Strategic Research Agenda

A vision for the future of the steel sector

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ESTEP

European Steel Technology Platform

Foreword

Steel is a key sector for Europe's economy and competitiveness. In the first decade of the millennium, EU-27 steel industry had a total annual production of around 200 million tons and generated about €190 billion in annual turnover. Besides providing direct employment for around 350,000 European Union citizens, 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 steel construction 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.

The ambition of the European Steel Technology Platform (ESTEP) launched some nine years ago is to assure a sustainable and global leadership of Europe-based steel industries in the coming decades. This means that steel must now look to the next generation of industries increasingly operating in a complex global marketplace.

Climate change is of paramount importance as steel industry processes are both energy-intensive and emissions-intensive.

Over the past 40 years, the energy consumption and CO_2 emissions for the production of steel have decreased by 50 % and 60%, respectively. These figures represent average values for the European steel industry and are calculated per ton of crude steel. In 1950, the consumption of reducing agent was around 1000 kg per ton of crude steel and in 2000 this figure reached a value of around 490 kg per ton of crude steel. This is now close to the minimum thermodynamic value, thus showing a significant improvement.

However, simultaneously, over the past 50 years, the production of crude steel in the world has considerably increased: from about 200 millions tons in 1950 to about 800 million tons in 2000, it reached 1500 millions tons in 2012. Consequently, the absolute quantity of CO_2 emissions has increased over the years, despite its significant *per tonne* reduction.

In this context, I would like to single out the essential role of ESTEP in launching the Ultra-Low CO_2 Steelmaking (ULCOS) research programme in 2004, supported by both the Framework Programme and the Research Fund for Coal and Steel (RFCS). The total budget for ULCOS was 75 M€, of which EC contribution from the FP was around 20M€ and from the RFCS around 11 M€. This shows the high importance that these two key research initiatives of the Commission, the Framework Programme and the RFCS (smaller but focused on steel and coal) ascribe to the aim of producing steel with a lower carbon footprint.

The good cooperation with ESTEP is not limited to funding individual research projects, though: the Commission appreciates the work carried out by ESTEP in the development of the Strategic Research Agenda (SRA) of the European steel sector and is pleased to see its updating in the form of this publication. It is now the time to look forward, not only to the steel industry and the RFCS, but also to the wider Horizon 2020.

Indeed, while the RFCS will continue to provide essential support to the entire steel sector, the European steel industry needs to integrate itself into future Public-Private Partnerships which will be the ideal platforms for a sizeable engagement of industry as a true partner. SPIRE, the envisaged partnership around energy intensive (and CO_2-emitting) industries comes obviously to mind.

Finally, I would like to remark how high-level strategic thinking is on-going in the Commission about the role of steel industry, and the challenges it faces, in a modern, competitive but environment and climate protection-sensitive European society.

The possibility for the steel industry to speak with one voice, and to bridge the continuum between the research and innovation dimension and the wider industrial and social dimension is an important one to seize.

This strategic research agenda is a demonstration of the active research and innovation potential of the European steel industry. In conjunction with industry and research actors from this and other industrial sectors it makes a valuable contribution to the strategic debate.

Herbert von Bose
Director for Industrial Technologies
European Commission – Directorate General for Research and Innovation

Introduction

On December 15th, 2004 the first Strategic Research Agenda (SRA) of the European Steel Technology Platform (ESTEP) was endorsed by its Steering Committee.

Priorities were given in the different themes and R&D&I areas to the three industrial programs of the platform with large societal impacts:

- Sustainable steel production
- Safe, cost-effective and lower capital intensive solutions
- Appealing steel solutions for end users focusing on three main areas:
  Transports, Construction and Energy to which a transversal activity regarding human resources was added:
- Attracting and securing qualified people to help meet the steel sector's ambitions.

This SRA has been used over the past seven years for the orientation of the different Working Groups of ESTEP. At the end of 2008, the European Commission launched the economic recovery plan with regard to green cars, energy efficient building and factories of the future, using 3 Public Private Partnerships (PPP) as instruments to manage these research & innovation initiatives driven by industry. ESTEP has brought contributions to these PPPs.

Part of this SRA has already been implemented within the different European funding instruments such as the Research Fund for Coal and Steel (RFCS) the Framework Programs FP6 and FP7, the Life + and the Lifelong Learning Programme: 12 projects have been selected in the FP program in which the stakeholders of ESTEP are coordinators or partners, 2 in the Lifelong Learning fund and 1 in the Life + program. Financing has also been sought with the NER 300 funding program (New Entrant Reserve of CO2 emissions rights) for the ULCOS-BF project, a blast furnace demonstrator combining Top Gas Recycling (TGR) and Carbon Capture and Storage (CCS).

After the FP7 program which covered the period 2007- 2013, the European Commission is preparing the new Research & Innovation program HORIZON 2020 for 2014-2020. R&I have therefore been placed at the center of the Europe 2020 strategy to promote smart, sustainable and inclusive growth. HORIZON 2020 will bring together all existing Union research and Innovation funding, including the existing FP program, the innovation related activities of the Competitiveness and Innovation Program (CIP) and those of the European Institute of Technology (EIT). This new program will focus resources on the following three pillars:

- Excellent Science
- Industrial Leadership
- Societal Challenges.

ESTEP has been involved from the very beginning to prepare this new program, as have all the 36 European Technology Platforms (ETPs). That is why it was decided in 2012 to update our existing SRA in order to show its coherence and consistency with Horizon 2020. This second edition of the SRA has been endorsed by the ESTEP Steering Committee in March 2013.

Dr. Heribert Fischer
Chairman of ESTEP

Member of the Executive Board of
ThyssenKrupp Steel Europe,
Responsible for Rolling and Metallic Coating

Executive summary

This document is the 2013 updated version of the Strategic Research Agenda of the European Steel Technology Platform (Vision 2030), which was officially launched in 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.

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.

To meet the strategic objectives of the European Steel Technology Platform, a Strategic Research Agenda (SRA) was written in 2004 and 2005, in order to launch determined, long-term and structured R&D actions.

Six working groups (WG) involving now around 150 persons and corresponding to the 4 pillars of the sustainable development framework of the Platform have been set up (Planet, Profit, Partners, split up as transport, construction and energy sectors, and People). They have developed several R&D themes and research areas gathered under each of the three large and complementary R&D industrial programs with large societal impacts.

Three industrial programs with large societal impacts were proposed:

- Sustainable steel production
- Safe, cost-effective and lower capital intensive technologies
- Appealing steel solutions for end users, focusing on three main areas (transports, Construction and Energy) and a transversal theme regarding the human resources aspects has been also developed:
- Attracting and securing qualified people.

Together they aim at playing a major role in boosting competitiveness, economic growth and the related impact on employment in Europe. The corresponding R&D themes and areas that have been identified in these programs bring a strong contribution to the sustainable development.

During the 2005-2012 period, part of this SRA has already been implemented within the different European funding instruments such as the Research Fund for Coal and Steel (RFCS), the Framework Programs FP6 and FP7, the Life + and Leonardo da Vinci (now named Life Long Learning Programme). Twelve projects have been selected by the FP program in which the stakeholders of ESTEP are coordinator or partners, 2 by the Leonardo da Vinci fund and one by the Life + program. Financing has also been sought with the NER 300 funding program (New Entrant Reserve of CO2 emissions rights) for the ULCOS-BF project, a blast furnace demonstrator combining Top Gas Recycling (TGR) and Carbon Capture and Storage (CCS).

This updated version was prepared by ESTEP's Working Groups and it was decided to keep the structuring of the document according to the three industrial programs with large societal impacts. Hence, the structure of this new document remains similar to the first version. However the content of each chapter has been thoroughly rewritten, taking into account on one hand what has been done over the past seven years and on the other hand the orientations of Horizon 2020.

This updated version has been endorsed by the Steering Committee in March 2013 and includes a description on how the steel sector intends to implement its Strategic Research Agenda within Horizon 2020.

The European steel sector is constantly addressing 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 transport, construction and energy sectors are regarded as priorities.

Protecting the environment (greenhouse gas emissions and more particularly CO_2 emissions) and increasing resource efficiency (including energy) both constitute major transversal issues in the universe of the RTD programs 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' everyday lives as users of steel solutions (surface transport, buildings, energy production, etc.) by developing new intelligent and safer steel solutions.

A major transversal theme regarding human resources has also been taken into consideration (attracting and securing qualified people to help meet the steel sector's ambition). In this respect, a large European network of 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 analyzing how the education system could meet the future requirements for qualified people of 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 dynamically optimized. A survey of the steps taken by European steel producers in terms of change management and progression towards "knowledge organizations", leading to exchanges of best practices, should significantly contribute to such optimization process.

ESTEP already integrates the European RTD partnership built in the frame of the previous ECSC Treaty (more than 8,000 researchers) and the Framework Programs. Indeed it constitutes large partnerships involving the whole European steel industry, its suppliers and customers (transport industry, construction sector and the energy sector), SMEs, private and public research, public authorities and representatives of trade unions. The Research Fund for Coal and Steel (RFCS) which has followed successfully the ECSC from 2002. Both within the RFCS and the Framework Program, the collaborative research within the European steel sector was fostered and reinforced over the past 10 years. ESTEP's Mirror Group gathers representatives of 20 Members States among the EU-27.

The European steel industry has already measured up to the challenge of lowering CO2 emissions by creating a consortium of industries and of research organizations that has taken up the mission of developing breakthrough processes, the ULCOS (Ultra Low CO2 Steelmaking) consortium.

This large-scale consortium plans to develop a breakthrough steelmaking process that has the potential of meeting of drastically reducing greenhouse gas emissions beyond 2020. The ULCOS I program, carried out from 2004 to 2009 has identified more than 80 different processes of which four have been selected to experiment pilots and demonstrators: ULCOS-BF with Top Gas Recycling and CCS (Carbon Capture and Storage), HISARNA, a new reduction & smelting reactor, ULCORED a new reduction process to be coupled with an Electrical Arc Furnace (EAF), and electrolysis with two areas of investigations for the long term, ULCOWIN and ULCOLYSIS. The ULCOS II program, launched in 2010 aims at implementing these new technologies. ULCOS-BF was proposed for a demonstrator at Florange (France), within the NER 300 funding scheme. HIRSARNA is a pilot plant built in Tatasteel Ijmuiden (NL), with the first experiments carried out in 2011 and 2012.

This revised agenda is well in-line with the main 3 pillars of HORIZON 2020 the new Research & Innovation program of the European Commission for the period 2014- 2020:

- Excellence science base
- Industrial Leadership
- Tackling societal challenges.

The new Research & Innovation roadmap proposed by the European Commission has been carefully analyzed by the ESTEP Working Groups, and this revised agenda included already the topics which are relevant with the steel sector.

For *excellent science base*, one of the challenges for the steel sector is to attract talented young researchers and to offer better career prospects within our industry. Another objective is for ESTEP to work closely with Universities and engineering high schools for developing the different domains of European science in order to meet challenges of the steel industry of the future.

For *industrial leadership*, the proposals of the EC to enhance the KETs (Key Enabling Technologies) are welcomed by ESTEP. In particular, the 2 items "advanced materials" and advanced processing and manufacturing" are developed in this revised roadmap.

For *tackling societal challenges,* the most relevant for our steel sector are "secure, clean and efficient energy", "green transport", "climate action, resource efficiency and raw materials" and "inclusive and innovative societies".

Horizon 2020 marks also a new start and new ambition for R&D&I with a clear need to identify the strategic targets and expected impacts. It is a new way of working, putting everyone together to promote not only research, but innovation in order to make the link with market expectations. In this context, the European Technology Platforms have a key role to play. We have to create the bridge from science and knowledge to the market, transforming results into industrial reality.

The implementation of this roadmap should take place from 2014 to 2020 for both Horizon 2020 and RFCS actions. In particular, on an annual basis, a significant part of the Research Fund for Coal and Steel (RFCS) program should be devoted to such

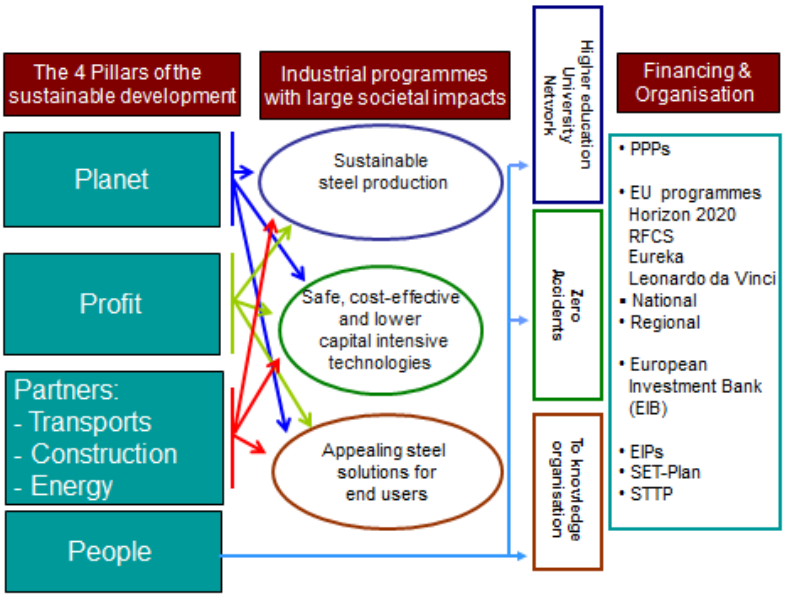

Figure 1: Structure of the S.R.A.

programs of this SRA, leading to the implementation of sectoral consensus-based R&D activities.

Moreover, ESTEP is involved already in the preparation of Horizon 2020, especially within the Public Private Partnerships (PPPs), in some of the European innovation Partnerships (EIP), such as the Raw Materials initiative, the Water Resources initiative and the Key Enabling technologies, as well as other initiatives like the Strategic Energy Technology Plan (SET-Plan) and the Strategic Transport Technology Plan (STTP).

As far as the Public Private Partnerships are concerned, the steel sector participated already in the three PPPs launched at the end of 2008 in the recovery plan, Factories of the Future (FoF), the European Green Vehicles Initiative (EGVI) and Energy Efficient Building (E2B). In addition, through cross-sectoral contacts with other ETPs and associations, ESTEP is involved so far for proposing new PPPs within Horizon 2020: SPIRE, Sustainable Process Industries through Resource and Energy Efficiency and EMIRI, Energy Materials Industrial Research Initiative.

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 (20), appropriately balanced. The Steering Committee has an annual meeting usually held in March.

- **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, reviewing the activities developed within the thematic Working Groups. Its participants are representatives of the main stakeholders. The Support Group holds three meetings per year.

In addition, a **Mirror Group** is composed of Member States representatives. 18 Member States out of the EU 27 are represented so far. The Mirror Group holds a meeting every 18-24 months. It serves to provide information and communication between the Steering Committee and Member States, as regards the implementation of this SRA within the different European funded programmes.

Glossary

A4M	Alliance for Materials
AHSS	Advanced High Strength Steel
AUST SS	High strength Austenitic Stainless Steels
BAU	Business As Usual
BF	Blast Furnace
BH	Bake Hardening steel
BOF	Basic Oxygen Furnace
CAD	Computer-Aided Design
CAM	Computer-Aided Manufacturing
CCS	Carbon Capture and Storage
CIP	Competitiveness and Innovation Programme
CMn	Carbon Manages Steel
CNG	Compressed Natural Gas
CP	Complex Phase steel
CSP	Concentrate Solar Power plant
CSR	Corporate Social Responsibility
DP	Dual Phase steel
DRI	Direct Reduced Iron
EAF	Electric Arc Furnace
E2B	Energy Efficient Building
ECTP	European Construction Technology Platform
EED	Energy Efficiency Directive
EGVI	European Green Vehicle Initiative
EII	European Industrial Initiative
EIP	European Innovation Partnership
EIT	European Institute of Technology
EMIRI	Energy Materials Industrial Research Initiative
EMS	Energy Management System
ESTEP	European Steel Technology Platform
ETP	European Technology Platform
ETS	Emissions Trading Scheme
EuMaT	European technology platform for advanced engineering Materials and Technologies
EWEA	European Wind Energy Association
FoF	Factories of the Future
FP6	6th Framework Programme (2000-2006)
FP7	7th Framework Programme (2007-2013)
GDP	Gross Domestic Product
Gen 3 HSHF	Third Generation High Strength, High Formability Steel
GHG	Green House Gases
HSLA	High Strength Low Alloy steel
HSS	High Strength Steel
I2M	Integrated Intelligent Manufacturing
IED	Industrial Emissions Directive
IF	Interstitial free steel
JRC	Joint Research Centre
IF-HS	Interstitial Free High Strength
IPPC	Integrated Pollution Prevention and Control
KET	Key Enabling Technology
LCA	Life Cycle Assessment
LCC	Life Cycle Costing
L-IP	Light Induced Plasticity steels
LCT	Life Cycle Thinking
LNG	Liquefied Natural Gas
Manufuture	European technology platform for Manufacturing
MART	Martensitic Steel
MFA	Material Flow Analysis
Mild	Mild steel
NER-300	New Entrant Reserve of CO2 emissions rights (300 million tons allowances)
OCTG	Oil Country Tubular Goods
OECD	Organization for Economic Co-operation and Development
ORC	Organic Rankin Cycle
PHS	Press Hardened Steel (hot stamping)
PPP	Public Private Partnership
REACH	Registration, Evaluation, Authorization, and restriction of Chemical substances
reFINE	research for Future Infrastructure Networks in Europe
R&D&I	Research & Development & Innovation
RFCS	Research Fund for Coal and Steel
RTD	Research Technology Development

SET-Plan	Strategic Energy Technology Plan
SF	Stretch Flangeable steel
SMR	Sustainable Minerals Resources ETP
SPIRE	Sustainable Process Industry through Resource and Energy efficiency
SRA	Strategic Research Agenda
SSC	Sulfur Stress Corrosion
STTP	Strategic Transport Technology Plan
Suschem	European technology platform for chemicals
TGR	Top Gas Recycling
TRIP	Transformation Induced Plasticity steel
TWIP	Twinning Induced Plasticity steel
ULCOS	Ultra Low CO2 Steel making
USC	Ultra Super Critic power plant
VD	Vacuum Degassing
VOD	Vacuum Oxygen Decarburization
WG	Working Group

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PART 1. BACKGROUND

The Steel sector has long been essential to the economy and the competitiveness of Europe and it will remain important for a long time in the future. EU-27's steel industry has a total annual production of approximately 190 million tons over the past 10 years and generates more than € 190 bn in annual turnover. It provides direct employment to about 360,000 European Union citizens, and several times this number is employed indirectly in its processing, in the user and in the recycling industries. Steel is a worldwide commodity and world crude steel production is still growing. It exceeded 1 billion tons for the first time in 2004 and was at 1.5 billion tons in 2012. Global steel demand is still expected to increase in the future, owing to the increased growth of emerging countries like China and India. Various scenarios (BAU and others) project a worldwide crude steel production between 2.0 and 2.5 billion tons in 2050.

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, sea and air transportation, construction, energy, chemical industry, household appliances, etc.). For example, the European steel construction industry and the automotive sector represent more than 2,000,000 jobs (EU-27). It is therefore vital for the future of Europe and of its citizens to maintain an active and competitive steel industry.

1.1. Ambition and long-term vision of the steel sector

The ambition of the European steel industry is to maintain and reinforce its global leadership in the world, and thus to remain sustainable and competitive in the face of the strong development of the steel sector elsewhere in the world, notably in Asia.

1.2. Main challenges for a sustainable global competitiveness

1.2.1. The growing impact of globalization

The globalization of steel customers has resulted in increased market power, stricter product requirements and standardization.

Collaboration with its traditional customers has been so deeply rooted in its culture that the European steel industry has taken the necessary steps 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 overseas.

However, the steel industry remains less concentrated than its major supplier or client industries. Thus it has been hard pressed to accelerate its concentration and rationalization on a global scale, to increase its negotiating power with its main clients and suppliers and to boost its ability to serve its customers, worldwide, with the same quality of products and services they already enjoy locally.

Moreover, the trend towards more liberalization of international steel trade, and thus towards increased international competition, has become more and more obvious. The steel industry, faced with this growing impact of globalization and responding to pressure on its markets, needs that the rules of fair trade be enforced fairly, worldwide.

1.2.2. Matching Steel supply and demand

Past experience shows that crises in the steel industry have had their roots in imbalances caused by rapid fluctuations in demand combined with supply structures that are too rigid and with global overcapacity. Fluctuation in demand is related to business cycles but also to deeper structural changes. Economic cycles control steel demand, as steel is used to make both consumer and investment goods. Thus, when the financial crisis hit in 2008, it impacted European Steel with a drop in production from 200 Mt to 135 Mt in 2009 (crude steel). A significant but partial recovery occurred in 2010, 2011 and 2012 with production moving up to 170, 177 and 169 Mt respectively. In the future, the consolidation of demand in Europe will be strongly linked to the recovery of the global steel value chain.

The European Union's vision for 2030/2050 sets strategies and pathways to shift the European economy towards a sustainable and efficient global energy system, the renewal of transport fleets (air, water, land) coupled to the establishment of a smart transport management system, the refurbishment of all buildings and their integration in smart supply grids.

This vision is intensive in materials and thus the availability of advanced materials, like steel, at the proper level of quality, volume and price is a prerequisite to the successful implementation of that vision. In terms of steel quality, the industry is preparing the emergence of new, high added value steel products through research and development, which should result in an increased demand in highly developed countries (durable consumer products, capital goods). European steel production and exports ought to focus increasingly on these higher value-added products.

1.2.3. New EU environmental regulations

Regarding environmental policy, various instruments are being introduced or under review at EU or national level. Initiatives with a potentially significant impact for the steel industry include:

- Integrated Pollution Prevention And Control (IPPC) permits,

- the Industrial Emissions Directives called (IED), which is the revision of this IPPC directive with the implementation of the BAT conclusions (Best Available Techniques) being the legal reference for permitting of installations,
- the new product and waste legislation (such as the Life Cycle Assessment approach and eco-design),
- thematic strategies on natural resources, waste prevention and recycling,
- the EU legislation on chemicals ('REACH')
- as well as the new Energy Efficiency Directive (EED)

In the pipeline are the implementation of the roadmap to a resource efficient Europe and the 7th Environmental Action Program.

Another piece of EU legislation that is important for the EU steel industry is the greenhouse gas Emissions Trading Scheme (ETS), which has been introduced in order to enforce commitments made by EU Member States in the context of the Kyoto Protocol. Across the whole EU economy the costs for implementing these commitments are considerable. With the 3rd phase of the EU ETS (period 2013-2020), the risk that European steel producers will see a further loss of business to non-EU competitors, which are not subjected to any CO_2 emissions limitations, is of major importance.

1.2.4. Strengthening the Steel sector in EU 27

The steel companies in the 12 new member states and in the candidate countries exhibit several characteristics, such as relatively low labor costs and a high level of technical expertise. However, production units would benefit from the implementation of modern production techniques, along with higher energy efficiency, better organization, and quality and services. This would result in higher productivity, in better product quality, and in a much-needed improvement in environmental performance.

1.3. Steel, an outstanding material

Steel is an important material in our societies and is bound to remain an important one in the future. Iron ore is abundant and energy required to produce the metal is relatively small, compared to other metals. Thus, steel has been developed into the most extensive alloy family in the engineering world over historical times, with a very broad range of applications.

Steel is rather inexpensive and offers a broad variety of functions and services, due to a unique combination of properties. First comes its tensile strength. Compared to other common materials like wood, concrete, stones or plastics, it exhibits high resistance under tension. This is the main reason for its huge success during the first industrial revolution. It can also be rather easily deformed using a wide variety of processes. This is the main reason why the ferrous sector, globally speaking, is so large with a lot of employees. Another interesting property is its very high stiffness; this is very important for some applications. Its main drawbacks are its density (compared to lighter metals such as Aluminum, Titanium or Magnesium) and its corrosion resistance in air.

Steel is often pictured as a material of the past. Iron and Steel are indeed enduring materials based on cumulative technologies, invented in the Neolithic period. The metallurgical sophistication of ancient swords made of Damascus steel, in the Middle East or in Japan, is astounding! But steel is also a very modern material and a material of the future, because of its wide range of properties: iron based alloys with some minor addition of other elements still offers many opportunities.

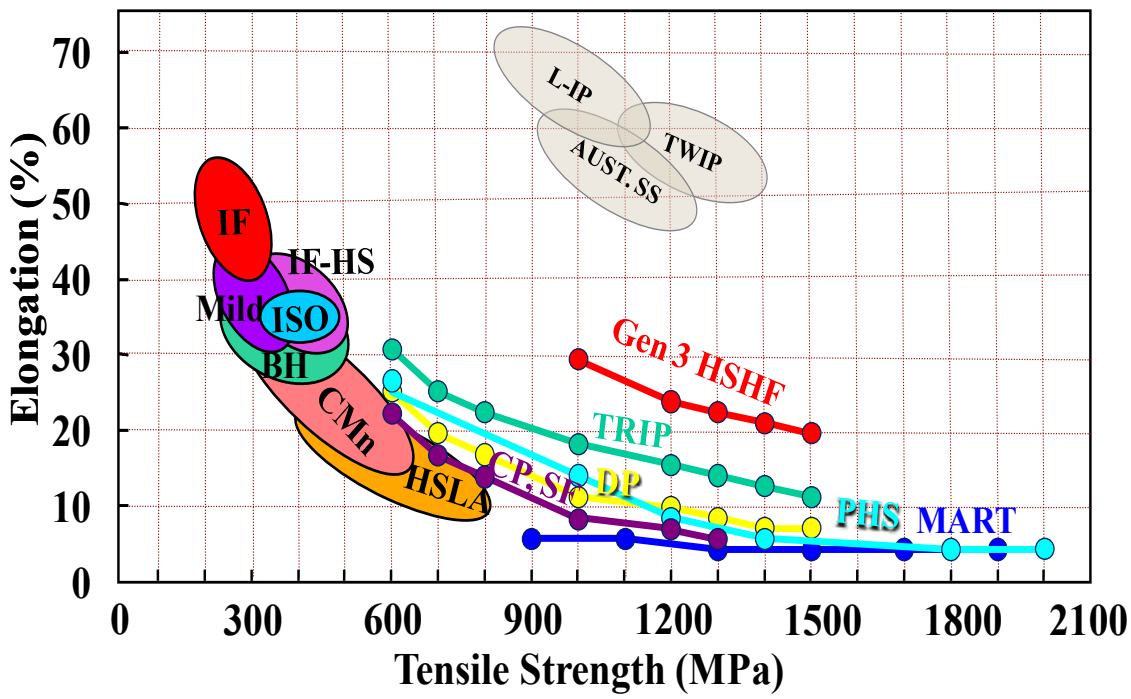


Figure 2: Range of mechanical properties of various steel grades

The present research agenda structures future prospects for new steels, according to their final application: transport, construction & buildings, energy production, storage & transport. This is the clearest way to identify what progress is required to reach the targets of our society for the years to come.

However, a more transversal and abstract view may be useful as it can provide a guiding light for the analysis. The metallurgy of steel can progress significantly along the following lines:

- increase strength at more or less constant deformation ability,
- or, conversely, improve deformation ability at more or less constant strength.

Figure 2 gives an example of such an approach and of the trade-offs that this entails.

On the vertical axis, elongation is a measurement of the formability of steel. Tensile strength is on the horizontal axis. The range of strength is wide, an order of magnitude between the stronger and the milder steels. Most families of steels are grouped inside the "banana" curve. Labels show specific metallurgical structures. A second generation of steel categories is shown, such as Complex Phase (CP), Dual Phase (DP) and TRansformation Induced Plasticity (TRIP) steels as well as a new third generation under development, the L-IP, TWIP steels and the new austenitic stainless steels, with large contents in alloying elements such as manganese, and, more classically also, chromium or nickel.

Beyond these new developments in metallurgy, a number of difficult technical questions have to be solved to properly answer market needs. For example, steel needs quite often to be welded and the reliability of the welds under critical conditions has to be demonstrated. Steel needs to be coated to withstand corrosion: the usual solution is zinc coating, but new steels that contain easily oxidized elements do not as a rule accept galvanizing; beyond zinc, new coating solutions based on other metals are under development. For higher temperature applications, a lot of new solutions are still under development. Last but not least, these new steels and new metallurgies have to be produced in large quantities with a very narrow control of process parameters in order to exhibit a narrow range of properties.

Optimal processing of these steel products of the future is a difficult challenge that can be addressed either by improving existing production technologies or by developing new processes or new technologies in combination with the new alloy design.

Based on its deep knowledge of the potential of its material, the European steel sector has been constantly addressing the challenge of meeting the demands of its customers to deliver a broad variety of ever more sophisticated high-performance materials. To achieve these goals, direct partnerships between steel producers and their immediate customers are an elegant and necessary approach. This constitutes the core of the development and promotion of new products by the steel industry.

Beyond these developments in fairly classical directions, longer term efforts are addressing more challenging issues than the strength or formability of steels.

On the one hand, the density of steel is one area of development, as the present density of 7.8 is not a barrier and there are ways to reduce it by 10 to 15%, thanks to the addition of specific alloying elements, such as aluminum. This is a promising approach to reduce the weight of steel artifacts beyond the increase in strength (AHSS), which was presented previously.

Similarly, Young's modulus is not upward bound by the classical value of 210 GPa. Various paths are being explored, among which the design of a new steel grade that would be a metal matrix composite with ceramic compounds, such as TiB_2 precipitates. This would also help reduce weight, without being limited by the value of Young's modulus, when thickness becomes small.

Multilayer steels are also at the core of new development efforts: the point is to associate steel qualities with very different properties (strengths) by joining them into layers (5-7), a kind of revival of Damascus steel, beefed up by the concepts of modern metallurgy. Defining the process used to create this lamination is at the core of the investigation: co-rolling, co-casting, etc.

Finally, one might stress the point that nanostructures have been present in steels, since long before the name of nanomaterials was coined - perlite and precipitates like NbC have nanometric dimensions - and that further efforts are devoted to developing the concept (Nanosteel, USA).

The SRA is engaging or planning to engage stakeholders in the automotive, construction and energy sectors, as a priority.

1.4. Strategic Objectives

The strategic objectives are developed around concepts based on the four pillars of sustainable growth: Planet, Profit, Partners and People, the 4P's.

- **Planet**: propose innovative technologies, including breakthroughs, to meet environmental requirements, promote sustainable steel production and develop Life Cycle Thinking and Life Cycle Assessment.

- **Profit**: ensure profit-making through innovation and new technologies within the production processes:

    - innovate with new production technologies
    - strengthen intelligent manufacturing
    - reduce time to market and implementing the supply chain concept

- **Partners**: respond to society's needs by working with partners of the steel sector for proposing innovative steel products and steel solutions in :

    - the transport sector
    - the construction & infrastructure sectors
    - the energy sector

- **People**: attract and secure human resources and skills

    - Become a worldwide reference for health and safety at work

- attract and secure human resources skills in a dynamic way
- Optimize the deployment of human resources as a key to the successful implementation of steel industry's competitive strategies
- Accommodate concerns of external stakeholders (clever and safer steel products)

1.5. R&D&I approach: three industrial programs with large societal impacts

To face such important challenges and to meet the objectives of the European Steel Technology Platform, it was decided in 2004 by the ESTEP Steering Committee to launch resolute and structured long term R&D actions. Six working groups corresponding to the 4 pillars of sustainable development of the Platform were set up in 2004 as well. They have developed 3 industrial programs with large societal impacts each of them encompassing several R&D themes and research areas. These themes and areas were described in the first SRA produced at the end of 2004. After 8 years of actions and progresses within these different areas, the six working groups are still running. In March 2012, it was decided to update this SRA with this present 2nd edition. The structure of the industrial programs remains the same, but the research areas have been totally reviewed and completed by the Working Groups. The present ESTEP organization is shown in figure 3. The approach and the structure of R&D themes and areas are shown in the figures 4 and 5.

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

- Sustainable steel production
- safe, cost-effective and lower capital intensive technologies
- appealing steel solutions for end users

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

- attracting and securing qualified people to help meet the steel sector's ambition

Figure 3: Organization chart of the Steel Technology Platform

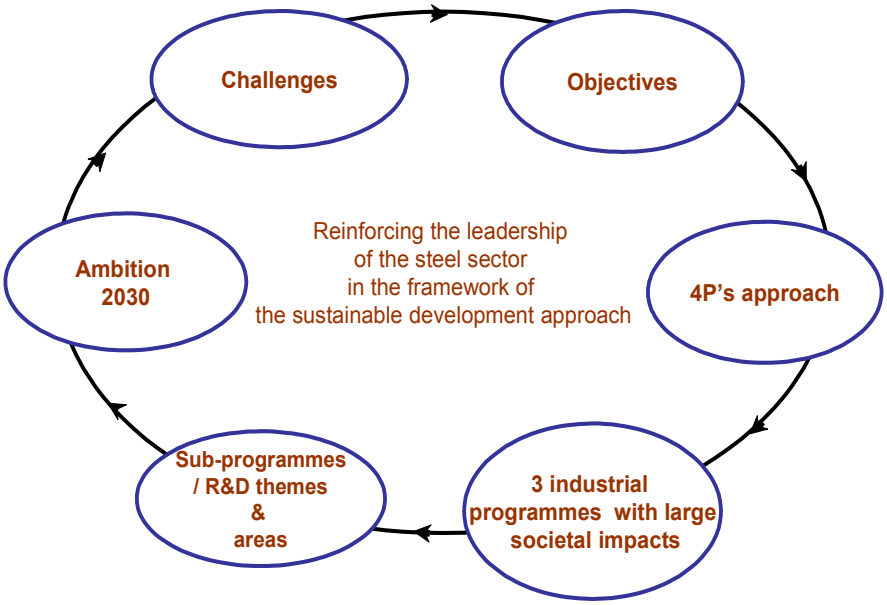


Figure 4: How to achieve ESTEP's long term ambition through innovation and R&D&I.

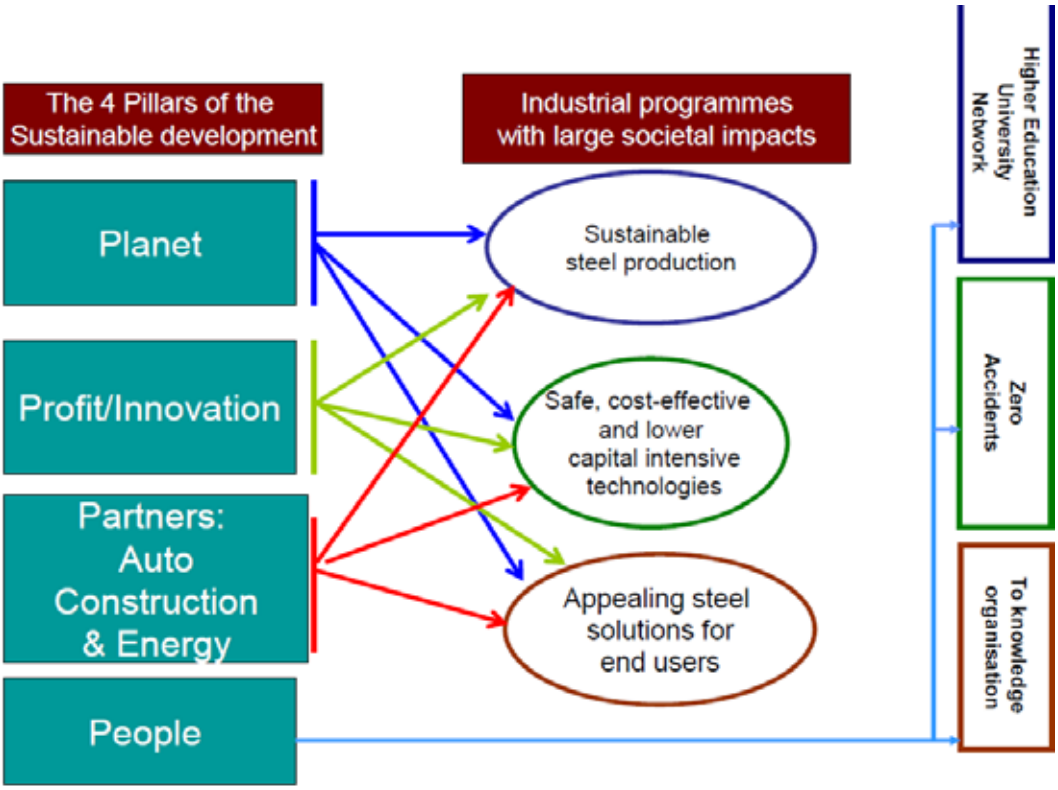


Figure 5: Three industrial programs with large societal impacts based on a sustainability approach.

PART 2. RESEARCH & INNOVATION APPROACH

This chapter presents the Research and Innovation areas that ought to be developed within the next 10 years. The 3 industrial programs presented in the previous chapter and the transversal activities regarding human resources have been fleshed out by the 6 ESTEP working groups. The respective R&D&I themes and areas of the working groups are presented in 2.1. to 2.6.

2.1. SUSTAINABLE steel production (Planet)

2.1.1. Context, ambition & foresight

Steel is ubiquitous, even if it often remains invisible underneath decorative, protective or functional layers of other materials.

Indeed, steel is so directly linked to human activities, for example through a consumption intensity per capita (215 kg/cap in the world in 2011 and 310 in the EU), that its importance grows with population, standard of living and quality of life. The core business of the steel industry is thus to organize the recovery of iron from natural or anthropogenic resources, in order to make possible the construction and the maintenance of the structure of the anthroposphere (or technosphere) and of its artifacts. This means that large amounts of raw materials, primary and secondary (32/68 % BOF/EAF routes, close to the virgin iron/scrap ratio), of energy (18.5 GJ/t steel) and of logistics (more than 2 t of raw materials per ton produced in an integrated steel mill) have to be marshaled in complex and very professional ways, literally at the global scale of the planet (60% of the iron ore consumption and 80% of the coal are traded internationally); this also requires the contribution and the talents of millions of people (2 million jobs, worldwide) and creates a GDP footprint that extends far beyond that of the steel sector (2%), along the value chain and the life cycle of steel (20%).

Steel is thus deeply and subtly interwoven with the environment, the whole planet and society. The natural and the economic worlds, the ecosphere of the planet and the anthroposphere of human society, are intersecting. This happens at a very deep level and the former descriptions of industry as having simply to comply with environmental regulations does not tell the whole story any longer: it is not so much a confrontation or a collision between antagonistic worlds, but rather a cooperation that can be described as a kind of metabolism, the emergence of which has been induced by the size of the world population and the extent of urbanization.

The agenda of the Planet working group of ESTEP has therefore been to manage this cooperation so that it takes place as smoothly as possible, with the mutual respect of the partners.

2.1.2. Issues and challenges

Meeting environmental regulation has become part of the day to day business of the steel industry and any remaining challenge in this area would lies in making steel production processes change incrementally in ways that ensures that they meet both economic and environmental targets at the same time and synergistically. This task falls within the duties of Working Group 1, Process innovation.

The issues tackled in the Planet Group are thus more holistic, prospective and longer term:

- life cycle matters and more global issues than can be handled by LCA, including social value and sustainability issues
- resource preservation (finite earth): energy and raw materials
- new energy frontiers (solar, electricity, renewables, energy savings at a grand scale)
- climate change solutions (ULCOS solutions but also thin slab casting, strip castings etc.)
- ecodesign of processes and steel solutions as a method to integrate the above concepts and methodologies and turn them into operational tools
- work synergistically with other industries and local communities (industrial ecology)
- work synergistically with nature (biomass, biomimetics, etc.) and integrate steel's activity with ecosystem services (how to deal with biodiversity in the steel's business model)
- prepare the close-loop economy for steel and the other elements(co-elements to iron), which the steel sector handles in its processes
- other emerging global issues (acid rain and dust are becoming global issues) and future rules for setting long term targets for the environment, as well as toxicity and ecotoxicity issues

- preparing for the future and for the other transitions that the planet and mankind will be facing (e.g. how to avoid the pain of the transition from ore to scrap iron units in large emerging economies)

2-1.3. Exploring solutions and turning them into opportunities for both business and planet

Life Cycle Assessment (LCA) and Life Cycle Thinking (LCT)

The status of LCA is somewhat paradoxical, as it is both ignored in matters where it would be directly needed and is over-extended in areas where it contributes to deleterious rebound effects. This distorts the picture of reality in general, and the image of steel in particular.

There are important areas where LCA is not yet properly used or not used at all. This is the case of EU rules and regulations for cars, which favor a concept called "recycled content" rather than a recycling ratio, a deep misunderstanding of the nature of time (past vs future) in life cycle methodology. In another instance, tail pipe emissions are used to classify the performance of commercial vehicles, where the proper indicator would be life cycle emissions: this confusion goes very far because it puts on a rostrum the rule of light weighting, which is not always a worthy objective when pursuing low GHG emissions. Moreover, it gives a preponderant weight to climate change without considering other is-sues and thus may be creating other difficulties somewhere else. This is for example the case when diesel engines are preferred in spite of their emissions of very fine dust (PM2.5, PM0.5 and less). In all these cases and in similar ones, LCA should be the basic yardstick for setting regulatory rules and the steel sector has to explain through many examples and pertinent studies that this is indeed the case.

Finally, there are areas where LCA is overused, specified as such by EU regulations for example. This may lead to odd or globally inadequate optimizations for society. This is the case when an LCA study concludes that electrical steel (EAF route) should be used rather than integrated mill steel, to minimize the environmental footprint: this may be true, marginally, but this solution cannot be implemented at a large scale as the amount of steel produced by EAF is entirely controlled by the amount of existing scrap, i.e. by the activity of the steel sector 20 or 30 years ago. LCA, which is a tool related to micro-economics, cannot take on board such issues which are related to macro-economics.

Life Cycle Thinking (LCT), the approach behind LCA, is a worldview that is beneficial to society and European Steel wishes to promote it. This ought to be done with balance and within reason, because the present methodology is still not perfect and other methodologies are needed to complement it.

Beyond life cycle thinking

LCA methodology needs to continue to progress beyond its present status and this will involve other disciplines "beyond LCA". This is needed to get a more exact description of the connection of economic activity with the ecosphere and to update it continuously to incorporate new knowledge and new global issues.

The present most common kind of LCA is attributional LCA. A different method, more ambitious and closer to the real world, is consequential LCA, already formatted by standards and practice but still rarely used. More forward looking methodologies are under development, such as foresight LCA, dynamic LCA, social LCA, Life Cycle Costing (LCC), introduction of end of life and recycling into LCA (presently still an open, controversial matter) - and any combination of these - and the Steel sector ought to pioneer their development to jump start them. To move up from the micro-economic description of the economy related to choosing the functional unit as the central concept of LCA, one should open the scope to macro-economic thinking with Material Flow Analysis (MFA) or Energy Flow Analysis, etc. which lie at the core of the analysis of recycling, a major issue for steel and for metals in general and for many other materials.

This will not be sufficient to deal with the most important issues and challenges: therefore, more ambitious methodologies, going beyond LCA and MFA have to be developed, or, rather, their development has to be further encouraged. In the steel and structural material sectors, this is called the SOVAMAT initiative, which put forward the concept of "social value", which is close in its attempts at being more holistic to some general definitions of sustainability. For example, the sustainability assessment of technologies (SAT) fostered by the EU through its FP7 project focused on this kind of concept, based on processes rather than functional unit. The LCA Community is exploring the idea of functionality beyond that of functional unit, etc.

The steel sectors needs to be at the forefront of methodological innovation in this area, in order to create a dynamics that would be otherwise controlled by a disciplinary community, in an area where fields have to open up to interdisciplinary cooperation, from sociology, socio-economics to scientific ecology but encompassing the various communities of LCA, MFA, economic global modelers, etc.

Resource issues due to energy and raw materials supply

Europe has recently become attuned to the issues of resource scarcity in relation to rare earth and the international trade tensions that they have raised. This is an interesting revival of a concept which was somewhat discredited after the first report of the Club of Rome, but which now stresses that resources come from a finite earth, both fossil resources and renewable ones, which are also bound by competition for land.

A more balanced view is thus being framed, acknowledging that many resources will remain abundant but that the growth of demand related to population growth and urbanization may have a faster kinetics that what the supply side of the economy can provide, thus creating a tension and a volatility on prices. The idea of a lean economy is thus getting stronger, of resource preservation by increasing energy and material efficiency. This includes recycling of steel in particular and recycling of the all the large volume of by-products generated by the sector.

The steel sector has to imagine incremental solutions to a leaner steel sector, which is again part of the task of the working group on process innovation (Process), but ought to maintain a global picture to prioritize the more ambitious parts of the potential technological agenda for dealing with these matters. Transversal, through-process issues are key, as well as the quick integration of new

technologies developed outside of the sector and cooperation with other economic actors (see further).

Steel and new energy frontiers

Even when it becomes leaner and moves towards a more closed-loop economy, the steel sector can "green" its energy sources.

This starts with demonstration projects where factory roofs are covered by solar panels or where wind turbines are erected on the extended piece of lands on which steel mills are installed.

A steel mill based on renewable energy alone will probably never makes senses, because of the large energy needs of making steel, due to basic thermodynamical needs. However, if renewable are inter-mediated by an energy vector, electricity today and maybe hydrogen tomorrow, then the transition can be as high as the renewable content of the grid. This is fairly obvious for EAF steelmaking, which melts scrap, but an electricity-based route directly using iron ore is being developed as part of the carbon-lean technologies of programs like ULCOS (ULCOWIN, ULCOLYSIS). The sector should be keen in under-standing when a switch to such technology will start being meaningful in middle-term future.

It should also be stressed that steel, as a universal and global structural material, is at the core of new energy efforts, in wind turbines, especially giant ones, solar farms, geothermal projects, sea turbines (hydroliennes), etc. Steel is also the almost exclusive material for the extensive grids of pipe, which will transport natural gas, frakking gas, shale oil, hydrogen and CO_2 from fields to urban-industrial consumption areas or to geostorage sites.

Carbon-lean steelmaking as a sectoral answer to climate change

The European Steel sector and ESTEP have been strongly backing the ULCOS program, which is the largest and most ambitious program in the world to propose solution for making steel with a major cut in GHG emissions, typically more than 50% at the very least.

Beyond the breakthrough, quantum leap solutions of the ULCOS family, more incremental innovations like near shape casting also need significant development effort, to extend their product capability (thin slab casting) or more simply to move them out of niches, where strip casting is still confined for example.

This effort should be accompanied by a communication effort that would show how steel is not simply cleaning its own house but also delivering solutions that make all other sectors become energy and carbon-lean. The amount of CO2 avoided in this manner is actually an order of magnitude higher than the direct emissions of the sector.

Ecodesign of steel solutions, steel grades and steel processes

Progress has been driven mainly by an economic rationale or by technology, with a historical back and forth oscillation between these two poles. Now is the time to enter a world of multi-criteria progress driving process that takes on board environmental issues at the same time, thus making ecodesign the central tool of all research and development agendas.

Tools and processes for doing ecodesign need to be developed further, success stories have to be told and the deployment of that methodology organized, first at the interface between steel production and steel market and within the steel sector as well.

Steel and its synergies with neighboring communities

The technosphere is part of the anthroposphere, to the point that the two expressions are sometimes used synonymously. In the case of steel, this means that the Steel sector is immerged in the economy and society, in various ways: we have already stressed the value chain and the life-cycle dimensions (section 2), but various other synergies exist, which operate in a transversal rather than in a longitudinal way.

A steel mill is at the center of a huge logistical hub, where more than 10 tons of matter and scores of energy are handled, transformed, exchanged and sometimes dissipated, discarded or landfilled per ton of steel. This puts large demands on logistics, which ought to be considered as a resource akin to raw materials, except that it is a more abstract kind of resource, based on seaways, harbors, rail tracks, roads and bridges on the one hand and on ships, cranes, trains and trucks on the other hand.

The steel mill connects with other economic sectors and with local communities in a horizontal manner, i.e. not through the logics of the value chain but with that of industrial ecology. Indeed, waste heat and residues can be used elsewhere and the mill itself can, in principle, use those of neighboring sites. This is usually mesoscale effect, as opposed to the global scale of nationwide or international trade. The filed is not virgin, as supplying heat to city districts has been a practice here of there for decades; similarly, for example, most of blast furnace slag is used as raw material for the cement industry, the rest being used as road bed material. The expectation today is that more can be done in the future to save energy and raw materials globally, across value chains, thus pushing energy and material savings and making the best use of nega-energy (energy savings, cf. negawatts) and nega-materials (materials savings).

Steel and its synergies with nature

The synergy of the Steel sector with Nature is mainly related today to its use of natural resources. In the future, biomass is likely to replace some of its fossil fuel consumption in most of its major reactor, from coke ovens to steelmaking and reheating furnaces. Biomass would most probably need to be converted by a high temperature treatment like pyrolysis to produce charcoal or char as well as synthetic gases. The industrial use of biomass competes with other sectors (e.g. paper mills vs steel mills) and with agriculture, in terms of land use. It also might threaten some ecosystem services (see further).

More challenging is the threat to biodiversity, mainly related to the increase of the footprint of mankind on land (and ocean) of which the steel industry is only a small part. However, the destruction of biodiversity is now analyzed in terms of a reduction in ecosystem services: in a global view of the world, where eco- and techno-spheres are analyzed together, the steel sector offers global ecosystems services, which compensate for some of the biodiversity destruction; fairly simply put, the ecosystem services of steel is their role as structural materials in organizing the boundary between natural space (the biosphere) and human space (the anthroposphere). This is part of what is

sometimes called the social value of steel or its sustainability value (cf. section 2).

The downside of steel activities in terms of impact on BES (Biodiversity and Ecosystem Services) needs also to be taken on board, as regulators are being more and more precise on what they expect of industrial operators in this area, which translates in new requirements when licenses to operate are re-quested or renewed. This is usually confined to the micro-scale of the steel mill itself but it might be extended to the meso-scale in the future, through the large call on logistics of one mill.

Last but not least, the steel sector can offer products and services, not simply ecological services, which can help maintain or restore biodiversity. For example, biodiversity corridors are likely to request new specific infrastructures, which will need large amounts of structural materials including steel.

Moving smoothly into a close-looped economy

Steel claims rightly to be the most recycled material in the world and this is often understood to mean that it is part of a closed-loop economy. This is a subtle and complex concept, as an economy can be close-looped for some material and not for others and it can be partially or totally closed (weak and strong meaning). Steel today is part of a partial closed-loop economy related to the generation and reuse of scrap but also to the reuse of steel without remelting it, as is commonly practiced for rails or pile sheets.

This practice will be as essential in the future, as it was essential in the past and, indeed, the steel sec-tor is organized with specialized steel mills, EAF mills, which have been erected to take care of using and melting scrap. Moreover, the collection of scrap and its treatment to turn it into a true secondary raw material competing with ore on an equal footing is mostly a profitable, value-creating business: this is actually why steel is recycled to such a high level. In the future, the fraction of scrap vs iron ore is expected to increase, as the steel produced in the past and especially since the explosion of production, which has taken place since 2000, will be coming back in the economy as scrap. This will raise delicate issues of adjusting the balance between integrated and scrap process routes, especially in China, which has invested heavily in integrated mills. But it will also call on new technology to sort scrap more effectively and to purify it after sorting.

Global threats and future environmental demands

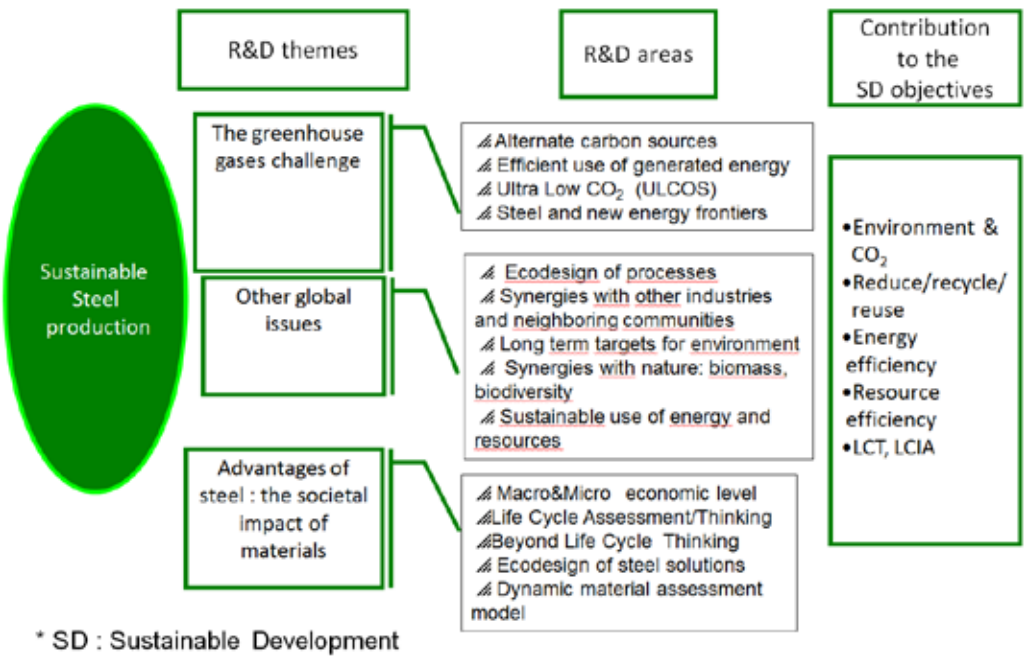
The environment has long been perceived as an externality in the economy and in neo-classical economics, but global environmental issues are gaining strength as they are becoming threats and grand challenges for mankind. The ozone layer and climate change were the major global threats perceived until recently, but more issues are becoming global, like acidification, eutrophication of fresh and sea waters and biodiversity (BES) issues. Projections of demands for the middle of the century show that environment in general will be posting limits on various emissions which as demanding as the one for CO_2 today (a factor 4 reduction).

From a practical standpoint, this will mean for steel demands on dust emissions, NOX and SOx for example, which are way beyond what is achieved or even achievable today. Therefore, this calls on deep research and development work to arrive in time at technological solutions, which are not simply waiting on the shelf today.

Other global issues

The future will have to meet challenges and threats which are not necessarily identified as more than "weak signals" today. The transformation of China into a closed-loop economy for steel is one of these future major trends. The emergence of more countries will also raise major issues to accommodate the need for raw materials and the circulation of scrap at a more international level. The need to adapt to Climate Change, as the window for mitigating the threat is rapidly closing, might also raise new demand on steel along with very difficult ones on society. The fight against poverty at the planet's scale will need help from technology and steel, deeply embedded in the technological episteme as it is, will contribute. All of this will happen, while population will probably still increase by 50% until 2100 and urbanization jump from 50 to 80% until 2050.

Figure 6: Synthesis R&D&I themes and areas for sustainable steel development



2.1.4. Partners, disciplines, level of the innovation step, bottlenecks and risks

In terms of partners, this industrial program (WG Planet) calls on industries of the steel value chain, but also of the end-of-life and recycling community and of other industries and urban communities with which waste energy and residues can be traded and exchanged. This means optimizing the reutilization, as secondary raw materials, of slags and dusts, including sludges, the recovery of metals, such as zinc, tin, the major alloying elements present in steels but also iron in non-ferrous metallurgy. Beyond energy and material exchanges, there are other synergies to explore in terms of innovative processes to be developed within the broad community of Process or Resource and Energy Intensive Industries (REII).

Disciplines include LCA and MFA, but also new methodologies like SAT and those being worked out in the SOVAMAT initiative – including economics, socio-economics and foresight, sociology, etc.; industrial ecology; process metallurgy; environmental science, scientific ecology, study of biodiversity and ecosystem services; climate change physics; design and eco-designs methodologies such as Design for Recycling (DfR), Design for Dismantling (DfD), etc.; recycling technologies (fragmentation, on-the-fly measurements and analysis, separation and automatic sorting of materials; foresight of environmental issues and threats, beyond climate change; long-term economic transitions of the steel sector.

This ambitious agenda involves mainly new and often breakthrough technologies and the development of new methodologies, like the SOVAMAT New Metrics, advanced ecodesign tools, etc. There are some technological bottlenecks like CCS, but also large uncertainties and thus risks related to the economic viability of industrial ecology approaches, which depend on the level of internalization of various environmental externalities: climate change technology will be implemented depending on the price of CO2, but also of energy and of raw materials like coke.

2.1.5. Stakeholders

- Steel industry
- Steel research centers
- Suppliers of iron ores and coals
- Equipment suppliers
- Worldsteel association
- Other energy intensive industries (cement, pulp & paper, glass, chemicals, etc.)
- Non-ferrous metals producers
- Electricity producers
- Public authorities
- Recycling industry
- Universities
- Modeling laboratories for eco-design and LCA studies

2.2. Safe, cost-effective and lower capital intensive technologies (Process)

2.2.1. Context, ambition & foresight

In a global World economy evolving continuously towards fiercer competition, the European Steel sector must continue to meet essential challenges: safe conditions at the working place, high standards of quality, steady renewal of the offer while applying highly productive, safe, clean, sustainable and cost-effective processes.

More specifically, attention is paid to promote key-enabling technologies and to develop new approaches with low capital expenditure and higher resource and energy efficiency along the value chain and the life cycle.

After the significant progress achieved by the European steel industry over the past 45 years with a decrease in energy consumption of more than 50%, more reduction is targeted, particularly in fossil energy intensity, by combining further process integration, introducing novel energy-saving processing routes, using alternative and renewable energy sources and implementing intelligent automation solutions.

Another major objective is the reduction in the consumption of high quality virgin or primary raw materials (including alloying elements) by improving global process yield and using more variable or diversified raw material including secondary (recycled) raw materials, by-products or land-filled waste.

Much investment has already been engaged in recent years by the steel industry to meet the objectives of the industrial program of this section. To go further, new R&D&I effort and technological development are needed in the following fields:

- **safety at work.** Besides the implementation of more efficient processing techniques, a priority remains the objective of "zero accident" by promoting the use of safer practices on the plant floor.
- **casting, rolling and thermo-mechanical production** steps will continue to change in the direction of the near net shape processing with the implementation of more continuous and interconnected processes, a way to implement processing route leaner in energy and raw materials, by increasing yields, for example.
- **higher energy efficiency of the BF-BOF route.** For this crucial topic, two directions have to be explored in parallel:
    - reduction of energy consumption by improving process efficiency or implementing alternative and new processing solutions,
    - recovery and/or valorization of wasted energy and heat.
- **Direct and alternative input of energy in the EAF.** A significant and increasing part of European steel production (~40 %) comes from EAF steel plants and thus from scrap, i.e. from recycled steel products. Economically and sustainably balancing energy input between electricity, the major input, and alternative energy sources remains a major objective as well as the enlargement of the product mix of the steel mills through an improvement of the quality of collected scrap and the feed of pure iron-based raw materials.
- **Leaner use of raw materials and alloying elements**. Besides further improvement in the chemical and physical transformation yields of existing processes, the most important actions will be focused on the development of processes allowing a broader scope of raw materials along with an economical optimization of cost mix and on the transformation of residues and by-products into valuable secondary raw materials.

- Adapting processing routes to the **production of advanced high strength steels** (AHSS). The production of these new sophisticated steel grades requires an intensive consumption of special alloying elements and thus needs specific development activities.
- **Integrated Intelligent Manufacturing** (I2M). The focus here is on integrating on-line automation of complete process chains by taking all interdependencies between processes into account, significantly improving inter-process logistics, implementing intelligent sensors to gather all the necessary input information from process or product to provide the inputs to this automation and developing various types of quality assurance techniques, for example to support engineers and operators in different decision making tasks.
- **Process integration** and **flexible multi-functional routes**. The target of steel producers for large scale uniform production with low production costs on the one hand and the demands of customers for tailored products exhibiting a wide range of properties on the other hand has to be solved by a greater flexibility and integration of the steel production chain. Moreover, the European Steel industry is a highly energy and resource intensive sector, where profit and efficiency are not the only targets. The challenges posed by a competitive market are forcing steel makers to switch over to cleaner production by adopting best practices at each stage of the steel production route. This shift requires a systematic methodology based on process integration.

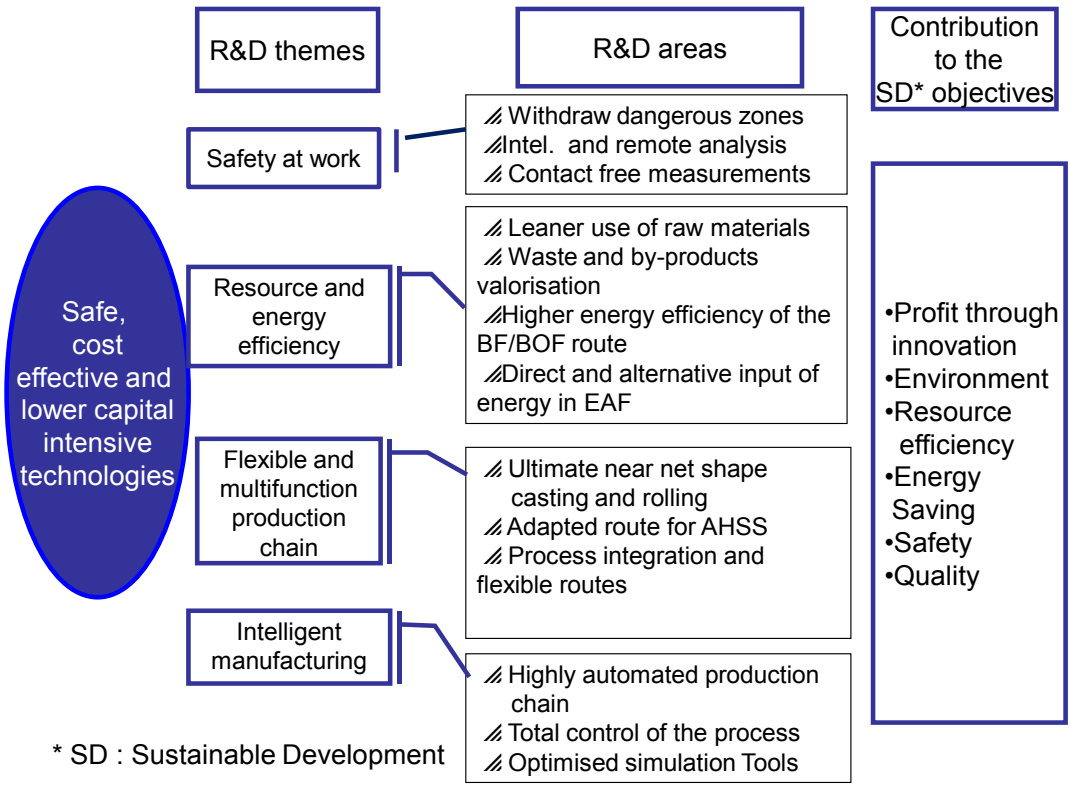
2-2.2. Exploring solutions: the R&D&I approach

Safety at the workplace

Besides the implementation of more efficient processing techniques, a major priority focuses on the objective of "zero accident" by promoting the use of safer practices on the plant floor. The managerial and organizational aspects are developed in chapter 2.6. In that context, two main directions have to be explored:

- withdraw human beings from dangerous zones (e.g. liquid metal) by customizing industrial robots (hardware and software) for use in steel mills
- promote new, intelligent and remote analysis and on-line contact-free measurement systems with no manual intervention. The scope of applications can be very wide, covering all processing steps on continuous or discontinuous lines. To be especially underlined is the use of wire-less and energy harvesting systems to improve the safety of personnel with control cabinet located far from dangerous zones and with no need to maintain the hardware placed in harsh environment.

Figure 7: safe, cost effective and lower capital intensive technologies. R&D&I themes and areas



Casting, rolling and thermo-mechanical production for near-net-shape processing

Based on the experience gained during the development of thin slab casting, strip casting and beam-blank casting, the main targets are the following ones:

- improve the continuity and reliability of casting and rolling operations, thus increasing plant productivity and reducing operating costs
- extend near-net-shape casting technologies to a larger range of applications. Both flat and long products are concerned with the aim of integrating solidification and shaping/rolling operations in a continuous process
- expand the steel grade capabilities of near-net-shape processes to additional or new materials and alloys, especially those that could benefit from fast cooling (very high strength, high formability, electrical steels..). High quality steels often exhibit heterogeneous distribution of alloying elements (macrosegregation), surface defects and the need to slow casting speeds down: this can probably be alleviated by adapting the cooling profile.

Higher energy efficiency of the BF-BOF route

There are two main routes to produce steel: the Blast Furnace, Basic Oxygen Furnace (BF-BOF) route and the Electric Arc Furnace (EAF) route. They differ by the type of raw materials they use, iron ore for the former and recycled steel (scrap) for the latter. In both routes, the efficient use of energy has always been one of the key priorities. Large improvements have been achieved in the past 50 years, which have brought production tools close to their thermodynamic limits. In terms of energy, BOF best performers consume 17-18GJ/t of hot-rolled product, while the average is around 21-22GJ/t. For the EAF route, the average is around 3 to 7 GJ/t. Installed plant capacity in the EAF route is significantly lower and the product mix does not include high quality flat carbon steel grades. Knowledge sharing of best practices and dissemination of Best Available Techniques (BATs: recognizing economically and technically viable conditions and integrated approach) will secure further energy savings. For today's best performers, there would be a maximum of 10% left for further improving energy efficiency.

Some R&D&I topics are common for both routes:

- Recovery of waste heat. A promising way is to recover energy from all possible sources, especially sensible heat of process gases, slag and cooling water. Some of these topics for EAF are detailed in the chapter on direct and alternative input of energy in the EAF. In the case of the BF-BOF route, additional recovery can be carried out also at various process steps: sinter, semis and finished products. In both cases, innovative technologies have to be developed for heat valorization at high, medium and low temperature. New efficient technologies such as novel heat exchangers, Organic Rankin Cycles, low- and high-temperature heat pumps, temporary energy storage, gas separation techniques are to be investigated.
- Optimization of operation and control. This topic is detailed in the chapter on Integrated Intelligent Manufacturing (I2M) regarding model-based process control. In addition, can be mentioned: the implementation of new energy-related measurement devices, the decentralized management of energy systems (including intelligent monitoring and diagnosis), motor controls with variable frequency/variable speed and burner and combustion control.
- Plant energy management. Energy management systems (EMS) have to be developed at plant level for off-line and on-line applications: models of energy and exergy balance, pinch analysis, standardized holistic approaches. The steel plant can also been included in an Industrial ecology approach, where industrial symbiosis can optimize energy flows of an entire industrial park where different industries share the same location using scenario simulation tools.
- Recovery of waste and residues. As explained in the chapter on leaner use of raw materials, the new technologies for the recovery of waste and residues, especially because of their content in iron and carbon, would have a positive impact on energy efficiency.

A specific issue relates to improving the valorization of the process gases of the BOF route. Process gases from BF, Coke plant and BOF are already valorized in most integrated plant. Nevertheless, there is room for development such as the recovery of the gas sensible heat, the optimization of their energy conversion (used as fuel for energy production), the utilization of optimized combined heat and power plants and the suppression of flares.

Direct and alternative input of energy in the EAF

The scrap based steelmaking route involves many different types of energy input. The main source of energy is electricity (60%), but, in many furnaces, a significant part of the total energy input comes from various types of chemical energy (mainly the C and H content in fossil fuels or sensible heat in the charge (charging of heated scrap, liquid pig iron or hot DRI/HBI). These energy sources are utilized in different ways and strongly affect energy efficiency, material and energy flow sheet in the EAF (figure 8). Some attempts are also on-going to use C substitute in EAF both using biomass (char coal and syn-gas) or by-products (plastics, car fluff, rubber, etc).

Much effort has already been devoted to optimize energy consumption in the EAF, but there remain options for further improvement. Usually the furnace shell and fume ducts are water-cooled to cope with the very high temperatures of off-gas (about 1700°C) and in many cases the energy transferred to the cooling water is lost into the environment. Energy losses from flue gases represent about 20-25% of the total input of energy (cf. figure 8), while shell losses amount to 10-15%. Direct recovery and use of a relevant part of this energy in the EAF process can be achieved by continuous scrap pre-heating (up to 800°C) and charging. More generally, the energy lost from the EAF off-gas can be recovered for instance by evaporation cooling technology producing saturated steam which can be used as an energy transfer media for the next process steps. Steam can also be used directly in the secondary metallurgy plant (VD or VOD), for generation of electric power or compressed air, for providing energy to external users (e.g. district heating or drying of binder materials).

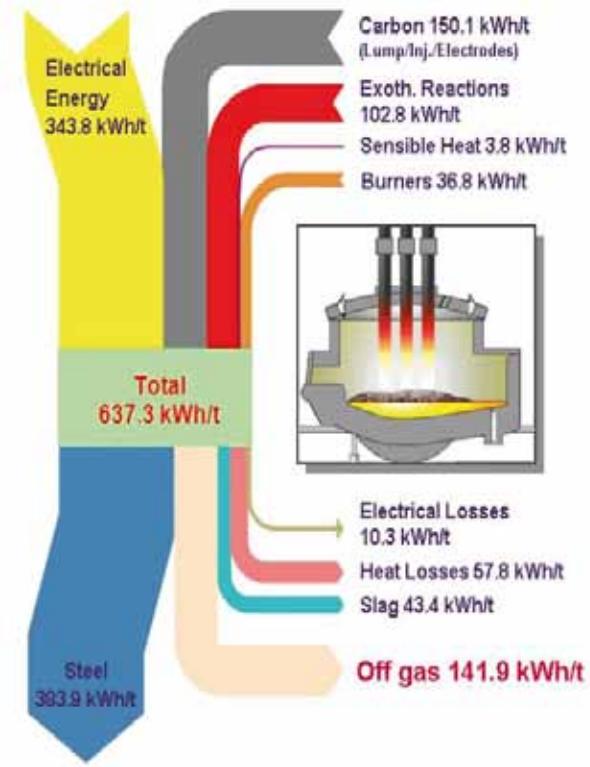


Figure 8: EAF Sankey diagram [A-P Hollands et al., METEC, Düsseldorf, 27 June – 1 July 2011]

One major objective is also to develop new technological concepts aiming at a more efficient and more flexible operation through the optimization of direct and alternative input of energy in the EAF with evident benefits in terms of production costs, productivity and environmental impact.

The EAF route can also use Alternative Iron Sources (AIS) besides scrap, in order to obtain higher quality steel production and/or to counteract the present shortage of high quality scrap. The most common AIS are Direct Reduced Iron (DRI) and Pig Iron. Processes to produce them will need to become leaner in energy and raw materials, which will also provide opportunities to substantially reduce global energy consumption and CO2 emission. For example, the concept of a DRI plant or of an iron smelter located inside the EAF mill results in ideal conditions to feed AIS in the hot stage to the EAF, recover a significant part of the additional energy required to melt DRI as compared to 100% scrap furnaces, even those using preheating processes.

The same concept could also be extended to any kind of materials (possibly pre-reduced or self-reducing mixtures) coming from the recycling processes that are produced locally and which might then also be hot charged in the furnace.

To reach these objectives, interdisciplinary teams should work to develop new technological concepts integrating a number of important key technologies, already available (i.e. holistic control system based on advanced measurement system, new generation of electrodes to improve electrical arc stability, optimized post combustion).

Specific efforts must be devoted to study alternative ways to recover, store and use lost energy with the following ambitious R&D&I objectives:

- develop a new generation of EAF panels that limit the shell losses, when the EAF is coupled with the new generation of continuous scrap preheater and with charging devices in flat bath condition;
- reduce cost and at the same time increase efficiency and reliability of high flux heat exchangers operating at high temperature, high dust concentration and in corrosive environment;
- develop thermal storage systems to improve the energy efficiency of batch processes by compensation of the mismatch between available waste heat and energy demand;
- find a general solution to recover the heat at medium-low temperature (<500°C) avoiding the risk of dioxin formation due to de novo synthesis;
- set up software solutions to achieve a better integration between different sources of recovered energy and an optimization of energy re-use;
- monitor raw materials (scrap and secondary raw materials) as their quality directly impacts EAF process efficiency, in particular in relation with preheating or alternative introduction modes.

Leaner use of raw materials and alloying elements

The ambition of ESTEP regarding resource efficiency is to reach "by 2030, up to 20 % reduction in non-renewable, primary raw material intensity versus current levels". The EU steel industry will therefore be committed to develop and demonstrate solutions that increase collection rates in various streams, by-products reuse and recycling rates, reduce the generation of waste, increase the yield of recycled materials and make access to by-products possible.

A complex multi-disciplinary work plan is foreseen to reach these ambitious objectives. The following main research directions have been outlined:

- Extraction of valuable materials (e.g. iron ore, metallic and non-metallic compounds, slag, oils, chemicals, etc.) from by-products through preferably new but also improved energy efficient treatment processes. The investigation must focus mainly on processes which are capable of treating large amounts of by-products of different natures and origins and possibly to avoid any landfilling. The implementation of the technologies at pilot/large scale is foreseen in order to demonstrate feasibility at industrial level and provide complete indications for a full industrial exploitation, including market potentials.
- Optimization of material fluxes by implementing decision support tools (off-line applications) and the development of new re-use pathways for the by-products of the steel industry inside and outside the steel production cycle. Modeling and optimization must take into account not only the entire steelmaking cycle but also the total system of process industries (e.g. chemical, petrochemical, pulp and paper, glass and food industries) in order to actually implement the concept of industrial ecology and industrial symbiosis and to exploit cross-sector synergies (raw materials and market from one another's residues) in order to achieve resource savings in the short term.

Customized processing routes for Advanced High Strength Steels

In Europe, High Strength Steels (HSS) are one of the fastest growing high-tech materials in the market. In the automotive sector, HSS and AHSS (Advanced HSS) significantly reduce the weight of the body-in-white. For example, the future steel vehicle program of World Auto Steel targets to use 97% of HSS and AHSS for the body structure, with 35% mass savings when improving the safety. In the construction sector, the use of HSS is a developing market with applications for bridges, steel frame buildings, skyscrapers, etc. AHSS can reach tensile strengths up to 1,600 MPa, with elongation range from 20 to 60%.

Along the steel production chain, adaptations and new technological developments are necessary:

- in secondary metallurgy, in order to reach the target analysis in alloying components as well as the proper inclusion cleanliness
- during casting, by managing surface quality (face and corner cracks), internal quality and segregation
- at the reheating furnaces by implementing specific heating patterns
- at the hot rolling stage, reinforce mechanical equipment (mill stands force, motors, crop shears, down-coilers) as well as adapt and develop intermediate and final cooling to maximize efficiency and minimize environmental footprint
- in the cold plant, reinforce mechanical equipment (mill stands motors, bridle rolls, tension reels shearing unit, welding machine) as well as adapt guiding, tension and flatness control
- in the annealing furnace, improve equipments to control temperature/time history to manage the microstructure of the new steels
- on the finishing lines, reinforce mechanical equipment (shears, levelers) and control flatness, straightness and residual stresses, as well as the ability to properly galvanize and coat the new products.

Integrated Intelligent Manufacturing (I2M)

New, breakthrough technologies are powerful solutions to bridge the technological gap required in process optimization to increase competitiveness. Where conventional techniques are mature and robust enough to guarantee stable performance, Integrated Intelligent Manufacturing (I2M) technology should contribute to develop more flexible, cost optimal and environmentally friendly operation of production processes. One important topic here is the complete and integrated process and plant automation, as well as the inter-process logistics of the global processing route to reach significant improvement in product geometrical accuracy and in process reliability. Furthermore various decision support tools (on-line applications), quality assurance techniques and methods to integrate engineers/operators knowledge are important to improve the overall performance of steel production. For all these activities it is essential to have the necessary input information with suitable accuracy at the right time and at the right place. Therefore sensors for gathering the data and powerful IT solutions to handle their processing are essential. All of these constitute the "Integrated Intelligent Manufacturing (I2M)" paradigm.

Important R&D&I themes that ought to foster the implementation of I2M in the steel mill are the following:

- develop hard- and soft-sensors, which ought to be at the same time reliable, fast, accurate and without contact, and intelligent self-optimizing measurement systems for all relevant process variables and products parameters along the whole production steel route, fully integrated in the automation environment of the plants.
- identify universal solutions for handling the large amount of data, methods to improve their reliability, techniques to assign them to products, ways to explain their meaning to all applications which use them, tools to analyze these data on- and off-line by using the newest technologies such as Data Mining, etc.
- integrate modeling of single processes into production routes by new and accurate mathematical models, using analytical, numerical and hybrid modeling. Modeling should be extended to all levels of automation, including scheduling and management systems as well as on-line decision making processes.
- integrate automation solutions based on the above information related to single processes as well as to complete process routes, by taking into account all aspects of automation (e.g. monitoring, diagnosis, assistance systems, process control, process supervision, tracking, logistics, etc.), by using the newest available techniques in all these fields (model predictive, robust or iterative learning control, self- learning technologies; rule-based or knowledge-based decision support, robust optimization techniques, etc.).
- Develop advanced maintenance tools and methods based on models, sensors, diagnosis and data analysis allowing to remote control the equipments, predict and prevent the failures, identify the drifts and avoid any loss of efficiency as well as unwanted stoppages.
- Implement integrated quality control factor-wide systems to monitor the evolution of quality across the production route. This implies calling on information technology (new IT paradigms) on better linking of process operations and on plant logistics to give production flexibility, guarantee product quality and meet end use requirements for 'just-in-time' order delivery. The full implementation of these systems is closely linked to development of models and sensors.
- integrate environmental targets like energy consumption, CO_2-emission etc. into all of the systems mentioned above, as an additional set of constraints to optimize the overall performance of steel production in terms of production costs, product quality, lead time and environmental footprint.
- integrate all the above technologies in a user-friendly way (improved HMIs), while at the same time improving their flexibility.

This is in line with the "Factories of the Future (FoF)" initiative of the 7th FP and now of the HORIZON 2020 program of the European Union.

Process integration and flexible multi-functional routes

Process Integration is the term used for system-oriented and integrated approaches to industrial process design for both new and retrofit applications. Such methodologies

can be based on mathematical, thermodynamic and economic models, methods and techniques. Examples of these methods include Hierarchical Analysis, Pinch Analysis, Artificial Intelligence and Mathematical Programming. Process Integration refers to Optimal Design and Sustainable Development; issues taken into account are capital investment, energy efficiency, emission control and mitigation, operability, flexibility, controllability, safety and yields. Process Integration also considers operation and maintenance. In most cases Process Integration is an off-line activity with a high optimization component, which differentiates it from Integrated Intelligent Manufacturing (I2M). Research on Process Integration, which originated from the awareness of the need for energy conservation in the industry, has broadened in scope to include raw material efficiency, emission reduction, sustainable development and process operations.

The implementations of Process Integration within the steel industry have been very limited so far, and mostly deal with modeling work to analyze process adaptations and developments aimed at lowering CO2 emissions, the use of energy and to improve materials efficiency. Future research efforts must aim at both the development of integrated tools for investigating the applicability of process-integration based solutions for efficient exploitation of resources (energy, raw materials, water, etc...), and the implementation of the most promising solutions up to the industrial scale.

The application of the various process integration techniques to complex processes, which involve numerous subsystems, requires an approach that can simultaneously consider the different systems individually as well as the interactions between them, cutting through complexity but neglecting unnecessary details. Iron and steel industries are an example of such processes in which inter-plant design, material and energy exchanges and operations can often be further optimized; process integration should allow to achieve significant resource savings in the short to medium term.

2-2.3 Stakeholders

- Steel industry
- Steel research centers
- Equipment manufacturers
- Coating Suppliers
- Other metals producers
- Universities
- Small & Medium Enterprises

2-3 Steel applications for transport

2.3.1 Introduction

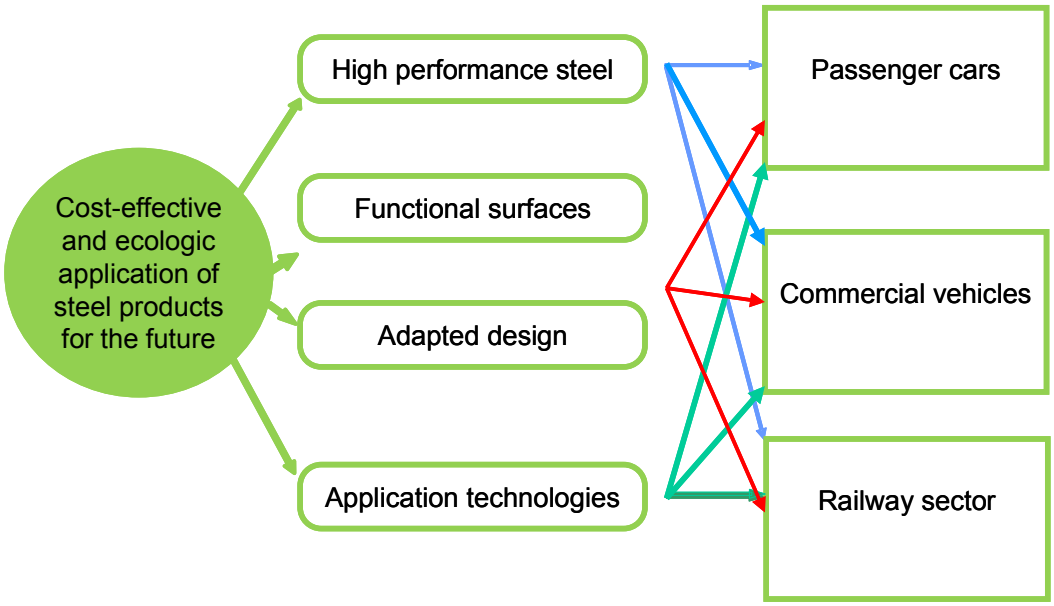
The European steel sector constantly addresses the challenge of meeting customers' demands for a broad variety of ever more sophisticated high-performance materials. To meet these needs, direct partnerships between steel producers and their immediate customers are a strong requirement. Such collaborations 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 transport, construction and energy sectors are regarded as priorities.

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

2.3.2. Issues and challenges

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.

Figure 9: Appealing steel solutions for end users: cost-effective and ecologic application of steel products to meet society's needs.



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 the increasing number of cars and lower passenger occupancy of cars. In addition to new powertrain technologies in combination with hybrid- or electric engines, new affordable lightweight concepts for passenger and goods transportation systems, new transport concepts and construction methods are required in order to be able to reduce greenhouse gas emissions despite increasing passenger and goods traffic.

The total 'Life Cycle Assessment' (LCA) of any product refers to the assessment of the environmental load during the complete lifetime of the product, from the raw material used for manufacturing, the emissions generated during the entire lifetime, and finally the disposal of the product. Steel is a very efficient material regarding GHG emissions while taking into account the whole life cycle, i.e. the production phase, the use phase and the end of life (the effective recycling).

Ancient practices took only into account the emissions arising from the fuel combusted by the engine, the so called 'tail-pipe emissions' or 'tank-to-wheel emissions'. In this case, the climate impact by the material production is not given any attention. However, as the drive-train gets more CO2-efficient by electrification or improved internal combustion engines, the significance of material production towards climate change will be higher. Therefore, to account for the environmental load of the complete life cycle, the following two phases should also be included: the fuel production phases (well-to-tank emissions) and the material production phase for vehicle manufacturing.

Every year many thousands of people are killed in Europe in traffic accidents and more than 1.7 million people are injured. Road deaths are still the primary cause of mortality among the young. New strategies for maintaining mobility while mitigating the consequences of accidents will therefore be necessary in the future. In this context, the safety of passengers and drivers is increasingly becoming an important priority, as recommended by the EU Commission which targets a decrease by two. With its highest strength level, steel plays an important role in securing safety requirements of today and future transport systems.

2.3.3. Research and innovation areas of the transport sector

Work in close cooperation with the customers is particularly important for the transport sector for proposing steel solutions meeting their requirements. The new solutions should use all technical progress: new metallurgy of steels, new functional coatings, new application technologies (forming, welding, joining, etc.) all included in a new design taking advantage of all these progresses. Mainly the automotive industry - as well as the whole transport industry in specific areas - 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 related to
  - energy consumption
  - CO_2 emissions
  - resource efficiency
  - dismantling
  - recycling behavior
- Safety
- Reliability
- Cost effectiveness

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

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 expertise 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.

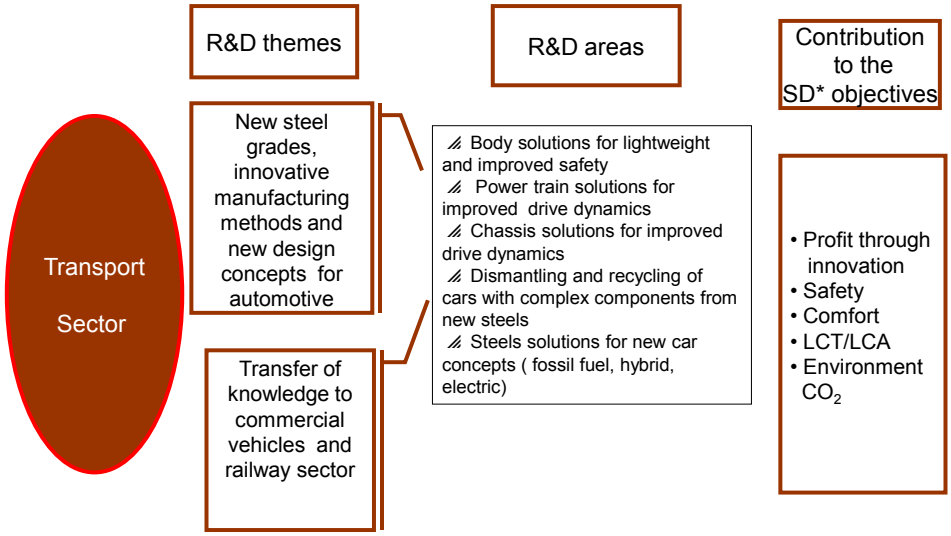
The automotive industry stimulates lightweight construction innovations. It is essential for the steel industry to exploit its material expertise through material development and component design for use in mass production and, in cooperation with the transport and especially the automotive sector, to achieve further improvements or totally new solutions for vehicle concepts. Multi material mixed structures need to be discussed and comparable, affordable steel solutions have to be offered.

The targeted development of a production and manufacturing chain using new high performance steels for lightweight constructions including new or modified forming and joining techniques and new coating processes will be a very ambitious R&I aim. The new hot forming steel grades with advanced corrosion protection coatings and new process technology approaches like tailored tempering for weight reduced steel cars are good examples of the capability of the steel industry - and the development is still going on.

The R&D&I themes to be derived from these challenges are:

- Complex components from new high strength steel grades using innovative manufacturing methods
- Development of new surfaces for optimized forming behavior and corrosion protection
- Development of steel solutions for the cars of the future
- Transfer of the knowledge to the whole transport sector especially to the truck and train industry

Figure 10: Appealing steel solutions for end users (transport sector): achieving the SD objectives through R & D



2.3.4. Socio-economic aspects of the automotive sector

The importance of the transport and especially the automotive sector for the EU economy is characterized 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 program 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 (LCA) into account car bodies, made e.g. with cold and hot forming high strength steels, tailored blanks and tailored tubes (closed profiles) 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 'Life Cycle Assessment' (LCA) 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 (370 million tonnes per year)
- Societal aspect of increasing the integrated safety for all road users

2.3.5. Stakeholders

- Steel industry
- Steel research centers
- Transport sector
- Suppliers (surface treatments and chemical industry)
- Suppliers to the transport industry
- Universities

2.4. Construction and infrastructure sector

2.4.1. Introduction: context, ambition & foresight

The European construction industry supports the EU economy, by providing it with buildings and infra-structure that supports all other economic and social activities. It is the

largest economic activity representing over 10% of EU GDP and the biggest industrial employer with about 20 million workers while another 20 million are indirectly affected by its activities. The industry's activities, through processing and transportation of products and components and energy consumption in buildings and infrastructure, are responsible for 40-45% of EU's energy consumption.

Steel is one of the most important construction materials, competing with other materials but also opening up completely new possibilities. Crude steel production in the EU amounts to over 180 million tons (or 12% of world production) of which about half is used in the construction sector. 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. Safety and health are the main performance aspects of the built environment essential for the security and quality of life of occupants and other stakeholders.

The quality of built environment has a strong influence on the performance of individuals and organizations and on the well-being of society in general. However, the level of funding from European and national programs does neither properly reflect the significance of construction as an economic activity, nor the significance of the built environment as a fundamental contributor to the quality of life.

2.4.2. Issues and challenges

There is a wide range of pressures, expectations and drivers seeking to influence and shape the construction and infrastructure sectors. The most important issues and challenges are presented by market demands. There is a need for the industry to deliver increasingly innovative products at competitive prices within tight environmental regulatory targets.

The challenge for the industry is, simply, to find new ways or delivering new products with less resources and raw materials. Internally, the industry as a whole is not yet geared for a coherent response to these challenges. It remains highly fragmented and there is a need for much closer cooperation between leading suppliers and major construction companies. A key aspect of the steel industry strategic plan over the next 10 years is therefore to work more closely with customers seeking strategic alliances with research organizations and commercial companies.

Strategic alliances with the EU construction sector would need to address the scientific, industrial and societal issues to meet the following global challenges:

- Impact of Climate Change
- Safety and health in manufacturing, construction and use of construction products
- Resource efficiency through improved recycling and reuse of construction material
- Life Cycle Thinking and Life Cycle Assessment for the construction sector
- Energy Efficient Buildings for new constructions and refurbishing of existing ones
- New EU directives and global challenges necessitating the tightening of regulations
- Resilience to and recovery from natural and accidental events like fire, earthquakes, flooding, and other accidental loadings
- Urbanization and other demographic changes
- Keeping pace, harnessing and facilitating information and communication technology integration with buildings and infrastructure and industry processes.
- Implementation of biomaterials and nanomaterials
- Integrating the supply chain and addressing the challenges of delivery
- Issues emerging from increasing partnership with customers.

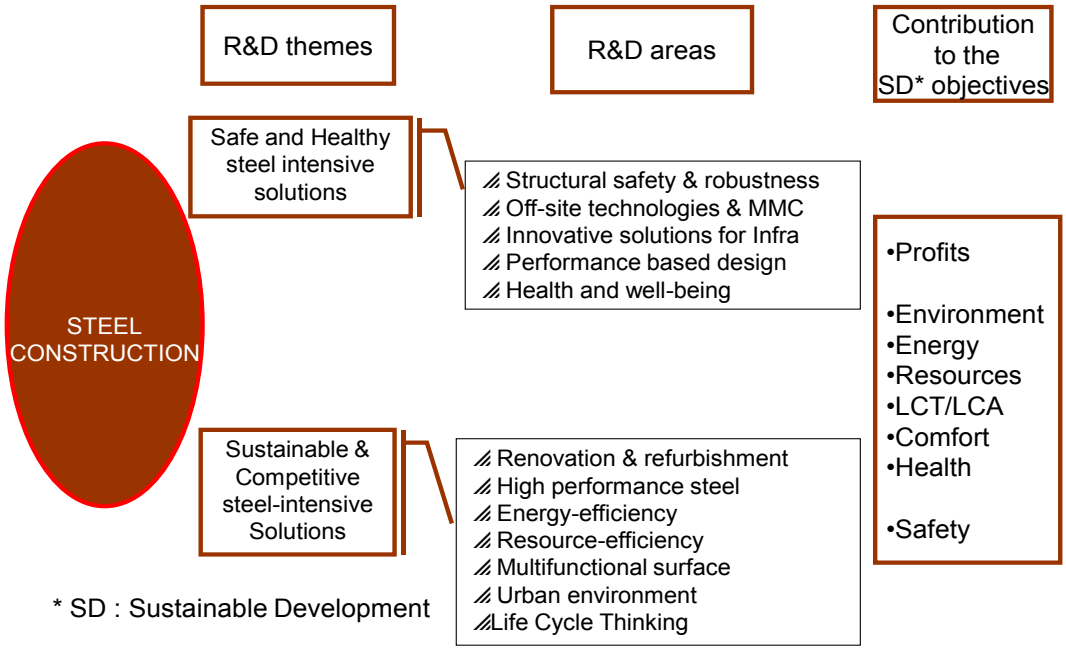


Figure 11: Appealing steel solutions for the Construction & infrastructure sector

2.4.3. Research and Innovation areas: exploring solutions and turning them into opportunities for both business and the planet

Safe and Healthy Steel Construction

Structural safety

New steel materials and structural applications, often combined with other materials, can be brought to market only after extensive research and development work. Structural safety comprises stability & robustness under earthquakes, other demanding environmental loads and fire-resistance, as well as reliable durability under several degradation mechanisms. The main R& D areas to be developed in the next ten years are:

- Strategies for steel structural safety in extreme events like seismis and fire
- Novel foundations solutions
- High performance bridges
- Development and use of high strength steels in structures, both for construction and infra-structures
- Performance–based design methods
- Risk-based fire engineering
- Promotion of Eurocodes for seismic and fire risks

Improved health and comfort through steel-intensive construction

The "sick building syndrome" must to be taken into account both in refurbishment of the old building stock as well as in new building concepts. It refers to problems such as moisture, dirt, ventilation, noise, vibrations, etc. Basic steel and coating materials can be developed for the requirement of a healthy environment.

Proposed R&D&I areas are:

- Advanced dry construction technologies
- Concept of steel intensive solutions
- Monitoring and maintenance
- Self-cleaning surfaces

Advanced prefabrication and execution technologies

Prefabrication is the key to high-level quality management of the building process, from the factory to the building site. The development of prefabricated products and systems offers the possibility to adopt the most intelligent user-oriented, performance-based technologies, reducing the overall foot-print of environmental impacts. Proposed R&D&I areas are:

- Products libraries for CAD/CAM applications
- Safe and fast construction site technologies
- Steel-intensive modular production
- Ecodesign approach for advanced and high-performance steel-based products to reduce building embodied energy & carbon footprint

Sustainable Steel-Intensive Construction

In construction, steel properties such as yield strength, stiffness, durability and weldability provide more design freedom than other materials. Using steel solutions, less material is needed to make a quality structure and smaller foundations are required. Steel is also lightweight compared to many other building materials used in construction. For steel-frame structures or combined-steel solutions with other materials, steel-intensive construction leads to less material use and less transportation, bringing advantages in building costs, embodied energy & carbon of used materials. Steel is by far the most recyclable and recycled material, but recovery, reuse and recycling of steel in the construction sector needs further development.

Energy Efficiency of steel construction

Steel has a major role to play in energy efficient construction, and that is why ESTEP's construction program addresses energy-efficient and eco-efficient solutions which are well in-line with the Public Private Partnership "Energy Efficient Buildings". Within E2B, the steel industry is involved in promoting steel-based solutions for energy savings, cost savings and reduction of CO2 emissions. For future initiatives, the R&D&I areas are:

- Development of higher strength steels for decreasing the overall consumption of steel in buildings and enabling very high rise buildings,
- Development of steel structured energy-efficient envelopes, both for new building and renovation
- More luminous spaces for maximizing passive solar heating and better natural light penetration,
- Steel joints for highly glazed façades,
- Further development of advanced coatings and technologies for new envelope steel-products with high/low solar reflectivity/absorbance in warmer/cooler climate conditions, respectively,
- Smart solar cells steel-based products for roofs and walls.
- Steel contribution to electricity generation and energy storage materials

Structural quality in renovation

A large potential for steel-based construction products can probably be realized in repair concepts of the existing building stock. In the 60s and 70s, reinforced concrete buildings were built with poor control on materials and old construction technologies. The structural quality, including improved safety and enhanced adaptability, can be achieved. The R&D&I areas are:

- Mitigation of floor vibrations,
- Improvement of acoustic behavior
- Seismic and fire safety improvement (see also structural safety)

Improvement of urban environment and infrastructures

Improvement in the accessibility of city centers, with intermodal networks and infrastructures will en-sure efficient urban and inter-urban mobility. This vision is share by the reFINE project, "research for Future Infrastructure Networks in Europe", a recent initiative of the European Construction technology Platform. ESTEP is part of the project, promoting innovative steel-intensive solutions. Three R&D&I priorities are indentified and relied on the concept of HLSI (High-Level Service Infrastructure):

- Multimodal hubs. Infrastructures networks are integrated, efficient and well-connected thanks

to multimodal hubs that constitute essential nodes of the integrated transport systems
- Urban mobility. Infrastructures networks support a high quality of life in sustainable European cities by ensuring a continuous and safe circulation of persons and goods and by improving the physical means for mobility to live and work
- Long distance corridors. Infrastructure networks support a competitive European economy by providing fast means to develop European trade in a sustainable way between city centers and along major routes connecting Europe with the rest of the world.

The reFINE project is also proposing transversal research areas such as materials & associated construction processes where steel has a role to play. The development of new materials and new construction methods and techniques using materials will lead to lower costs, longer product lifetime, higher performance and lower life-cycle environmental impact

Recyclability, reuse and durability

Metal collection and recycling are already performed to a high degree. Throughout the whole value chain, there is still a potential for new development, both for recycling and reuse. New eco-design solutions have to be developed for improving disassembly and reuse. It concerns steel roofing, cladding, purlins, walling and structural steel elements.

The R&D&I areas are:

- New eco-designs for disassembly and reuse of steel in construction
- Life- time engineering of buildings
- Verification of durability and design life
- Environmental information of steel products in construction.

Life Cycle Thinking, Life Cycle Assessment

Life Cycle Thinking is a worldview that is beneficial to society and European Steel industry. In the case of construction, LCA (Life Cycle Assessment) provides a holistic approach to evaluate the environmental performance by considering the potential of impact from all stages of manufacture, products use and end-of-life stage. Generally, the LCA approach comprises the Life Cycle Inventory (with data collection), the Life Cycle Impact assessment (LCIA) and the interpretation of results. In the case of construction there are a lot of developments to be carried out for the overall LCA methodology and generic enough to be used for all construction materials with data related to resources, energy and GHG emissions.

R&D&I themes are:

- Applications of the LCA methodologies to construction
- Development of new advanced methods for the evaluation of material durability,
- Development of new advanced methods for the evaluation of energy and other emissions data over the whole life cycle of the materials used in construction (upstream data, construction phase, in-use phase, disassembly and recycling/reuse)

2.4.4. Socio-Economic Aspects

Steel is one of the most important construction materials, competing 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, standardization, 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.

Steel and synergies with neighboring communities

Steel is a key component of any construction activities. In fact, in terms of construction, some structures and forms would not be possible without steel. Therefore, steel is linked naturally to various other construction projects. This also extends to research and innovation. As a platform, ESTEP has synergies and collaborates with various platforms and initiatives such as ECTP, E2B, Building UP, reFINE, etc.

2.4.5. Stakeholders

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

2.5. Steel products and applications for the energy sectors.

2.5.1. Introduction

This work is part of the effort to keep the SRA of ESTEP updated, to prepare HORIZON 2020 and future research proposals on key strategic issues. More generally, it is meant to make sure that ESTEP is ready to face the challenges that lie ahead of it in a proactive and pioneering way. Energy sector is very important for the future of Europe as our society is willing to switch from a carbon based energy system to another one based on renewable resources. This change will require huge efforts from many different actors and for very large investments. Materials used for the production, storage and transport of energy are very important elements to achieve the required performances at an affordable cost. The EMIRI proposal for a new PPP within Horizon 2020 (Energy Materials Industrial Research Initiative) is exactly for this purpose. In this general landscape, steel has a very important role to play. Working in collaboration with its customers, the European steel industry is ready to answer the challenge through innovative product and solutions.

2.5.2. Methodology

In order to better define the required steel applications to be developed, the energy industry has been subdivided in three main sectors:

- Energy Transportation (Oil & Gas, not standard fluids)
- Power generation and CCS
- Renewables (wind energy, Photovoltaic, CSP, Hydrogen, marine energy, others)

The time frame extends until 2030, as changing the energy system is a long-term endeavor. The approach of the working group has been to carry out a foresight analysis, trying to imagine how to bridge the present to the future.

In this context an ordered and rational set of research areas that could become populated by research proposals especially in the period up to 2020 has been proposed.
More specifically, the working group has proceeded as follows:

- picture the needs of Energy Industries up to 2030
- proceed, using a backcasting method, to draw the roadmap that bridges the gap between that future and today
- translate the needs in terms of R&D&I areas
- prioritize the areas in terms of time and funding instruments (HORIZON 2020, SET -Plan, RFCS, others).

2-5.3. Energy transportation: Oil & Gas, other less standard fluids

Exploration, production and transportation

As the indigenous supplies for 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. As new competitors have entered the field, Europe's central concern is to maintain its position and competitiveness in the future. This requires permanent innovation and continuous engagement in R&D&I. Many of the oil and gas companies and pipeline transportation companies have placed substantial funds into research and development. Any improvement in the design, materials or construction processes can yield extremely large cost savings.

Areas of particular interest include fracture control for demanding applications of higher strength steels fitness for purpose and defect assessment of Higher Grade/ Higher Pressure Pipeline (as grade ≥ X80, service pressure ≥ 15 MPa), pipeline operation in harsh environments such as corrosive and cryogenic conditions, improved loading systems for gas transportation by LNG/PNG and safe transportation of CO2, H2 and gas mixtures.

The aging of pipeline network is also a very important topic in Europe as well as the security of supply. First wish is to extend life times of running systems. A better knowledge of the limits for these aged pipelines will create sooner or later the need for new pipelines.
As main R & D themes have been identified:

- Highly performing tubular materials and technical solutions for Oil & Gas wells and relevant infrastructures
- Steel pipes & components and technical solutions for High Productivity Energy Transportation

Highly performing Tubular materials for Oil & Gas wells

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 realistically pursued, due to the availability of so-called "In-Situ Expansion" (ISE) technologies. This however calls for the availability of steel pipes with superior suitability in terms of deformability, mechanical and corrosion properties after expansion and a generally higher performance in terms of collapse resistance. Also the development of appropriate solutions for the joints is needed when ISE is applied. The reduction of the total weight of the casing structure through the use of ultra -high strength OCTG (Oil Country Tubular Goods) is a major issue. C-steel seamless pipes with yield strength of 980 MPa and higher are likely to be require d in the future. Additionally, reasonable sulfide stress corrosion cracking (SSCC) resistance in moderately aggressive environments will be necessary.

Flowlines & Risers. The frontier of deep-water field which can be suitably exploited by current technologies has moved fast in the last decade. Challenges coming from ultra-deep waters of 2000 m and over, as well as from new concepts and technologies require the design of new or improved steel products (seamless and welded pipes, special forged components).

For subsea Flowlines, main future developments are related to laying in ultra-deep water and to increasingly severe operating conditions. Two specific requirements will be stressed in the near future: the deformability of pipe strings (including also the girth welded joint) and its fatigue resistance.

Steel pipes & components for High Productivity Energy Transportation

Politically, the issue of securing the energy supply to Europe is becoming of major concern. Alternative pipeline routes and increased gas supply by LNG and CNG (LNG: Liquefied Natural Gas, CNG: Compressed Natural Gas) can support this.

All involved modes of energy transport either by onshore pipelines as well as offshore trunk lines and by vessel (LNG and CNG) will require new or optimized steels as well as design, operation and production concepts to comply with operation at higher internal pressures, higher usage factors, severe loading conditions and an anticipated increased share of corrosive and multiphase gases. Complementary to this, safe transport of CO_2 from power plants and other emitters of CO_2 to storage areas will play an important role in the future.

H_2 in connection to wind energy is a more and more important topic. Energy storage in gas pipelines (max 10% H_2) may be the most practical solution to solve the "energy storage problem" Research in this area (transport of gas mixtures) is absolutely needed.

Onshore pipelines: Steels with a high amount of deformability have to be developed as well as plastic design

criteria to understand pipe and pipeline behavior. A key issue for pipeline safety is the avoidance of corrosion and external damage, especially in thin-walled structures. More than 80% of all pipe-line failures can be devoted to corrosive attack or external interference.

Modeling 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.

From the construction and operation point of view, developments and improvements are needed in cooperation between steel and pipe producers, laying contractors and operation companies like:

- Advanced girth welding processes such as dual tandem, laser and/or hybrid laser.
- Development of optimized and, if possible, automated pipeline construction techniques (e.g. in-creasing offshore laying speed, tie-in equipment, pipeline crossing techniques
- Advances in the inspection, measurement, interpretation and repair of pipeline construction and operational damage
- Improvement of the long term behavior of pipe coatings in accordance with pipeline operation and cathodic protection methods

Offshore trunk lines.

Currently, 90% of the world's offshore structures with their related transmission pipelines are in shallow waters, less than 75 meters deep. However, an increasing number of transmission lines in deep (>400 m) and ultra-deep (>1500 m) waters are to be expected. Key issues for offshore pipelines are the resistance against the extreme loading conditions (bending, tension, external pressure) during pipe laying and to allow a high speed of welding aiming at higher laying speeds, wall thicknesses and diameters, moreover their resistance to external damage can be a key point for shallow water pipelines. An excellent roundness of pipes is the basis for high speed joining as well as for collapse resistance.

Liquefied natural gas (LNG)

Liquefied natural gas (LNG) transportation represents an increasingly important part of the natural gas supply picture in the world For Europe, an increase in LNG supply could contribute to an improved security of gas supply. Current and future R&D&I activities are aiming at a new generation liquefaction, new and larger storage options and expandable LNG trains. Also the development of thermally insulated sub-sea LNG pipeline systems has to be anticipated. These would allow the loading and off-loading terminals to be located much further from shore with easier access by tankers. This technology presents a number of challenges including materials selection, highly stressed pipeline systems, thermal behavior of all components, operational monitoring and operational procedures and mitigation against contingency.

Compressed Natural Gas (CNG)

The Compressed Natural Gas transportation can be an interesting solution useful in some specific scenarios. Also this technology presents a number of challenges both in terms of strength/ductility of material, weight/ performance (in term of maximum pressure) of pressure vessel.

Transportation of alternative gases

Transportation of CO_2. Carbon capture and storage technology (CCS) has the potential to reduce emissions from fossil fuel power stations up to 90%. CCS involves capturing the CO2 emitted from fossil fuels, transporting and storing it in secure spaces such as geological formations, including old oil and gas fields and aquifers under the seabed. CO2 will preferably be transported as a dense fluid. Offshore transportation can also be done by vessels making use of the CNG/PNG (compressed) technique.

Transportation of H_2. The transport of hydrogen is the major component of a clean sustainable energy system in the longer term. Although there are currently more than 2000 km of hydrogen transmission pipelines in service in Europe and in the U.S., several technological issues need to be resolved and significant cost reductions are required for effective hydrogen pipeline transmission and distribution.

Transportation of aggressive gas mixtures. Pipes are facing new challenges coming from new and/or more demanding material requirements, related to specific performances and applications when very aggressive gas mixtures (high H_2S, CO2, CO, pressure) have been transported in very hard conditions (high temperature, high pressure, high flow, hostile external environment). As an example, wells/fields in the North Sea, in the Kashagan field and/or Gulf of Mexico.

2.5.4. Power generation and CCS

Today's energy consumption for electricity production is composed by a mix of fossil sources (coal + natural gas + oil = 65%), nuclear power (17%), hydropower (16%) and renewable (solar+wind+renewables+geothermal+ waste= 2%). In the next 20 years the fossil sources will still be the main fuel for the production of electricity in the world with an increase up to 72% of the total.

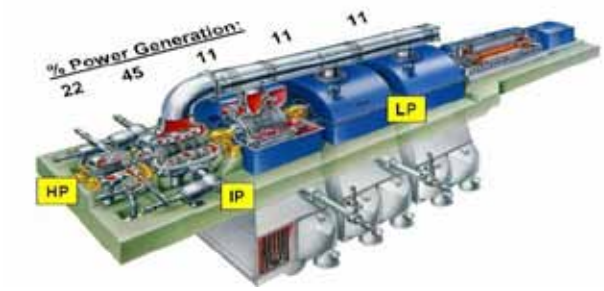
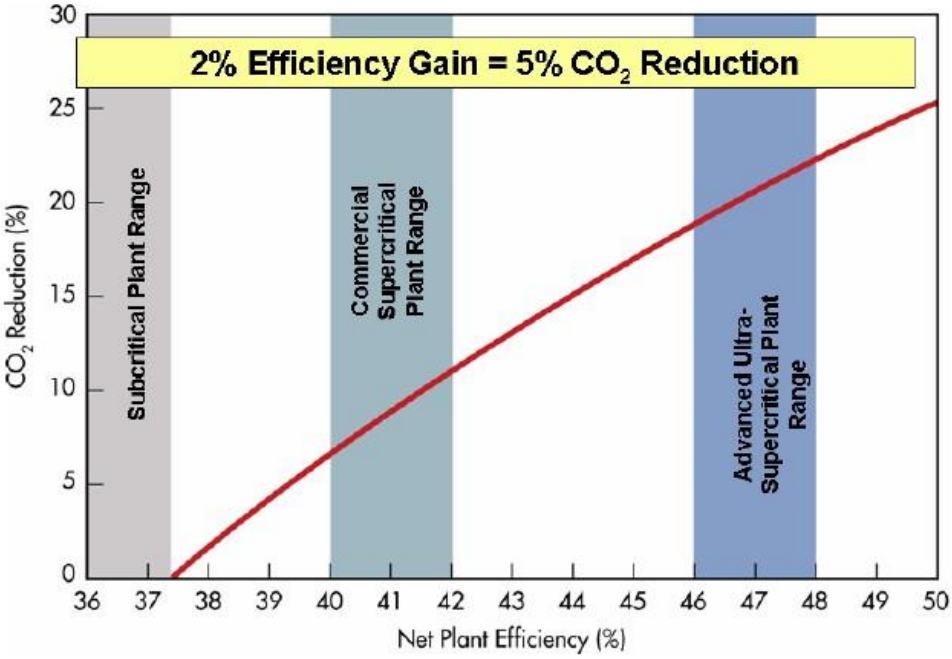


Figure 12: Steam Turbine for power generation

A large increase of electricity demand will come for China, India and the other emerging countries. Therefore several hundred power plants will be built in the main fossil fuelled. Also some new nuclear power plants are under construction, but for the strong increase of this technology the next plant generation is awaited. Therefore the nuclear seems will be reduced as percentage of the total energy supply in the near future. In the decade 2011-2020, the International Energy Agency (IEA) forecasts that the OECD (i.e. Europe plus the United States) will add 184 GW of new coal capacity, compared to 168 GW in China.

The development of the advanced USC fossil power plant with steam temperature up to > 700°C is urgently needed to reduce CO_2 emissions.

Figure13: Efficiency improvement for advanced USC fossil power plant



Nuclear

Nuclear Energy contributes to the SET-Plan's objective to develop low carbon energy technology. In this framework, the SET-Plan aims to design and build over the next decade prototypes and demonstrators of fast neutron reactors, technologies for a more sustainable nuclear energy through better resources utilization and the reduction of potential impact of ultimate radioactive waste. On the other hand, the higher temperatures and irradiation levels as well as different coolants than Generation II/III reactors, foreseen for these systems, will require other materials to those used for Light Water Reactors. In response to these needs the materials roadmap for nuclear fission proposes a research and development program on commercially available material (steel and Ni-alloys) for the prototypes and demonstrators; and advanced materials for the industrial scale systems. The focus is put on cladding application (Oxide Dispersion Strengthened -ODS- steels for liquid metal fast reactor) with the aim to improve high fuel burn-up capabilities and high temperature resistance; on coating technologies to enhance corrosion and erosion/wear resistance in liquid metal fast reactor. Based on the research results, projects to validate manufacturing routes of 9Cr steel heat exchanger, of fuel cladding tubes with ODS are also needed.

2.5.5. Renewables (Wind, PV, CSP, H2, Marine energy, others)

Globally, the energy sector emits 26 billion tonnes of CO2 each year and electricity production alone accounts for 41% of emissions. The International Energy Agency expects CO2 emissions in 2030 to have increased by 55% to reach more than 40 billion tonnes of CO2. The share of emissions coming from electricity production will increase to 44% in 2030, reaching 18 billion tonnes of CO2. Europe is going to be importing a growing share of its energy at unpredictable but most likely higher prices, from unstable regions, in competition with the rest of the world and at staggering environmental cost.

Wind

At present, the largest turbines are designed for 6 MW and higher capacity (offshore) while much smaller units are locally applied in windy areas to generate the home supply electricity.

The European Wind Energy Technology Platform has a vision in which wind energy covers 12 -14% of the EU's electricity consumption by 2020, with a total installed capacity of 80 GW. By 2030, it sees this increasing to cover 25% of electricity consumption, with 300 GW of installed capacity. Satisfying our energy needs over the coming decades will be a big challenge. The economic future of Europe can be planned on the basis of known and predictable energy costs, derived from an indigenous wind energy source free from all the security-related, political, economic and environmental disadvantages associated with the current energy supply structure. Europe can go a long way towards an energy supply that is superior to the business-as-usual scenario, offering greater energy independence, lower energy costs, reduced fuel price risk, improved competitiveness and more technology exports. Over the coming 25 years, wind energy will play a major role in that development.

Figure 14: Offshore wind farms

Photovoltaic

The challenges of the photovoltaic sector is to further improve the competitiveness and ensure the sustainability of PV technology and to facilitate a self-sustaining large-scale penetration in both urban areas and free- field electricity production units, as well as its integration into the electricity grid. Materials are key enablers in all PV systems. There is a need to design and manufacture PV systems that are both efficient and low cost enough to meet specific grid parity targets within the next few years. The materials supply chain needs to be able to supply sufficient quantities of the required elements, and thus, cost effective recycling solutions should be developed along with standardized performance testing and reliability/ageing test protocols needs to be developed to provide confidence (and so bankability) for PV devices employing newly developed materials in a wide range of operating conditions (from Europe to Sunbelt environments).

To this end, the materials roadmap proposes a comprehensive research and development program on the optimization of materials usage through predictive modeling down to quantum devices at the nano-scale, the improvement of intrinsic performance and reduction in layer thickness of constituent materials for both inorganic and organic PV cells and modules.

The roadmap focuses also on materials for light management (anti-reflective, anti-soiling, anti-abrasion coatings, light trapping/guidance, spectral conversion and optical concentrators materials); the development of high throughput, low cost manufacturing processes for film/layer deposition/thin film (epitaxial) growth.

Concentrated Solar

The aim is to support the competitiveness and readiness for mass deployment of advanced concentrated solar power (CSP) plants, through scaling-up of the most promising technologies to pre-commercial or commercial level. Achieving these objectives will require large-scale CSP plants with better technical and environmental performance and lower costs with increasing power availability. This necessitates materials with higher performance than those of today.

Our materials roadmap proposes a comprehensive research and development program on low-cost, spectrally selective, high mechanically stable absorber materials suited also for higher temperatures; and the development of higher reflectance and/or specularity, cost competitive, sustainable reflector materials. The roadmap focuses as well on materials to allow for higher temperatures, better heat transfer; the development of more sustainable, reduced cost, corrosive-resistant structural materials such as steel and the development of storage materials (heat storage materials and materials for thermo-chemical storage) to increase the performance and extend the operating temperature up to 600°C. of heat exchangers also metal structures for central receivers as well as piping and tank structures are deeply needed.

Fuel Cells and H_2

The aim is to support the development and test, of cost competitive, high energy efficient fuel cell systems and sustainable hydrogen infrastructure technologies under real market conditions for transport and stationary applications. Achieving this goal will necessitate dramatic improvements in the economics, performance and reliability of fuel cells and hydrogen technologies. The need for new materials is overarching.

We focus on developing novel steel and composite materials with enhanced performances to obtain low-cost functional components for hydrogen transport and storage, coal gasification and thermo-chemical cycles technologies (improved chemical and mechanical properties); the development of low cost, reliable and corrosion resistant structural steels and composite structures also for pressurized and cryogenic hydrogen storage.

Transportation of H_2 and H_2 mixtures

The transport of hydrogen is the major component of a clean sustainable energy system in the longer term. Although there are currently more than 2000 km of hydrogen transmission pipelines in service in Europe and in the U.S., several technological 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.

2-5.5.5. Marine Energy

Of all the large natural resources available for generating electricity, ocean energy is one of the last investigated for its potential. Although there are other marine energy sources — the thermal energy resulting from the large temperature differences between deep and cold ocean waters and sun-warmed surface waters, the chemical energy in ocean salinity gradients, and marine biomass, wave and kinetic stream energy are the most well-known.

There are two forms of tidal energy: potential (i.e., harnessing the potential energy changes associated with the tidal rise and fall of sea level) and kinetic (i.e., harnessing the kinetic energy associated with the motion of the tidal stream). There are three types of kinetic energy from water: tidal, ocean current, and river streams.

But how much marine energy is available? What is the amount of electrical capacity available and ex-tractable from two forms of marine energy: wave and kinetic stream?

Estimates of the total renewable energy available from the marine environment can be made by summing together the individual components available from the principal subdivisions of this energy source (Wave, Bio -mass, Ocean Thermal, Tidal, Subsea Current and Salinity Gradient). Estimated availability varies widely with researchers such as Isaacs and Seymour[1] posting estimates of between 1,000 and 10,000 GW. All estimates identify a highly significant energy source, even if only a limited percentage of the available energy can be recovered, either due to the remoteness of the source, transformation inefficiencies, or impact on marine ecosystems.

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[1] Isaacs & Seymour, The Ocean as a Power Resource, Int. J. of Environmental Studies vol. 4(3), p201-205

The technology to convert these resources to electricity has been deployed in demonstration projects, but remains the main challenge to see a large development of the Marine Energy. Commercial projects are expected in the next five to ten years. Given proper care in design, deployment, operation, and maintenance, ocean wave and kinetic stream energy could be two of the most environmentally benign electricity generation technologies yet developed.

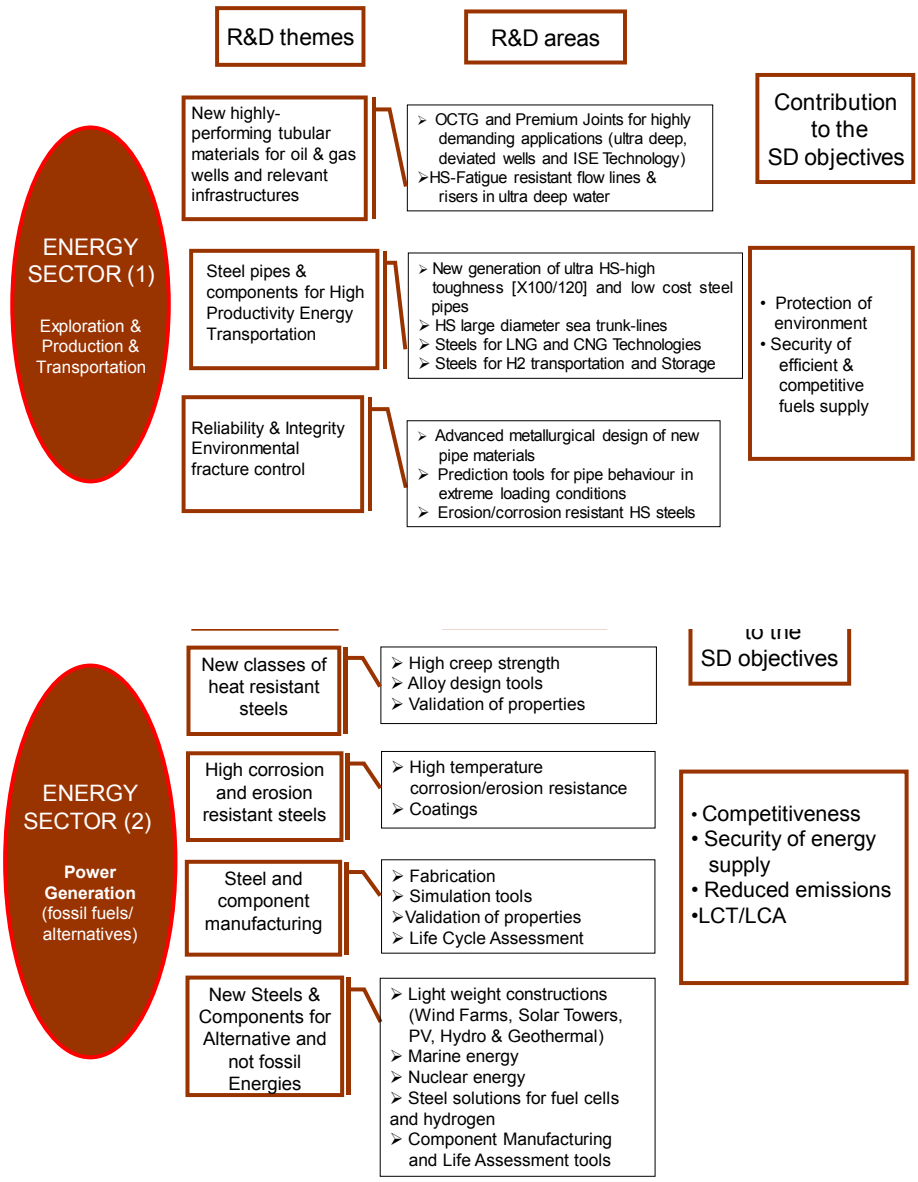
Interest in wave and tidal stream energy has picked up over the last few years. Currently, many different device concepts compete for support and investment, and while some are more advanced than others, all are at early stages compared to other renewable and conventional generation systems. Optimal designs have yet to be converged upon. A few large-scale prototypes have been built and tested in real sea conditions, but no commercial wave and tidal stream projects have been completed to date.

Marine renewable energy has the potential to become competitive with other generation forms in future. In present market conditions, it is likely to be more expensive than other renewable and conventional generation systems until at least hundreds of megawatts capacity are installed. By way of comparison, this capacity is equivalent to several offshore wind farms at the scale currently being constructed.

Fast learning or a step-change cost reduction is needed to make offshore wave energy converters cost competitive for reasonable amounts of investment.

Considerable emphasis needs to be placed on cost reduction to ensure commercial viability for wave and tidal stream technologies. We need to accelerate the progress of technology development, through concept and detailed engineering design to bring substantial reductions in cost.

Figure 15&16: Steel applications for energy: R&D&I themes and areas



2.5.6. Stakeholders

- Steel industry
- Steel research centers
- Contractors
- Energy Equipment suppliers
- Oil and gas companies
- Electricity producers
- Public authorities
- Universities

2.6. Attracting and securing qualified people to help meet the steel sector's ambition (People)

2.6.1. Introduction

From now until 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 globalization of the world economy and the world steel market, which will induce continuing rationalization 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 processes of change, 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 population pyramid 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.

Requirements concerning labor organization and labor policy are increasing. The question about conditions of preservation and further development of innovation capacity at the level of organization of human work will become the central future issue of public innovation policy, where economic, techno-logical and social innovations interact. One of the greatest current challenges of management is to organize effectively utilization of manpower in what deals with core processes of interactive value creation and innovation. At the same time, in light of demographic change and apparent skilled worker shortage, the capacity of companies, to train, to recruit and to make qualified workers stay for a long period, is becoming a decisive success factor. In this context, it will become more important for companies to offer attractive workplaces. Issues of workplace quality will regain importance. The outcome of workplace innovation is to contribute to sustainable changes related to the economy, ecology and employability and to sustainable innovative capability of organizations and individuals.

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. In relation to health and safety and due to technological changes green skills, expertise and awareness have to be developed continuously. All these trends converge on and represent different facets of Talent Management. During the last thirty years, Talent Management has become the nexus of steel companies' competitive strategies, securing the coherence of their implementation and, more generally, seeking the optimization 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 organizational configurations tending to transform enterprises into "knowledge organizations".
Talent 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 Talent Management is essential to the successful implementation of the steel sector's long term vision regarding profit, partners, the planet, and people.

2.6.2 Research theme and implementation of actions

The main objective of attracting and securing qualified people to help meeting the steel sectors ambition will be operationalized by five research and development themes:

1. Health and safety
2. Innovation management
3. Attracting and retaining qualified people
4. Leadership development
5. Talent management

Within the topics health and safety, attracting and retaining qualified people as well as talent management a lot of activities were already carried out within ESTEP's WG 5 (people) from a perspective of best practice exchange and first research activities. These themes will be further developed within research activities and the acquisition of projects, integrating innovation management and leadership development as new priorities. Needless to say that the existing and future cooperation with the Social Dialogue Committee will be fed by these themes and its results as well.

Health and safety: Zero accidents still being the ambition

The European steel industry has long been a pioneer in promoting and carrying out research to improve health and safety 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.

However, steel companies and organisations of the steel industry created specific methodologies and activities in the management of health and safety with the objective of reaching the "zero accident" target. 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. In order to foster breakthroughs, health and safety is and 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.

But working conditions are still changing rapidly, switching from physical to mental loading, and the consequences of new working conditions on workers should be investigated. The steel industry nowadays is characterised by a high internal risk potential due to the highly technology driven production process. Also the increasing number of subcontracting accumulates the operation risks because of the lower standards of risk management in most of these enterprises (estimated up to five time higher accident rates).

New safety concepts focus on technical and organisational, human and cultural factors. The acceptability and the achievement of these concepts could only reached by a risk sensitive workforce. Therefore awareness programmes and technologies have to be developed also than organisational models and risk decreasing tools and methods (simulation, monitoring, etc.), in line with the new paradigm of social innovation combining different perspectives in an overall approach (see e.g. the Horizon 2020 programme).

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 organizational aspects in research or research and development projects, as well as in designing new plants, production lines and products. WG5 started with an exchange of good practice within the different companies engaged and went on to develop new research projects combining technological and behavioral development strategies supporting sustainable, fundamental and continuous improvement of performances towards a zero accident workplaces. This includes strengthening managers' understanding of their role and responsibility in health and safety and to provide managers with an overview of good practices and tools available within the company (see also leadership development).

Innovation management: A comprehensive approach embedding technological innovation in a social innovation process

Requirements concerning labour organisation and labour policy are increasing. The question about conditions of preservation and further development of innovation capacity at the level of organisation of human work will become the central future issue of innovation policy, where economic, technological and social innovations interact. Again, this will be done in line with the EU 2020 Strategy: "Creativity and innovation in general and social innovation in particular are essential factors for fostering sustainable growth, securing jobs and increasing competitive abilities, especially in the midst of the economic and financial markets crisis." (Barroso 2009, Rapid Press Release IP-09-81).

Innovation management from a peoples´ perspective is different from a pure technological perspective. Every technological or economic innovation is also a social innovation because of the social adaption, implementation or refusal of these innovations. Therefore innovation management has to be seen as new strategies, concepts, ideas and organisational models to meet social needs of the employees. Within joint initiatives between ESTEP, companies and universities research (even from other industry sectors than the Steel Industry) innovation management will be fostered or initiated by the development of innovation

- to create, develop and implement innovation in different fields like organisational development, work practices, collective intelligence, knowledge and change management
- to foster the ability to change practices taking into account constraints and opportunities, to lead change, to take into account new expectations from personnel and society
- to advance working conditions and to enable work place innovation.

Taking this approach serious the integration of technological innovation within social innovation processes (every technological innovation is a social innovation as well) a more intensive co-operation between WG5 and the other working groups is intended.

Attracting and retaining qualified people: The ground for a competitive steel industry

Due to the relevance of the steel industry for the industrial European added value and to ensure the ongoing competitiveness of a safer, cleaner and more technologically developed steel industry, a highly skilled workforce is required. In fact, highly skilled people are the vital resource for the industrial added value in Europe today and tomorrow.

For this very reason it will be the sufficient supply of qualified and trained workforces which will decide the future success of businesses. Current and future social challenges like demographic change, an over aged workforce, skill shortages and others have to be proactively solved by the steel companies within competitiveness with other advanced manufacturing industries.

Therefore the steel industry is developing its capacity to attract, recruit and retain highly skilled workers in a com-

petitive labour market. It will be people, independent of organisational or technical innovations, which will create innovation and success in the end. The challenge is

- 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?

Actions to be implemented of the WG5 are

- surveys to evaluate the attitudes of school pupils and students towards the steel industry
- concepts and activities to promote the image of the steel industry
- supporting resources and teaching for technical education (mathematics, physics, chemistry, design, technology and engineering)

Talent Management: Crucial for Current and Future Innovation and Competitiveness

Talent management is one of the main current and approaching challenges for the competitiveness of the European steel industry in particular and the European economy in general. In line with the main European strategies[2] high qualification and competence of the workforce is seen as the prerequisite for the European industrial added value. In particular the steel industry of today with its high-tech production processes needs young talents to keep its European companies competitive by a continuous improvement of innovation in products and production (technologically, organisational, and environmental).

Of course, talent management is primarily a company's task and enormous activities and strategies already put in place by steel companies: Events, fairs, target group specific and young potential programs, mentoring and management training programs, internship and trainee programs, systematic personnel development. Cooperation between steel companies and schools and universities seems quite normal nowadays. These activities are adjusted to short-term recruiting as well as to long-term retention and attractiveness.

The performance of talent management includes all phases of lifelong learning: it runs from informing and explaining pupils about technical professions in industry at (primary and secondary) schools over to students and graduates. The development of talents comprises systematic measures in personnel development and target group oriented training seminars and coaching for all workforce members.

Collaboration between companies, regional and local education, training institutions, job centers, vocational schools, "steel related" universities, and also primary and secondary schools, management and training academies as well as faculties and universities have to be developed further in a more reliable way. New kind of co-operations like dual study, pathways between higher education and vocational education have to be established between companies and educational systems and in between the different educational systems.

A comparative analysis of enterprise approaches as learning organisations will help to analyse the critical factors for success and constraints for future innovation and competitiveness.

Leadership development: The key for human resources and innovation development

Leadership development is a key element for innovation processes, including all the other research and development topics. It is the ground to support and promote new training methods and packages, to ensure knowledge management, but also to promote innovation management, health and safety, talent management and attracting and retaining qualified people.

Within its research and development activities WG5 will focus on the support and promotion of new training methods and packages to improve leadership competences as well as on activities to support knowledge management within and across the companies.

2.6.3. Social Responsibility and inclusive business

Beyond the people slogan and the classical orientation towards Human Resources, a broader vision of social responsibility has emerged, exemplified for example in the Corporate Social Responsibility reporting (CSR) that business has been issuing for some year now.

Overarchingly, Europe 2020 strategy aims at fostering growth with smart, sustainable, and inclusive dimensions. Together with governments and ONG, the steel sector, as part of the process industry, is a critical player of this agenda and its commitment calls for a new business model in the private sector. Steel is indeed clearly committed to sustainable development, as explained in the Planet section of this SRA. However, the social value of steel and of materials, more generally, is often forgotten in the debate, because social is often limited to people (HR) and the impacts of activities developed among stakeholders is not easily nor frequently measured in a quantitative way.

An ambition of ESTEP is thus to demonstrate the role and the social value of steel in a modern and greener economy.

To address this ambition, different approaches ought to be developed. For instance, one approach will be the development of inclusive business, defined as profitably engaging low-income populations across companies' value chains and developing affordable products and services that meet the needs of low-income populations. By engaging locally through concrete activities, the steel sector ought to support the sustainable growth of the so-called Base of the Pyramid (BOP) to better understand the needs and constraints of this population, which indeed constitutes both suppliers and future clients. ESTEP will draw lessons from experiments, identify stakes, challenges, and opportunities, and propose actions to leverage on good practices.
A second approach, inspired from the well-being indicators proposed by OECD, will develop methodologies to value this social responsibility commitment, for example the contributions to income and wealth, Jobs and earn-

[2] Particularly Europe 2020 strategy and its flagship initiative "An Agenda for New Skills and Jobs", Communication Paper on Integrated Industrial Policy putting competitiveness at centre stage

ings, health and safety, environmental quality, education and skills, civic engagement and governance, etc. These indicators would of course eventually be combined with environmental and economic indicators to provide a comprehensive sustainability metrics.

Other approaches will materialize, as steel companies are often international groups with social influence in the countries where they are doing business. They ought to be able to react rapidly at world-wide level by collaborating with the major economic and scientific actors and thus will become key innovation drivers in the transition to a more sustainable world!

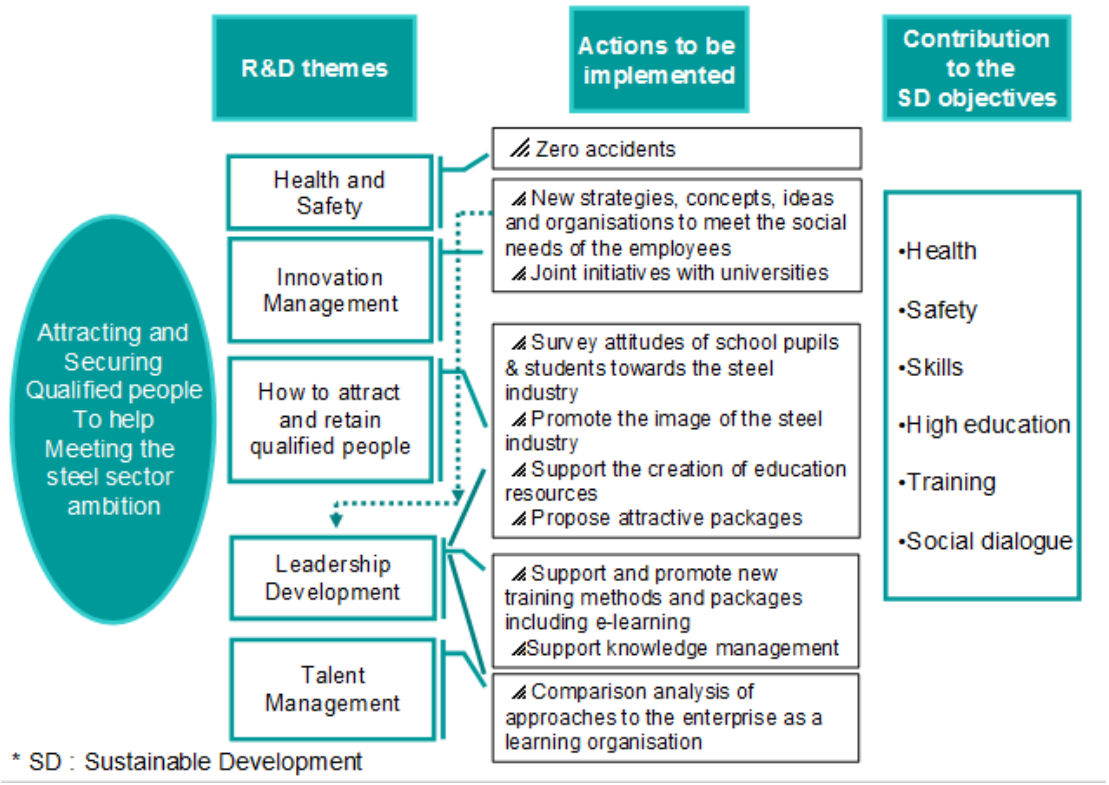
2.6.4. Socio-economic dimensions

- 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.

2.6.5. Stakeholders

- Steel sector
- European universities dealing with steel developments
- Steel research centres
- Unions organisations
- Stakeholders in the European Steel Technology Platform

Figure 17: Attracting and securing qualified people to help meeting steel sector's ambition



PART 3. OVERALL VIEW OF ESTEP'S SRA AND CONSISTENCY WITH HORIZON 2020

This new SRA offers a global vision of the innovation and R&D&I efforts that should help the steel sector and its value chain reach the objectives highlighted by ESTEP to retain a sustainable world leadership of the sector in the coming decade.

Priorities have been identified for the themes and R&D&I areas of the three industrial programs of ESTEP and of the 6 domains described in the previous chapters

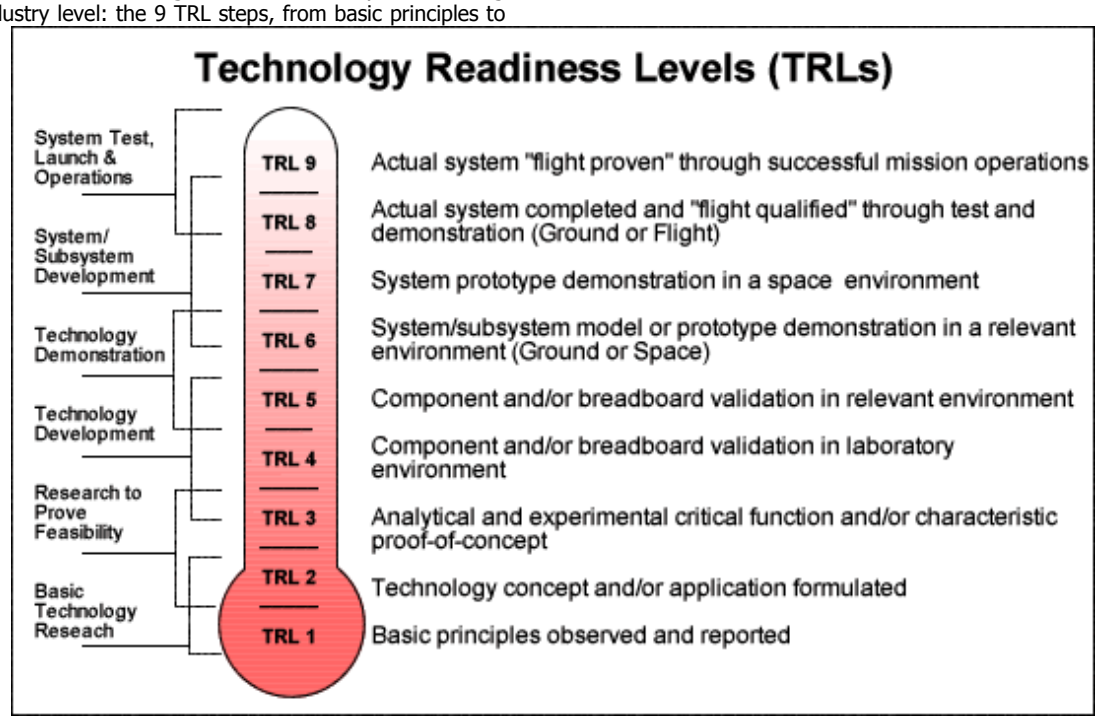
- Sustainable steel production
- Safe, cost-effective and lower capital intensive technologies
- Steel solutions for transports
- Steel solutions for construction and infrastructures
- Steel solution for energy
- Attracting and securing qualified people for the steel sector.

Another important aspect of this program is to cover the whole chain of innovation, addressing basic and applied research, pre-industrialization and deployment. The activities of the research & innovation cycle can be represented by the Technology Readiness Levels (TRLs). This methodology has become recognized internationally and is being at industry level: the 9 TRL steps, from basic principles to market commercialization are shown in Figure18.

In the next chapter (4-Implementation), a deployment scheme will be proposed for the different R&D&I themes over the next decade, using TRL methodology.

Private funding from stakeholders as well as public funding from the EU, National and, possibly, Regional institutions will be necessary to implement the 3 industrial programs and a transversal one.

Figure 18: TRLs describing the whole chain of innovation



3.1. Horizon 2020

The new Research & Innovation roadmap proposed by the European Commission [3] has been carefully analyzed by the ESTEP Working Groups, and this revised agenda already includes the topics which are relevant to the steel sector.

Within Horizon 2020, the implementation would follow 3 key priorities:

- Excellent science
- Industrial leadership
- Societal challenges

For *Excellent Science,* one of the challenges for the steel sector is to attract talented young researchers and to offer better career prospects within our industry. Another objective is for ESTEP to work closely with Universities and engineering high schools for developing the different domains of European science in order to meet challenges of the steel industry of the future.

For *Industrial Leadership,* the proposals of the EC to enhance the KETs (Key Enabling Technologies) are welcomed by ESTEP. In particular, the 2 items "advanced materials" and "advanced processing and manufacturing" are developed in the present revised roadmap.

For *Societal Challenges,* the most relevant items for the steel sector are "secure, clean and efficient energy", "Smart, green, and integrated transport", "climate action, resource efficiency and raw materials" and "inclusive and innovative societies".

Horizon 2020 also marks a new start and a new ambition for R&D&I with a clear need to identify strategic targets and expected impacts. It is a new way of working, putting everyone together to promote not only research, but also innovation, in order to make the link with market expectations. In this context, the European Technology Platforms have a key role to play. We have to create the bridge from science and knowledge to users and customers, transforming results into industrial reality.

This implementation of this SRA should take place between 2014 and 2020 for both Horizon 2020 and the Research Fund for Coal and Steel (RFCS) activities.

The Research Fund for Coal and Steel program should refer to the SRA in formulating the annual priorities, looking for a significant number of projects in line with the SRA and these priorities.

ESTEP has been involved already in the preparation of Horizon 2020, especially within the Public Private Partnerships, the Key Enabling Technologies, and some of the European innovation Partnerships (EIP) such as Raw Materials, Water Resource and Key Enabling Technologies.

[3] Reference: COM(2011) 808 final – Horizon 2020 - The Framework programme for Research and Innovation
COM (2011) 809 final - Establishing Horizon 2020
COM (2011) 810 final - Changing down the rules for participation and dissemination in Horizon 2020
COM (2011) 811 final - Establishing the specific programme implementing Horizon 2020

3.2. Public Private Partnerships

At the end of 2008, the onset of the economic crisis, the European Union launched its Economic Recovery Plan, based on the need to reinforce Europe's competitiveness through innovation. Three Public Private Partnerships (PPP) were created: Factories of the Future (FoF), Energy Efficient Building (E2B) and the European Green Cars Initiative now called the European Green Vehicles Initiative (EGVI). The steel sector decided to participate to these three research PPPs. Some of ESTEP' stakeholders are already involved in these PPPs, as partners in several FP7 calls. ESTEP is in favor of pursuing these three PPPs within Horizon 2020: the themes and some areas developed in chapters 2-1, 2- 2, 2-3 and 2-4 are well in line with FoF, EGVI and E2B:

- **FoF**, Factories of the Future. The new 2020 roadmap identifies significant impact for the whole value chain of production, with increased value added by advanced processing and manufacturing. The environmental impact makes reference to the reduction of energy consumption, of waste generation as well as the consumption of materials, well in line with themes and areas of chapters 2-1 and 2-2. The most relevant domains of Research & Innovation proposed by FoF are: processing novel materials, advanced joining technologies, material efficient manufacturing, product life cycle management for advanced materials, adaptive and smart manufacturing systems, intelligent maintenance systems, energy monitoring and customer-focused manufacturing.
- **EGVI**, European Green Vehicles Initiative. The objective of this PPP in Horizon 2020 will be "energy efficiency of vehicles and alternative powertrains", including electrification, hybridization, advanced Internal Combustion Engines and adaptation to alternative fuels. The roadmap proposes the development of technologies at all product layers from modules to systems and vehicles. Chapter 2-3 of this SRA is well in line with the domains "modules" and "systems" of the EGVI roadmap. The development of resources, like new steel products, is not directly in the scope, but the integration of resources for the definition of modules and systems is covered. The application of new materials leading to the weight reduction of a module is given as an example.
- **E2B**, Energy Efficient Building. The new roadmap aims at developing R&D&I activities covering the components of the value chain of production. Some of them are fully relevant to chapter 2-4, promoting steel- based solutions for construction: structural parts where material processing innovation will allow further reducing CO2 embodied footprint of the structural components over the life cycle of new buildings, building envelopes reducing heating/cooling demands by a smart use of renewable energies, construction processes combining pre-manufacturing of critical components and self inspection/automation of construction, end-of-life optimization in view of recycling/reusing demolition waste.

Building on the experience of the PPPs under the European economic recovery plan, the European commission considers that within Horizon 2020 " there will be greater scope for establishing such Partnerships without recourse to new legislatives procedures". That is why through cross-sectorial contacts with other ETPs and associations, Estep is involved so far for proposing new PPPs within Horizon 2020:

- **SPIRE**, Sustainable Process Industries through Resource and Energy Efficiency. The steel sector is one of the main European process industries producing structural materials and ESTEP is one of the founding members of this initiative, well in-line with the chapters 2-1 and 2-2 of our roadmap.
- **EMIRI**, Energy Materials Industrial Research Initiatives. The purpose is to develop materials solutions for the production of energy, both for conventional means of production (fossil fuel, nuclear) and for renewable energy (wind turbines, photov oltaics, concentrated solar, etc.) ESTEP is a partner in the project, well in-line with chapter 2-5.

3.3. European Innovation Partnerships

The **European Innovation Partnerships** (EIPs) have been proposed by the European Commission as part the flagship initiative Innovation Union, communicated at the end of 2010. ESTEP has been involved in several EIPs, which will help coordinate with Horizon 2020 over the period 2013-2020.

- **The Raw Materials Initiative**, dealing with the issues of sustainable supply of raw materials. ESTEP is active within work package 1, Developing New Innovative Technologies and Solutions for Sustainable Raw Materials Supply, especially in the area of "secondary" raw materials providing innovation for the valorization of waste and by-products. ESTEP also participates to work package 2, Substitution of Critical Materials, providing inputs for steel alloying elements.
- **The Water Resource Initiative**, dealing with the sustainable use of water in the industry. ESTEP has worked closely with the Water Technology Platform (WssTP) in order to identify new topics of R&D&I for a better use of water in the steel industry (chapters 2-1 and 2-2).
- **Key Enabling Technologies** (KETs). ESTEP is active for two KETS: Advanced Materials (steel is of course an advanced material) and Advanced Manufacturing and Processing. For this last KET, it is important to notice that our SPIRE initiative is well in-line with what was proposed in the HORIZON 2020 communication for increasing the competitiveness of process industries by drastically improving resource and energy efficiencies.

3.4. Other initiatives

The **SET-Plan**, Strategic Energy Technology Plan, adopted by the European Union in 2008, aims at establishing an energy technology policy for Europe over the next 20 years. The implementation of the SET-Plan started with the establishment of the European industrial Initiatives (EIIs), aiming at the rapid development of key energy technologies at European level for the production of renewable and conventional energy. ESTEP participated actively to the preparation of the materials roadmap of the SET-Plan, proposing innovative material solution for energy production and energy efficient buildings[4] . Chapters 2-4 and 2-5 of our SRA are well in line with this material roadmap. The SET-Plan includes also initiatives for the "energy intensive industries" like chemicals, cement, metal, which have since been renamed process industries. In 2011 a technology map was written for the European iron & steel industry[5] and, in 2012, the JRC (Joint Technology Center) carried out a technological forecasting study based on scenario modeling and focusing on energy efficiency and CO2 emissions in the EU iron & steel industry from now till 2030[6]. ESTEP and its stakeholders have contributed to this work and the chapters 2-1 and 2-2 of our SRA are consistent with the SET-Plan view.

The **Strategic Transport Technology Plan** (STTP), adopted by the European union in 2011 , sets ambitious objectives for reducing Europe's dependence on imported oil, improving the environment, reducing accidents and sharply cutting greenhouse-gas emissions. In 2012, a Research & Innovation approach was proposed for this STTP[7], identifying three main areas for R&D&I:

- Clean, efficient, safe, smart transport means
- Infrastructure & and smart systems
- Transport services and operations for passengers and freight

With regard to means of transport, the development of clean and safe vehicles proposes the R&D&I areas of the Green Vehicles PPP initiatives. Trains and vessels are also in the scope. The plan includes development in components, materials and enabling technologies where steel has a role to play (cf. chapter 2-3).

In the area of infrastructure, progress is needed on smart, green, low-maintenance, climate-resilient infrastructures at competitive costs. ESTEP supports the **reFINE** initiative ("research for Future Infrastructure Networks in Europe"), proposed by the European Construction Technology Platform (ECTP) (cf. chapter 2-4). The reFINE project has written a research roadmap, to be implemented in the next decade, on three main infrastructures areas for transportation: multimodal hubs, urban mobility and long distance corridors. A transversal theme on "materials & associated construction processes" is of the utmost interest for the steel industry.

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[4] SEC (2011) 1609 Final- Materials Roadmap Low Carbon Energy Technology

[5] SET-Plan 2011 Technology Map- EUR 24979 EN-2011

[6] JRC Scientific and Policy Reports-2012- prospective Scenarios in Energy Efficiency and CO_2 Emissions in the EU Iron and Steel Industry

[7] COM (2012) 501 final – Research and Innovation for Europe's future mobility developing a European Transport Technology strategy

The Alliance for Materials, A4M. The driver for this A4M collaboration is to ensure a value-chain coverage in the frame of Materials R&D for improving the speed of implementation of innovation within Horizon 2020. Created in 2011, and initiated by EuMaT, the European technology Platform for Advanced Engineering Materials and Technologies, A4M gathers six ETPs with a strong materials agenda in their respective strategies: EuMaT, Suschem (the chemicals platform), Manufuture (the platform on manufacturing), FTC (the platform for textiles), ESTEP and SMR (the platform on mineral resources). Materials R&D is by definition a crosscutting and enabling technology area that affects every industrial sector. This value-chain coverage is essential for the steel applications and ESTEP is active within A4M for contributing to this coordination need along the value-chain of production.

The flagship initiative "an agenda for new skills and jobs". When defining the Europe 2020 strategy in 2010, the European Commission was putting forward flagship initiatives, and one of them is targeting new skills and jobs.[8] Our ESTEP transversal group for attracting and securing qualified people takes into account this challenge for new skills and jobs in the steel industry, especially when proposing cooperation in education and training involving universities and social partners.

[8] COM (2008) 868 final - New skills for new jobs - Anticipating and matching labor market and skills needs.

PART 4. IMPLEMENTATION OF THE SRA

As regards implementation of this SRA, both private and public sources of funding are necessary to meet the ambitious objectives of the European steel sector. It is foreseen that all necessary resources of existing instruments will be combined at different levels.

These include:

- Horizon 2020 and RFCS as described in the previous chapter
- EU Life Long Learning Programme
- National programs and
- Regional programs

4.1. Indicative timeline for the SRA's implementation

The first priorities of this updated SRA will target projects that can generate impact on the short term and the medium term, within the period of Horizon 2020, 2014-2020,

The remaining part (second priorities) should be implemented over the long term, over a period of 10-20 years (2020-2030).

We present 6 templates, one per chapter of the main domains of research, giving indications for the implementation of themes and areas.

4.2 Implementation Chapter 2-1 : Sustainable Steel Production

Themes	S1 2013	S2 2013	S1 2014	S2 2014	S1 2015	S2 2015	S1 2016	S2 2016	S1 2017	S2 2017	S1 2018	S2 2018	S1 2019	S2 2019	S1 2020	S2 2020	beyond 2020
LCA, LCT and sustainability assessement	TRL1							TRL7									
resource efficiency and preservation		TRL3									TRL9						
new energy implementation			TRL3					TRL9									
climate changes solutions	TRL7 (ULCOS-BF)	TRL4 (Ulcolysis)			TRL8 (HIsarna)			TRL5 (ULCORED)							TLR9 (ULCOS-BF)	LR8 (Ulcolysis)	TRL-9 (Hisarna) TLR9 (Ulcolysis) TLR9 (ULCORED)
ecodesign process & steel solutions	TRL3								TRL6							TRL9	
industrial ecology solutions with tohers		TRL9/TRL3			TRL9			TRL3					TRL9				
biomass																	
biodiversity and ecosystem services					TRL2									TRL8			
logistics scarcity & efficiency issues																	
close-loop steel economy	TRL5				TRL9						TRL3					TRL9	
other global environmental issues			TRL1					TRL9									
(eco-) toxicity																	
other issues for adpating to major paradigm shifts			TRL1									TRL5					

TRL: Technology Readiness Levels from TRL1 to TRL9

4.3. Implementation Chapter 2-2: Process of Production: safe, cost effective and lower capital intensive technologies

Themes	S1 2013	S2 2013	S1 2014	S2 2014	S1 2015	S2 2015	S1 2016	S2 2016	S1 2017	S2 2017	S1 2018	S2 2018	S1 2019	S2 2019	S1 2020	S2 2020
Safety at work		R			R, P				P, I				I			
Casting, rolling & thermo-mechanical production for near net shape processing							R, P				P		I			
Higher energy efficiency of the BF-BOF route		P					I									
Direct and alternative input of energy in EAF			R, P				P, I									
Leaner use of raw materials and alloying				R			P				I					
Adapted processing routes for advanced high strength steels			R, P				P, I									
Integrated Intelligent Manufacturing (I2M)		R, P					P, I									
Process integration and flexible multi-functional routes				R			P				I					

R: Research & development phase
P: Pilot phase
I: Demonstration & Industrial Implementation

4.4.Implementation Chapter 2-3: Steel applications for transport

Themes	S1 2013	S2 2013	S1 2014	S2 2014	S1 2015	S2 2015	S1 2016	S2 2016	S1 2017	S2 2017	S1 2018	S2 2018	S1 2019	S2 2019	S1 2020	S2 2020
Body solutions for lightweight and improved safety		R			R/P				R/P/I		R/P/I					
Power train solutions for improved drive dynamics		R					R/P				R/P/I					
Chassis solutions for improved drive dynamics				R				R/P			R/P/I					
Dismantling and recycling of cars with complex components							R				P, I					
Steel solutions for new car concepts (hybrid, electric)		R			R/P						R/P/I					
Transfer of knowledge to commercial vehicles						R/P			R/P/I							
Transfer of knowledge to railway sector								R/P			R/P/I					

R: Research & development phase
P: Pilot phase
I: Demonstration & Industrial Implementation

4.5. Implementation Chapter 2-4: Construction & Infrastructure sector

Themes	S1 2013	S2 2013	S1 2014	S2 2014	S1 2015	S2 2015	S1 2016	S2 2016	S1 2017	S2 2017	S1 2018	S2 2018	S1 2019	S2 2019	S1 2020	S2 2020
Structural Safety		R			R, P				P, I				S			
Improved health and comfort through steel-intensive construction							R				R,P		I			
Energy efficiency in steel construc-tion		R			R,P				P,I							
Structural quality in renovation					R				P				I			
Improvement of urban environment and infrastructures							R				R,P		I			
Recyclability, reuse and durability			R				I		S							
Life Cycle Thinking Life Cycle assessment		R			R,I											
Other																

R: Research & development phase
P: Pilot phase
I: Demonstration & Industrial Implementation
S : Standardisation

4.6. Implementation Chapter 2-5 : Energy Sector

Themes	S1 2013	S2 2013	S1 2014	S2 2014	S1 2015	S2 2015	S1 2016	S2 2016	S1 2017	S2 2017	S1 2018	S2 2018	S1 2019	S2 2019	S1 2020	S2 2020
Energy transportation: Oil & Gas						R				P			I			
Energy transportation: Non-standard fluids including CO2		R					P				P			I		
Power Generation Efficiency improvements		R			P			I								
Renewables: Wind		R			P						P, I					
Renewables: PV		R					P				I					
Renewables: CSP			R, P				P, I									
Renewables: Biomass		R					P				I					
Hydrogen		R			P						I					
Marine Energy		P						I								

R: Research & development phase
P: Pilot phase
I: Demonstration & Industrial Implementation

4.7. Implementation Chapter 2-6: People

Themes	S1 2013	S2 2013	S1 2014	S2 2014	S1 2015	S2 2015	S1 2016	S2 2016	S1 2017	S2 2017	S1 2018	S2 2018	S1 2019	S2 2019	S1 2020	S2 2020
Health and Safety		RFCS			P	RFCS			P	RFCS			P	RFCS		
Innovation Management	P	P	H20	R	R	R	H20	D			H20	R	R	R	R	D
Attract and Retain Qualified People	R	R	E4A					R	E4A			P	E4A			
Leadership Development			P	P	E4A	R	R	R	R	D	E4A	R	R	R	R	D
Talent Management			R	R	P	P	E4A	R	R	R	D			P	E4A	

P: Exchange of Best Practice
R: Research and Development
A: Acquisition of Projects: Erasmus for All (E4A), Horizon 2020 (H20), Research Fund Coal and Steel (RFCS)
D: Dissemination (Conferences, Events, etc.)

A platform for the future
The European Steel Technology Platform (ESTEP) brings together all the major stakeholders in the European steel industry. Our membership includes major steel manufacturers; universities and research institutions active in steel research; major users of steel such as car manufacturers; and public bodies like the European Commission and national governments – which have great interest in this vital industrial sector that is so important for Europe's future.

Creating growth and jobs
The European steel industry is a key contributor to economic growth and employment in Europe and a global leader in steel technology. It generates around EUR 200 billion in turnover and provides jobs to over 350 000 Europeans. It is also the source of millions of additional jobs in other industrial sectors that use steel – such as car manufacturing and construction. This is why it is so important to ensure that ESTEP's members maintain their global leadership and consistently improve their competitiveness.

Forging a vision
ESTEP's ambition is to maintain and reinforce the global leadership of the EU steel industry. This means using research and innovation to develop new products and processes that will foster competitiveness while meeting both growth and environmental targets. To achieve this ambition, ESTEP has launched a Strategic Research Agenda (SRA) that sets out what must be done over the coming decades. The SRA proposes three large and complementary industrial programmes that are now being implemented by ESTEP's working groups.

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