrastructure sector

Background

The European construction industry has a total annual turnover of approximately € 1098 billion. It provides employment directly to 12 million workers accounting for 7% of total employment and 28% of industrial employment. It is estimated that 26 million workers depend in one way or another on the construction sector. The provision of buildings and infrastructure is recognised as being essential for economic development (figures n°28 to 33).

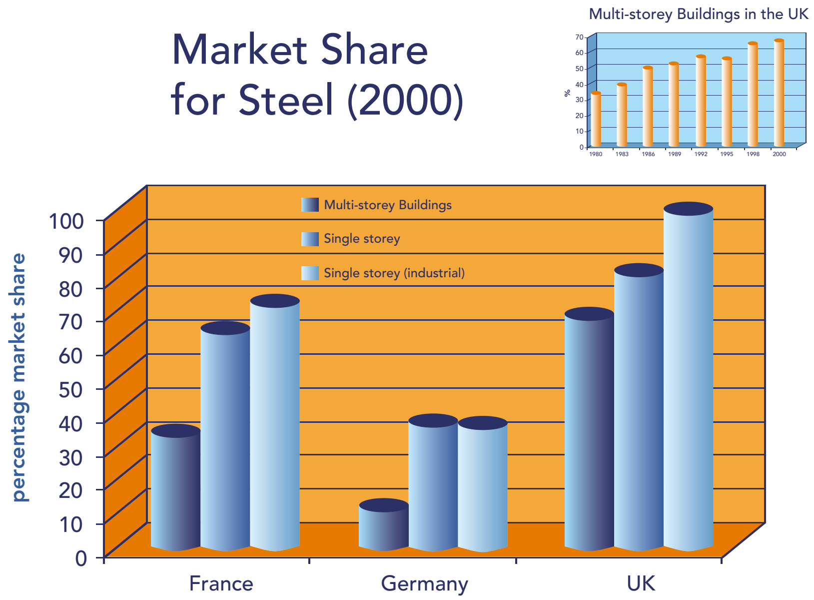


Fig. 28: Market share of steel construction in three EU Member States (2000) and of multi storey buildings in the UK (from 1980 to 2000)

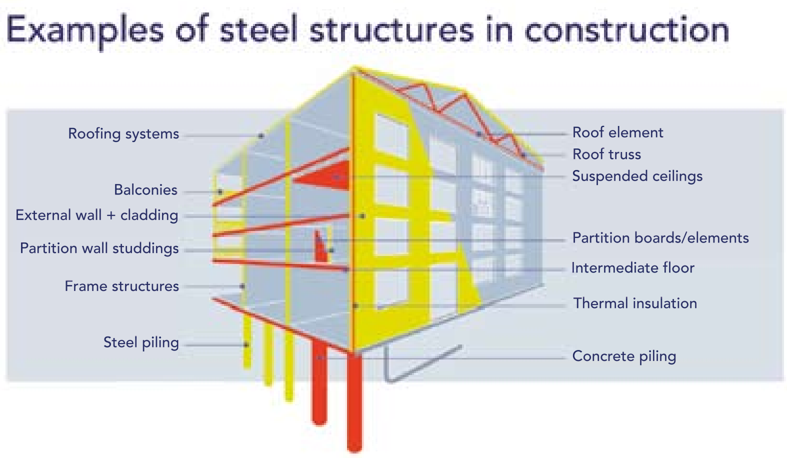


Fig. 29: Steel construction: building structure

Fig. 30: Steel based systems for residential construction

Steel is one of the most important construction materials competing to some extent with other materials but also opening up completely new possibilities. Almost half of the steel produced is used for construction purposes. To exploit the full potential of steel as a construction material, the development of new grades, building components and systems, composite structures, and construction technologies is needed. The safety and health are the main performance aspects of the built environment essential for the security and quality of life of occupants and other users.

The quality of the built environment greatly influences the performance of individuals, organisations and the well-being of society in general.

Nevertheless, the percentage level of funding from European and national programmes reflects neither the significance of construction as an economic activity nor the significance of the built environment as a fundamental contributor to quality of life.

The construction industry is highly fragmented and there is need for much closer cooperation between leading suppliers and major construction companies. A key aspect of the steel industry strategic plan over the next 30 years is therefore to work more closely with customers seeking technical and commercial alliances.

Different challenges should be addressed to meet Society's needs:

- *Sustainable development*

The construction industry consumes large quantities of raw materials accounting for 40% of all resource consumption. It also produces a large amount of waste, in the range of one tonne per capita annually. Building services account for around 45% of energy consumption in Europe, with a further 5 to 10% being used in the processing and transport of construction materials. The construction sector is one of the main emitters (about 25%) of GHGs.

Environmental issues in construction are characterised by their complexity and the diversity of factors concerned and the need for innovative and multiple solutions. As the largest and most fragmented industry, the construction sector faces a huge challenge in pursuit of sustainability, but, as an infinitely recyclable material, steel offers a great potential in solving environmental issues. Selecting materials according to their life cycle impact on

the environment will promote and encourage the use of steel.

Excessive uses of materials, energy, and water must be decreased. Noise and dust must be minimised during construction and better sound insulation is needed in urban areas. Sustainability issues drive the steel construction sector to develop and design new products according to new regulations. The current creation of the Construction SRA of ESTP is meant to facilitate the contribution of steel to construction and to the built environment towards sustainable development

- *Urbanisation*

Urban development in the EU continues to accelerate. People move into large cities and other densely populated areas with limited access to workplace. This creates new needs and widens the scope for improvement of existing solutions and innovations.

Fig. 31: Urbanisation : existing solutions and innovations

Steel-based solutions have good merit in refurbishing, extension and performance improvement of existing structures e.g. schools, hospitals, and transport infrastructure. This is especially true in those countries where the knowledge of its potential is less developed.

- *Demographic changes*

The average age of population is increasing, which means, for example, that in multi-storey buildings stairways do not provide sufficient access but elevators are needed. There is a growing need for more responsive buildings and improved services for the elderly. Greater adaptability is needed in apartments, as a result of the changing needs of smaller families, as well as development of new solutions for renovation of existing buildings and reducing the costs of housing.

Millions of new homes are needed in Europe owing to migration and too low a quality of housing in certain areas. Existing building stock is ageing and needs servicing, repair renovation and refurbishment to improve the quality of living environment. Development of new steel-based solutions for residential construction, single family housing, and multi-storey apartment buildings is needed.

- *Information and communication technology*

The ever-increasing capacity of information and communication technology offers a powerful tool for innovative product development and the realisation of construction projects. Multiple individuals, functions and, increasingly, even separate companies can contribute to any given concept.

Information technology can be used to monitor and control the operational performances of buildings and structures. Inhabitants expect that all modern information services are available in private homes.

- *Safety and health*

Traditional construction work is often considered as dirty, ineffective, dangerous and of low quality. The development of steel solutions, e.g. prefabricated steel based components, would improve safety in building construction areas and reduce both costs and construction time.

Safety should be also improved by exchanging best practices in the erection of buildings. In the EU-15 one million site accidents occurred in 2003, killing one thousand people. Ageing is also a great challenge to training and education of workforce. More attention has to be paid to better usability of technologies

The living environment is greatly influenced by construction materials. No adverse effect of products is allowed in indoor quality, so more attention has to be paid to the long term impact of gases released by construction materials. Being a non-emitting material steel offers a reliable solution in this respect.

- *Recycling and reuse of construction material*

For economic reasons most construction materials are neither reused nor recycled to their maximum potential. To improve the conservation of resources and to decrease the amount of waste generated, existing recycling methods should be promoted and fully implemented while new more effective technologies have to be developed.

In this respect steel offers a unique alternative, because it is fully and infinitely recyclable. Taking recycling into consideration at the planning phase means that the dismantling of structures and collection of steel scrap can be done more effectively and at lower cost.

- *Earthquakes and other accidental loadings*

Traditional concrete and masonry buildings are prone to severe damage in earthquakes and other accidental loadings. The safety level of reinforced concrete depends very much on the construction as well as the quality of the work. Steel-based solutions offer an efficient protection against earthquakes in both old and new buildings. Steel can also be used to strengthen old masonry structures. Still there is a need for improved steel structures and materials for seismic energy dissipation.

- *Fire*

Steel has the natural weakness that at high temperatures it gradually loses parts of its strength, therefore steel structures have to be designed to ensure safe escape from building in the case of fire. Despite extensive development, standards and regulations in this field vary greatly from country to country and local authorities can apply different practices. Reasons for various regulations should be investigated and generally accepted code created. This code should be developed based on performance based fire safety engineering and modern risk analyses.

Fire safety of steel-based construction can be evaluated by different methods. Development of fire-resistant steel grades that have good ductility and weldability is one option. Effective combination of steel with other materials offers also a potential solution.

- *New EU directives*

The Construction Products Directive is one of the New Approach Directives that establish a level playing field for free circulation of products in the internal market introducing the CE marking. The progress towards a common market for steel and steel-intensive construction products will take place through technical specifications and structural Eurocodes.

Several other EU Directives are concerned with construction products and works. The Directive on Energy performance of buildings aims at the improvement of the energy-efficiency and its influence together with related measures and action plans is expected to grow.

To achieve its specific objectives the steel construction sector will have to address the following key features:

- *Performance based design*

The construction industry is labour intensive and relies on traditional manual methods. Moreover, as a highly fragmented sector, it is slow to adopt new innovations and technologies, and development is initiated from the technical needs inside the supply chains. Many operators are small and their resources are very limited. Owing to high price-based competition the main focus is on initial building costs. New social and technological drivers for the sector have brought forth ideals and business models emphasising the performance of the end product.

The performance of a completed building results from the individual performance characteristics of the different structural and technical systems and their interaction and influence on each other. For a construction product development, the consideration of fitness for use instead of fitness for manufacture is a new kind of approach.

Various performance indicators have been developed but they are not used effectively. The regulated building requirements have to be incorporated in the performance analysis. Thus, performance-based regulations, codes and specifications should be more widely used. Faster adoption of new technologies would require joint efforts in the dissemination and demonstration of new solutions and technologies.

• Supply chain and the challenge of delivery

The construction process consists of several successive, partly linked steps that have to be carried out in smooth harmony for the optimal result. Firstly, the structure has to be designed from a constructability point of view, using life cycle engineering and performance approach. Secondly, for effective production, an integrated management approach has to be applied. Just-in-time delivery requires close co-operation with upstream and downstream operations. The whole construction chain should evolve more into a manufacturing process. The use of prefabricated steel-based components and systems would reduce the time of delivery.

• Partnership with customers - potential of steel construction

The expectations of customers are initially related to prompt delivery, investment and operation costs, and upgrading possibilities. In the long term, efficient customer relationship management must be available.

Direct partnership with customers is the tool through which the steel industry will meet the needs of consumers. In order to respond to these needs, three kinds of actions should be developed:

Effective implementation and dissemination of results achieved in joint projects and adoption of best practices should be performed initially. Steel's market share varies from country-to-country and is very dependent on the type of construction, but it has always been used in heavy infrastructure, bridges, pipelines and high-rise buildings. However, in small houses and in some civil engineering structures, such as pilings and foundations the market share of steel remains low compared to its potential.

The main emphasis should be directed to the technical and scientific development of materials and products, including composite structures, and the development of new products, new construction systems, production and construction processes. Product development is already focused on the evolution of standardised products and mass customised production systems. However, further innovations must be carried out to develop new steel grades with improved corrosion resistance and fire safety, new technical solutions for combining steel with other materials, and associated innovative design features. This would offer new potential for a healthier lifestyle, such as minimisation of noise and vibrations, improvement in thermal insulation systems, and the capacity to integrate alternative energy systems. Finally, the development of new assembly processes would contribute to reductions in on-site costs.

Fig. 32: Steel construction: Millau Bridge (France)

In industrial design, the orientation should be towards multi-material and multifunctional concepts. Lightweight dry construction, metal - glass solutions and building with modules should be favoured. Individual design and manufacture of complicated forms can only be economical for extraordinary buildings

Ways and means – research areas

Two main R&D themes have been identified:

- Safe and healthy steel construction
- Sustainable steel construction

1. Safe and healthy steel construction

Safety and health are the main performance aspects of the buildings and other construction works essential for the security and quality of life of occupants and other users. Efforts to ascertain and improve the overall performance of steel construction are continually needed owing to advancements in materials and production methods of steel-based products as well as in design and building methodologies. Changes in business models cause new process interfaces whose effects on overall structural safety need to be thoroughly investigated and managed. The global climate change means on the other hand changes in environmental loadings that influence the requirements of materials and structural systems.

Research areas

- Structural safety of houses and infrastructure in environmental, accidental and exceptional loading situations
- Improved health and comfort through steel-intensive construction
- Advanced prefabrication technologies
- Performance based design

Structural and seismic safety

New steel materials and structural applications, often combined with other materials, can be brought to the construction market only after extensive research and development work. The innovative solutions are usually launched together with new kinds of testing and design methods by means of which the safety can be verified during erection and use. The creation of harmonised safety levels for structural design throughout Europe, with more exact quantification, is a long-term target for a safe and competitive steel construction sector.

Advanced calculation technologies and structural modelling create a wide range of possibilities for extraordinary applications and for unique aesthetic features in the built environment. However, they should be more effectively used in projects of common multi-storey buildings as a part of performance analysis and toolkits. New approaches of integrated risk-based structural and fire-safety engineering are based on advanced calculation tools. Structural safety comprising capacities, stability and robustness under demanding environmental loads, exceptional or accidental loads or earthquakes can be analysed and verified based on the development of analysis methods and tools.

Structural safety must be maintained during the relatively long periods of use. Methods to obtain reliable verification of durability under different degradation mechanism need experimental research and combination of material and structural know-how. Special attention is needed for multi-material products and systems.

The long term objective is to make the process of maintenance/safety a real-time operation, by taking advantage of the introduction of new technologies, leading to the development of a new concept of civil smart structures, conceived and designed as high performance systems capable of self-diagnosis, active response to external actions and to changes in the environment characteristics (intelligent steel solutions to alert people to fatalities).

Improved health and comfort

The problem of sick building syndrome must be solved as soon as possible both in refurbishment of the old building stock as well as in the new building concepts. Problems associated with moisture, water, dirt, poor heating, ventilation and lighting and emissions can be solved with innovations in materials, products, technical systems and building processes.

The changing needs of occupants and users of buildings and other structures with respect to comfort are an essential part of product development activities. Sensitivity to noise and vibrations has increased as urbanisation, individualism and demographic changes have taken place. Methodologies to gather and analyse user information and to develop novel solutions for active attenuation are needed.

Basic steel and coating materials are developed to provide more adequately for the requirements of healthy and non-emitting built environment. The development of steel-based construction technologies provides that not only the steel products but the participation of the other materials are controlled in order to meet the needs of better indoor environments. Clean pollution free methods based upon 'dry construction' are already regarded as a remarkable potential and their adoption in different local markets and resources is the next step in transfer of research-based products to the construction market.

Advanced prefabrication technologies

Prefabrication is the key to high-level quality

management of a building process from the factory to the building site. Development of prefabricated products and systems offers a possibility to adopt the most intelligent user-oriented performance-based design technologies, with which the safety can be reliably analysed and demonstrated as a part of the building concept. Fast and cost-effective connection technologies suitable also for use of robotics are envisaged when load-bearing systems are under development.

From a user-oriented development point of view, adaptability and flexibility must be provided in prefabricated technologies. This calls for advanced product development methods and intensive use of ICT technologies in design and manufacture. The enormous needs for new buildings in urban areas and in Eastern countries can be solved with efficient use of modular prefabrication with integrated technical systems.

Fig. 33: Villa 2000 (Finland)

Implementation

R&D areas	Priority	Frame	Term (S = Short, M = Medium, L = Long)	Budget (Mio Eur) 1st priority	2nd priority
1) Structural safety (safety, robustness and reliability)				**27 (50 % RFCS 50% FP 7/ National)**	**18 (50 % RFCS 50% FP 7/ National)**
• Strategies for safety in extreme events (seismic and fire)	1	RFCS/ FP 7	S		
• Solutions for energy absorption	1	FP 7	S		
• Novel foundation solutions	1	RFCS/ FP 7	S to M		
• Design of steel-glass structures	1	RFCS	S		
• High-performance bridges	1	RFCS/ FP 7	S to M		
• Development and use of ultra-high strength steel in structures	1	RFCS	M to L		
• New families of steels for critical applications (seismic and fire)	1	RFCS	M to L		
• Underground structures	2	RFCS/ FP 7	M to L		
• Performance-based design methods	2	FP 7	M to L		
• Risk-based fire engineering	2	FP 7	M to L		

R&D areas	Priority	Frame	Term (S = Short, M = Medium, L = Long)	Budget (Mio Eur) 1st priority	2nd priority
2) Improved health and comfort (overall performance and indoor climate)				**12 (66 % RFCS 34 % FP 7)**	**8 (64 % RFCS 36 % FP 7)**
• Advanced dry construction technologies	1	RFCS	S to M		
• Concepts of steel-intensive construction	1	RFCS	S to M		
• Harmonization of serviceability criteria	1	FP 7	S		
• Monitoring and maintenance	2	FP 7	S to M		
• Smart materials and solutions for acoustics	2	FP 7	M to L		
• Improved thermal performance	2	FP 7	M to L		
• Self-cleaning surfaces	2	FP 7	M to L		
3) Advanced prefabrication and execution technologies (knowledge-based business, productivity)				**24 (50 % RFCS 50 % FP 7/ Nat)**	**16 (50 RFCS 50 % FP 7/ Nat)**
• Utilization of laser in manufacture	1	RFCS	S		
• Product libraries for CAD/CAM applications	1	FP 7	S to M		
• Safe and fast construction site technologies	2	RFCS	S to M		
• Steel-intensive modular production	2	RFCS	S to M		
• New wave of robotics	2	FP 7/ Eureka	M to L		

Fig. 34: Appealing steel solution for end users - Safe and healthy steel construction - implementation of the 1st R&D Theme

2. Sustainable steel-intensive construction

Sustainable steel construction is based on competitive business that satisfies the needs of customers and societies. It is best achieved by the simultaneous development of materials, products and processes. Knowledge of evaluation and verification methods of sustainability needs to be developed and shared in order to implement sustainable practices in the supply chains.

Research areas

Energy-efficiency of construction and real estate sector

Products and processes for improving the thermal behaviour of the outer skin (envelope) are urgently needed in order to reduce the consumption of energy uses in existing buildings. In cold climates, heating raises high-energy consumption and in hot seasons in warmer climates, energy is consumed for air-conditioning. The lack of any heat insulation provokes also a lot of health problems in the summer in the Mediterranean area, especially for old people.

Structural quality in renovations

The great potential for steel-based construction products needs to be realised in repair concepts for different segments of existing building stock. Reinforced concrete buildings were built in the 1960s and 70s with poor controls on materials and old construction technologies: seismic and fire safety were not sufficiently considered; no attention was paid to thermal, noise and vibration insulation or to durability. In particular, in historical centres buildings are often very ancient ones characterised by masonry vaults with wooden floor and wooden roofing.

The structural quality, including improved safety and enhanced adaptability, can be achieved by using current technical and scientific knowledge of verification methods and on-site testing, strengthening systems, relief systems and insulation systems. The emphasis is on the kinds of refurbishments and reconstruction methods that increase the independence of the technical systems from the supporting frame and the independence of one compartment from the others. Reliable and durable connection systems (also in seismic areas) between different materials (masonry-steel, reinforced concrete-steel, masonry-steel re-bars embedded in concrete) need to be used in the renovation works.

Improvement of urban environment

Improvements inthe accessibility of city centres – nowadays under a great demographic pressure, due also to tourists in many historical cities – in terms of good and quick urban connections with the residential areas in the surroundings, proportionate numbers of car parks, pedestrian networks with vertical connections and, where required (in many medieval cities, for example) abolishing barriers is a priority.

Recyclable steel-based construction

Recovery, reuse and recycling of steel in the construction sector need further developments in parallel with new technologies.

The policy-makers and decision-makers need reliable information on the current state of sustainable topics and the future influences of human activities, which are obtained on the basis of the best knowledge of the art. However, problems of fundamental nature still need to be solved in searching for the general acceptance of sustainable assessment methodologies.

The objective is also to develop competitive sustainability indicators of steel-based construction (recyclability of steel, dry construction, LCC, LCA, LC design). In this respect, we also refer to the R&D theme identified above in part B (advantages of steel: the societal impact of materials) where the developed tool will serve this purpose.

Furthermore, generally accepted sustainability evaluation methods for the building sector and sustainability evaluation incorporated in product and process development methods and procedures should also be developed.

Implementation

R&D areas	Priority	Frame	Term (S = Short, M = Medium, L = Long)	Budget (Mio Eur) 1st priority	2nd priority
1) Energy-efficiency of steel construction (environmental sustainability and high-tech)				**24 (20 % RFCS 80 % FP 7/ National)**	**16 (20 % RFCS 80 % FP 7/ National)**
• Verification methods for use of energy	1	FP 7	S		
• Energy-efficient building envelopes	1	RFCS	S		
• Business models for low-energy buildings	1	FP 7	S to M		
• Applications for wind and solar energy use	2	RFCS / FP 7	M to L		
• Energy saving service systems	2	FP 7	M to L		
• Alternative energy systems	2	FP 7	L		
2) Structural quality in renovations (improving safety, adaptability, usability)				**24 (20 % RFCS 80 % FP 7/ National)**	**16 (20 % RFCS 80 % FP 7/ National)**
• Mitigation of floor vibrations	1	RFCS / FP 7	S to M		
• Life-cycle engineering methods (inc. LCC)	1	RFCS / FP 7	S to M		
• Improvement of acoustic behaviour	2	RFCS / FP 7	M		
• Low-intrusive on-site technologies	2	FP 7	M		
3) Improvement of urban environment (quality of life, security and aesthetics)				**15 (20 % RFCS 80 % FP 7/ National)**	**10 (20 % RFCS 80 % FP 7/ National)**
• Solutions for extentions and additional floors	1	RFCS	S to M		
• Solutions for accessible routes	2	FP 7	M to L		
• Improving security of the built environment	2	RFCS / FP 7	M to L		
• Life-cycle management methods	2	FP 7	L		
4) Recyclability and durability (service-life design and product information)				**12 (50 % RFCS 50 % FP 7/ National)**	**8 (50 % RFCS 50 % FP 7/ National)**
• Environmental information of steel-int. products	1	RFCS	S to M		
• Probabilistic rules for corrosion	1	RFCS	S to M		

R&D areas	Priority	Frame	Term S = Short M = Medium L = Long	Budget (Mio Eur) 1st priority	 2nd priority
• Life-cycle engineering methods	1	RFCS / FP 7	S to M		
• Verification of durability and design life	2	RFCS / FP 7	M		
• Life-time engineering of buildings	2	RFCS / FP 7	M		
• Life-time engineering of bridges	2	RFCS / FP 7	M		

Fig. 35: Appealing steel solution for end users - Sustainable steel-intensive construction - implementation

Socio-economic aspects

Steel is one of the most important construction materials, competing to some extent with other materials but also opening up completely new possibilities. Almost half of the steel produced is used for construction purposes. New applications for steel can be found through the development of new grades, building components and systems, composite structures, and construction technologies.

Research themes are relevant in various fields including new buildings, renovation of old buildings, infrastructure, developing new materials, improving value chain, standardisation, and dissemination of results.

Sustainable steel construction is based on competitive business that satisfies the needs of customers and societies. It captures economic and environmental goals along with social desirability. Steel-based construction with accurate and pre-fabricated components enables resource savings and waste reduction, and steel itself is an endless recyclable material.

Instruments common to both R&D Themes

Selected research themes are realised through joint projects, in which all interested parties can participate. The steel industry has a long tradition in carrying out joint research and well established forms of co-operation are available and should be fully exploited.

Effective dissemination and transfer of best practices and creation of value added processes require large consortia. This is especially true in the areas of standardisation, harmonisation, and adoption of best practices, where wide participation is a necessity. Partners are committed to results, rules and practices through their direct involvement into projects.

The steel industry would be the main contributor for R&D. In practice much of the work would be carried out in research institutes that could develop high levels of expertise due to extensive development tasks and long-term commitment from industry and other players. Many universities have produced excellent work on steel construction and they could also join projects. By creating new basic knowledge, the scientific community could open up completely new horizons for development. Research would be supported through intensive networking of acting partners and innovation centres.

Stakeholders

- Steel industries
- Suppliers
- Architects, designers
- Construction sector
- Raw material producers
- Steel Research Centres
- Universities
- Public authorities and communities

C3. Sub-Societal Programme: Energy sector

Background

Today's energy consumption is composed by a mix of fossil sources (coal 23.5%, oil 34.9%, and natural gas 21.2%), nuclear power (6.8%), hydropower (2.2%) and combustible renewables and waste (10.9%).

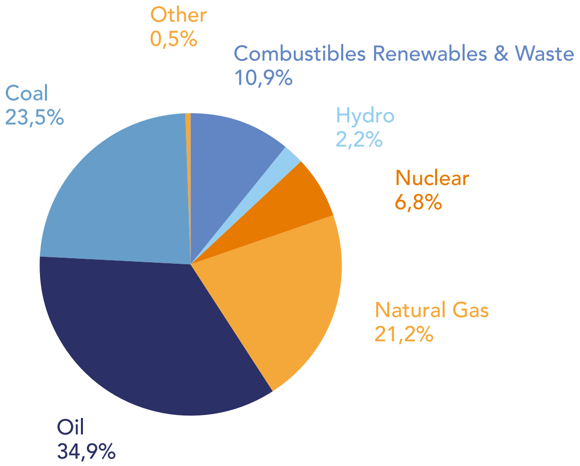


Fig. 36: Total primary energy supply worldwide in 2002

Within the forthcoming 30 years, the International Energy Agency predicts a roughly similar mix for the total primary energy supply ,which it is expected to expand by roughly 60% , i.e. to 16 300 Mt (Mil. tonnes of equivalent oil) from 10 230 Mt in 2002. The trend will be intensified by demand from Asian and other countries which modernize society and lifestyle, thus increasing GDP and energy consumption.

As far as the fossil fuels portion, the total consumption is predicted to remain totally around 80% , but a distinction has to be made between oil & gas on one side and coal on the other. While coal in fact is considered as almost inexhaustible, the reserve of oil and gas are limited.

This implies in the medium-long term an absolute growth of new energies ,so that the mix of energy sources is expected to change, driven by various factors, including environmental regulations (Kyoto protocol), new technological achievements in power generation systems, and a potential establishment of hydrogen as an energy carrier ,but quantitative estimates for the future evolution are difficult to obtain.

What seems however certain is that for several decades - certainly the period addressed in this Strategic Research Agenda – fossil fuels will continue to remain the major source of energy supply to the world. In absolute terms a huge increase of gas in particular is expected , a large portion of which planned for combustion in the new gas turbines of Power Generation Plants, further to the increase for domestic and industrial use.

Looking now at the upstream part of this "Energy Chain", i.e. to the industry of fluid Extraction and Transmission, one has therefore to expect it will continue to develop even in the long term perspectives. The very broad subjects to be faced cover Drilling, Completion and Production of oil & gas wells, especially in the offshore fields with their complex underwater gathering apparatus, and the whole Transmission systems via pipeline or LNG technology. Steel is the natural candidate for the realisation of all necessary infrastructures, but the grades presently available might not be matching completely the dual ambitious target of huge productivity and superior levels of safety for the transportation systems.

It is therefore a "must" for the future steel industry to provide strong support to the continuous process of this industrial sector by developing high performance, low-cost, environmentally friendly and safe solutions in terms of steel products. The theme is of interest both for on-shore and off-shore application, each one keeping its own specific peculiarity.

The constant interaction with the various actors of the chain, including fabricators, is a key factor for success.

Moving now to the "downstream" part of the energy chain, the overall challenge is constituted by the realisation of a new generation of high efficiency-zero emission Power Generation plants, together with the consistent improvement of the existing ones, by the increase of the working temperatures well above 600°C and pressures beyond 250 bar.

The coal, as a primary energy source, features more

granted resources and stable price if compared with mineral oil and natural gas. Therefore it is expected that it will be able to meet the future world energy demand for many of the coming decades ,even though the use of natural gas , intrinsically less pollutant than coal, will certainly constitute a good companion to other technological options for power generation.

The increase in temperature however demands the development of new steels (high Cr-steels) and alloys (super-stainless steels) with high creep strength and high resistance to corrosive acids and condensates, not so simple to obtain in ferrous alloys. The inter-material competition aspects may characterise future technological developments in this field, but the exact knowledge of the stability limits of the alloys at high temperatures is a crucial point where to concentrate the efforts.

What is therefore illustrated in the above, represents a strong motivation for the implementation of a new Chapter in the present Strategic Research Agenda devoted to the identification of the relevant Research Themes and Areas pertaining to new performing materials for the future challenges of the entire Energy Chain, considered to be composed of both aspects related to energetic fuels: production and transportation and eventually utilisation.

Main concern will be concentrated on Energy based on fossil fuels, but other "future energies" like Wind energy, Hydropower and Hydrogen, must receive a proper attention, as far as their need of appropriate and high performance materials. Steel can in fact be absolutely relevant in the creation of all such systems, which are mostly large-scale by their nature.

The follow-up of this document is split in two parts. The first addresses Exploration, Production and Transmission of oil & gas whilst the second deals with Power Generation, both streamlines being analysed from a common point of view: looking at the development of technologies and examining, when possible, different options having an influence on material design and selection.

Exploration, production and transportation

1. Background

Existing situation and future trends

As the indigenous supplies for the US and European oil & gas markets decline and Asian oil & gas markets continue to develop there is a growing need to exploit fossil fuel reserves that are increasingly farther from market, beyond the existing technology or in deeper waters off the continental shelves around the world.

Most of these regions are outside Europe and its continental shelf with a challenge to European operators, contractors and suppliers to establish adequate skill, resource and material availability to take an active part in the exploration, transportation and operation of these developments.

2. Common challenges to Oil and Gas and steel industries

The ability of the European pipeline industry (suppliers and contractors) to achieve a state of readiness to compete for the international pipeline contracts needs to be addressing. Certainly the European Steel Industry is a leading supplier to the worldwide pipeline market and has sustained this position in the past decades in spite of great turbulences in this business.

From the point of view of pipe productions associated with the corresponding market sectors the situation in terms of volumes deserves a general pronounced interest. An estimated figure of 75 to 80 mio tons/y of steel pipes can be derived for the world wide consumption, with a proportion of 50% to 60%, i.e. 40 to 45 mio tonnes ,devoted to energy applications in total.

Europe has a share in production of about 20% and reasonable assumptions based on many years statistics would indicate that out of these 8 to 9 mio tonnes of European pipes, approximately 75% are used for oil & gas industry and 25% for power generation (boilers and other components).

As new competitors now attempt to enter the field, Europe's central concern is to maintain its position and competitiveness in the ample markets of the future. This requires permanent innovation and continuous engagement in R&D as outlined in this Research Agenda and, definitely, a strict cooperation among the various playing actors (Oil & Gas Companies, Contractors, Steel Companies and Pipe Producers) appears as a factor of success.

Many of the oil and gas companies and pipeline transportation companies involved with the major international pipeline projects have placed substantial funds into research and development. The massive scale and linearity of these pipeline projects, means that any improvement in the design, materials or construction processes can yield extremely large cost savings. Areas of particular interest include fracture control and design of crack arrestors for very high strength steels, fitness for purpose and defect assessment of X100, strategic assessment of worldwide availability of raw materials to meet the future line pipe supply/demand.

Materials such as steel composite pipe and non-metallic pipe suitable for highly corrosive flow line service as an alternative for expensive corrosion resistant alloys. The challenge is to produce a pipe structure that will tolerate high pressure and temperature duty.

3. Ways and means – research areas

Three main R&D themes have been identified:

- New-highly performing Tubular materials for Oil & Gas wells and relevant infrastructures
- Steel pipes & components for High Productivity Energy Transportation
- Reliability & Integrity Environmental fracture control

New-highly performing Tubular materials for Oil & Gas wells and relevant infrastructures

Background

- Oil/gas wells structure:

The increasing exploitation of remote or marginal field call for innovative solutions able to cut costs for deep wells in harsh environments, also looking to reduce their environmental impact. Major improvements are to be expected by the introduction of new technologies allowing for a leaner design and easier construction and maintenance of the well structure and completions. Some of these technologies are likely to have a significant impact on material requirements for Oil Country Tubular Goods (OCTG), where steel (including Fe-based corrosion resistant alloys, CRA) is by far - and it is likely to remain - the leading material.

The selection of the optimum choice in terms of OCTG material for any specific field conditions is a need which calls for the development of tailored steel products. C-steels, martensitic stainless (13Cr, SS 13Cr), duplex and austenitic steels will be all involved in the process to develop new tailored solutions. This is especially true for tubing, where the transported fluids show the greatest variety in term of chemical aggressiveness.

A step-wise decrease in cost and environmental impact of O&G wells should come in the future by the adoption of new design concepts for the well structure. The simplification of the "telescopic" casing structure toward an ideal mono-diameter casing is a goal which can be now be realistically pursued, due to the availability of so-called "In-Situ Expansion" (ISE) technologies. This however implies that high amount of ISE (at around 30%) could be performed without detrimental effect of collapse, mechanical and corrosion properties of the casing pipe. This in turn calls for the availability of steel pipes with superior suitability to ISE. The development of appropriate solutions for the joints when ISE is applied is another key-issue. Threaded Connection, welded joints and non-conventional techniques should be considered in this regard.

The reduction of the total weight of the casing structure trough the use of ultra-high strength OCTG is a major issue. C-steel seamless pipes with a yield strength of 980 MPa and higher are likely to be required in the future. Here, the challenge for steel producers is enhanced by the fact that such product should provide also a reasonable sulphide stress cracking (SSC) resistance in moderately aggressive environments.

The availability of premium connection (PC) with suitable sealability in increasingly demanding conditions in term of loading pattern, pressure and temperature is another issue. The trend here is toward compact-design solution for PC (flush

or semi-flush), which also allow for a reduced environmental impact. In the same line, PC with innovative self-lubricating systems (e.g. dopeless PC) will be increasingly required due to concern for pollution induced by conventional oil lubricants.

- Flowlines & Risers:

The frontier of deep-water field which can be suitably exploited by current technologies has moved fast in the last decade and water depths of 2000 m and over are currently regarded as ultra "deep".

The impact on materials, primarily on steels as dominant material in this field, is expected to be significant in the future as in the past decade. Moreover, the design of new or improved steel products (seamless and welded pipes, special forged components) should be driven by and strictly related to the challenges coming from new concepts and technologies.

Concerning subsea flowlines, connecting the well head to the risers system, main future developments are related to laying in ultra-deep water and to increasingly severe operating conditions. Fatigue resistance is an important issue for Risers, both of the "Suspended Steel Catenary "and the "Top Tension "systems.

A strict dimensional control of such pipes is an obvious additional requisite to assure a suitable alignment and geometry of welded joints, thus providing superior resistance to fatigue crack initiation. This is an important open issue especially but not only for seamless pipes.

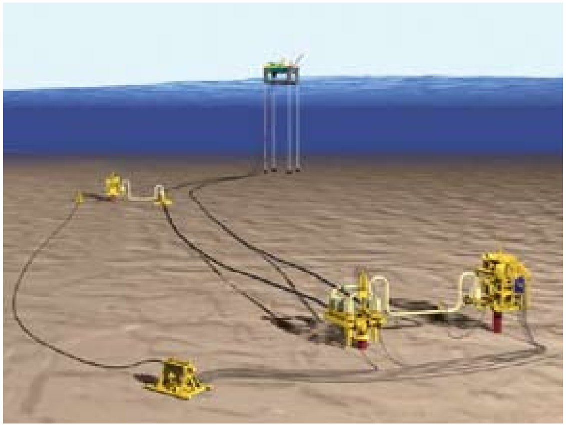


Fig. 37: Typical "sub-sea" field development

Implementation

R&D areas	Priority	Frame	Term (S = Short, M = Medium, L = Long)	Budget (Mio Eur) 1st priority	2nd priority
1) OCTG and premium joints for highly demanding applications				**20 40 % RFCS 60% FP7**	**14 70 % RFCS 30% FP7**
• New steel products for High-Pressure-High-Temperature (HTHP) service	1	RFCS/ FP7	S to M		
• Lean design of the well structure through the exploitation of "In Situ Expansion" (ISE) technology	2	RFCS/ FP7	S to M		
2) HS-Fatigue resistant flowl ines & risers in ultra deep water				**10 40 % RFCS 60% FP7**	
• Heavy-wall tubular products for deep-water O&G fields	1	RFCS/ FP7	M		

Fig. 38: Appealing steel solution for end users - New highly-performing tubular materials for oil & gas wells and relevant infrastructures - Implementation

Steel pipes & components for High Productivity Energy Transportation

Background

- Pipelines:

The construction and operation of both, onshore and offshore pipelines is governed by economical constraints. Transportation of gas over longer distances under arduous conditions is one of the major future challenges. At the same time, the present-day high safety standards have be to be improved, or at least to be maintained. With regard to external interference not only pipeline integrity but also security can be expected to be more and more a future issue.

Requirements for pipeline steels, e.g. by application of limit state design concepts, are becoming more and more severe to comply with pipeline operation at higher internal pressures, higher design factors (internal pressure related to the yield strength) and severe loading conditions. The transmission of corrosive and multiphase gases will increase.

New or optimized steel and pipe manufacturing technologies are needed to cover these increasing requirements and to be more competitive. In this context a target will be to replace rare or expensive alloying elements to contribute to cost reduction aspects. The applicability of duplex and Cr-steels as well as clad pipe have to be studied and improved.

Modelling will gain prime importance in development of new steels, pipe production, pipeline design, pipe laying and pipeline operation. Development and improvement of welding technologies will be also a main task as well as the determination of appropriate material and pipe properties, full scale testing and field validation.

Offshore trunk lines

Currently, 90% of the world's offshore structures with their related transmission pipelines are in relatively shallow waters, less than 75 metres deep. However, the new field development projects will result in an increasing number of transmission lines in deep (>400 m) and ultra deep (>1500 m) waters.

To allow a high speed of welding aiming at higher laying speeds, wall thickness, diameter and ovality of pipes have to meet tight tolerances. Manufacturing processes may need optimisation.

Development of design and material models and their experimental validation is essential to understand the response of pipes and pipelines to extreme loading conditions during laying as well as during operation. The development of new steels for both sour and non-sour service and improved pipe manufacturing capabilities are needed to comply with future requirements.

Apart from structural strength, key considerations are:

- Toughness of parent linepipe material and all welded joints
- Corrosion performance of lines that operate 'wet'
- Weldability, including repairs and hyperbaric requirements
- Compatibility with external environment
- Availability of bends and fittings required to complete a piping system
- Suitability for operational modifications repairs and hot taps

Onshore pipelines

Current developments and research activities in the field of on-shore pipelines are aiming at cost effective gas transmission over long distances and operation of high pressure pipelines at low temperatures as well as in areas of extreme loading conditions.

Pipelines built to plastic design criteria are needed especially in areas where earthquakes and landslide cannot be excluded. Steels with a high amount of deformability have to be developed as well as design criteria to understand pipe and pipeline behaviour.

From constructions and operations point of view, developments and improvements are needed as cooperation between steel and pipe producers, laying contractors and operation companies like:

- Advanced pipeline girth welding processes such as dual tandem, laser and hybrid laser
- Development of a new generation of pipeline construction equipment that will improve the productivity and hence the costs of pipeline installation

- Development of automated pipeline tie-in equipment
- Use of lighter than air vehicles for transportation and cranage
- Extending the range of crossing techniques to avoid environmentally sensitive areas
- Improving construction safety through improvements in transportation of personnel, equipment and materials
- Improvements in the best practice for identification, mitigation and monitoring of geo-hazards and environmentally sensitive areas
- Advances in the inspection, measurement, interpretation and repair of pipeline construction and operational damage

A key issue for pipeline safety is the avoidance of corrosion and external damage. More than 80% of all pipeline failures in Europe can be devoted to corrosive attack or external interference. The long term behaviour of pipe coatings has to be studied to be improved in accordance with pipeline operation and cathodic protection methods.

The possible consequences of external damage were shown in 2004 by the gas pipeline accident in Ghuislinghien, Belgium. More than 20 people died and more than 50 were injured. This accident has shown the need of developing proactive damage prevention technologies; contributions from both sides, pipeline operators and pipe manufacturers, should be considered.

- LNG / CNG:

Transportation is an essential aspect of the gas business, since reserves are often quite distant from the main markets. Most gas is transported by pipelines and there is a well developed network in the former USSR, Europe, and North America. Where long distances are involved, transporting gas in its liquid state becomes economical. Often, it is the only means of transporting gas across oceans. Transportation of pressurised or compressed natural gas offers commercial solutions for fields with small quantities of associated gas or for the supply of communities or industrial areas not served by pipeline distribution systems.

LNG

Liquefied natural gas (LNG) transportation represent an increasingly important part of the natural gas supply picture in the world. Major operators have R&D activities aimed at reductions in capital expenditure, new generation liquefaction, new and larger storage options and expandable LNG trains. The expectation from a single LNG train in the late 1990's was 4 million tonnes per annum. This has now risen to 8 million tonnes per annum in 2005.

The location of an onshore LNG export terminal relative to the gas field or import terminal relative to the market may be a compromise between, marine/civil considerations, minimizing the scale of the onshore pipeline system and availability of adequate depth mooring access for tankers. A current technology development is a thermally insulated sub-sea LNG pipeline that would allow the loading and off-loading terminals to be located much further from shore. This technology presents a number of challenges including materials selection, highly stressed pipeline systems, thermal behaviour of all components, operational monitoring and operational procedures and mitigation against contingency.

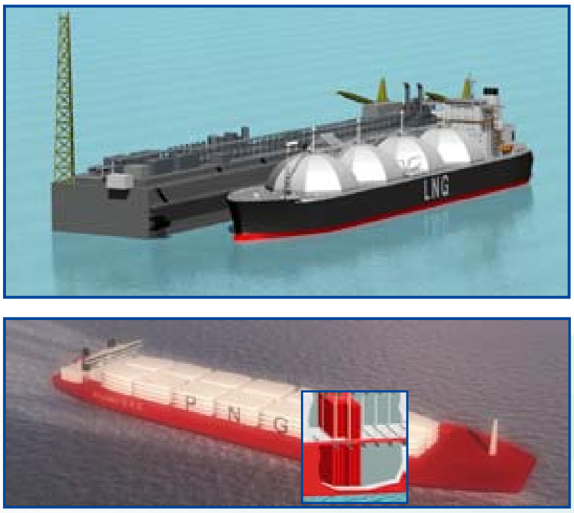


Fig. 39: Liquid natural gas transportation and pressurised natural gas transportation

Associated with the tanker loading further from shore is the interest to use offshore loading systems with the LNG tanker moored to a loading arm or buoy and weathervaning in a similar manner to that used for crude oil.

Placing improved loading systems further from shore has the advantages of increased security, no visual impact from shore and no impact on the inshore marine traffic.

CNG / PNG

Some 30% of the today's known gas reserves are considered as stranded because of the distance to market and the size of the reservoir or market are such that neither pipeline nor LNG transportation can be established economical.

An additional 20-30% of the today's known gas reserves are associated to crude oil production and are not utilised due to the above mentioned conditions of size and distance.

These reserves are either flared or re-injected.

In the CNG (compressed natural gas) technology the natural gas is simply taken from the reservoir and loaded into cylinder installed on a vessel. To enlarge the storage capacity the gas is either compressed to pressures of about 250 bars or slightly cooled under moderate pressure. The CNG or PNG (pressurised natural gas) system is a gas transportation solution that fills the gap between the pipeline and LNG concepts.

CNG/PNG transportation by barges and vessels has to be established on the market as already valid for road transportation. Rules to class vessels for CNG transportation have been published and are accepted by many maritime organizations. Much attention is being given to the design of the cylinders with respect to internal pressure fatigue and leak before break behaviour. Future developments will aim at improving the technological properties being in accord with economical production routs. Development and use of alternative material concepts like fibre reinforced cylinders will be a focal future point for light weight storage of the gas in tankers, barges and also for rail and road transport.

- Hydrogen Transmission/Transportation:

Hydrogen is expected to become the major component of a clean sustainable energy system in the longer term. It is relevant to all of the energy sectors - transportation, buildings, utilities, and industry. Hydrogen can provide storage options for intermittent renewable technologies such as solar and wind, and, when combined with emerging decarbonisation technologies, can reduce greenhouse gas emissions from continued fossil fuel utilisation.

The transport and delivery of hydrogen in pipelines, as well as hydrogen storage in high pressure tanks in the near-term, will be an important part of the hydrogen infrastructure that will help enable a hydrogen economy. Although there are currently more than 2000 km of hydrogen transmission pipelines are in service in Europe and in the U.S., several technology issues need to be resolved and significant cost reductions are required for effective hydrogen pipeline transmission and distribution. These issues include: a better fundamental understanding of hydrogen embrittlement and diffusion to enable the development of lower cost hydrogen resistant steels, or composites for hydrogen pipelines, improved welding or other joining techniques, improved coatings and seals. Grant applications are sought to develop advanced and novel approaches to significantly reduce the cost of new hydrogen pipelines (by as much as 50%) and/or technology to retrofit existing natural gas or petroleum pipelines for pure hydrogen transmission and distribution.

Implementation

R&D areas	Priority	Frame	Term S = Short M = Medium L = Long	Budget (Mio Eur) 1st priority	 2nd priority
1) New generation of ultra HS-high toughness [X100/120] and low cost steel pipes				**30 30 % RFCS 70 % FP7)**	**15 30 % RFCS 70 % FP7)**
• New steel products for ultra high strength grades	1	FP 7 / RFCS	S to M		
• New steel products for low cost high strength grades	2	FP 7 / RFCS	M		
2) HS large diameter sea trunk-lines				**5 100% FP 7**	**15 100 % FP7**
• New steel products for collapse resistant pipes	1	FP 7	M		
3) Steels for LNG and CLNG Technologies				**15 30 % RFCS 70% FP 7**	**30 100% FP 7**
• New steel products for offshore storage and subsea pipeline transmission of LNG	1	FP 7	M		
• Advanced steel vessels for ultra-high pressure CNG transport and construction of a prototype CNG Vessel	1 / 2	FP 7 / RFCS	S to M		
4) Steels for H2 transportation and Storage		**FP 7**			**10 100% FP 7**
• New steel products for hydrogen transport and high pressure storage	2				

Fig. 40: Appealing steel solution for end users -
Steel pipes & components for High Productivity Energy Transportation - implementation

Reliability & Integrity Environmental fracture control

Background

The development of super high strength pipeline steels like X100 and X120 was driven by the need to make the gas transmission from more distant locations viable. The use of line pipe grade X100 and above for pipeline construction will result in decreased overall costs. The operators evaluated possible reductions of CAPEX between 7 and 30%, compared with respective pipeline projects based X70 or X80 pipe grades. These savings can be derived from cost reductions in several fields, including materials, construction, compressors and integrated project design. The increase of operating pressure and the design factor from 0.72 to 0.8 will furthermore reduce costs and is also an issue for regular pipe grades up to X80. Demonstration projects in Europe and North America have shown the general feasibility of super high strength steel pipelines, ≥ X100. Nevertheless, there are still technical issues still to resolve such as fracture control and defect/damage tolerance. Further improvements of material and pipe production will support the acceptance. Development of cost-effective crack arrestors seems to be inevitable to ensure pipeline safety at reasonable costs.

Modelling will gain prime importance in development of new steels, pipe production, pipeline design, pipe laying and pipeline operation. Development and improvement of welding technologies will be also a main task as well as the determination of appropriate material and pipe properties, full scale testing and field validation.

Implementation

R&D areas	Priority	Frame	Term S = Short M = Medium L = Long	Budget (Mio Eur) 1st priority	 2nd priority
Advanced metallurgical design of new pipe materials				5 20% RFCS 0% FP7)	10 20% RFCS 80% FP7)
• Modelling of steel design and numerical simulation (alloying concepts, process technology, heat treatment)	2	RFCS/ FP7	M to L		
• Prediction tools for pipe behaviour in extreme loading conditions (Earthquake, Land slides and Fatigue)	1	RFCS/ FP7	M to L		
• Erosion/corrosion resistant HS steels	2	RFCS/ FP7	M to L		

Fig. 41: Appealing steel solution for end users - Reliability & Integrity Environmental fracture control - implementation

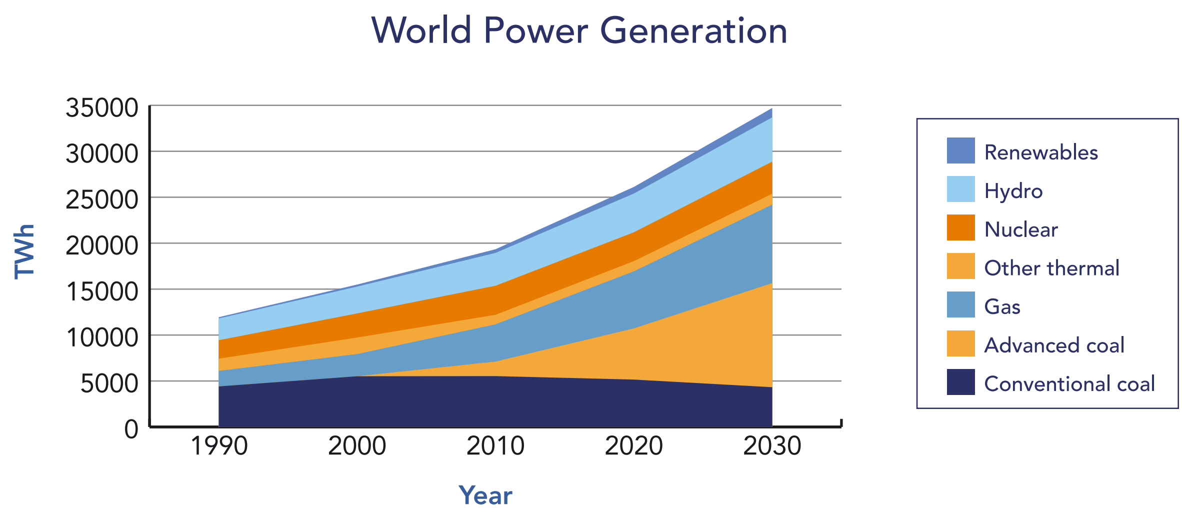


Fig. 42: Projected world trend in technologies for power generation

Power Generation

1. Background

According to the World Energy Outlook 2004 the world electricity demand is expected to grow faster than the world total energy demand. A doubling of the electricity demand is expected between 2004 and 2030, and the power sector will need about 4800 GW of new capacity to meet the increasing demand and to replace ageing infrastructure. By 2030 power generation is expected to account for nearly half of the world consumption of natural gas, but coal will maintain its position as the most important fossil fuel for power generation.

A scenario study by the European Commission DG Research[1] of technology development for power generation suggests that in 2030 more than half of the total electricity production will be provided by technologies that emerged in the 1990ies and afterwards, like gas turbine combined cycles, advanced coal technologies and renewables. All

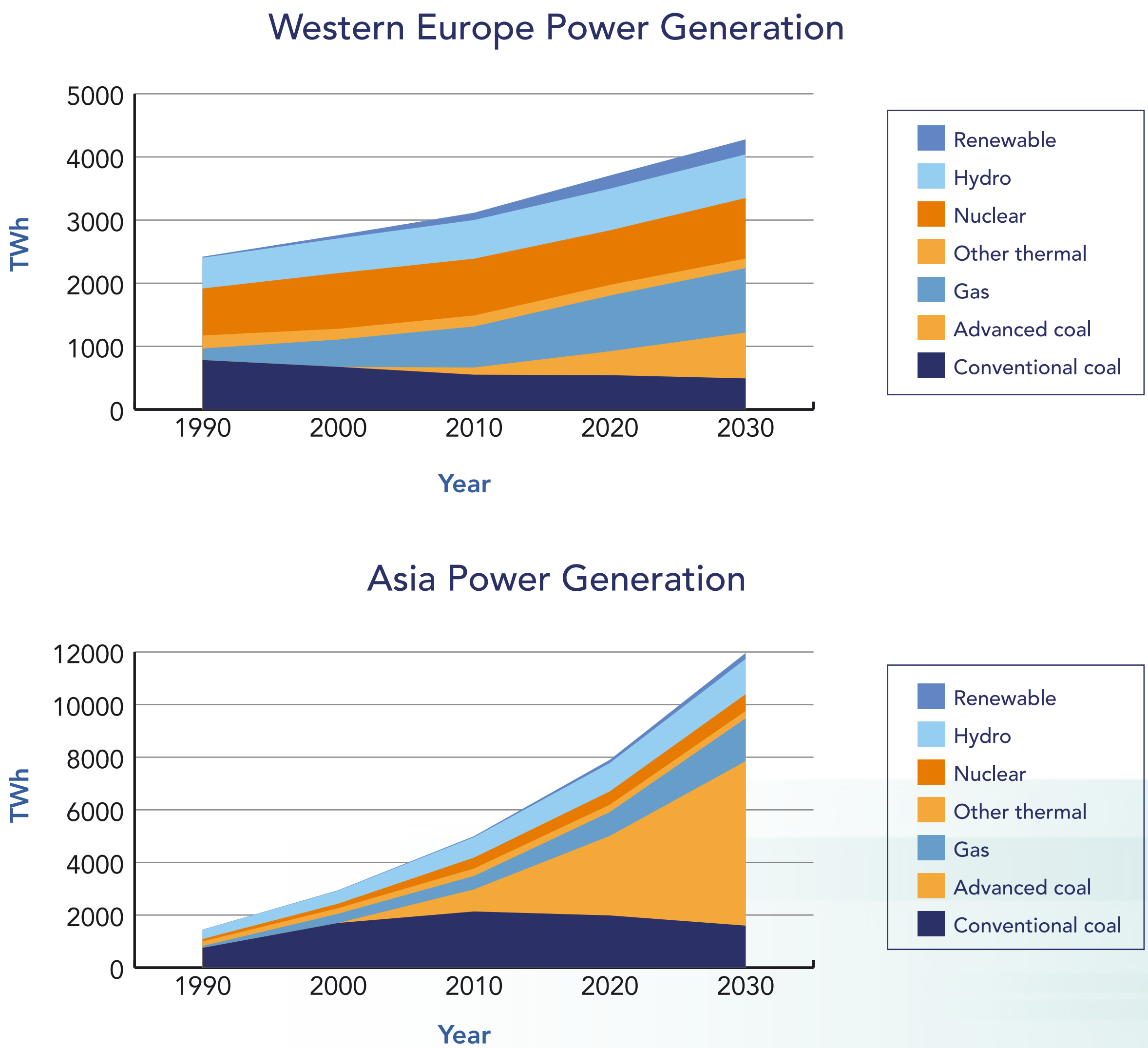


Fig. 43: Projected regional trends in technologies for power generation for Western Europe and Asia.

power generation technologies are expected to increase their output over the period, but the gas and coal based technologies expected to take the major part of the growth, see figure n°42.

The technology developments show huge regional differences as illustrated in figure n°43. In Western Europe only moderate increases in electricity demand are expected, but due to ageing power plants there is a large need for replacement of production capacity. In Asia the electricity demand in 2030 is expected to be four times higher than in 2004. The Asian development is led by the fast growing economies in China and India, and their increasing demands will be met mainly by use of local coal resources in newly constructed plants.

Uncertainties in the technology scenario are mainly related to competition between the different technologies based on the generation cost of electricity, which is determined by fuel prices, specific plant investment and operation/ maintenance (O&M) costs and by the achievable plant efficiency.

2. Challenges for power generation

The midterm challenge for the power generation industry is to provide society with a steady supply of electricity at affordable prices. This challenge must be met by technological developments of all generation technologies in order to secure the electricity supply in case of restrictions on the supply or drastic price increases of certain fuels. The technological developments should aim to reduce plant investment and O&M costs and to improve the plant efficiency.

The mid- to long-term challenge for the power generation industry is to offer affordable technologies for the reduction of greenhouse gas emissions. Even though efficiency improvements of fossil plants will enable huge specific reductions of CO_2 emissions together with lower electricity prices, it is expected that further measures will be needed driven by policy decisions. These could include increased use of renewable energy sources and nuclear power and introduction of CO_2 sequestration and storage technologies.

3. Challenges for the steel sector

The main technological challenges to the European steel sector with respect to power generation are related to efficiency improvements of the thermal power plants, i.e. advanced coal firing, gas turbine combined cycle technologies and thermal plants for electricity production based on renewables (biomass and municipal waste). Efficiency improvements are highly related to increases of firing temperatures in gas turbines and of steam cycle temperatures and pressures in steam plants. Materials properties define the limitations on the achievable temperatures and pressures as discussed below, and efficiency improvements can be achieved by development of better heat resistant materials, many of which are steels. Further challenges are related to reductions of plant investment and O&M costs by supply of low price high quality steel products and development of more efficient component manufacturing technologies.

4. Ways and means – research areas

Four main R&D themes have been identified:

- New classes of heat resistant steels
- High corrosion and erosion resistant steels
- Steel and component manufacturing
- New Steels & Components for Alternative Energies

New classes of heat resistant steels & High corrosion and erosion resistant steels

Background

In order to improve the efficiency of steam power plants by increasing steam temperature and pressure a number of improved steels are needed for critical high temperature components in the steam cycle, i.e.

- Furnace panels
- Super heaters
- Thick section boiler components and steam lines
- Turbine rotors, casings, valves and bolts

The limitations on achievable steam parameters defined by each of these components are defined by creep properties (all components), fatigue

properties (thick section components) oxidation properties (all components), corrosion properties (super heaters) and by fabricability (e.g. weldability of furnace panels) of the steels.

Developments over the recent decades have resulted in a number of new steels for all of the critical components. Limitations on the achievable steam temperature set by each of the steels for a 400 MW coal fired power plant with 325 bar live steam pressure are presented in table 1. It should be noted that most of the new steels have been developed in Japan, which underlines the challenge to the European steel industry.

The current bottlenecks for increases in steam parameters of steel based power plants are the thick section components in boiler, steam line and turbine. The materials in these components are ferritic/martensitic 9-12%Cr steels, which are used for their creep and fatigue properties. Austenitic steels have higher creep strength, but they can not be used in thick section components because of their limited fatigue strength, which will impair the cycling ability of the plant.

As seen the strongest available ferritic/martensitic steels are based on 9%Cr, and in order to increase steam parameters above 610°C/325bar improved steam oxidation resistance is needed together with improved creep strength. The goal for new ferritic/martensitic steels is to reach a creep rupture strength of 100 MPa at 100,000 hours and 650°C.

In the recent decades many attempts have been made to develop a ferritic/martensitic steel based on 11-12%Cr, which has the required steam oxidation resistance and creep strength for 650°C. All of these attempts have failed due do unforeseen microstructure instabilities leading to breakdowns in the long-term creep strength.

Computer based microstructure stability models based on thermodynamic and kinetic descriptions (like e.g. the Thermocalc and DICTRA) have undergone strong developments recently. Experiences in the field of high temperature steels show high accuracy of the models, and with further development of underlying databases they could serve as strong predicive tools for alloy design.

If the alloy development fails to combine high creep strength and oxdation resistance into the alloy it might become necessary to develop surface coatings to obtain the oxidation protection.

In the field of high temperature heat exchanger steels there is a request to develop low price high strength austenitic alloys for superheaters in coal fired plants. Furhter, there is a request for steels with high corrosion resistance in more aggressive environments like biomass and waste firing and (petro)chemical plants.

Implementation

R&D areas	Priority	Frame	Term (S = Short, M = Medium, L = Long)	Budget (Mio Eur) 1st priority	2nd priority
1) High creep strength (for 325 bar 650 °C)				**10 25 % RFCS 75 % FP7)**	**10 100% FP**
• Ferritic steel for thick section and austenitic steel for superheater	1	RFCS/ FP7	S to M		
2) Alloy design tools				**10 25 % RFCS 75 % FP7)**	
• Thermodynamic databases	1	FP7, 8	L		
• Microstructure and Creep modelling	1	FP7, 8	L		
3) Validation of properties		**FP7**			**5 100% FP 7**
• Long-term testing and data extrapolation	2	FP7	M to L		

Fig. 44: Appealing steel solution for end users - New classes of heat resistant steels - implementation

R&D areas	Priority	Frame	Term (S = Short, M = Medium, L = Long)	Budget (Mio Eur) 1st priority	2nd priority
1) High temperature corrosion/erosion resistance				**5 100% FP 7**	
• Flue gas corrosion/erosion, Steam oxidation, Hydrogen attack and modelling	1	FP7	S to M		
2) Coatings					**3 100% FP 7**
• Corrosion, erosion, wear and steam oxidation resistant	2	FP7	M		
• Application processes	2	FP7	M		

Fig. 45: Appealing steel solution for end users - High corrosion and erosion resistant steels - implementation

Steel and component manufacturing

Background

Heat resistant steels for pressure vessels and other equipment are special because they need long-term validation of the creep properties, including stress rupture testing up to 30,000-50,000 hours before reliable design strength values can be established and the steels can be applied. The lead-time from laboratory to application for new high temperature steel can be as high as 8-10 years.

After laboratory optimisation of a new steel composition to obtain the best properties it has to be demonstrated that the steel can be fabricated into all the component forms necessary for construction of a power plant, i.e:

- Seamless pipe and tube for boiler and steam line, including bending and welding
- Large forgings for steam turbines, etc.
- Large castings for steam turbines and valves, etc.

Necessary steps in this demonstration include upscaling of steelmaking, trial productions of full scale components, development of weld consumable and documentation of properties including the long-term tests.

Similar to the alloy development the fabrication demonstration should involve an increasing use of simulation tools in order to optimise the manufacturing processes and properties of the components and to lower component rejection rates and the necessary amount of repair.

In power plant the steels will applied for a service life up to 300,000 hours at the maximum, during which they will degrade due to creep, fatigue and corrosion/oxidation. It is thus necessary to perform inspections and assessments at several points during the service life in order to determine the remaining life of highly loaded components and the necessary amount of repair and replacement. Many well documented methods and calculation models exist for such life assessment procedures, but they all have to be validated for a new steel.

Implementation

R&D areas	Priority	Frame	Term S = Short M = Medium L = Long	Budget (Mio Eur) 1st priority	 2nd priority
1) Fabrication				**15** **100% FP 7**	**10** **100% FP 7**
• Steelmaking, casting, forming, welding and heat treatment	1 / 2	FP 7	S to M		
2) Simulation tools				**5** **100% FP 7**	**5** **100% FP 7**
• Microstructure, process, properties and performance	1 / 2	FP 7	L		
3) Validation of properties					**3** **100% FP 7**
• Prototyping, demonstration tests and long-term tests on welds, etc...	2	FP 7	M		
4) Life assessment					**2** **100% FP 7**
• Damage evolution, Component and feature testing	2	FP 7	M		

Fig. 46: Appealing steel solution for end users - Steel and component manufacturing - implementation

New Steels & Components for Alternative Energies

Background

The limitation of conventional resources, the anticipated high demands for energy and Kyoto regulations – which penalize the emission of CO_2 – are factors which motivate the search for other energy options. Also, the risk of European economies depending too strongly on oil and gas stimulates the quest for alternatives.

The European Union recommends to produce up to the year 2010 about 20% of the electric current from renewable energy sources. An objective of the German Federal Government is it to take approximately 50% off of the power supply up to the year 2050 by renewable energies. In order to achieve these energy-political goals, the introduction process of renewable energy technologies to crucial extent must be accelerated. Basic condition for this is an efficient research and technology development.

- Water power

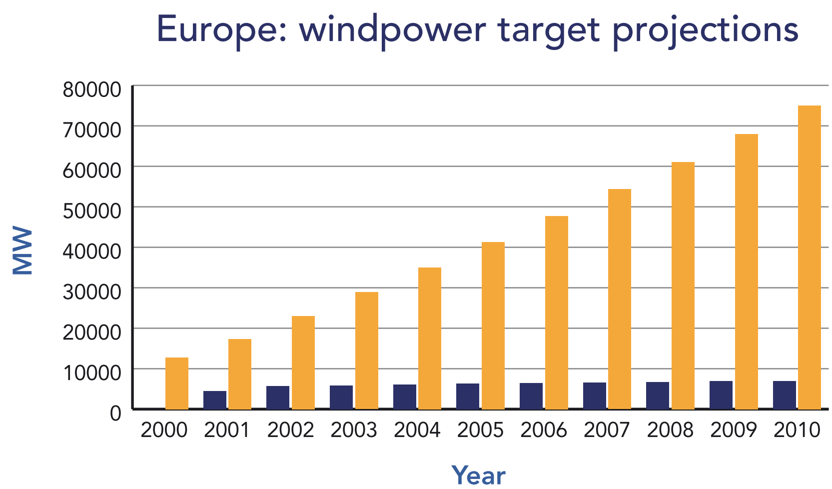
Hydroelectric power is generated by flowing water, usually from a dam, which drive turbines. Such plants are highly efficient and supply a considerable portion of today's world electricity. Hydroelectricity is entirely CO_2-free, and can almost instantaneously respond to changing electricity demand, thereby supplementing other less flexible energy sources.

For steel products this sector offers opportunities both with conventional materials, but also with higher strength plate steels, which have to withstand demanding engineering requirements in penstock linings and powerhouse components.

Tidal power harnesses the tides in a bay or estuary in areas with a large tidal range. The trapped water drives turbines as it is released through the tidal barrage in either direction. Installations in France, Canada, China and Russia represent a capacity of 271 MW. There are plans to invest into further tidal power stations. This opens a certain field of steel applications.

- Wind energy

Wind turbines capture wind energy with rotors connected to a turbine. At present, the largest turbines are designed for 5 MW capacity (offshore) while much smaller units are locally applied in windy areas to generate the home supply electricity. In 2003 the world capacity was about 40 GW worldwide, out of which 28.5 GW in EU-25. The growth is dynamic, stimulated by legislation and strong government support, at a predicted rate of 6 - 7 GW/year up to 2010.



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
New capacity	0	4500	5700	5900	6100	6300	6450	6600	6750	6900	7000
Cumulative capacity	12800	17300	23000	28900	35000	41300	47750	54350	61100	68000	75000

Fig. 47: EU : Windpower target projections (MW)

In the future, the largest progress is expected through offshore wind parks, because of higher and more permanent wind supply. With the start-up three new offshore wind farms (191 MW in total) in 2003, Denmark has confirmed its leading status. Due to the aggressive maritime climate and the need for strong, although economical, supporting structures and towers, the requirements on steel products are ambitious. This constitutes a significant demand on high quality plate steels. Further components (rotor shaft, nacelle frame, yaw bearing) are manufactured from steel or cast iron. Even the vessels for the installation of offshore wind towers require ambitious plate steels, as have been supplied from Germany recently.

Very interesting figures of steel quantities, in the range of 400 – 600 ton/year, come from predictions and render this growing application field very promising.

- Biomass

The energetic use of biomass can make in the coming decades an important contribution for solar power supply, also to compensate the varying performance of photovoltaic systems and wind generators. For Germany the usable potential amounts at least 10% of the present energy consumption.

The solar power won as biomass can be converted into all forms of energy. It is storable and for the substitution of fossil sources of energy it is already used today.

- Electric power from solar cells

The photovoltaic energy conversion by solar cells possesses in Central Europe a high technical potential. Their present contribution for generation of current is however still energy-industry insignificant. It is assumed that it will take still some decades until the photovoltaic can contribute noticeably to the generation of electrical current in Europe. This energy conversion technique will play however a very important role on a long-term basis with the creation of a lasting power supply system.

The steel intensity of photovoltaic systems is rather small. Possibly in the context with supporting constructions steel can play a role.

Other possible "steel intensive" energy production alternatives a re at the stage of attentive monitoring:

- Electric power from solar thermal power stations
- Heat from solar thermal collectors
- Energy from terrestrial heat

Implementation

R&D areas	Priority	Frame	Term S = Short M = Medium L = Long	Budget (Mio Eur) 1st priority	 2nd priority
1) Light weight constructions (Wind Farms, Solar Towers, Hydro & Geoth. P.G. Plants)				5 30% RFCS 70% FP 7	10 100% FP 7
• Wind Farms					
(New Steels and new Tower Concepts)	1	RFCS	S to M		
(Corrosion, Welding and Life Time Assessment of Components and Structures)	1	FP 7	S to M		
• Solar Towers (Highly efficient Solar Collectors and Coating for absorbers)	2	FP7	M to L		
• Hydro and Tidal (Efficient Steel Structures)	2	FP7	M to L		
• Geothermal (New steels resistant to down hole aggressive environments)	2	FP7	M to L		
2) Component Manufacturing and Life Assessment tools				5 30% RFCS 70% FP 7	
• New high performance Steel and Weld joints					
(New design for High corrosion resistant steels)	1	RFCS	S to M		
(Wear and fatigue resistant steels and joints)	1	FP 7	S to M		
• Manufacturing	1	FP7	S to M		
(Joining Technologies for open & closed sections and Foundations for offshore structures)					
• Life Assessment	1	FP7	S to M		
(Statistical approach, Failure Mechanisms, validation of properties and Simulation tools)					

Fig. 48: Appealing steel solution for end users -
New Steels & Components for Alternative Energies - implementation

Socio – economic aspects

The importance of the energy sector is characterised by a turnover of around € 520 bn (power producers) and around 900 000 employees:

A very rough estimate of the demand for high temperature steel for the Power Generation sector can be made on the following basis. For the most recent 400 MW steam plant built in Denmark the following quantities of heat resistant steel tubes and pipes were used for the boiler and steam lines: Low alloy steel: 1250 t, 9-12% Cr steel: 450 t Austenitic steel 400 t. If it is assumed that 2500 GW out of the 4800 GW of new capacity over the next 25 years will be steam plant, the need for steel will be:

- Low alloy steel: 7 800 000 t (300 000 t/y)
- 9-12% Cr steel: 2 800 000 t (110 000 t/y)
- Austenitic steel: 2 500 000 t (100 000 t/y)

Further to this there will be a demand for cast and forged steels to the steam turbine.

All the different Energy sectors address the following common targets of:

- Security of inexpensive and competitive supply of fuels and electricity
- Efficiency and safety through integrity control
- Protection of environment

Stakeholders

- Steel Industries
- Research Centres
- Contractors
- Oil and gas companies
- Equipment suppliers
- Universities
- Electricity producers

D. Attracting and securing qualified people to help meeting steel sector ambitions

Introduction

From now to 2030, the world will undergo major changes, many of which will be brought about by the evolution of science and technology. The European steel industry will contribute its share with new processes and new products conceived to strengthen its competitiveness, answer evolving customer demands and to preserve the environment. Other changes will come from the increasing globalisation of the world economy and the world steel market, which will induce continuing rationalisation and concentration in the steel industry. Further changes will come from the evolution of society in a dynamic exchange with its own altered surroundings.

People, in the steel industry and in society in general, will be the drivers who make such changes happen, but they will also be those who will have to live through them, and may in some instances oppose them. This illustrates the key role of people in the success of the change processes, as well as the need to prepare people to address constructively the changes ahead.

During this period the European steel industry will also be faced with an unprecedented and demanding situation. The age structure in most steel producing companies is such that more than 20% of its workforce will leave it during the next ten years, and close to 30% during the following ten years. Needless to say, this huge transformation will not only be quantitative, but will also have a crucial qualitative dimension. It represents, at the same time, a daunting challenge and a welcome opportunity.

The opportunity comes from the possibility to use this substantial transformation in the composition of the industry's workforce as an instrument of change.

The challenges lie in making sure that the education system will keep the capacity to supply the steel industry with the number of people and with the competencies it needs, while developing the steel industry's capacity to attract relatively scarce highly skilled people in a competitive labor market.

However, both the old and new parts of the workforce will need to espouse life long learning to cope with new technologies and processes, acquire new competencies, and secure the positive evolution of their career. In this context, new approaches should be devised to ensure that appropriate training is available and that its quality is such that it maintains the excellence of the workforce. In addition, life-long learning should be part of the proactive process of developing positive attitudes towards change. On the other hand, in a world where people would anticipate that their career will cover various functions, potentially exerted in several companies from different sectors, the quality and flexibility of the life-long learning schemes offered by the steel industry might become a differentiating element in the competition for contracting highly skilled people.

The continuously improving record of the steel industry in the field of health and safety should also contribute to the attractiveness of the sector. The high priority given by the industry to its "zero accident" objective and the elimination of fatalities is a guarantee of further progress. Further, as reaching these objectives implies significant behavioral changes, improving health and safety at work also comes to be a potent agent of change management.

All these trends converge on and represent different facets of human resources management. During the last thirty years, human resources management has become the nexus of steel companies' competitive strategies, securing the coherence of their implementation and, more generally, seeking the optimisation of one of their key assets. Indeed, human resources are the holders of a company's core competencies, which are one of the main sources of its competitive advantages.

Thus, it comes as no surprise that most steel companies, in a way or another, have been pursuing new organisational configurations tending to transform enterprises into a "knowledge organisations".

Human resources management also plays a key role in change management. In this capacity, it is instrumental in developing an industrial relations system supportive of innovation, improvement of job quality, and competitiveness, thanks to a constructive social dialogue.

In the end, an effective human resources management is essential to the successful implementation of the steel sector's long term vision regarding profit, partners, the planet, and people.

Health and Safety

1. Background

The European steel industry has long been a pioneer in promoting and carrying out research to improve health and safety (H&S) at work, mainly through the ECSC Social Affairs research programmes, which started in the early 1950s. The improvement of working conditions was in fact one of the most important objectives of the ECSC Treaty, and huge resources, amounting to approximately € 240 million, were dedicated to health and safety research until the programme lapsed in 1994. Subsequently, health and safety issues were only partly covered by ECSC Technical Research that ran to the end of the ECSC Treaty, and now, in the current Research Fund for Coal and Steel Research programme.

Nowadays, all 25 European member states have the same basic legislation concerning health and safety in the workplace. The European steel industry, as an important part of European industry, has to fulfil the same obligations but with its own specificity concerning the characteristics of risks.

The basis for all policies and choices at European, national and company level should be the objective knowledge of the reality, based on reliable statistics, adequate for comparing the evolution of the situation at company level, and between companies and countries.

Unfortunately, in spite of a joint undertaking of EUROSTAT and the Directorate General Employment of the European Commission, in the second half of the 1990s, statistics concerning accidents and work related health diseases are not yet comparable throughout Europe, or on a sectoral basis, mainly due to the objectives difficulties of harmonising national systems based on different criteria for data collection and results analysis.

However, regional and international organisations of the steel industry, like the IISI and Eurofer, created specific working groups for the benchmarking of results and methodologies in the management of health and safety with the objective of reaching the "zero accident" target.

A IISI pilot study, involving only some of the most important steel producing countries (without China and other important producers) for the decade 1990-1999, included data from 35 companies located in 16 countries and provided a good cross-section of health and safety performance around the world. The results are very encouraging since major improvements were made in the reduction of both fatalities and frequency rates of lost time injuries (figure n°49). Globally, fatalities were reduced by 40%: from 115 in 1990 down to 68 in 1999, while lost time injuries were reduced nearly fivefold from 25,634 in 1990 down to 5,722 in 1999. Such statistics can be used as a powerful message to improve the image of the steel industry.

However, notwithstanding substantial improvements, the European steel industry is still far behind other areas of the world with comparable amount of steel production and technology level, like north Asia and North America.

2. Analysis

All experts agree that in spite of the unquestionable progress that has been made, there are still too many accidents and health diseases occurring in the steel industry, even in the best cases.

One of the most important problems to be addressed is the harmonisation of health and safety policies and practices among steel companies' employees and their subcontractors' employees. The IISI study pointed out that of the total 953 fatalities observed between 1990 and 1999, 492 were related to steel companies' workers and the other 461 to contractors' workers. Furthermore, the "Preliminary Results of the Five-Year Review of Safety Statistics for 1998 to 2002" recently produced by the IISI provides evidence of a worsening situation in the safety of subcontractors.

Indeed, many steel producers, still, do not require their subcontractors to submit safety data, and subcontractors' fatalities, as reported, increased from 46 in 2001 to 50 in 2002, while five-year subcontractor fatalities reached 254 at an alarming fatal accident frequency rate (FAFR) of 7.3 per one million man-hours for the five years under review.

Although the European Directive 89/391 foresees a direct responsibility for the contracting company with regard to the health and safety conditions of contractors operating in the company, the harmonisation between the health and safety management teams has far to develop in the general situation, with very few exceptions.

The results of these studies highlight the challenge ahead for the steel industry. Indeed, while they show some slight improvement in total five-year employee fatalities (309) and lost-time injuries (55,385), they also illustrate that progress in health and safety has reached a plateau: the FAFR actually worsened slightly in 2002 to 4.6 per 100 million man-hours while the lost time injury frequency rate (LTIFR) improved only slightly from 7.7 to 7.6 per one million man-hours in 2002.

Moreover, work-related stress has been identified at international, European and national levels as a concern for both employers and workers. Having identified the need for specific joint action on this issue and anticipating a Commission consultation on stress, the European social partners included this issue in the work programme of the social dialogue 2003-2005 and recently signed a framework agreement on work-related stress. Stress can potentially affect any workplace and any worker, irrespective of the size of the company, field of activity, or form of employment contract or relationship. In practice, not all workplaces and not all workers are necessarily affected.

Tackling stress at work can lead to greater efficiency and improved occupational health and safety, with consequent economic and social benefits for companies, workers and society as a whole. Diversity of the workforce is an important consideration when tackling problems of work-related stress.

In order to foster new breakthroughs, health and safety must be considered among the most important company objectives, with all hierarchical levels aware of its relevance and with adequate human and financial resources provided to achieve them. The most advanced steel companies in this field put health and safety at the top of the agenda of the periodic meetings of the board of directors, giving a clear signal to all the underlying layers down to the shop floor.

3. Needs

The IISI identifies the following topics as the Health & Safety topics to be discussed in its Health and Safety Plan for 2004 / 2005.

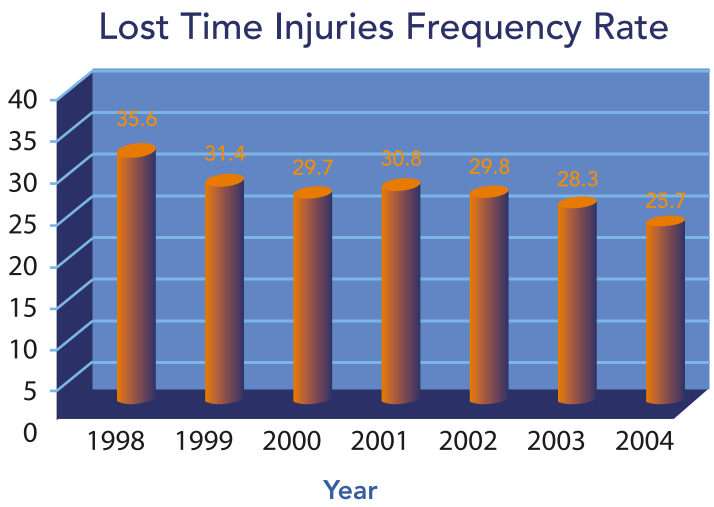


Fig. 49: Lost Time Injuries Frequency Rate

Data: contractor and restrictive duties statistics, safety and occupational health booklet per department, healthy workplace, occupational disease, structure of safety and occupational health in the company, sickness rate reduction, standardisation of safety data sheet, free time accident / illness problems.

Causes: relationship between seniority and accident, lost time factors, driver safety.

Remedies: safety audits, investment to reduce high risks, integrated risk management systems, behavioural safety and global health promotion programmes.

4. Ways and means

Benchmark

Iron and steelmaking has long been a hazardous occupation. However, great improvements in safety figures have been recorded (frequency figures of the order of 10^{-5} to 10^{-6}), at least in some companies, showing that there is place for a definite improvement in the safety of personnel.

Consequently, two main actions should be promoted:

- Benchmarking between companies should be promoted, by taking the example of the best and sharing the information about safety
- Apart from the proper design of the industrial operation and operating procedures, stress must be put on the behavioural attitudes of everybody within the company from management to workers and to sub-contractors – exchanges of best practices should be encouraged

Safer production and consumption

Safety concerns not only people working in steel shops but also steel customers. Many efforts are presently made in some companies to create safer production and consumption conditions, as far as chemicals are concerned, with risk assessment studies and safety data sheets.

Such an effort is involved in the forthcoming implementation of new European regulations about chemicals. In consequence, the efforts of the steel industry to implement these new regulations should be encouraged through financing joint actions to promote product safety studies, research into alternative less toxic solutions and promotion of their implementation.

Working conditions

Working conditions are still changing rapidly, switching from physical to mental loading, and the consequences of these new working conditions on workers should be investigated.

5. Recommendations

The long-term vision is the achievement of the zero accidents objective. This in turn calls for a multidisciplinary approach to prevent accidents and treat injuries, i.e. call for the integration of health and safety ergonomic, and even organisational aspects in research or R&D projects, as well as in designing new plants, production lines and products.

The following recommendations are aiming at the achievement of this objective:

- Support a sustainable, fundamental and continuous improvement of performances towards zero accident workplaces.
- Secure a high level health and safety management system.
- Integrate risk management and health and safety topics into business decision making processes.
- Harmonise health and safety statistics among European companies and countries and publish regular updates to the zero accidents steel, focused in the areas of:
  - Leadership - visible involvement and recognition system
  - Accident prevention and the use of root cause analysis (including human error analysis)
  - Occupational illness prevention and cost mitigation strategies.
  - Prevention, radical reduction of work-related stresses.
- Develop benchmark performance systems that measure progress in health and safety.
- Develop meaningful indicators to be integrated into health and safety and performance statistics.

- Deepen the understanding of causes of unsatisfactory health and safety performances
- Establish effective and timely communication processes that involve WG initiatives and serious accidents.

Demand for highly skilled educated people

1. Background

The demographic and technological evolution, the complex structure of the production tools generated by the continuous process of technology introduction, the push towards increased productivity both in terms of return on capital employed and human resources, the need to have a deep knowledge of the metallurgical processes taking place during the various production stages, and managing a qualified workforce in the context of labour shortage, are all driving factors in the demand for highly skilled educated people.

Steel industry employees in Europe have an education structure, which reflects the European school and university systems of some 30 years ago. The dramatic change in the educational system has so far had only a small impact on the total structure even if it has had a substantial influence on recruitment during the last fifteen years. The industry's decreasing number of employees has been achieved through huge retirement programmes and cautious recruitment.

In order to be competitive and to continue to be at the leading edge of knowledge in the future, the steel industry needs different groups of people like engineers, economists, marketing people, operators etc. The present report is focused on engineers, mainly graduates and postgraduates, and only marginally discusses the needs of other categories.

2. Analysis

The requirements for graduates and post-graduates will increase. Historically, the increase has been some 4% each year in Sweden (for example). There are several key reasons, for the forecast continuous increase of these categories of qualified employees. In the future the steel industry must continue to create systems, conceive technical solutions and process configurations, which make it possible to reduce production costs, improve the quality of the existing products and develop new products in response to the demand for sophisticated components.

It is not unrealistic to say that the need will in the future increase a little more, say 5%, which would imply an increase of the present number up to approximately 2300 up to 2024, which means the recruitment of approximately 1900 people, or 95 per year.

If it is accepted that 50% of the students come from other areas, the steel industry needs to recruit annually something like 45 students from steel related courses. If by contrast 50% of those students come to the steel industry, an additional 100 students per year need to be educated, i.e. an increase of the education rate of approximately 100%. Great attention should be placed on this demand by universities and companies.

In contrast, the declining numbers of university departments wholly dedicated to metallurgy has been a growing concern over the past 40 years, these departments having been diluted into materials science. Within the past decade, materials science itself has in many universities lost its identity within broader engineering faculties. For instance in the USA from 1991 to 2000 the number of PhDs in metallurgy fell from 71 to 24 per annum. Many professors, with in-depth experience in ferrous metallurgy, and science school teachers have retired or are about to retire. These specialists are not being replaced by an equivalent number of young academics who have the ability or interest in teaching and conducting research on steel processes, products and applications. Hence there are fewer young teachers to act as role models to excite and enthuse their pupils into science at schools or universities and subsequent careers. Consequently the graduates who do join the steel industry and its supply chain do not have sufficient ferrous metallurgical knowledge that the industry needs and so expensive in-company training and other courses have to be used to bring them up to the required standards.

It is proving to be very difficult to break out of this vicious and potentially terminal circle. Some governments have recognised this and have made

additional resources available to schools and universities to re-equip science laboratories and to offer financial incentives to science teachers.

What kind of knowledge do companies want new entrants to have?

Managers

Engineers who want to be managers need to have a broad education. Besides a technical education they need tuition in economics, management and innovation. As an example of such education, industrial economy, or a pure technical education completed with a comprehensive management programme, can be mentioned.

Research and development of technical processes

To solve cases belonging to this category the steel companies, suppliers and research institutes have to recruit people with deep knowledge in different areas, graduates and post-graduates, not least the last group. Besides the usual topics within the steel area, competencies in fields like energy, environment, recycling are needed.

Research and development of products

Full competition must prevail within this field. That means that every single company has to do the job either by itself or in co-operation with others, for example universities. In addition, in developing new products they need co-operation with customers.

Other employees

Marketing and Distribution

Within these areas engineers and people with masters degrees in marketing are needed. They should have knowledge of the materials and the relevant requirements to develop future products in co-operation with the customers, and knowledge of the problems posed by new transportation systems that are designed for effective delivery performance, sound environments and energy saving.

3. Needs

From the analysis here above, the following needs have been identified:

- To quantify the schedule of workforce losses from the steel industry, at European and national levels, and according to competencies lost.
- To quantify the share of the leaving workforce that will be replaced, the schedule of replacement and the corresponding competencies, also at the European and national levels. i.e; quantify the recruitment needs of the European steel industry supply chain, in terms of discipline, knowledge, skills, competencies and level (technical, bachelor, master, doctoral, post-doctoral) at five year intervals from 2005 to 2030, taking account of the current and anticipated age distribution and staff turnover.
- To quantify the capacity of the educational system to supply the needs of the European steel industry, both at national and European levels. In particular:
  - Conduct a survey of European Universities providing metallurgy, materials science and engineering graduate and masters degree programmes, doctoral and post-doctoral research activities and quantify the numbers of graduates and postgraduates they expect to produce in 2005, 2010, 2015, 2020, 2025 and 2030.
  - Identify who in European universities will teach and conduct research in ferrous metallurgy in 2005, 2010, 2020, 2025 and 2030.
  - Conduct a study of the ferrous metallurgy content of the university programmes and identify the training needs of the graduates from these courses when they join the steel industry supply chain and prepare appropriate material for them.
- Compare the identified needs of the European steel industry with the capacity of the educational system to satisfy them
- According to the results of the aforementioned analysis, devise the appropriate actions to secure the adequate supply of highly skilled workers to the European steel industry.

4. Ways and means

Besides the actions that would be undertaken as a result of the analysis proposed above, the following approaches should be pursued:

Co-operation between steel companies and universities

From case studies it results that twice as many talented people are needed than at present to follow steel related courses at university. In order to get a more relevant education it is necessary to interchange people and experiences between steel companies and universities.

Education material

It is very expensive and time consuming to create professional education material. In order to make this process more effective, universities and companies should co-operate and design material, which could be utilised by the industry in the EU. The EU Commission could encourage and manage such an activity.

Lectures

It would also be interesting to organise the delivery of lectures from specialists via the Internet to all who should be concerned. This would be especially interesting for the students during their fourth and fifth years when they have chosen their own speciality or when the best lecturers are no longer at university.

Responding to the challenges of energy / environment - competition with non EU countries

Materials, including steel, form the backbone of the future development of the society. Three main challenges are faced that will require the talents of the new generation: energy, environment and competition. This will require skilled people in the fields of materials, chemical engineering, fluid mechanics, material science (metallurgy and surfaces).

Creating a competitive workforce advantage in the field of material science

As stated in the European White Paper on fundamental research in material science, this plays a pivotal role in improving the economic performance and the quality of life (living environment, consumer goods and transportation). The development of materials research laboratories and the training of highly skilled people should bring a competitive advantage to Europeans in world competition; it should therefore be supported by the European Commission.

5. Recommendations

European networks in the field of material science and training are necessary and should be further encouraged as follows:

- Training networks that may be part of the student curricula
- Research networks that can strengthen the efforts of European laboratories by a multidisciplinary work on joint projects.
- Building up advanced education programmes with matching technological progress and organisational evolution and disseminating acquired knowledge throughout students.

How to attract qualified people

1. Background

The European steel industry, in common with those in other parts of the world, especially North and South America, the Far East and Australia, continues to struggle to recruit sufficient high calibre graduates and post-graduates to meet its needs, particularly in metallurgy, materials science and engineering subjects. However, in China and India the steel industry is regarded by graduates as one of the most attractive industries to join. Whilst this submission concentrates on graduates with scientific and engineering degrees, it should be remembered that the steel industry also needs graduates with other skills, e.g. finance, marketing, legal, IT, language, business, etc. Without a continuous influx of young, ambitious and skilled people, who have the ability and potential to innovate and become its future leaders, the European steel industry will not maintain its competitiveness over other steelmakers and other materials. This situation is not unique to the steel industry - a meeting organised in Copenhagen in 2001 by European Industrial Research Management Association (EIRMA) on how to attract young people into technological subjects attracted delegates from oil, food, pharmaceutical, automotive, biotechnology and chemical companies. The same concern for attracting qualified people was shared by all sectors.

The decline in applications to register for science and engineering courses is a reflection also of the

reducing proportion of pupils who study science at post-16 years prior to university, given the diversity of options now available to them and the perception that science exams are difficult. Metallurgy and materials science courses suffer particularly in this regard as their most obvious recruits are those who have studied and want to continue to study a combination of mathematics, physics and chemistry and possibly also design and technology. The materials science courses are often filled with students who did not originally select this subject, but because they did not get high enough grades for their first choice - not an ideal situation to attract the most talented students. Those that are attracted to materials science are more interested in biomedical, aerospace, nanotechnology and other advanced materials and not initially in steel and metallurgy.

2. Needs

This report proposes three stages to the discussion on how to attract qualified people. These three stages and critical questions are:

- How to raise awareness of young people at an early stage and broadly enough in the vast amount of possibilities technology can mean to them?
- How to communicate the leading technologies of the European steel industry in order to attract talented young people to study metallurgy/ materials science and engineering?
- How to tempt talented people to find their way into steel industry, and to stay to further develop technology, products and solutions for customers and customers' customers?

The steel industry must accept some of the responsibility for not making its requirements more clearly known and quantified to the educational community, but another highly important factor is the very poor image the steel industry (together with the engineering and manufacturing sectors at large) has in the eyes of the public and media. When the only news about the steel industry that hits the headlines is another steelworks closure and job losses it is not surprising that young people and those that advise and influence them consider the job prospects limited and do not immediately think that they might have a rewarding career in the industry. Despite losing many jobs through improved technology, the steel industry must do a much better job at convincing society and young people in particular that it can offer excellent careers.

At each stage are presented a variety of activities performed for raising awareness, communicating attraction to high-level studies and finally keeping those talented who have chosen steel as their industry.

Raising Awareness

How can awareness be raised in young people at an early stage and broadly enough with regard to the vast range of possibilities technology can offer them? This involves influencing, strengthening and nurturing positive attitudes towards mathematics, physics, chemistry, design and engineering early in children's lives.

It is generally recognised that for maximum effectiveness, it is vital to inspire and capture the imagination of children at a very early age. Thus, stimulating science resources should be provided for teachers and for pupils at all ages from 5 to 7 upwards. However, especially at the younger end of this age range, it is important that industry is not seen to be overtly advertising itself and its products, otherwise such resources may be treated with contempt and ignored. To be effective they should be completely integrated into the appropriate curriculum so that they are of direct value to teachers and their pupils and not seen as an extra task or burden. To make trainee teachers aware of the resources available is recommended as an efficient means of getting these resources adopted in the classroom.

Ways and means offered to raise awareness at school level: lessons, science and design clubs, quizzes and competitions in schools, run by steel industry employees acting as science ambassadors. Lectures to undergraduate and graduate students by steel industry employees. Unpaid work experience for school children in steelworks or laboratories., and/or summer camps for school pupils. Education curriculum support resources - books, brochures, circulars, magazines, games, videos, posters, workbooks, lesson plans, CDs, audio tapes, floppy discs, Internet for schools. Visits by school children and teachers to metallurgy, materials science and engineering departments at universities.

Communicating Attraction to High-level Studies

How is it possible to communicate the technological leadership of the European steel industry? How can talented people be tempted to study metallurgy/ materials science and engineering? People inside and outside this modern industry need to be informed clearly about the challenging career opportunities the sector can offer, now and in the future. Innovative, highly qualified and open-minded professionals are what the industry needs and requires to join in developing new products and advanced production technologies to confront the energy and environmental questions posed to the steel industry. This requires a major initiative to enhance the image of the steel industry, steel technologies, steel products/applications and career opportunities in the steel industry supply chain throughout Europe (public, media, education and politicians), building on the strength of the "Made in Steel Campaign" .

Ways and means offered to communicate the leading technologies at university level: Visits of students and lecturers to steelworks and laboratories, sometimes with overnight or up to one-week accommodation and refreshments, and opportunities for more informal interaction with recent graduate recruits and managers. These can be courses run over several days and may also involve speakers from industry.

Develop new school curricula and content, e.g. level course in material science, and support those parts of the curriculum, e.g. in physics, chemistry, design, technology and engineering that relate to materials. Steel industry employees on university committees and boards to advise and guide curriculum developments.

Paid industrial work experience and industry-based projects for undergraduate students, as part of their assessed studies and during vacations, sometimes involving experience in other countries. Steel industry stimulated undergraduate research projects and provision of materials, data, access to works and laboratories under supervision by steel industry experts. Provision of financial contributions from industry to universities to purchase research equipment/laboratories.

Sponsorship of undergraduate students and post-graduate researchers during their courses (involving tax-free annual payments of up to € 4,000 to undergraduate and € 10,000 for post-graduate PhD students). Industry sponsored PhD and postdoctoral research projects, carried out at least partly in industry, addressing the needs of the steel industry. Marie Curie Fellowships in which post doctoral researchers spend 2 years in another EU country engaged on an industry based research project.

Engagement of steel industry employees as part-time visiting professors for teaching and research in a university. Internships for professors, other academics and schoolteachers to spend time in a steel company to understand the issues and challenges facing industry and to increase their contacts. Development of networks of academics and industrial partners to share knowledge and to identify and develop research collaborations. Provision of financial support to university faculties and departments for courses, grants and equipment, industry-sponsored professors and other lecturers. Technical and promotional presentations and refreshments provided by company representatives at targeted universities and departments. Steel industry cash prizes to students and graduates with high achievement. Travel grants to enable the best students to visit other countries.

IISI initiative to develop highly interactive Internet delivered e-learning resources on steel processes, products and applications and the underlying metallurgical, scientific and engineering principles.

Other activities at all educational levels and to address the general public: Attendance at careers fairs, exhibitions, posters, brochures, websites and adverts in press and Internet, to promote recruitment and career development opportunities in the company. Free or subsidised attendance of students at conferences. Industrial support and resources to science museums and science adventure centres. Lectures, presentations and exhibits at teachers' conferences. Major advertising campaigns, involving TV, newspaper and magazine adverts and posters have been undertaken in Europe (Made of Steel) and USA (Strength of Steel) to improve public perceptions and image of the

steel industry.

Advertising campaigns to improve the image of the steel industry appear to have been relatively successful.

Compared with the pharmaceutical, telecommunications, automotive and aerospace industries, steel industry expenditure on these activities is quite modest.

Despite all the activities carried out, the problems of attracting highly qualified graduates of the right calibre into the steel industry persist, both in terms of quantity and quality. The issues are multifaceted and multi-layered, requiring a mixture of tactics with a variety of timeframes and payback times.

Attracting and keeping the Talented

Finally, probably the most critical question is how to maintain the interest and motivation of talented people who have chosen to study, to teach and to work for positions requiring high qualifications in the steel industry? The true reality of the sector needs to be shown – the challenges, the opportunities and the perspectives to grow both professionally and personally within and along the steel sector. Close personal experience with steel companies and their employees is the key element in introducing the attraction of creating high-tech innovations in steel, and working both for the future of individuals and the industry.

The evidence from industry and students suggests that the most effective way of attracting young people into our industry is a close personal experience with a steel company and its people. Young employees up to 30 years old are seen as the most powerful role models. Students want to know what jobs are like in industry - what will it entail, what are the working conditions, what decisions and activities will they perform, what are their career prospects, what additional training will they receive, what responsibilities will they have and how much will they be paid? Answering these questions in a very practical, first hand, direct and personal way is most likely to attract students to join the steel industry.

Students who do study materials science and engineering subjects at university are also highly attractive to the accountancy and consultancy organisations that value their numeracy and team working skills. These companies offer higher salaries and good promotion prospects. Other industrial sectors, including aerospace, automotive, defence and energy, which recruit materials science graduates also tend to offer higher starting salaries than steel companies.

If steel companies cannot recruit new graduates then it has to look to recruiting more experienced people, with probably higher salary and responsibility experience, without specific knowledge of steel, or recruit younger staff direct from school and ensure that they progress to graduate level of competence and knowledge. One consequence of a continued shortage of suitable recruits is that the salaries and employment packages offered in order to satisfy the needs of the industry will inevitably rise and this will have knock-on consequences for existing staff and also should start to alleviate the problem.

Steel companies should publish case studies of talented young people who have joined them during the past decade to demonstrate how their careers have developed, the responsibilities they have accepted, the experiences, knowledge and professional development they have gained and their promotions and potential for further development and progression. These examples should be drawn from a variety of functions and disciplines within the industry, illustrate the different types of jobs that can be undertaken from a scientific, materials or engineering degree and should present powerful and stimulating the role models.

3. Ways and means

- Conduct a survey of the attitudes, motivations and aspirations of school pupils, undergraduates, graduates and post-graduates with respect to careers in the steel industry.
- Enhance current initiatives to attract new recruits and promote the image of the industry in the minds of school pupils, parents, teachers, careers advisers, students, professors and lecturers, graduates and researchers, not forgetting government and media.
- Support education resources and teaching of maths, physics, chemistry, design, technology and engineering. This should include the development of Internet-based e-learning

resources for schools from the age of 7 to 18 with the aim of informing and exciting pupils and their teachers about materials, design, engineering and manufacturing. Such resources should be made available in the national languages of Europe and should involve the support and participation of a wide cross-section of European industries and education providers. The Internet-based e-learning resource for undergraduates materials science and engineering students and employees in the steel industry supply chain being developed by the IISI, should be translated into the major national European languages.

4. Recommendations

Research is needed to address the following major issues with these objectives:

Efforts have to be made across Europe to engage and excite school pupils, their teachers and parents about materials and engineering. This is too big an issue for the steel industry to tackle on its own and should be undertaken jointly through collaboration between the steel sector and other sectors, e.g. automotive, construction, engineering sectors etc. Each sector and indeed company then has to focus its own unique promotional efforts with the undergraduate student population. Support the development of undergraduate and masters programmes in materials science and metallurgy at universities and explore the feasibility of creating cross border networks and collaborations between universities and the steel industry – to demonstrate the attractions of studying and working in multinational and multicultural environments.

Help schools and universities to provide the best and most inspirational teachers of materials science and metallurgy, especially those universities which offer a common first year in engineering or science, with the aim of persuading the students to select materials/ metallurgy in subsequent years.

Open the doors of steel shops towards local communities (authorities, schools, families, people, non- governmental organisations, ecologists etc.) to make them aware that the steel industry is nowadays a sector that is clean and not polluting, traditional but highly innovative, mature but with a future, and that the steel products are not old fashioned commodities but products which respond to the most sophisticated demand of the market.

Promote cross-border exchanges with special focus on students, engineers and technicians exchanges and on joint university-industry multinational seminars.

Finally, to attract qualified people, it is compulsory to support the reconciliation of working and non-working life. This in turn demands suitable social infrastructures, which might facilitate the management of personal life of the whole employee population.

Life-Long learning

1. Background

A graying Europe: new opportunities for the younger generation

Most steel companies developed strongly in the 1970s and the present working population can be divided into three, roughly equal parts: the 50-55 years class, the 40-50 years class – the 20-40 years class. In consequence, many people will retire in the next ten years and this movement will continue during the following decade.

The situation is the same in universities and technical universities. Such a trend is reinforced in the field of material science and especially metallurgy where retiring professors are not replaced. This represents a strong challenge, since a new generation needs to be trained in a field that represents one of the backbones of European economy. Due to the definitely urgent need to recruit the next generation of teachers in universities, EC support is expected to create networking, sharing and exchange among all the universities in that field.

Strong changes in business and work styles

The expected change in the demography will also be accompanied by strong changes in the steel business and in the way of life of the new generation.

In less than 10 years, the steel industry has moved from a nationally-based industry towards a European operating industry and more recently towards a world operating business.

The relevant workforce tends to become multinational, which requires the fluent practice of languages and an open mind towards other cultures or lifestyles.

The rapidly changing business world has two main components that will strongly shape the future of the sector: energy and customers.

- Energy will be, in close connection with the environment, a strong issue in the coming years. Materials science will play a key role in the field of new products, that will directly or indirectly save energy during their use, and in the field of processes; this in order to adapt or change the present steel production processes into those with lower specific energy consumption or with greater flexibility with regard to energy sources (natural gas, nuclear, solar energy…). New competencies must be developed along these two lines by promoting closer process/product teaching.
- Customers are increasingly shaping the professions of all those who are concerned with the steel industry, as their requirements are now introduced into steel production processes. In the future, production will have to be designed increasingly to make products smart in terms of energy consumption, safety and function.

This requires a personal flexibility to adapt to new situations, to acquire continuously the required know-how corresponding to position changes throughout the working life. Continuous training is an essential prerequisite.

Work styles are also changing rapidly. Project management requires managerial know-how and also a broad multidisciplinary culture to take into account the various facets of the project (from the technical up to the financial and management aspects).

Furthermore, two developing skills are now increasingly required: entrepreneurship and risk taking. An early development of these skills is acquired mainly through personal experience - from university or engineering school - or at a later stage through continuous training. The necessary theoretical background must be given, but since a great part of it is related to individual behaviour and attitude, personal projects have to be encouraged. Even if initial training can provide this expertise, it requires continuous adaptation according to the state of business evolution worldwide and the personal adaptation along the career path.

From traditional education to continuous learning

At present, the effort of training personnel varies between countries and companies. A comparison of figures is not easy as the definition depends on national laws and all training actions are not taken into account.

Continuous training includes internal (direct training in the workplace and classroom training) and external actions (school and university training). In general, it is considered that about 1 to 2% of working time is devoted to training, such as 2 days per year in average. In some countries the law requires that the continuous training investment be higher than 4% of the wage bill; other figures are of the order of € 1,100 per employee and per year. It may be concluded that approximately 2/3 of the training is carried out internally, 1/3 externally.

The traditional education of the "baby-boom" generation was mainly scientific and technical with substantial effort being devoted to the detailed analysis. Later on, education became technically much more specialised, thus leaving limited space for building up a broad open culture.

By contrast nowadays, a different educational scheme is needed, through which this broad and continuously updated open culture can be achieved. In this respect the development of IT creates large opportunities and training tools, which takes into account the personal rhythm and learning path to suit to any individual.

2. Analysis: Life-long learning: a challenge for companies and universities

Competencies & careers: requirements for continuous training

The required skills for the new engineers are changing rapidly. They will be increasingly entrepreneurs / innovators and change / project managers. The following skills need to be developed:

- Entrepreneurship capability
- Attitude for innovation

- Capability to analyse and manage change
- New engineering fields

Corresponding skills are also required for technicians, with special focus on the requirements of continuous adaptation to fast evolving techniques especially in the fields of measurement and computer use (networking, process control, computing techniques…).

Technology life is now shorter than the working life so that there is need not only for know-how heritage between generations but also for:

- Allowing companies and people to adapt continuously ever-changing situations
- Developing the new skills that are required
- Keeping a lifelong high level of qualification

As a consequence, greater and stronger links are being created between the initial training, R&D and on-going training to refresh and adapt continuously the knowledge and know-how transmission.

New training methods have to be further developed and encouraged.

The needs of both the younger generation for new training methods better matching their curricula, and the availability of teachers put the emphasis on acquiring know-how by the following methods:

- **Autonomous training** – Learning to learn must be already experienced at school and must be further extended by developing communities of practice. The development of information technologies offers many opportunities to develop tools to reach that goal (websites, interactive training, structured courses with links…)
- **Practical training** should be encouraged by sharing experience between European universities and companies for building joint training schedules and schools
- **Coaching, accompanying and validating** the training will remain at the heart of the teacher's role.

3. Needs

Reinforce Industry-University relations and promote new training methods are needs that have been identified:

Reinforce Industry – University relationships to build relevant and tailored training

The rapidly approaching departure of baby boomers from the industry requires urgent actions relevant to both initial and continuous training.

Initial Training

Precise industry needs (WG industry - universities to define curricula)

Enlarge accessible basic courses such as already done by IISI

Encourage and sponsor trainees on a European basis

Sponsor the creation of professional e-courses and interactive courses

Further support new methods implementation and cross-border seminars

Life-Long Training

Support knowledge management projects to keep the existing knowledge accessible to the younger generation

Support the development of e-learning methods and sites

Engage universities to offer continuous training in some fields

Finance university / company cross border seminars

Favour the access to European research results (through an e-library)

4. Recommendations

The achievement of these targets requires the development of projects that bring together people from university and industry. The projects should follow three main axes:

- Promote a network of material science universities at a European Level
- Sponsor programmes for developing new methods and tools for knowledge management and e-learning
- Launch high-level courses (e.g. Eurosteel Master) for transferring acquired knowledge throughout with employees turning from technical to managerial or entrepreneurial responsibilities.

Each of these three axes should be self-funding.

Human Resources Management

1. Human Resources Management: Key to the implementation of a company's vision

The conclusions of Eurofer's project "Management of Change and Human Resources", which was carried out between 1997 and 2000, presented an overview of the evolution of human resources management (HRM) functions in a context of change management (figure n°50). It showed, in particular:

- A Cardinal change of perspective: Human resources were essentially considered as a cost, now they are predominantly envisaged as a strategic asset.
- An indisputable evolution towards decentralisation of some HRM functions to accompany the streamlining of organisational structures and the empowerment of manpower and teams.
- The growing importance of proactive approaches in HR management

Indeed, human resources are among a company's key assets. They are the holders of a company's core competencies, which are one of the main sources of its competitive advantage. Accordingly, HR management should play a key role in such an environment, as every change in the workforce has an impact on the stock, distribution, and use of knowledge in the company.

Furthermore, HRM is essential to the implementation of a company's vision for the future. This usually involves organisational changes, changes in the organisation of work, behavioural changes, flexible working time arrangements, planning of future needs in terms of workforce numbers and competencies, training, career planning, competitive and attractive remuneration packages coherent with the company's objectives. Last but not least, it is instrumental in developing an industrial relations system, supportive of innovation, improvement of job quality and competitiveness, thanks to a constructive social dialogue

In the end, HRM is at the crossroads of most company policies to improve its market position, and return on investment.

HRM should be viewed, in this light, as seeking the optimisation of a key strategic asset, while minimising its cost.

HRM Functions have evolved from traditional to evolved functions

Fig. 50: Management of Human Resources

2. Recent trends in HR management

- Management has become involved in and committed to HRM
- Decentralisation: HRM has become increasingly a line responsibility and many of those responsibilities have been delegated down that line, in some cases to the level of the self-managing teams on the shop floor
- HR units have in many companies become decentralised, smaller, and more professional owing to their focus on special support, new developments and on the transfer of knowledge across units

Conversely: risks presented by current/recent trends in HRM.

- Concerns regarding HRM remaining high on the management agenda when the sense of urgency has cooled down
- Has line management the time and the competencies necessary to carry out the HRM functions that have been devolved to them?
- Have new patterns of behaviour been sufficiently rooted in the workforce mentality, so that there are no recurrences of old habits, in particular, under stressful situations?

3. Challenges confronting HR management

Recruit on a large scale new generations of workers

- Propose attractive packages competitive with competing industries and responding to the value of generations:
- HRM in charge of closing the gap between the evolutions of society and the company
- Secure the necessary transfer of knowledge in such transition and the role of elderly workers

Develop effective approaches to knowledge management

- Competency planning, career planning, training, competence centres, knowledge banks, skill-based pay, knowledge platforms are not measures that stand on their own, but have to become part of new organisational configurations of the firm as a "knowledge enterprise"
- Maintain steadfast policies to ensure the continued rooting and development of new patterns of behaviour

4. HRM Conclusions

The analysis above has clarified the need for a more in-depth knowledge, at European level on two major topics:

Future recruitment (see topics 2 & 3)

- Quantify the evolution of the industry's needs by speciality, over the years
- Quantify the capability of the education system to supply the people needed by the industry
- Design the appropriate approaches according to the results of the comparison of the two former quantification processes
- Investigate possibilities to counter the decrease of professional training specifically dedicated to the steel industry by inciting cross border "joint ventures" between universities, thus offering multicultural training
- Survey the attitudes of students towards working in the steel industry and devise ways to address effectively their perception

The enterprise as a learning organisation

- Survey of approaches to the enterprise as a learning organisation
- Role and forms of life long learning in a learning organisation
- Comparison of "pros" and "cons" of the different approaches within the companies
- Identification and exchange of best practices

Socio-economic aspects

- Ensuring safe work conditions;
- Exchange of practices in view of the "zero accident" target;
- Close relationships with a network of top level universities taking initiatives to attract the best students in the steel industry; disseminate a steel culture;
- Support and development of training at European level; support EUROMASTER initiative.

Stakeholders

- Steel sector
- The T.I.M.E network (European universities)
- Steel research centres
- Stakeholders in the European Steel Technology Platform

Implementation

R&D areas	Priority	Frame	Term (S = Short, M = Medium, L = Long)	Budget (Mio Eur) 1st priority	Budget (Mio Eur) 2nd priority
1) Health and Safety				**4 100% FP 7**	
• Zero accidents (H&S statistics, ergonomics and organizational aspects among European Companies-Countries)	1	FP 7	M to L		
2) Demand for highly skilled educated people				**1 100% FP 7**	
• Quantitative & qualitative analysis of education systems'capacity to supply the needs of the industry	1	FP 7	M to L		
• Joint initiatives with universities	1	FP 7	M to L		
3) How to attract and retain qualified people				**10 100% FP 7**	**10 100% FP 7**
• Survey attitudes of school pupils & students towards the steel industry	1	FP 7	M to L		
• Promote the image of the steel industry	1	FP 7	M to L		
• Support the creation of education resources	1	FP 7	M to L		
• Propose attractive packages	2	FP 7	M to L		
• Creation of a network of European high schools & universities related to the steel industry technical matters	2	FP 7	M to L		
4) Life – long learning				**10 100% FP 7**	
• Creation and setting up of packages including e-learning	1	FP 7	M to L		
• Support knowledge management	1	FP 7	M to L		
5) Human Resources Management				**1 100% FP 7**	
• Comparison analysis of approaches to the enterprise as a learning organisation	1	FP 7	M to L		

Fig. 51: Attracting and securing qualified people to help meeting the steel sector ambition - implementation

E. Implementation of the Strategic Research Agenda

This document is the updated version of the Strategic Research Agenda of the Steel Technology Platform which was endorsed on December 15th, 2004. It includes a new sub-programme focussed on the use of steel for the energy sector (production, transportation). The document offers a global vision of the innovation and R&D effort that is intended to lead to the achievement of the objectives identified to retain a sustainable leadership of the steel sector in the coming decades.

Priorities have been given to the different themes and R&D areas of the three industrial programmes with large societal impacts of the platform:

- Safe, clean, cost-effective and low capital intensive technologies
- Rationale use of energy resources and residues management
- Appealing steel solutions for end users

and in addition programme regarding human resources.

Private funding from the stakeholders as well as public funding from the different European, National and, possibly, Regional institutions are envisaged to implement the 3 industrial programmes according to the schematic diagram of figure n°52.

The total budget of the first priorities (to be launched first) amounts around € 0.8 bn.

On an annual basis, approximately 25% of the Research Fund for Coal and Steel programme should be devoted to programmes leading to the implementation of sectoral consensus-based R&D activities.

This implementation should take place from 2007 to 2013 for both RFCS and FP7 actions.

In compliance with the objective of the EU-Commission of increasing industrial participation in the 7th Framework Programme, it is proposed to implement the R&D areas of the 3 industrial programmes of ESTEP by using the relevant priority Themes identified for the specific programme "cooperation" of the FP7: Nanosciences,

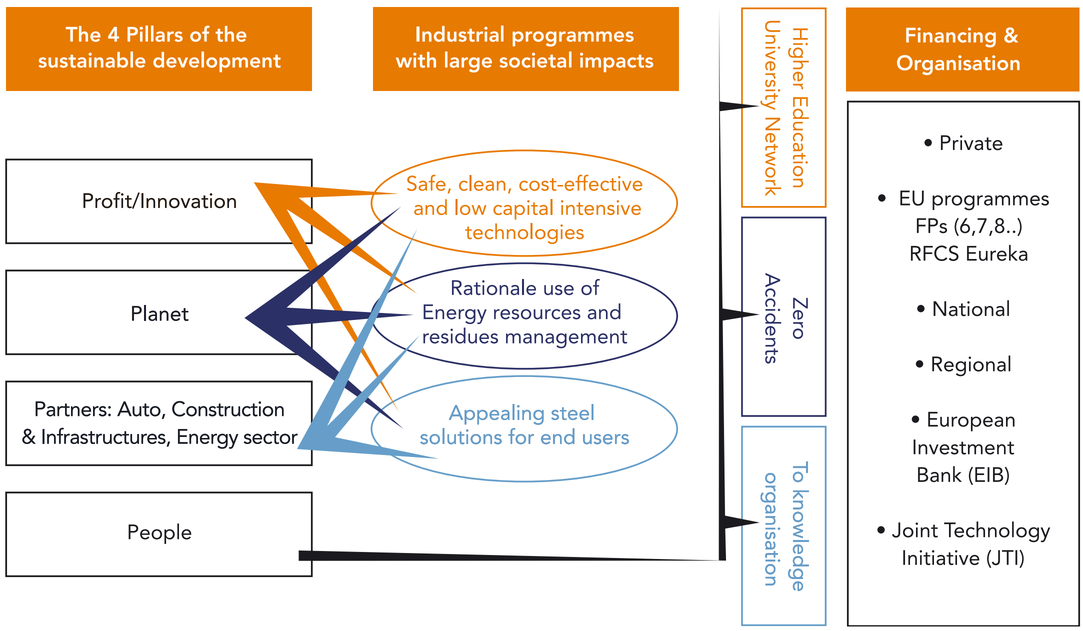


Fig. 52: Implementation of the SRA: need for a critical mass of means

Nanotechnologies, Materials and new Production Technologies; Energy; Environment (including climate change) and Transport.

Ideas and People specific programmes of the FP7 should be suitable as well to launch the activities regarding the human resources programme of ESTEP. A major transversal theme regarding the human resources aspects has indeed been taken into consideration (attracting and securing qualified people to help meet the steel sector ambition).

The remaining part (second priorities) of the SRA should be implemented over a period of 15 Years. The total budget of the second priorities amounts around € 1bn so that the total budget of both priorities I and II amounts around € 1.7 bn. However, within this total budget the ULCOS part represents € 0.7 bn.

The main characteristics of large European ULCOS projects are:

- a subject that concerns the whole of Europe and is incorporated in the FP7
- clearly identified industrial objectives which are important for the long-term competitiveness of the steel sector and for the EU commitment under Kyoto Protocol and beyond
- an already existing consortium agreement in which the leading players in the European steel industry committed themselves
- an important financial commitment of the steel industry
- a need for a critical mass of financial and technical resources (European, National and even Regional)

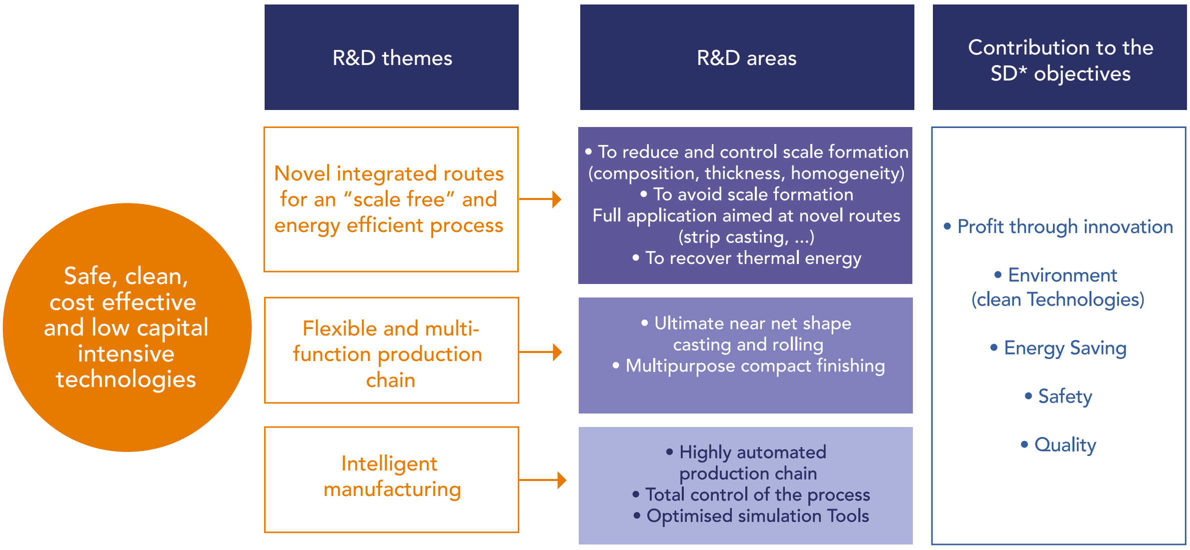
Following the phase 1 that consists of identifying the new technologies to be implemented (2009), a phase 2 (2009-2015) is intended for carrying out trials of the selected technology in an industrial plant. The phase 3 shall be concerned with the industrial development. The two latter phases will require major industrial investments and it might be useful to call upon the European Investment Bank in due course.

This is the reason why a Joint Technology Initiative (JTI - article 171) framework is desired for ESTEP.

The Steel Technology Platform will further integrate and broaden the scope of the European R&D partnership (currently more than 8,000 researchers) built in the frame of the ECSC Treaty and later of the European Framework Programme. Indeed it will constitute large partnerships involving the whole European steel industry, its suppliers and customers (automotive industry, construction sector and the energy sector), SMEs, private and public research, public authorities and representatives of Trade Unions.

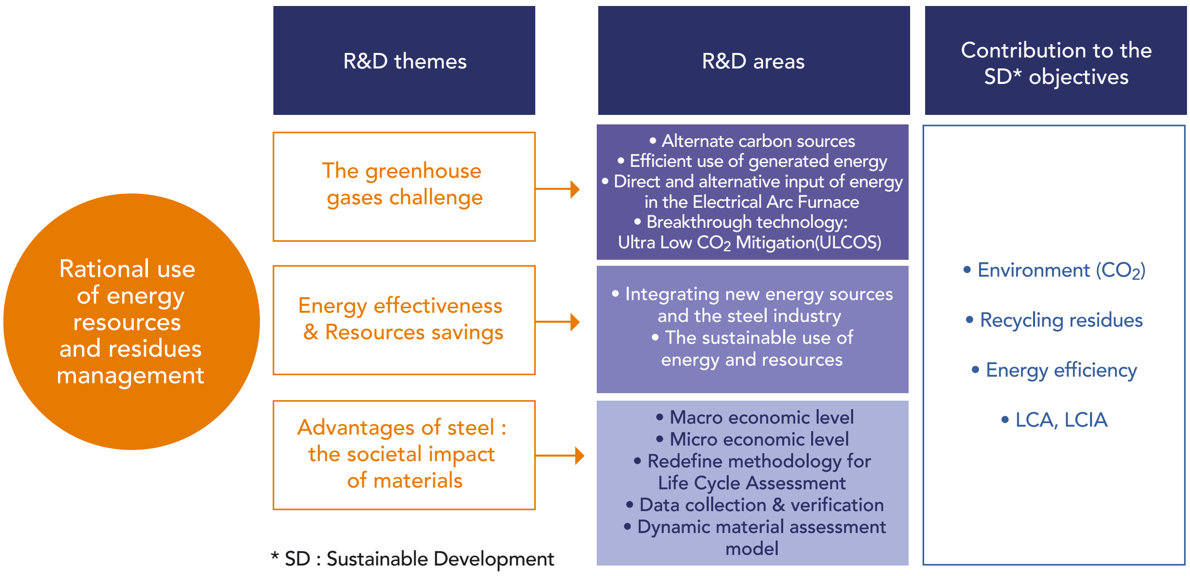
Annexes

Consistency between Societal Programmes and Sustainable development pillars



* SD : Sustainable Development

Fig. 53: Safe, clean, cost-effective and low capital intensive technologies: achieving the SD objectives through R&D



* SD : Sustainable Development

Fig. 54: Rational use of energy resources and residues management: achieving the SD objectives through R&D

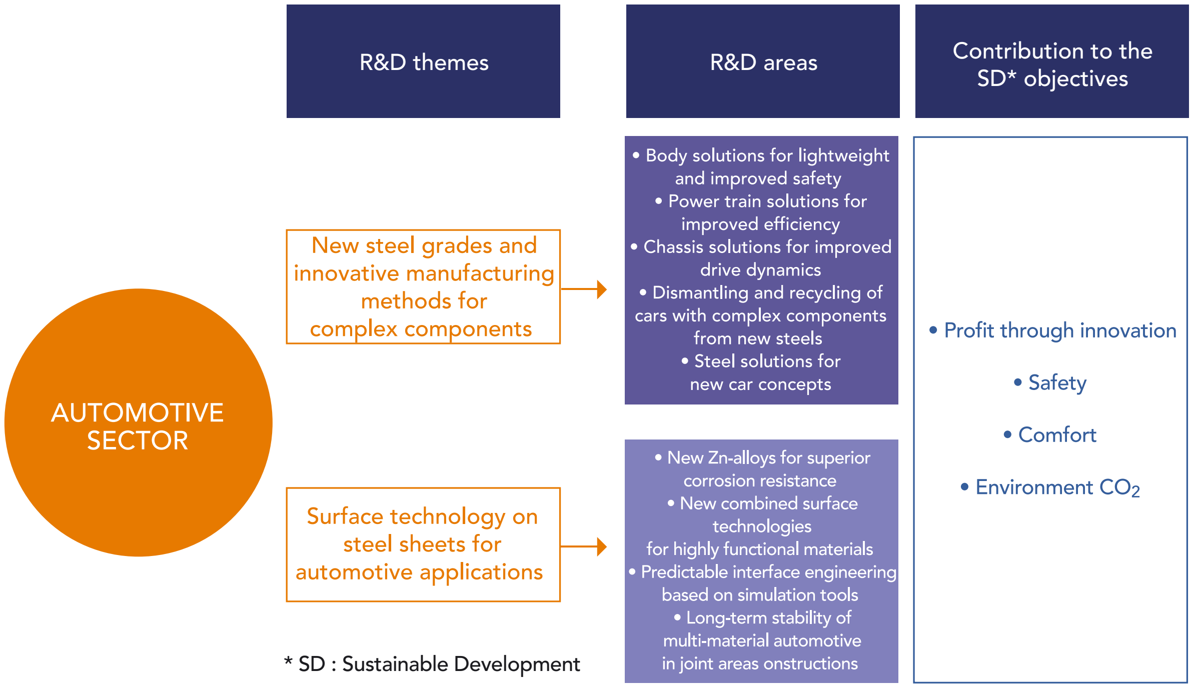
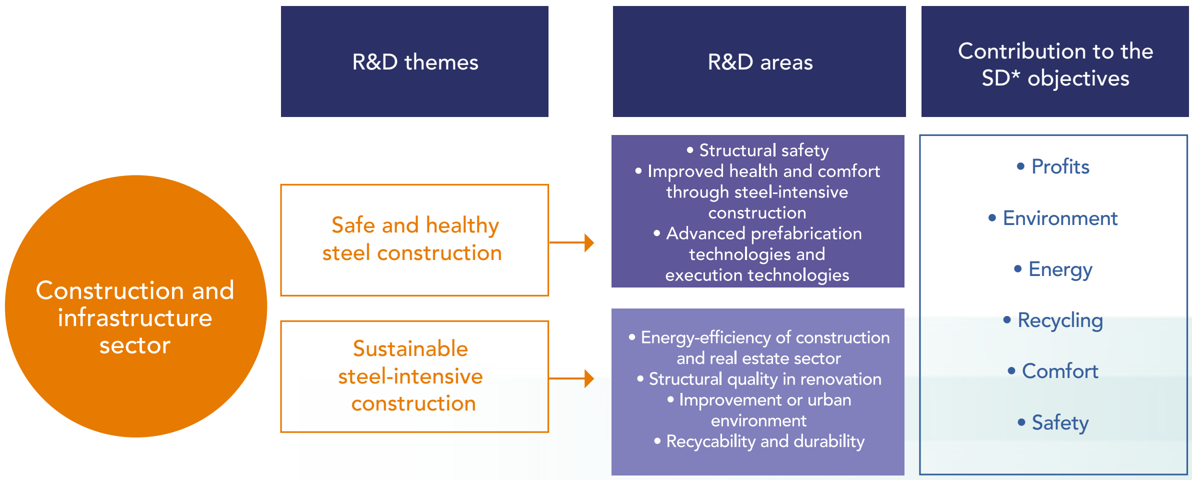


Fig. 55: Appealing steel solutions for end users (automotive sector): achieving the SD objectives through R&D



* SD : Sustainable Development

Fig. 56: Appealing steel solutions for end users (Construction Sector): achieving the objectives through R&D

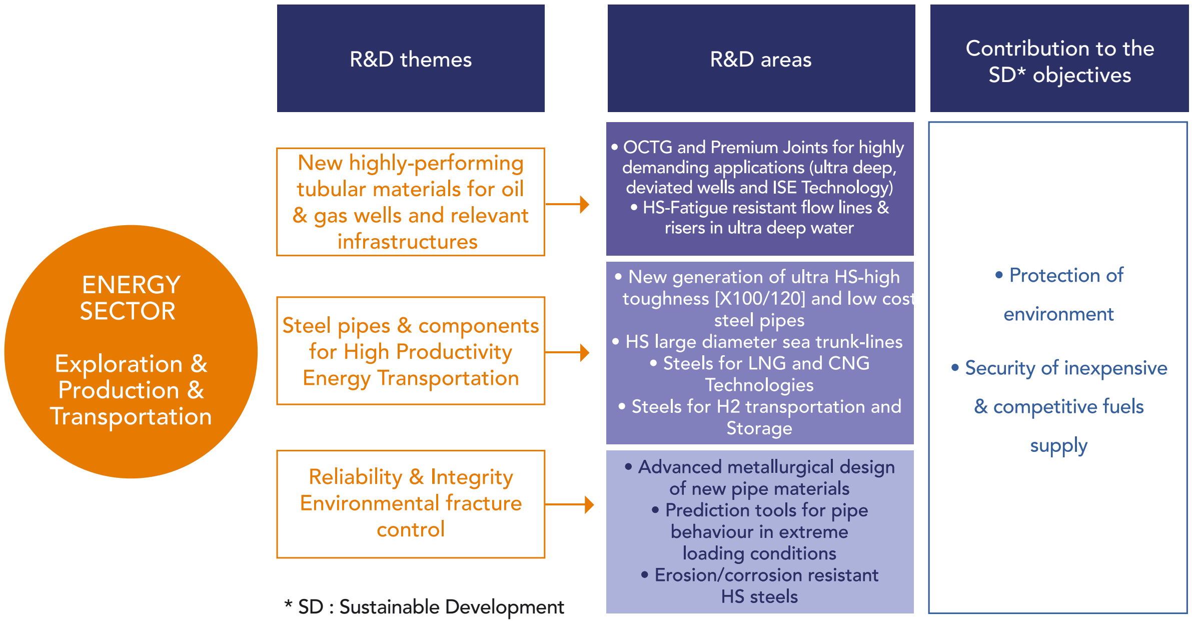


Fig. 57: Appealing steel solutions for end users (Energy Sector - EPT): achieving the objectives through R&D

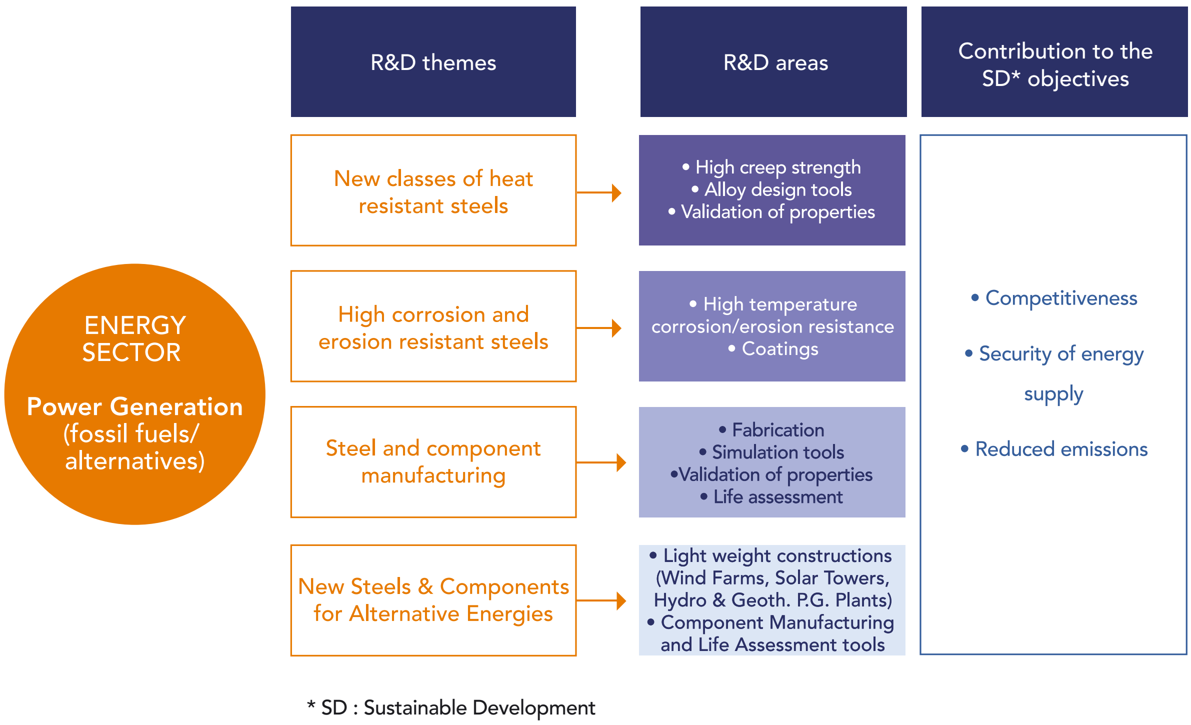
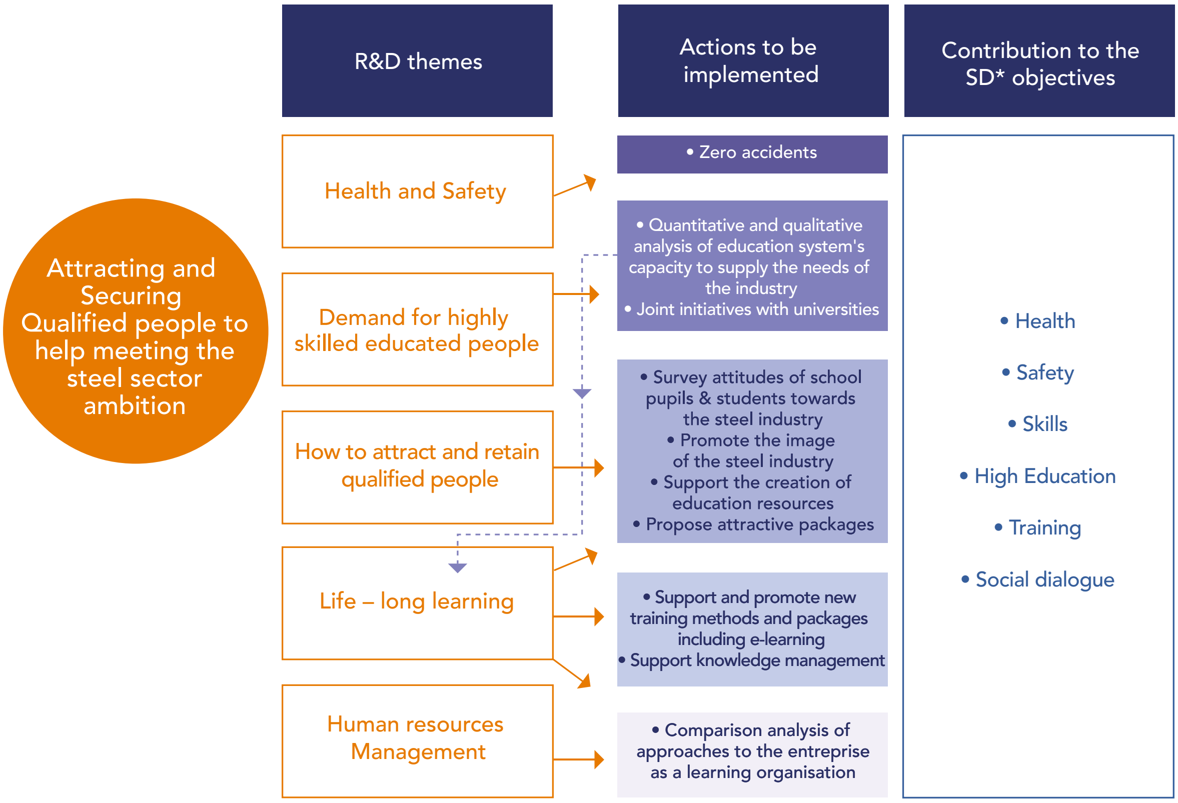


Fig. 58: Appealing steel solutions for end users (Energy Sector - PG): achieving the objectives through R&D



* SD : Sustainable Development

Fig. 59: Attracting and securing qualified people to help meeting the steel sector ambition

Membership of Governing bodies and working groups

1. The Steering Committee

Steel companies :

- Arcelor: Jacques Chabanier, Member of the Executive Board (Chairman)
- Celsa: Francisco Rubiralta, Chairman and Chief Executive
- Corus: Nelson Cunha, Chief Operating Officer
- Outokumpu : Pekka Erkkilä, Chairman Outokumpo Stainless (Vice-Chairman)
- Riva: Claudio Riva, Chief Executive Officer of ILVA S.p.a.
- ThyssenKrupp: Karl-Ulrich Köhler, Member of the Executive Board ThyssenKrupp AG and ThyssenKrupp Steel AG
- voestalpine: Franz Hirschmanner, Member of the Executive Board

Industrial stakeholders linked to the priorities of the Platform:

- Georges Gendebien, General Secretary of the CECM (Convention Européenne de la Construction Métallique)
- Arnold Van Zyl, Director, EUCAR (European Council for Automotive R&D)

Steel Research Centres:

- BFI (Betriebsforschungsinstitut): Dieter Ameling, Chairman of the Board
- CSM (Centre Sviluppo Materiali S.p.a): Roberto Bruno, Chief Executive Officer
- MEFOS: Göran Carlsson, Chairman of the Board

Universities:

- Dominique Depeyre, General Coordinator of the T.I.M.E. Association (Top Industrial Managers for Europe)

Representatives of national EU governments – Presidency of the EU (to be nominated by the Member states): United Kingdom, Austria and Finland for the time being

Representatives of the Consultative Commission on Industrial Change:

- Enrico Gibellieri, EESC/CCIC

Representatives of the Trade Unions (ETUC/ European Metalworkers' Federation)

- Enrico Gibellieri, EMF Steel Expert and Advisor

2. The Support Group

Steel companies :

- Arcelor: Jean-Claude Charbonnier, Director International and Scientific Affairs. Innovation Direction (Chairman)
- Corus: Peter Jongenburger, Chief Technology Officer
- ThyssenKrupp: Klaus Peter Imlau, Department Director
- Outokumpu: Jorma Kemppainen, Senior Vice President - Technology
- Voestalpine: Peter Schwab, R&D Director (vice-Chair)
- Riva: Giuseppe Corbo, Responsible Research Policies
- Unesid: Faustino Obeso, Director Research, Development and Innovation
- Eurofer: Jean-Pierre Debruxelles, Technical Director
- Slovenian Steel Group:

Industrial stakeholders linked to the priorities of the Platform:

- CECM: Derek Tordoff, Director General The British Constructional Steelwork Assocation Ltd
- EUCAR/EGM: Martin Goede Konzernforschung – Fahrzeugtechnik – Group Research – Vehicle Technology (VW)

Steel Research Centres:

- BF: Carl-Dieter Wuppermann, General Manager
- CRM: Christian Marique, Member of the Board

- CSM: Manlio Mirabile, Director International Affairs
- MEFOS: Ake Sjöström, Managing Director

Universities / Network T.I.M.E.: Wolfgang Bleck, Professor (Aachen)

Representatives of the Consultative Commission on Industrial Change:

- Enrico Gibellieri, EESC/CCIC

Representatives of the Trade Unions (ETUC/ European Metalworkers' Federation)

- Enrico Gibellieri, EMF Steel Expert and Advisor

Steel Construction: Bernd Wehling (Wuppermann), Managing Director

EU Commission :

- Philippe Vannson, Head of Unit G5, Research Fund for Coal and Steel, DG Research,
- Alberto Canevali, Deputy Head of Unit E2, Steel, Non-ferrous metals and other materials DG Enterprise

3. Working Groups

WG1 - Profit through innovation & technology: Christian Marique, CRM (group leader)

Participants	Designated Experts
Arcelor	Jean-Marc Steiler
Arcelor (and Unesid)	José Luis Rendueles
BFI	Reiner Stelzer
Corus	Wim Moonen
Eurofer	Günter Paul
MEFOS	Åke Sjöström
Orgalime /DMS	Jean Ledoux
Siemens VAI	Bruno Lindorfer
SMS-Demag AG	Jens Kempken
Outokumpu	Jörma Kemppainen
Riva	Ruggero Cola
voestalpine Stahl GmbH	Klemens Mraczek

WG2 – Automotive sector: Carl-Dieter Wuppermann, Stahlinstitut – VDEh (group leader)

Participants	Designated Experts
Arcelor	Carlos Espina
Centro Recerche Fiat	Daniele Bassan
Cetim	Jean-Paul Peyre
Corus	Nico Langerak
EUCAR	Martin Goede
Eurofer	Günter Paul
Kendrion Sweden AB	Richard Persson
Orgalime	Eric Moleux
Outokumpu	Erik Schedin
Max-Plank-Institut für Eisenforschung GmbH	Guido Grundmeier
Salzgitter	Matthias Niemeyer
Saarstahl	Günther Roth
SSAB Tunnplåt	Bo-Erik Pers
	Joachim Larsson
ThyssenKrupp Steel	Klaus-Peter Imlau
Rivagroup/Fiat	Massimiliano Pagliaro
Stahlinstitut VDEh	Hans-Joachim Wieland
	Reinhard Fandrich
	Rolf Steffen
Institut für Eisenhüttenkunde RWTH Aachen	Wolfgang Bleck
Tecnalia-Labein	Fernando Espiga
voestalpine Stahl GmbH	Peter Schwab

WG3 –Construction and Infrastructure sector: Veikko Heikkinen, Ruukki (group leader)

Participants	Designated experts
APTA-Aceralia/Celsa	Genaro Seona
Arcelor	Thierry Braine-Bonnaire
Corus	Bob Scholfield
Eurofer	Günter Paul
Outokumpu	Tero Taulavuori
Riva	Walter Salvatore
Tecnalia-Labein	J. de la Quintana
VDEh	Horst Hauser
voestalpine Krems GmbH	Werner Suppan
VTT	Heli Koukkari

WG4 – Planet: Karl Buttiens, Arcelor (group leader)

Participants	Designated experts
Arcelor	Karl Buttiens
	Jean-Pierre Birat
	Christian Josis
BFI	Günter Harp
CENIM	Félix Antonio López Gómez
Corus	Raymond Fisher
CRM	Jean Borlée
CSM	Susanna Ramundo
Eurofer	Jean-Pierre Debruxelles
Luleå University	Bo Björkman
Outokumpu	Mikko Ylitalo
Riva	Valentina Colla
ThyssenKrupp	Gunnar Still
Unesid	Santigo Oliver
	Félix López Gómez
Voestalpine	Hermann Wolfmeir

WG5 – People: Manlio Mirabile, CSM (group leader)

Participants	Designated experts
Arcelor	Rémy Nicolle
EESC/CCIC	Enrico Gibellieri
ETUC/EMF	Enrico Gibellieri
Corus	Peter Lennon
Eurofer	Christian Mari
Finnish association of steel	Sirpa Smolski
German federation of steel	Martin Kunkel
IISI	David Naylor
Rivagroup	Maurizio Pacilio
SSAB Tunnplåt	Staffan Meyer
Unesid	Juan Arias
voestalpine Stahl GmbH	Georg Heckmann

WG6 – Energy: Giuliano Buzzichelli, CSM (group leader)

Participants	Designated experts
Alstom	Derek Allen
Arcelor/Industeel	Philippe Bourges
Arcelor/Ocas	Philippe Thibaux
	Pieter Vanduyslager
	Michel Vermeulen
Aubert & Duval	André Grellier
BP	Norman Sanderson
CRM	Jean-Claude Herman
CSM	Augusto Di Gianfrancesco
	Mauro Pontremoli
Dillinger	Karl Hermann Tacke (Coordinator New Energies)
DTU/ELSAM	John Hald (Coordinator Power Generation)
Eurofer	Günter Paul
Jernkontoret/Sandvik	Sven Sundberg/Monika Kristel
Riva	Alberto Segre Fantoli
SZMF	Walter Bendik
	Marion Erdelen-Peppler
	Manfred Keller (Coordinator New Energies)
	Gerhard Knauf (Coordinator E&P&T)
Tenaris Dalmine	Giuseppe Cumino
Total	Olivier Ricard
UNI	Herminio Sastre
V&M	Ulrike Zeislmair
VDEh	Gregor Steinbeck
	Hans Joachim Wieland
Voestalpine Stahl GmbH	Rainer Grill

European Commission

From a Strategic Research Agenda to Implementation (Full Text)

2006 – 116 pp. – 21.0 x 29.7 cm

ISBN 92-79-01283-5

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KI-73-06-986-EN-C

On 15 of December 2004 the Strategic Research Agenda (SRA) of the European Steel Technology Platform (ESTEP) was endorsed by the Steering Committee. This document established by the Support group of ESTEP describes a way to implement the R&D programme of the SRA.

Priorities have been given within the different themes and R&D areas to the three industrial programmes of the platform with large societal impact:

- Safe, clean, cost-effective and low capital intensive technologies
- Rational use of energy resources and residues management
- Appealing steel solutions for end users

to which a transversal activity regarding human resources has been added:

- Attracting and securing qualified people to help meeting the steel sector's ambition

Private funding by the stakeholders and funding from different European, national and regional institutions is foreseen. However, the launch of a Joint Technology Initiative is envisaged and together with possible loans from the European Investment Bank, it will cover, where appropriate, both the pilot and demonstration and the industrialisation phase of the ULCOS (Ultra Low CO2 Steelmaking) project.

The total budget for the first priorities amounts to around € 0.8 billion and their implementation should take place from 2007 to 2013 for the Research Fund for Coal and Steel (RFCS), the Seventh Framework Programme (FP7) and other programmes. On an annual basis, approximately 25% of the Research Fund for Coal and Steel programme should be devoted to programmes leading to the implementation of sectoral consensus-based R&D activities. The remaining part should be funded through the different relevant thematic subprogrammes of the next FP7 and national or regional R&D programmes.

The estimated total budget corresponding to the SRA activities amounts to around € 1.7 billion over 15 years.

The way to implement the SRA was endorsed by the Steering Committee on 7 of July 2005.

The way to implement the SRA has been officially endorsed by the steering committee of the steel technology platform in December 2005

This is the full text, a short version has been published in a separate document

For further information, please visit http://cordis.europa.eu.int/estep/

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ISBN 92-79-01283-5

9 789279 012839