European Commission

European Steel

The Wind of Change

Energy in Future Steelmaking
Steel in the Energy Market Applications
Greening European Steel



Research and Innovation

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Edited by Prof. Nigel Lucas and Dr. Domenico Rossetti di Valdalbero

Directorate-General for Research and Innovation
2018 Key Enabling Technologies EN

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FOREWORD

The EU is the second largest producer of steel in the world with an output of more than 160 million tonnes per year. This includes a large quantity of advanced high strength steels used in hi-tech applications. Steel plays a fundamental role in many key industrial sectors such as transport and the automotive industry, construction, robotics, advanced machinery and tooling, and home appliances.

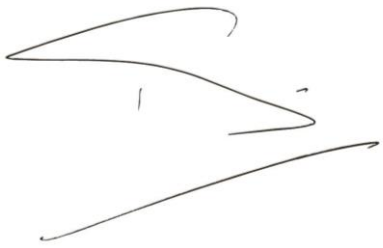
Steel is, therefore, vital to the EU economy, which is why steel production is highlighted as a strategic sector in the European Commission's proposal for 'A renewed EU Industrial Policy'. But steel production is an energy-intensive industry, responsible for 30 % of EU industrial CO_2 emissions. How can we square this circle?

What is clear is that no single company or even Member State can do this alone. We need a pan-European approach to drastically reduce industrial greenhouse gas emissions over the next decades. The Commission supports new clean and smart investments, including research and demonstration of low carbon technologies in the energy-intensive industry through its Investment Plan, Horizon 2020 and the Research Fund for Coal and Steel. Substantial incremental progresses have been made by the steel industry in collaboration with research centres and universities through these programmes, but this is still far from being sufficient to achieve the European energy and environmental targets for 2030 and 2050. We must do more.

In the pages that follow, the deliberations of steel producers, experts, policy and decision makers are brought together to set out a vision for the future as well as identify the technological paths that will lead us there. The report highlights the need to work together to develop the new and innovative technologies that will safeguard the long-term competiveness of European steel production while at the same time minimising its carbon footprint.

The bottom-line is that to build industrial leadership and foster a vibrant innovation ecosystem in the steel sector, both public and private sectors across the EU must commit to substantial investment in research and innovation.

Robert-Jan Smits
Director-General for Research and Innovation
European Commission



TECHNOLOGICAL RENEWAL FOR AN EU STRATEGIC INDUSTRY

This report resumes the deliberations of an important seminar entitled "European Steel: the wind of change" held in Brussels on the 31st January, 2018. Hosted by the Directorate General for Research and Innovation (DG RTD) of the European Commission, the meeting attracted over 100 invited participants from across the EU, including senior staff from the major steel producing companies and trade associations, the European Parliament and different services of the European Commission. The purpose of the seminar was to explore the prospects for a substantial joint programme of work between the industry and European institutions that would secure the commercial future of a vital strategic industry whilst simultaneously adapting its technological basis to new green processes. The seminar presentations (and the list of participants) are available on the Europa web site. The last year seminar reports are also available[1].

Mr Peter Dröll, the Director of Industrial Technologies in DG RTD of the European Commission opened the seminar together with Mr Reinhard Bütikofer a Member of the European Parliament, member of the Parliamentary Committee on Industry, Research and Energy and vice-chair of the Parliamentary Delegation for relations with the People's Republic of China.

A strong and competitive steel industry

Mr Dröll emphasised the importance of its steel industry to Europe. The strategic importance of the industry has been recognised since the earliest days of European integration; the ECSC Treaty, signed in Paris in 1951 was intended to create free movement of coal and steel and free access to sources of production, precisely because these resources were of strategic value and fundamental to economic growth. Much has changed since then, but Mr Dröll stressed that steel remains a key part of industrial value chains, closely linked to many downstream industries such as transport, construction, manufacture, space, defence, and energy. The EU is the second largest producer of steel in the world after China; its output of more than 160 million tonnes of steel a year represents 10 % of global output. The industry has a significant cross-border dimension; 500 production sites across the Union employ more than 300,000 people in 23 Member States.

In the early days of the ECSC the problem was to create fair access and reform oligopolistic markets. Today market conditions are entirely different. After the financial crisis of 2008, global demand for steel diminished overcapacity in some countries stimulated unfair competition that severely affected European producers. The Commission reacted firmly. Now the situation is better, although not yet fully satisfactory. The issues and actions were addressed in an earlier seminar and a discussion can be found in the associated report[2].

Despite its decisive recent actions in favour of the industry, steel still remains high on the agenda of the European Commission: the report by a High Level Group on maximising the impact of EU Research & Innovation Programmes (Lamy report) called for a mission "*producing steel with zero CO2 emissions in Europe by 2030"*;[3] and the renewed EU Industrial Policy Strategy, adopted on 13 September 2017, draws attention to the special measures already adopted for particular industries such as steel, space and defence to complete and extend industrial policy[4].

A joint and ambitious partnership ensuring sustainability

Technological, process and social breakthroughs are required to secure the industry for the future. 'European steel' should be cost-effective, safe and reliable and conform to the constraints of a circular economy, but it should also integrate new business models and social innovations, develop new applications for high-steel products and promote dynamic skills answering to the Industry 4.0 requirements in terms of automation, data sharing and management[5].

Mr Dröll affirmed that the scale and scope of the effort required to develop and deploy new technologies for steel production and new steel products goes beyond the capacity of a single

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[1] The Future of European Steel: innovation and sustainability in a competitive world and EU circular economy. European Commission, DG RTD, Luxembourg, 2017 and Smart Steel – RFCS: supporting steelmaking and use in the 21th Century, European Commission, DG RTD, Luxembourg, 2016.
[2] The Future of European Steel, op. cit.
[3] LAB - FAB - APP - Investing in the European future we want, European Commission, DGRTD, Luxembourg 2017.
[4] Investing in a smart, innovative and sustainable Industry: a renewed EU Industrial Policy Strategy, Communication from the Commission, COM (2017) 479, Brussels, September 2017.
[5] See for example. Industry 4.0, Study for the ITRE Committee, European Parliament. 2016.

company or a single national public research institution. Industrial policy and technological developments should take into account citizens' concerns. Impacts and successes should also be measured across society. Europe should transform its potential into reality and become leader in technological, regulatory, social and business-model innovation.

Discussions on a "Post Horizon 2020" EU programme for research and innovation are now well underway following the Lamy report[6], the debate on the Framework conditions for high-growth innovative enterprises[7], and the report on the Economic Rationale for Public R&I funding and its Impact[8]. The different "Post Horizon 2020" programme 'clusters' of R&I activities start to take shape and the role of the European Innovation Council (EIC) becomes clearer.

Open but not dumb

Mr Reinhard Bütikofer offered a political perspective in which to position Mr Dröll's exposition of the technical, economic and legislative background for the seminar. He began by noting that it might seem odd to find a green-thinking MEP introducing a seminar on the steel industry, but he saw no contradiction between support of the industry and safeguard of the environment: the root problem of the industry is not climate policy, but depressed demand, over-capacity and a lack of innovation. He agreed 100 % that Europe needs a strong competitive steel industry. Steel is a particular case when it comes to climate policy, but nevertheless it must be subject to the same overriding constraints.

He reminded participants that, over the last three years, the Parliament had been proactive in supporting the steel industry and the Green parties had been vocal in that effort. When discussions arose around the Market Economy status of China, many relevant players and institutions were willing to grant China its demands. A part of Parliament in collaboration with industry and the trade unions resisted these pressures: they advocated an approach that was "open, but not dumb". More generally Mr Bütikofer praised the cooperation of Parliament and industry as a vehicle to influence policy. In the matter of scientific potential, he detected an increasingly optimistic note: the prevailing view not so long ago was that the potential for technical progress was exhausted – and this thermodynamic limit was requested by many experts during the seminar - but breakthrough technologies seem to appear.

Mr Bütikofer concluded by reaffirming that he was in favour of sustained support for development of novel steel technologies at all phases from research to deployment, as a quid pro quo for environmental compliance by the industry. He felt the wind of change and wanted to help it along.

Research and Innovation EU instruments

The European institutions have at their disposal a range of instruments that could in principle be deployed to support the technological renaissance and market positioning of the steel industry.

Mr Hervé Martin and Mr Domenico Rossetti of DG RTD joined Mr Roman Doubrava of DG CLIMA to guide participants through these EU instruments.

Mr Martin began by elaborating on the importance given to steel within the political agenda of the EU touched upon by Mr Dröll in his introduction. He noted the Commission Communication on steel of March 2016 that included both new short-term measures to strengthen the defence against unfair trade practices, as well as long-term action to guarantee the competitiveness and sustainability of energy-intensive industries[9]. Steel also was well-represented in the first European Industry Day held on 28 February 2017 in Brussels that brought together more than 400 key industrial players and high-level policy makers to debate on the future of European industry. The event included speeches from Commission President Jean-Claude Juncker, Vice-President Jyrki Katainen, and European Commissioner Elżbieta Bieńkowska[10]. Following that event, EUROFER hosted the European Steel day on 10 May 2017 to investigate the potential for CO2 mitigation with steel and using steel, and the impacts of digitisation and industry 4.0. Ms Elżbieta Bieńkowska, the European Commissioner for Internal Market, Industry, Entrepreneurship and SMEs provided a

[6] Lamy, op. cit.
[7] Framework conditions for high-growth innovative enterprises (HGIE), DG RTD, Luxembourg, 2017.
[8] The Economic Rationale for Public R&I funding and its Impact. Policy Brief Series, DG RTD, Luxembourg, March 2017.
[9] Steel: Preserving sustainable jobs and growth in Europe, Communication from the Commission, COM (2016) 155, Brussels, 16.3.2016.
[10] First European Industry Day - Summary of the discussions, DG GROW, 2017.

keynote address; Mr Jean-Claude Juncker and Mr Antonio Tajani, the President of the European Parliament addressed the conference by video.

As a part of the deliverables of the Energy Union, the European Commission has adopted a Communication for an Integrated Strategic Energy Technology Plan. The Plan identifies ten priority actions; Action 6 aims to make EU industry less energy intensive and more competitive; it contains a list of priorities for various energy-intensive industries including the steel industry[11]. The Commission has also acted to protect the industry from unfair international competition. On 13 September 2017, in his annual State of the Union address, President Jean-Claude Juncker announced measures to strengthen the European trade agenda and in particular its defences against dumping[12]. On the same day the Commission announced the renewed EU industrial policy[13].

Mr Domenico Rossetti explained the instruments at present available to support the adaptation of the industry. Of direct interest to the steel community is the Research Fund for Coal and Steel (RFCS) managed by Unit D4 of DG RTD with inputs from Member States and advisory groups. Finance for this Fund come from revenues arising from the historic assets of the European Coal and Steel Community: about 73 % of the funding is allocated to steel. The legal structure of the Fund is based on 37 of EU Treaty and Council Decision in 2008[14] with subsequent amendments to adapt arrangements to the expiry of the ECSC Treaty; the research objectives are specified in the Decision and may be summarised as:

- Conservation of resources and improvement of working conditions
- New and improved steel making and finishing techniques
- Utilisation of steel

The available RFCS budget is around € 30 million for steel research.

RFCS priorities are set annually. The current priorities for steel are listed in the **Table 1**. At present some 150 steel research projects are on-going through these funds; the scheme lies outside Horizon 2020, but procedures are similar and are closely coordinated with those of the EU Framework Programme.

Steel annual priorities 2018
➢ Embedded real-time analytics of large data streams to predict reliability of steel production plants and processes or to realise machine supported decisions on steel product quality along the production chain or to improve flexibility of production scheduling including human sustainable ergonomic aspects.
➢ Improvement in resource or energy efficiency in iron or steelmaking processes, by use of by-products/residuals or waste heat.
➢ Pilot/demonstration projects or Accompanying Measures of emerging and innovating technologies leading to energy efficiency improvements and CO2 emission reduction

Table 1. RFCS steel priorities in 2018

Mr Rossetti also pointed out that Horizon 2020 is open to calls for proposals of interest to the steel industry, especially the Industrial Leadership pillar: this pillar aims to accelerate development of the technologies and innovations that will sustain the businesses of the future and to help innovative European SMEs to grow into world-leading companies. There are three components to this pillar. The first part is the programme of "Leadership in enabling and industrial technologies (LEIT)"; this initiative provides dedicated support for research, development and demonstration in, amongst other topics, advanced manufacturing and processing. Other components aim to improve access to finance and to stimulate innovation in SMEs. The interests of heavy industry are covered

[11] Towards an Integrated Strategic Energy Technology (SET) Plan: Accelerating the European Energy System Transformation, Communication from the Commission, C (2015)6317, Brussels, 15.9.2015.
[12] A Balanced and Progressive Trade Policy to Harness Globalisation, Communication from the Commission, COM(2017)492, Brussels, 13.9.2017.
[13] Investing in a smart, innovative and sustainable industry – A renewed EU industrial policy strategy, COM(2017)479, Brussels, 13.5.2017.
[14] Council Decision on the adoption of the Research Programme of the Research Fund for Coal and Steel and on the multiannual technical guidelines for this programme, (2008/376/EC), 29.4.2008 – Council Decision 2017/955, 29.5.2017.

in particular by the contractual public-private partnership (cPPP) known as SPIRE (Sustainable Process Industry through Resource and Energy Efficiency) launched by the European Commission in cooperation with eight process industries, including steel, to develop novel technologies and to promote best practices along all stages of large-scale existing value-chain productions. The intent is to contribute to a resource efficient process industry and to encourage cross-fertilisation among participants. The total contribution foreseen from the European Union budget is € 900 million over the seven-year period of Horizon 2020; a matching contribution should be provided by the private stakeholders. A dedicated European Association known as A.SPIRE comprising a consortium of interests from industry is committed to manage and implement the SPIRE Public-Private Partnership. The steel industry is represented by EUROFER. SPIRE activities are based on a dialogue between participating private and public interests, contained in a 2014-2020 multi-annual roadmap. Topics are co-funded under H2020 in the normal way; those to be addressed in 2018-2020 are listed in the **Table 2**.

SPIRE topics for 2018-2020
➢ Energy and resource flexibility in highly energy intensive industries (IA 50 %) – CE-SPIRE-03-2018
➢ Efficient integrated downstream processes (IA) - CE-SPIRE-04-2019
➢ Adaptation to variable feedstock through retrofitting (IA) - CE-SPIRE-05-2019
➢ Digital technologies for improved performance in cognitive production plants (IA) – DT-SPIRE-06-2019
➢ Improved industrial processing using novel high-temperature resistant materials (RIA) - CE-SPIRE-08-2020
➢ Making the most of mineral waste, by-products and recycled material as feed for high volume production (IA) - CE-SPIRE-09-2020

Table 2. SPIRE topics for 2018-2020

Another Public-Private Partnership (cPPP) of relevance to the steel industry is that for Energy-efficient Buildings (EEB). This programme was initiated in December 2008 under the European Economic Recovery Plan and then brought into Horizon 2020. The multiannual roadmap for the years 2014-2020 proposes research and innovation priorities agreed amongst a wide community of stakeholders across Europe, after an extensive public consultation. The aim is to deliver the technologies needed for the new sustainable and competitive European construction industry. Topics to be covered from 2018 to the end of H2020 are listed in **Table 3**.

EEB topics for 2018-2020
➢ ICT enabled, sustainable and affordable residential building construction, design to end of life (IA) - LC-EEB-06-2018-20
➢ Integration of energy smart materials in non-residential buildings (IA) – LC-EEB-01-2019
➢ New developments in plus energy houses (IA) - LC-EEB-03-2019
➢ Industrialisation of building envelope for the renovation market (IA) - LC-EEB-04-2020

Table 3. EEB topics for 2018-2020

The third area of activity in Horizon 2020 of significant relevance to the steel industry is the Energy Programme (the third Societal Challenge). Within this programme are topics on carbon capture and storage and carbon utilisation, which potentially are of critical value to the industry. **Table 4** lists the outstanding topics.

SC3-Energy topics 2018-2020
➢ Advanced CO2 capture technologies (RIA) - LC-SC3-NZE-1-2018
➢ Conversion of captured CO2 (RIA) - LCE-SC3-NZE-2-2018
➢ Strategic planning for CCUS development (CSA) - LC-SC3-NZE-3-2018
➢ Low carbon industrial production using CCUS (IA) - LC-SC3-NZE-5-2019-2020

Table 4. SC3- Energy topics 2018-2020

Lastly, developing the necessary skills for the future is as important as developing the technology. The Erasmus plus programme caters for this through the Skills Alliances. A Skills Alliance is a transnational project involving industry and training partners that identifies a need for emerging skills in a specific economic sector and translates those needs into vocational curricula. Alliances under Lot 3 of the programme are relevant to steel. Under this Lot, projects develop a sectoral skills strategy that will ensure appropriate quality and levels of skills to support growth, innovation and competitiveness in the sector. The steel industry is one of six industries eligible for this programme[15].

Mr Roman Doubrava of DG CLIMA continued the presentation on instruments with an account of the Innovation Fund. The European Parliament and Council reached an agreement on the revised EU emission trading system (EU ETS Directive), which includes the creation of an Innovation Fund[16]. The Innovation Fund should be endowed with 450 million allowances to support large-scale demonstration of activities in carbon capture and storage, renewable energy and low-carbon innovation in energy intensive industry, including carbon capture and use. The volume of funding derived from the endowment will depend on the carbon price, but is estimated at between € 3 billion to € 11 billion. The funds will be released progressively until 2030. Management of the Fund will build upon experience from the existing NER300 Programme for renewables (and CCS), applying the lessons learned[17]; the scope of activities will be extended to include promotion of low-carbon innovation as summarised in the **Table 5**.

The Fund will be open for big and small projects in all Member States; the first round of support is planned for 2020.

Scope of Innovation Fund
➢ Innovation in low-carbon technologies and processes including CCU, and products substituting carbon intensive ones produced in ETS Annex I sectors
➢ Environmentally safe CCS projects
➢ Innovative RES and energy storage

Table 5. Scope of Innovation Fund

The Commission undertook a wide consultation with experts from energy-intensive industries, the energy industries and financial services to determine the critical design elements of the Fund. A summary of the consultation is available[18]. This consultation revealed that there was no shortage of low-carbon solutions that might be demonstrated in the coming decade: over 80 known technologies were identified that combined could create a wide variety of decarbonisation pathways. In addition, individual industries identified a range of specific incremental and

[15] Erasmus+ Programme Guide, European Commission - DG EAC, 2017.

[16] Proposal for a Directive of the European Parliament and of the Council amending Directive 2003/87/EC to enhance cost-effective emission reductions and low-carbon investments, COM(2015)337, Brussels, 15.07.2015 [to be updated after ETS Directive adoption].

[17] Commission Decision of 3 November 2010 laying down criteria and measures for the financing of commercial demonstration projects that aim at the environmentally safe capture and geological storage of CO2 as well as demonstration projects of innovative renewable energy technologies under the scheme for greenhouse gas emission allowance trading within the Community, 2010/670/EU.

[18] Finance for innovation: Towards the ETS Innovation Fund, Climate Strategy & Partners, June 2017

breakthrough technology options. Many processes could also benefit from incorporating Carbon Capture and Storage/Use, Green Hydrogen, Intelligent Energy Management systems, and the integration of renewable energy and energy storage.

The expert consultation recommended that the operation of the Fund should be flexible because markets, technologies and investments change and evolve rapidly and this can require a change of strategy and evolution in a project. There was substantial support for cooperation across industries to share the financial burden of putting technologies together, with the advantage that such cooperation can lead to cross-fertilisation of ideas and reveal unexpected new value chains and economic benefits.

Recommendations from the consultation pertaining to the financial instruments to be deployed included the advice that financial support for projects should be linked to their risk profile. Different risks may well be mitigated by different instruments at different stages of a project. There was a strong consensus for milestone-based support: project design would include visible milestones that would unlock subsequent tranches of funds. Among the advantages of this approach is the facility to limit support to underperforming projects and redirect funds.

The technologies identified by experts from the steel industry as initial candidates for innovation are shown in **Table 6**. The experts noted also two innovation initiatives that were already active: ULCOS ("Ultra-Low Carbon dioxide (CO2) Steelmaking") comprising a consortium of 48 European entities (including all major EU steel companies, some engineering partners, research institutes and universities) engaged in activities intended to reduce CO2 emissions by at least 50 %; and the CO2 Breakthrough programme (conducted within the world steel organization).

Innovation for low-carbon steel
➢ Improving energy efficiency beyond the state-of-the art
➢ New smelting reduction technologies
➢ Direct reduction technologies, based on natural gas
➢ Direct reduction technologies, based on hydrogen
➢ Direct use of electricity for iron ore reduction
➢ Use of biomass in steel production
➢ More recycling of steel
➢ Other breakthrough solution paths for low-carbon steel production

Table 6. Innovation for low-carbon steel

After this introduction and review of Commission instruments, the core of the seminar was arranged in three parts. The first session dealt with "Energy in Future Steelmaking" and the implications of various economic and technical developments for energy demand and climate change; the second on "Steel in the Energy Market Applications" examined the importance of steel for the development of energy infrastructure and renewable energy technologies, demonstrating the crucial part the material plays in EU energy security. The final session on "Greening European Steel", was devoted to an exploration of the potential for a European Joint Initiative for clean steel and what it might comprise.

ENERGY IN FUTURE STEEL MAKING

The presentations in this session described how energy is used in steel making and reviewed some of the breakthrough technologies that might radically change the relationship between steel production and energy supply. Mr Jean-Theo Ghenda of VDEh Stahlinstitut gave a technical overview of present practice and future options; Ms Helén Axelsson of the Swedish Steel Association described how a country might design a strategy that meets its objectives, based on the case study of Sweden, and Mr Johann Prammer of voestalpine in conjunction with Ms Katharina Rechberger of K1-MET described in more detail some of the technologies that they found particularly promising. The session therefore provided for complementary technical, national and corporate perspectives on this central topic.

A panoply of technological options

Mr Ghenda started from the status quo. There are two main steel production routes in EU: the Blast Furnace – Basic Oxygen Furnace (BF/BOF) route and the Electric Arc Furnace (EAF) route; they are shown schematically in the **Figure 1**.

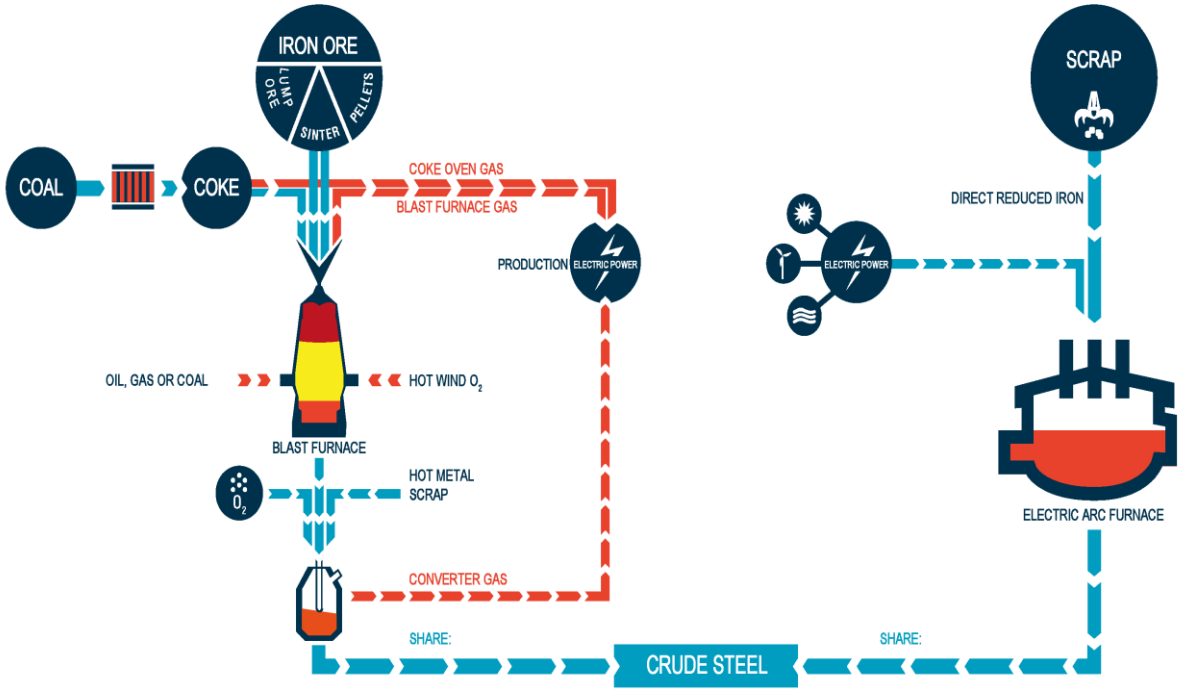


Figure 1. Steel Production routes in the EU

The BF/BOF route is based on iron ores and carbon as the reducing agent with addition of steel scrap. The EAF route is based on steel scrap and electric power to melt the scrap. The two routes are complementary in the sense that neither process is always superior, but choice depends on the details of the particular case. The production shares in the EU since 2012 have fluctuated close to a 40 % EAF, 60 % BF/BOF split. The EU is a net exporter of scrap and will remain so for some time; the share of EAF in the EU production route is expected to increase only moderately to about 44 % by 2050.[19]

Much effort over many decades has gone into the improvement of the resource efficiency of steel production. Individual processes have been optimised and then coupled by the recovery of by process gases and waste heat; by-products have found use as feedstocks for other industries, e.g. slag as building material and in the production of cement. Recycling of scrap steel has much increased. These activities were reported in detail with many case studies in the previous seminar of this series[20].

The consequence of these multiple incremental improvements is that the EU steel industry has achieved very high resource efficiency and producers are reaching the thermodynamic limits of

[19] Steel's contribution to a low-carbon Europe; Boston Consulting Group and Steel Institute VDEh, 2013.
[20] The Future of European Steel, op. cit.

current processes; this is evident from **Figure 2**. Any substantial further improvement of energy efficiency and reduction of CO2 emissions requires breakthrough technologies.

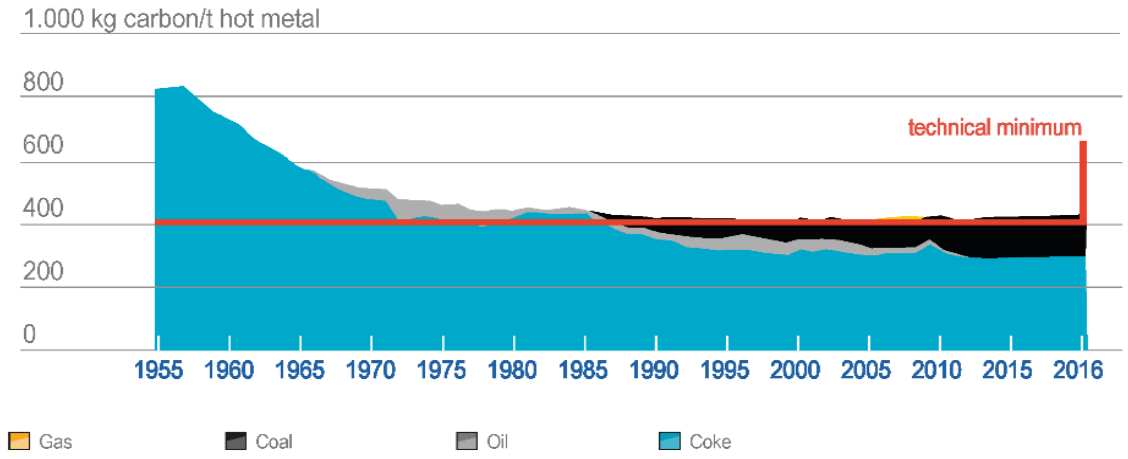


Figure 2. Consumption of reducing agents in the blast furnace

The two main clusters of technological pathways to make radical reductions in emissions from steel-making are by using the carbon in some possibly unrelated application of value or by avoiding the use of carbon in the process. The first cluster is smart carbon usage (SCU); the second is Carbon Direct Avoidance (CDA). Mr Ghenda chose examples of these ideas to describe in more detail.

HIsarna is an example of SCU; it aims to develop a more efficient substitute for the blast furnace. To make liquid iron in a blast furnace the raw materials (iron ore and metallurgical coal) need to be pre-processed into sinter and coke to provide a porous burden. HIsarna avoids this; it comprises a reactor with temperatures above the melting point of iron throughout the vessel, the raw materials can be injected as powders, directly converting them into liquid iron thereby avoiding the energy loss in sintering and coking. If HIsarna can be successfully developed at an industrial scale, future production of steel with a 20 % smaller carbon footprint will be possible. In conjunction with Carbon Capture and Storage or Carbon Capture and Use, HIsarna technology can lead to an 80 % smaller carbon footprint. The approach also opens the possibility of using non-coking coals and lower quality iron ore fines. The technology is now undergoing a six month test campaign that started in October 2017.

The second option offered by Mr Ghenda was IGAR (*Injection de Gaz Réformé*) shown schematically in **Figure 3**. It can be described as a form of Smart Carbon Usage in that it upgrades waste steel plant gases for injection into the blast furnace. Upgrading is achieved by a plasma torch and reactor to heat and reform the gases.

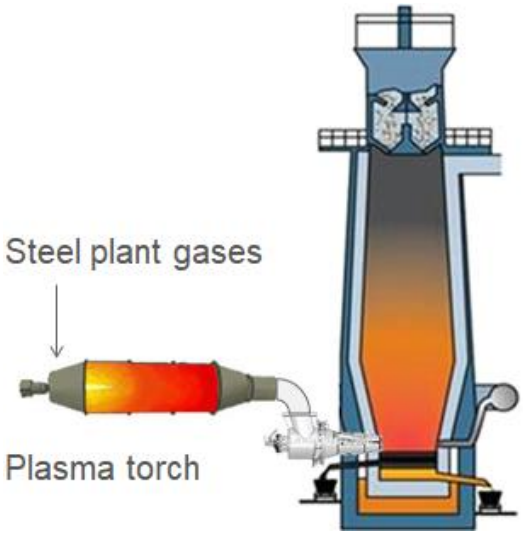


Figure 3. *Injection de Gaz Réformé*- IGAR

More generally there are several potentially attractive options to use the CO and CO2 in off-gases from the steel mill as raw materials in the chemical industry for fuels, fertiliser and other valuable products. Upgrading the off-gases requires inputs of hydrogen and electric power that come preferably, if the processes are genuinely to reduce GHG emissions, from renewable sources. In this respect there is a strong symbiosis between the steel industry and the chemical industry, power generation and producers of hydrogen gas. The relationships are indicated in **Figure 4**.

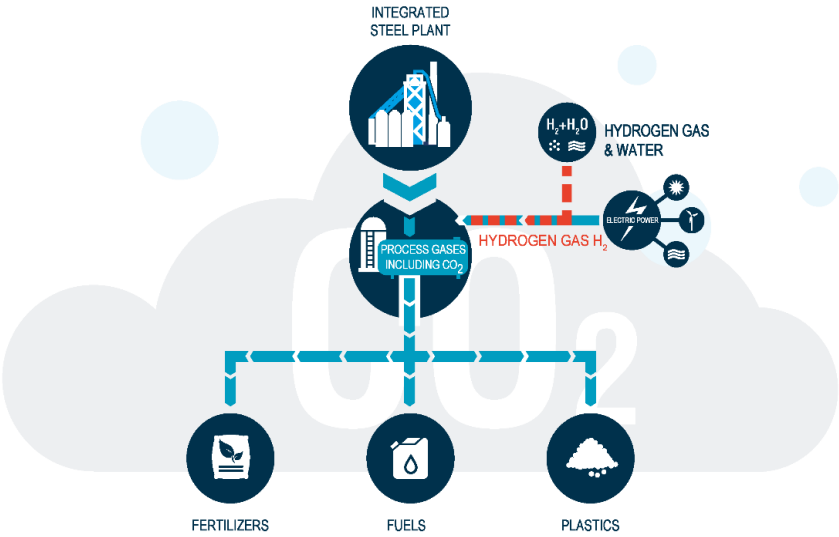


Figure 4. Pathways of carbon valorisation

The project Steelanol is a fine example of SCU. This is a project to synthesise ethanol from steel gases it is coordinated by ArcelorMittal and partly financed by the European Union under Horizon 2020. The process for ethanol production employs a technology developed by LanzaTech, whereby gases produced during the chemistry of steel production are fermented by microbes that secrete ethanol; it will be demonstrated at the ArcelorMittal steel mill in Ghent. The capture and reuse of a portion of carbon emitted by the steel mill will be achieved with minimal rebuilding of the plant and will produce high grade biofuel, which does not compete in any way with food crops or land for food crops. A schematic representation of the process is shown in **Figure 5**.

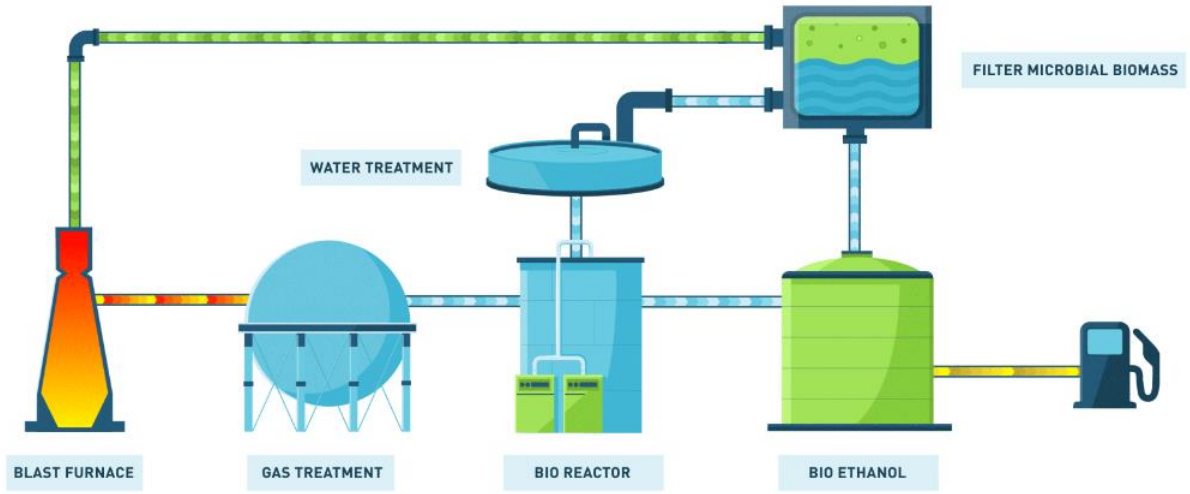


Figure 5. Steelanol process

An interesting project with a similar strategic goal – to valorise off-gases – but a quite different approach is the Carbon2Chem concept of the ThyssenKrupp group. The linkage of this project to electricity generation from renewable energy is especially interesting as it aims to combine chemical synthesis with cost-effective load management services for the electricity grid. A typical steel mill gas is 44 % nitrogen, 23 % carbon monoxide, 21 % carbon dioxide, 10 % hydrogen and 2 % methane. Nitrogen and hydrogen can be used to make ammonia which is a feedstock for fertiliser. The Haber-Bosch catalytic process for this conversion is long-established. The carbon

monoxide and carbon dioxide content of the off-gases together with the hydrogen also form the basis for methanol. The hydrogen present in the off-gases is insufficient for the ammonia and methanol synthesis; it must be supplemented by hydrogen from renewable sources. The chemical process is activated when large quantities of surplus renewable electricity are available at low prices; the steel mill gas streams are then split so that part is available for steel production and part for chemicals. This provides load management that helps stabilise the power grid and contributes toward penetration of renewables, but the intermittent operation does bring technical challenges to the project because the ammonia and methanol syntheses have been optimised as continuous processes.

The last example of carbon valorisation noted by Mr Ghenda was FreSME, also partially funded by the EU under Horizon 2020. The project aims to demonstrate the chain of processes that converts CO2 captured from the steel industry to methanol to be used as fuel for ships. The project builds on the results from two previous EU funded projects: one on the capture of CO2 (STEPWISE), and the other on the production of methanol from CO2 (MefCO2).

Mr Ghenda then moved on to direct reduction using hydrogen. He observed that until enough hydrogen was available from renewable resources, an intermediate solution would be to use natural gas for the reduction; hydrogen based direct reduction offered good potential symbiosis between the steel industry, power generation and hydrogen production. He identified HYBRIT, H2Future and SuSteel as projects of interest. These projects were presented by later speakers and therefore are not summarised here.

Steel production can also be achieved through a fully electric route; Mr Ghenda chose SIDERWIN as the exemplar: see **Figure 6**. The objective of SIDERWIN is to develop a breakthrough innovation based upon an electrolysis process using renewable energies that will transform any iron oxide, including by-products from other metallurgical operations, into steel with significantly lower energy use than traditional processes. The electrolysis rapidly decomposes naturally occurring iron oxides such as hematite under mild condition into iron metal and oxygen gas. Compared to traditional steelmaking plants, SIDERWIN is expected to have several positive impacts including: a reduction by 87 % of the direct CO2 emissions; a reduction by 31 % of the direct energy use; the possibility to produce steel from by-products rich in iron oxides from non-ferrous metallurgy residues, and an increased integration with renewable energies with a more flexible process. The project is led by ArcelorMittal.

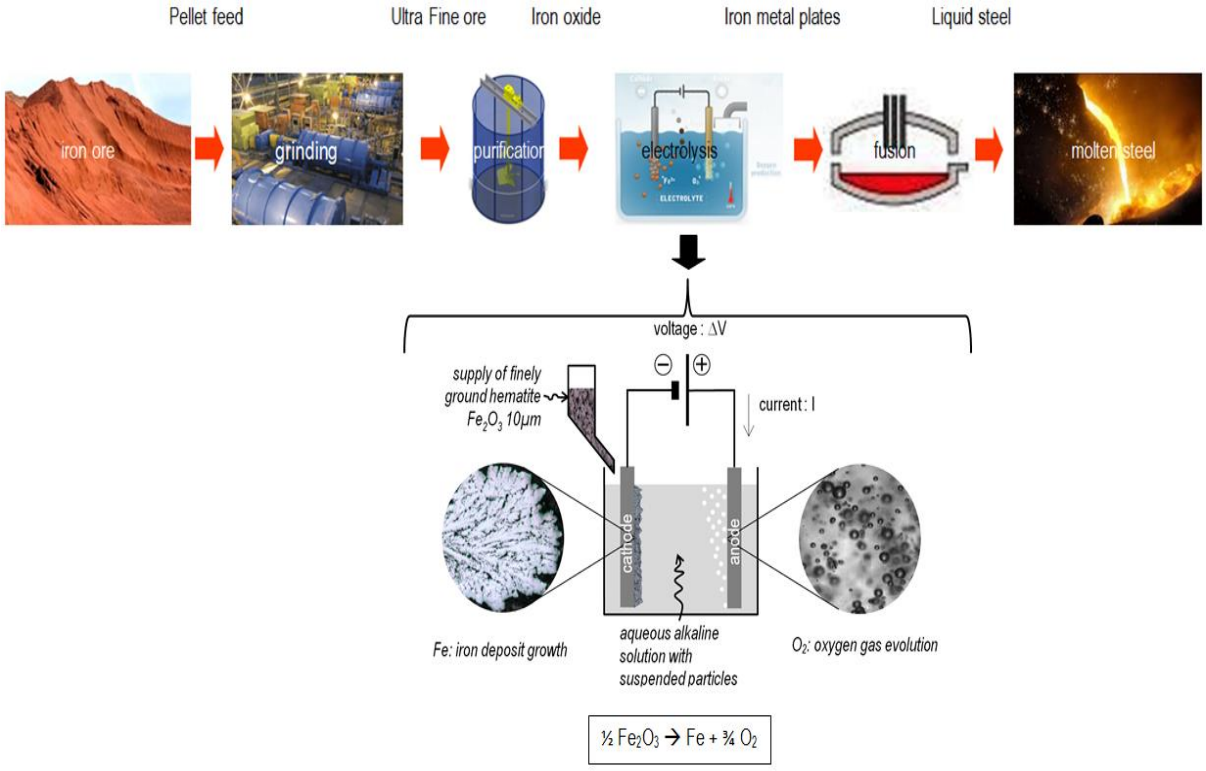


Figure 6. SIDERWIN process

Mr Ghenda concluded by examining the many factors that will affect the structure and nature of energy supply to the industry in the next few decades. They include: International agreements and Treaties; market development and the evolution of trading patterns; the availability of feedstocks

and energy, and the experience with innovative technologies. These influences are so varied, that assessing the likely evolution of demand is problematic. The main factors are summarised in **Table 7**.

Factors affecting the future energy demand of the steel industry
➢ Energy and climate policies - Paris agreement - EU energy and climate framework targets, national targets ➢ Global goals –Agenda 2030 ➢ Market development - Future steel consumption, steel production, steel production structure - Global competition, Trade issues ➢ Raw material and energy availability - Quantity, Quality, Price ➢ Technology development - Processes (Implementation of innovative solutions, structure of producing technologies, Energy efficiency, carbon efficiency, resource efficiency) - Products

Table 7. Factors affecting the future energy demand of the steel industry

Fossil-free steel production

Developing a national strategy of transition to a future green steel industry is a complex task. There is much uncertainty about the technical and economic performance of many of the potential green options and added to these uncertainties are the constraints that arise out of the specificities of the national conjuncture: energy resource endowment, the wider industrial structure, the legacy assets of the existing steel industry. And on top of this there is the requirement not only to define the desirable vision of the future, but to plot a practical transition from the present to the desirable future.

Ms Helén Axelsson of Jernkontoret (the Swedish Steel Association) took the seminar through the Swedish approach to this task. For many years now, Sweden has had a forceful policy for the environment. Recently the Prime Minister of Sweden in a speech to the UN General Assembly announced that his country will work towards becoming "one of the first fossil fuel-free welfare states in the world", and in June 2017 the parliament voted to adopt the Climate Act with a pledge to reach net-zero greenhouse gas emissions by 2045. Even now, renewable energy accounts for over half of Sweden's energy production.

The steel industry has been proactive in this debate. In March 2013, the steel industry in Sweden had already decided to adopt a shared vision to 2050, based on three principles:

- We lead technical development

  Our research and innovation revolutionise technology for tomorrow's society. Our steel constantly challenges the frontiers of engineering.

- We nurture creative individuals

  Our working environment fosters new solutions for communities through global collaboration. Our creativity constantly challenges the limits of contemporary thinking.

- We create environmental benefits

  Our production uses resources so efficiently that only products of value to the community leave our plants. Our ambition constantly challenges the limits of the possible.

An important technical element of the proposed vision is direct reduction technology. In 2016, SSAB, LKAB (Europe's biggest iron ore producer) and Vattenfall formed HYBRIT – a joint venture to implement a project that would replace coking coal with hydrogen: a schematic flow diagram is shown in **Figure 7**. In spring 2018, a pilot plant for fossil-free steel production will be constructed near Luleå and the Norrbotten iron ore fields. If successful, HYBRIT will reduce the emissions of CO2 in Sweden by 10 %. The project reflects well the specificities of the Swedish situation: good

access to fossil-free electricity, high quality iron ore deposits and a specialized, innovative steel industry.

The Swedish Energy Agency is contributing partial finance. The pilot phase will last until 2024, moving to demonstration during 2025-2035. The direct reduction technology ensures CO2-free iron making, but the subsequent conversion to steel still needs coal and heat. The solutions, in the context of green steel, are biocoal, biogas, hydrogen and electricity. The estimated cost of fossil-free steel, at present prices for electricity, coal and CO2 emissions, would be 20-30 % greater than current technology. With falling prices in electricity from fossil-free sources and increasing costs for CO2 emissions there is reasonable expectation that fossil-free steel will be competitive. The success of this project cannot be assured by the industry alone. Significant policy and regulatory support is needed from the government. There has to be good access to fossil-free electricity, improved infrastructure and rapid expansion of high voltage networks, research initiatives, faster permit processes and financing.

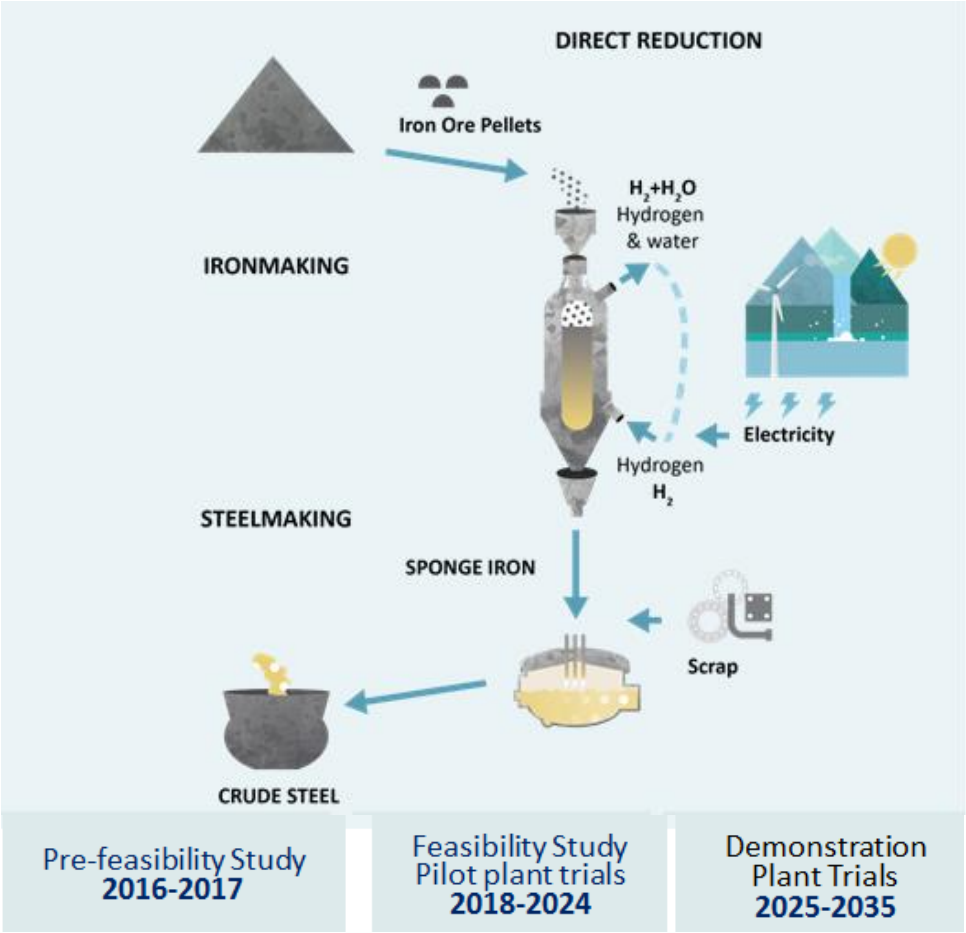


Figure 7. HYBRIT project

Gradual decarbonisation

In the third presentation of the session, Mr Johann Prammer of voestalpine and Ms Katharina Rechberger of K1-MET shared with participants their insights into the challenges facing the steel industry, as well as the options and conditions for success.

Mr Prammer concurred with the assertion of previous speakers that the limits of existing production techniques had been reached and that the development and implementation of new breakthrough technologies would be needed to comply with target for GHG emissions, which in turn would necessitate parallel strengthening of energy infrastructure and services. The challenge is not only technical, but economic and commercial. He argued that a realistic and competitive decarbonisation required coordinated energy policies and funding strategy on a European level. As Mr Ghenda had previously explained, there are numerous options and it is likely that immediate progress will involve a basket of concepts. The strongest long-term solutions are CDA and CCU, but evidently the best way of dealing with CO2 emissions is simply not to produce them in the first place: which is why voestalpine is focusing on carbon direct avoidance based on the use of "green" hydrogen produced with renewable energy sources.

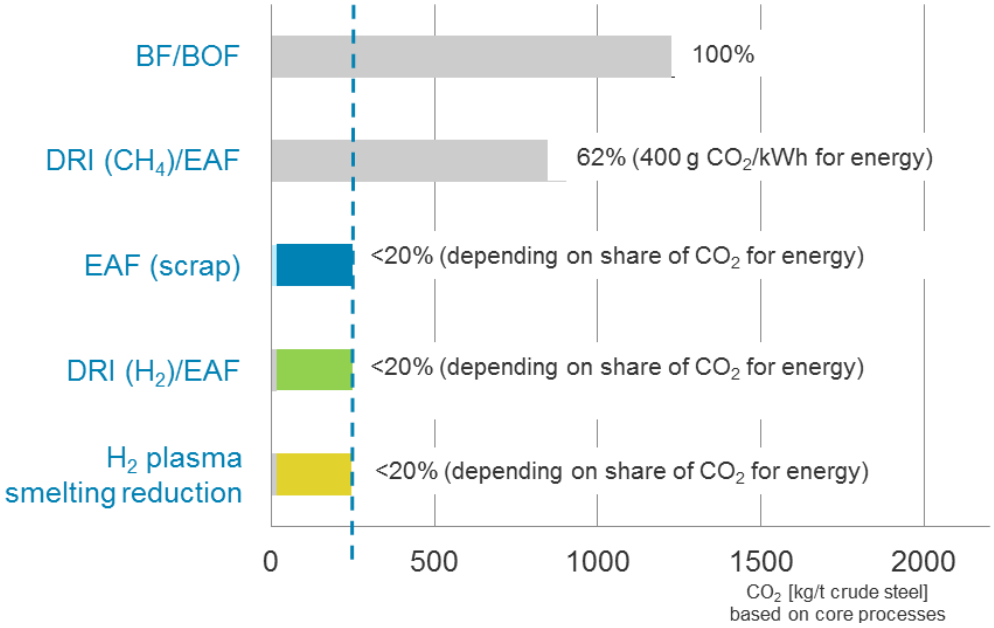


Figure 8. Carbon intensity of steel-making options

The **Figure 8** shows the carbon intensity of the principal options for steel making. Compared to the conventional BF/BOF route, which emits about 1,300 kg of CO2 per ton of crude steel, direct reduction routes can achieve a reduction to 60 % of this amount. Coke is replaced by natural gas and the produced hot briquetted iron is melted in an electric arc furnace. If natural gas is replaced by hydrogen in the DRI process, only 20 % of CO2 are emitted compared to BF/BOF; the same result is achievable with H2 plasma smelting reduction. However, Mr Prammer advocated caution, noting that these technologies are still in a state of development and will not be available within the next 20 years, particularly as the transformation has to be technically and economically feasible.

He then elaborated on the question of economic feasibility. The company's estimates for the operation cost of breakthrough technologies are that operating costs would increase 80 % on top of an investment of about € 30 billion, if voestalpine were to maintain its present 7.5 million t/a output using these new processes and hydrogen produced by a Proton Exchange Membrane (PEM) electrolyser: the breakdown of operating costs is shown in the Figure 8. On top of this, the investment would comprise about € 7 billion for the steel-making, € 3 billion for the PEM electrolyser and € 20 billion for renewable electricity. To make steel in this manner in a region open to international competition would simply not be commercially feasible unless relative prices changed dramatically.

Ms Rechberger continued the exposition by elaborating on their gradual decarbonisation concept. This concept is presented in three linked and progressive projects which are resumed in **Table 8**. The first step in this progression is to develop direct reduction using natural gas at the voestalpine plant in Texas. This may be seen as a bridging technology. The direct reduction occurs in a sealed low-pressure reduction reactor, which is not vented to the atmosphere. Iron oxide pellets enter through feed pipes, are reduced to metallic iron and discharged from the furnace cone; despite the high temperature of the reactor the product is not molten. This is an advantage, since product handling is safer and environmentally friendly. For transport, the product is briquetted into palm-sized hot briquetted iron (HBI). The capacity of the plant is 2 million tonnes/year of HBI. The HBI can substitute for hot metal and high quality scrap in EAF steelmaking and is a suitable feedstock for high quality carbon-steel grades. The plant began operation in October 2016; it has the potential to introduce green hydrogen gradually from renewable energy as it becomes available.

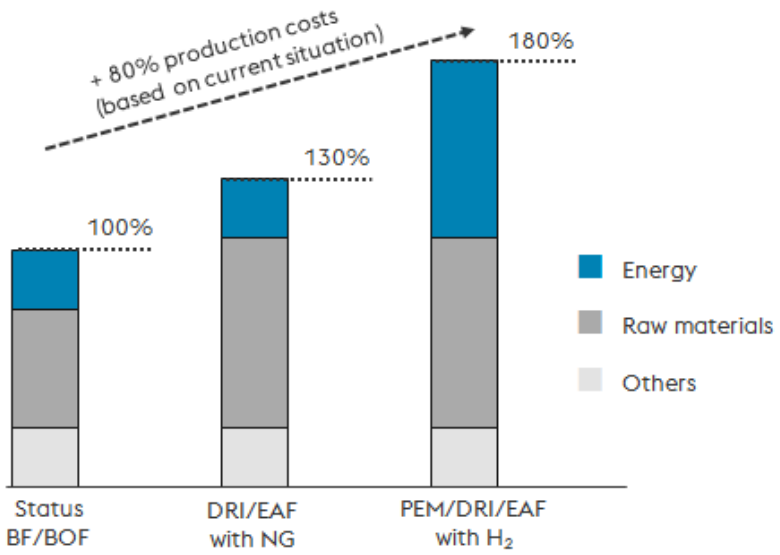


Figure 9. Breakthrough technology production costs

The next step in the chain is to demonstrate the technical and economic performance of modern electrolysers and the prospects of providing hydrogen in parallel with grid services. This is the objective of the project H2FUTURE that started in January 2017 with finance from the Fuel Cells and Hydrogen 2 Joint Undertaking (FCH2JU); the FCH2JU in turn being funded by Horizon 2020, Hydrogen Europe (a consortium of largely industrial interests) and N.ERGHY (a consortium of research groups). Under the coordination of the utility VERBUND, the steel manufacturer voestalpine and Siemens will install and operate a large-scale 6 MW proton exchange membrane (PEM) electrolyser at the voestalpine Linz steel plant in Austria. The Austrian transmission system operator, the Austrian Power Grid (APG), will support the prequalification of the electrolyser system for the provision of ancillary services. The Energy research centre of the Netherlands and K1-MET will study the replicability of the experimental results on a larger scale.

Gradual decarbonisation- A corporate example
➢ Bridge technology: Direct reduction plant in Texas (USA); using natural gas as reducing agent in direct reduction plants; potential for gradual introduction of green hydrogen generated using renewables. ➢ Renewable hydrogen generation: H2FUTURE project in Linz (Austria); investigating hydrogen electrolysis technology on an industrial scale. ➢ Breakthrough technology: SuSteel ("Sustainable Steelmaking"); reduction of iron ore using hydrogen plasma, ongoing research using pilot plant at the Donawitz site (Austria).

Table 8. Gradual decarbonisation – A corporate example

The last project for sustainable steelmaking that Ms Rechberger presented was SuSteel the objective of which is to demonstrate the direct transformation process from iron oxides to steel by means of hydrogen plasma smelting reduction process. At present this is essentially a fundamental research project in progress at voestalpine's Donawitz site. The process concept is to achieve a direct transformation from iron ore to steel in one step. The hydrogen-plasma is used for the reduction of the oxides and energy of the plasma provides the heat for melting the metallic iron. Based on previous research results with lab-scale tests, a 50 kg batch reactor will be installed at voestalpine as the next step in scaling up to an industrial application.

Energy-Steel symbiotic opportunities

Mr Prammer and Ms Rechberger concluded with some reflections on the implications of the transformation of the steel industry for the world. Low-carbon steel technologies are not only a challenge for the steel industry. In terms of GHG emission reduction, the most effective technologies make big demands on renewable energy generation and to a lesser extent on grid ancillary services. It is a precondition of the steel transformation that it be matched by a fundamental transformation of energy generation, supply and infrastructure.

Additional electricity supply from renewable sources will have to be available not only for steel, but also for other energy-intensive industries, for e-mobility and many other competing demands. It will need ambitious, but realistic planning of by energy companies, sustained by supportive government policies. As an example, transformation just of steel production, just in Austria will require an additional 40 TWh from renewables per year, equal to half of Austria‘s current annual electricity production. For European steel industry this corresponds to an additional 500 TWh. These are staggering figures and it is not clear that the region is gearing up for this. It is not only the volume of power that is critical, but also the quality. Renewables are intermittent; grid stability is essential 24/7, 365 days a year. R&D and investments in storage, transmission, and infrastructure technologies is essential. There are of course some possibilities for contributing to grid stability through load management of steel-making processes, but this will certainly affect costs and performance in ways and to an extent that are not clear at present.

Competitiveness of novel technology needs to be assured, certainly on European scale and probably internationally also. This cannot at present be guaranteed. A cross-sectoral approach bringing together energy-intensive industries, energy suppliers and national and European officials will be needed for success: to ensure mutual understanding of needs and possibilities; to share experience and identify symbiotic opportunities.

STEEL FOR ENERGY SECURITY

Access to steel of the right qualities, in the right quantities and at the right price is a strategic requirement for much of the economy: transport, construction, manufacture, space, defence, energy are all sectors that would struggle to compete and even to survive if this condition was not observed. The seminar chose to look in particular at how this obvious general dependence is manifest through particular design and quality considerations in the energy sector, partly because it serves as a suitable example and partly because energy security is recognised as being a national and EU policy priority in a way that perhaps some other sectors are not.

Renewable energy technologies

Renewable energy uses a lot of steel. Mr Pietro Gimondo the research manager for the Centro Sviluppo Materiali introduced his analysis of the relationship between steel and energy with a striking and in some ways surprising figure showing the steel content of different forms of energy supply technologies: see **Figure 10**.

The present energy system is built around steel; this was true in the last century, is true today and will be true in the future. What has changed is that energy generation based on renewables is several times more material intensive than are fossil-fuel technologies: specifically more steel intensive. This is because the energy fluxes in the dominant renewable technologies are low and require large structures to capture the large quantities that modern economies need. The solar flux for example, is orders of magnitude lower than the heat flux to a modern water-tube boiler. As a corollary the capital cost of renewable energy plant per MW is high compared to fossil-fuel plants; reducing the cost can be achieved in part by skilful selection and use of steels which is often the main material of construction. Seamless access to the best steel products and designs is therefore of critical importance to the future of renewable energy.

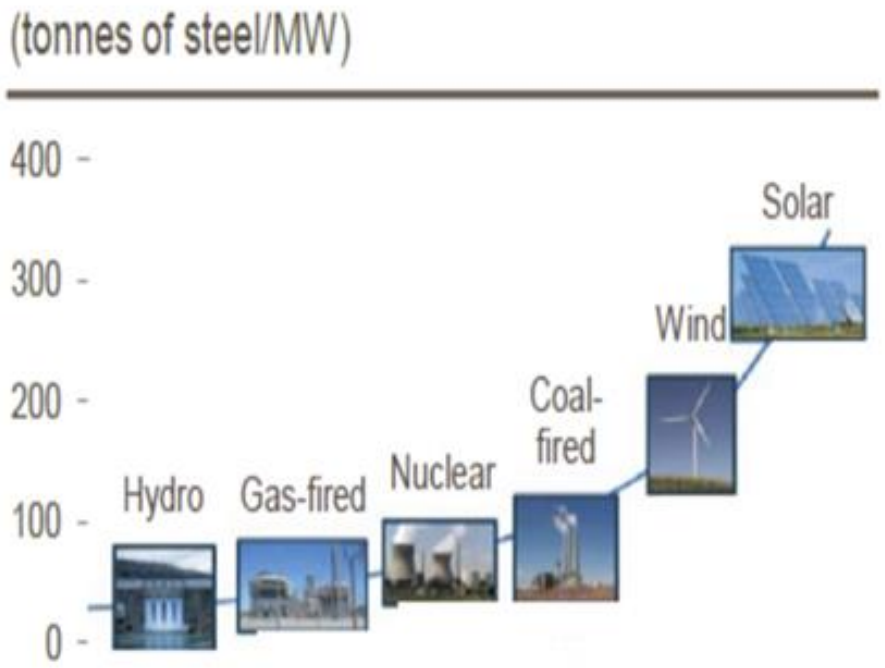


Figure 10. **Steel intensity of electricity generation**

Steel is the main material used in onshore and off-shore wind turbines. Every part of a wind turbine depends on iron and steel. The main components of a wind turbine are the tower, the nacelle, and the rotor; a foundation connects the turbine to the ground or seabed. Blades are normally made of carbon-fibre or alloys, but steel holds the blades in place using a cast iron or forged steel rotor hub. As they turn they must cope with severe stress. A nacelle can weigh as much as 300 tonnes, about 14 % of the weight of a large offshore turbine. The strength of steel makes it the preferred choice for frame, housing and machinery of the nacelle. The nacelle also contains high-value steels including energy efficient electrical steels. The low-speed shaft transferring the rotational force of the rotor to the gearbox and the gears themselves are machined from special hardened steel components. Screws and studs are needed to hold the main components in place and must be designed for extreme loads.

Most of the steel in a wind turbine is in the tower. As wind-turbines get bigger, towers get taller. Higher steel grades can be applied to achieve lighter and taller towers. By upgrading the steel of a wind tower structure, substantial savings in weight can be realised; lighter towers reduce transport and construction costs. A tubular tower is made of a cylindrical steel tube with diameters and wall thicknesses that vary according to power. Criteria to be met by every tower are, for example: steel for flanges with metric weight exceeding 300 kg/m; bars for bolts with diameters up to 65 mm; merchant bars and sections for cable ducts, ladders and platforms; galvanized sections for transformers, control panels and cooling systems. Lattice towers have numerous advantages: they are less expensive; they give more power by accessing increased wind speed at greater height; they are lighter, require less foundations, are easier to deliver in difficult terrain, can be protected from corrosion by galvanizing, and have lower life-cycle costs for sustainable energy production. Foundation solutions must be adapted to high loads and dynamics but also contribute to reducing the total environmental footprint of the foundation. Some of the solutions are pictured in **Figure 11**.



Figure 11. **Steel solutions for wind-turbines**

Steel plays a critical role in converting solar energy into electricity or hot water. As noted earlier, the solar flux is weak compared to the energy transfer that could be achieved with fossil-fuels. To capture solar energy consequently requires larger structures than with other options. As **Figure 10** shows, photovoltaics are the most steel-intensive of the main electricity generating options. Steel is the obvious choice for the load bearing functions to support large areas of panels. The speed of construction and therefore capital costs can be particularly reduced by pre-assembly; the use of long products over the large areas to be covered makes an essential contribution. Thanks to the extensive range of available profile dimensions the design of solar installations can be optimized and the dimensions of the solar modules can be closely controlled. The corrosion protection available from hot dip galvanizing ensures virtually maintenance free operation which again is important given the large areas that an installation might cover.

Engineers from the steel industry have been and are closely involved in the design of structural elements, construction details, surface protection, fire safety, metallurgy and welding processes for the renewable energy industries. New steel grades were developed for these applications combining high yield strength with excellent toughness at low temperatures and outstanding weldability. For the same bearing capacity, in these new materials high strength steel sections are 25 to 50 % lighter than conventional steel profiles. This improved performance of steel qualities and design allow significant reductions in construction cost, weight and carbon footprint.

Energy networks

Ms Marion Erdelen-Peppler of the European Pipeline Research Group addressed the seminar on the importance of steel as a key component of the EU energy security of supply and in particular its fundamental significance for future gas supply networks in Europe. She began by demonstrating the great opportunities for Europe in pipeline gas from neighbouring regions and the importance that it would have in future energy supply to the EU. The base case scenario of the IEA Energy Outlook 2016 shows a 30 % rise in global energy demand to 2040; renewable energy grows the fastest, but among fossil-fuels natural gas does best, with consumption rising by 50 % and becomes largest single fuel[21]. US shale gas revolution turns to export and by the mid-2020s, the US becomes largest LNG exporter. Total proven reserves of natural gas have been growing rapidly and are widely distributed – see **Figure 12**[22].

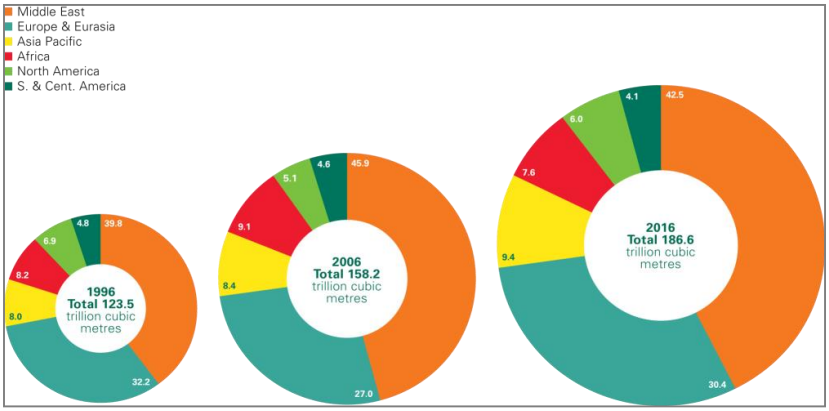


Figure 12. Growing proven gas reserves

Gas is plentiful, relatively clean and easy to use; it is a preferred fuel in many applications. The large and increasing need for imported gas into Europe, and its relatively central location amongst several major LNG suppliers, makes Europe a natural market for LNG. On the other hand, Europe's access to plentiful supplies of pipeline gas, particularly from Russia, but also from North Africa and the Middle East, means pipeline gas is a strong competitor. A typical scenario for pipeline gas and LNG into Europe in 2030 is shown in **Figure 13**[23].

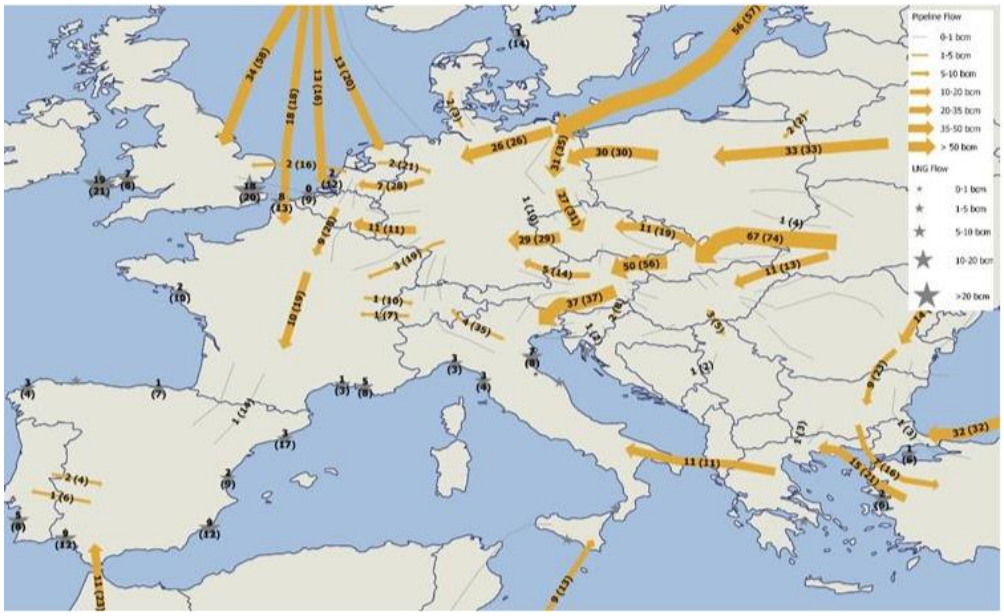


Figure 13. Possible LNG and pipeline gas supplies to Europe in 2030

[21] World Energy Outlook 2016, IEA.
[22] Statistical Review of World Energy 2017, BP.
[23] Future European Gas Transmission Bottlenecks in Differing Supply and Demand Scenarios, The Oxford Institute for Energy Studies, June 2017.

Most of the European LNG import terminals are located in Western Europe; constraints in transporting gas from the West to the East, it means that eastern European countries still depend on Russian gas imports. Both LNG and pipeline gas technologies are very dependent on special steels; Ms Erdelen-Peppler focused on the requirements for pipelines. A great competitive strength of steel is the possibility of modifying its properties to suit the often demanding requirements of specific applications.

Figure 14 shows by means of a spider diagram how widely the desirable properties of pipeline steel do vary for four different pipeline projects according to their character and location. Steel derives its mechanical properties from a combination of chemical composition, heat treatment and manufacturing processes, but changes in any of these elements to enhance one particular property can adversely affect other properties. In every case also the use of more expensive high-grade steels has to be justified by a correct economic evaluation.

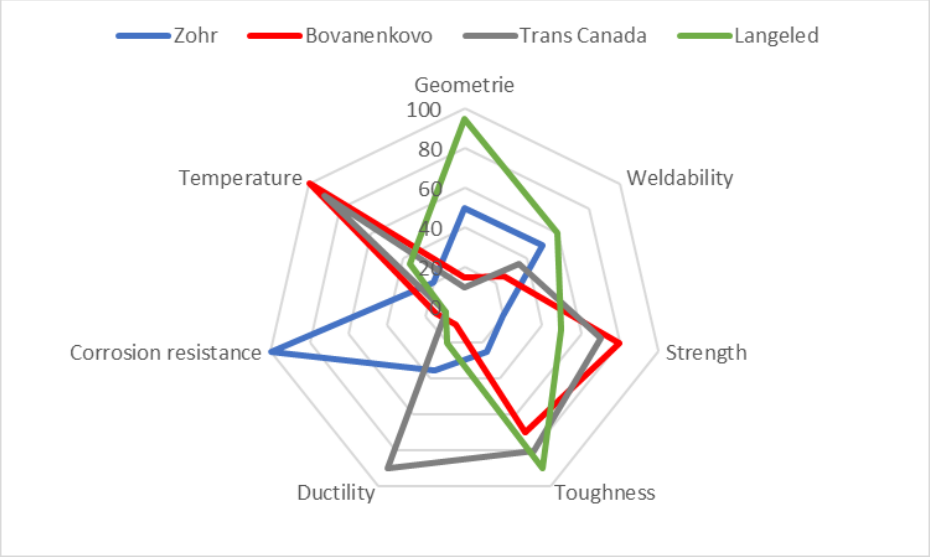


Figure 14. Steel properties tailored to pipeline applications

On-shore and Off-shore pipelines

Ms Erdelen-Peppler illustrated her argument with several case studies, starting with an on-shore pipeline. Bovanenkovskoye is Yamal's largest natural gas production field. The Bovanenkovo gas trunk-line is one of several that convey gas from the Yamal Peninsula into Russia's Unified Gas Supply System. The length of each gas pipeline is around 1,200 km with a base diameter 1,420 mm, operating at a 120 atmospheres; the temperature of gas flowing through the pipeline is kept below minus 2°C to avoid melting the permafrost; the minimum external temperature was minus 30°C. The main criteria in the case of this extraordinary project were strength, toughness and low-temperature performance; the steel selected was L 555.

Off-shore pipelines present different challenges. Off-shore pipes are laid from barges either in long sections or from a reel. Ductility and weldability are important properties. Permissible ovality is restricted because non-circularity inhibits welding and pigging. Ms Erdelen-Peppler gave as examples the Langeled 1066mm pipeline, laid in 360 m of water to transport Norwegian natural gas to the United Kingdom, which was constructed from L490 grade steel, and the NordStream 1219mm pipeline in 210m of water carrying natural gas from Vyborg in the Russian Federation to Greifswald in Germany; at 1,222 km this is the longest sub-sea pipeline in the world; it is constructed with L485 grade steel.

Pipelines to service sour gas deposits present special problems. The capacity to resist corrosion becomes imperative. Two examples are the 660mm pipeline bringing gas from the Zohr field in the Mediterranean to the Egyptian shore with high levels of hydrogen sulphide and the pipeline servicing the world's largest gas field in South Pars. Both are constructed from L365 grade steel. For onshore and offshore pipelines that need to achieve a balance between mechanical properties and corrosion resistance, clad and lined pipes can be employed to prevent contact between steel and sour medium. There is good potential here for research and innovation seeking new developments and smart products. Another potentially fruitful area for innovation is the possibility of supported steel using crack arrestors: when intrinsic toughness does not suffice, a combination with fibres may provide a solution.

Ms Erdelen-Peppler concluded her presentation with a brief summary:

- Steel products can combine different properties as a function of the needs of the application
- Tailor-made solutions can be devised for individual cases
- Challenging property combinations are needed for modern projects
- Steel products have an excellent safety record
- Future innovation should be enhanced in clad products and composite materials
- Research is needed in digitalisation and the creation of smart pipes, e.g. data recording, predictive maintenance

GREENING EUROPEAN STEEL

The third session of the day was devoted to transforming the greening of steel production in Europe from a nice idea to a practical prospect. Successive previous presentations had shown that such an effort would have to be on a big scale; the technical concepts are promising, but the obstacles are daunting; success is not within the grasp of industry alone; it can only be realised through a joint effort by industry, financial services, European institutions and member states. Recognising this imperative, the final session began with a presentation by the European Steel Platform (ESTEP) and the European Steel Association (EUROFER) arguing for and scoping an ambitious Joint Initiative over the next Framework Programme, together with an EU Masterplan to ensure a supportive regulatory and legislative framework. This proposal was followed by a panel discussion with representatives of the relevant EU Directorates and a view from a Member States.

Mr Klaus Peters, the Secretary General of ESTEP, and Mr Danny Croon, Director of EUROFER opened the session with their examination of the prospects and preconditions for a European Joint Steel Initiative within "Post Horizon 2020" programme, together with a proposal of the industry to develop jointly with the EU institutions an EU Masterplan for a Low-Carbon, Competitive European Steel Value Chain addressing not only the technical and commercial issues lying within the purview of the industry, but also the necessary reform of legislative and regulatory frameworks, and the provision of financial aid, that lay outside its competence.

A European Joint Initiative and a Masterplan for Steel

Mr Croon recapitulated some of the critical themes from earlier presentations that would underpin the logic of the Joint Initiative and a Masterplan. Energy consumption and CO2 emissions have been somewhat decoupled in the last 60 years: CO2 and energy emissions per tonne of crude steel produced have been reduced by nearly 50 % since the 1960s: see **Figure 15**.

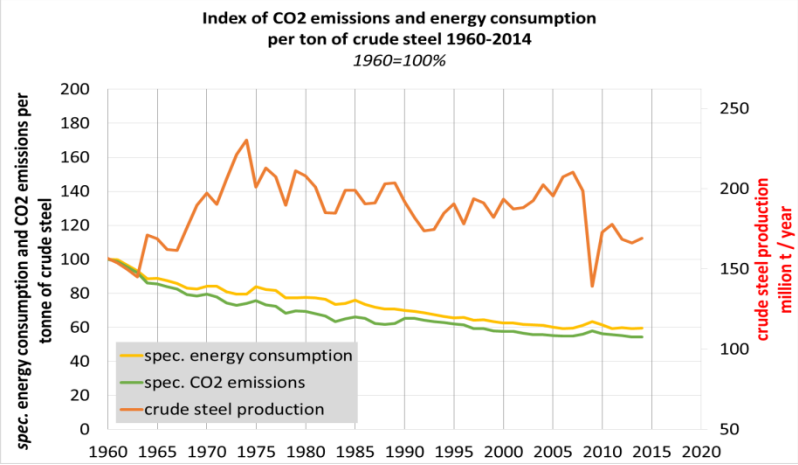


Figure 15. Energy and CO2 per tonne of steel

Despite this achievement, production of steel is still responsible for a large share of global emissions: globally 6-7 % of total GHG emissions and EU producers are beginning to test the thermodynamic limits of current processes. Breakthrough technologies are needed to deliver the emission reductions set out by the EU and summarised in **Figure 16**. Such breakthrough technologies need long term development to industrial scale, but also regulatory, financial, and infrastructural conditions must be supportive.

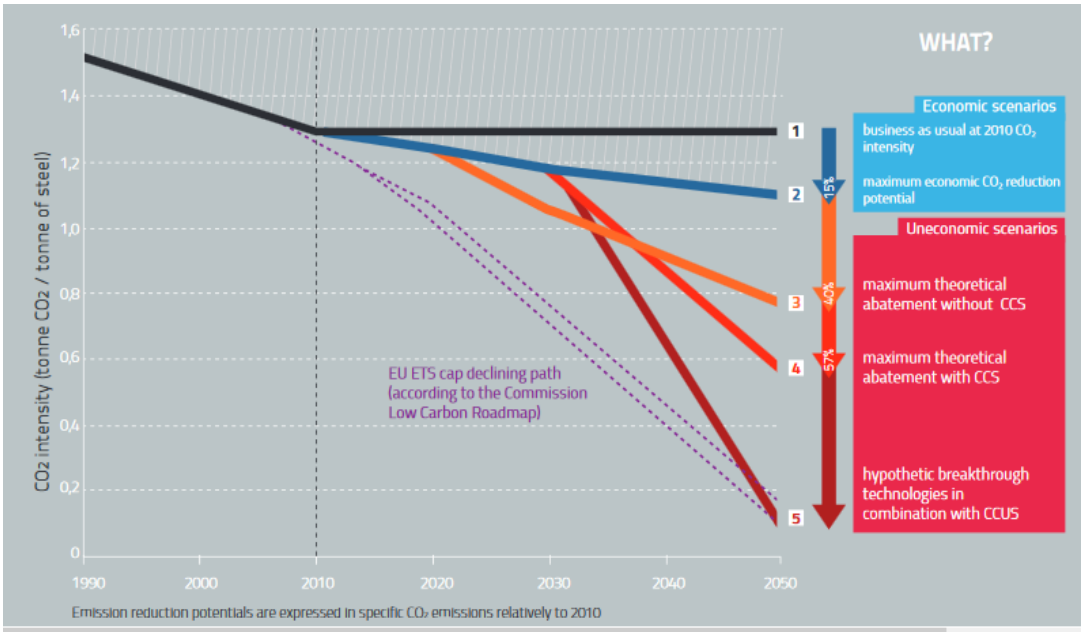


Figure 16. CO2 intensity to 2050

The EU steel sector has a broad research footprint dedicated to low-carbon innovation, founded in a strong collaboration with universities, research establishments and companies and it has some sources of funding for R&D, including internal company contributions, national financing schemes, the EU Framework Programmes and RFCS. There are other sources that can be deployed more generally, such as the Juncker Plan, the EIB and the European Structural and Investment Fund (ESIF). What is lacking is a clear pathway towards deployment with financial instruments that are well-adapted to the risks at different stages of maturity. A much discussed gap in financing is the celebrated "valley of death" between speculative research into ideas and confident investment in proven technologies. On each of the sunlight uplands there is plentiful funding: on the one hand from research councils and governments for basic and applied research, on the other from venture capitalists, stock markets and banks. But in the dark valley of death, technologies that have shown promise in research struggle to find funding to move them to prototypes and commercial viability, until finally they give up the ghost and expire. Research and technology organisations do not have the scale; companies cannot take the risk.

What are the solutions to the "Valley of Death"? EUROFER estimated that about € 10 billion of funding would be needed over 10 years. More expansive risk financing solutions are part of the solution, to make the leap from research to industrial deployment. Greater flexibility in EU programmes has evolved in recent years: the Framework Programmes have developed PPP concepts; the ETS Innovation Fund is promising. It may now be time to consider reviewing policy and regulatory frameworks where they inhibit investment. The prime areas of policy where some rationalisation might be achieved are: renewable energy, climate & environment, and the single market. In the latter cases it is necessary to avoid disruptions arising from different implementations at national level. Among regulatory issues to examine are: state aid regulations, where it is necessary to avoid infringements that might arise from collaboration between companies on commercial deployment of promising technologies; trade regulations that commit to preventing dumping which would otherwise destroy the investment case; all regulation that undermines the ability to invest in deployment of breakthrough technologies by imposing excessive cost penalties.

As previous presentations suggested, the low-carbon innovation projects within the EU steel industry can be structured into two main pathways. One pathway continues with fossil fuel based metallurgy, the other shifts to non-fossil fuel based metallurgy. The two pathways can be respectively styled Smart Carbon Usage (SCU) and Carbon Direct Avoidance (CDA). These are flanked by overarching circularity projects, such as enhancing energy efficiency, the recycling of steel and its by-products, to help tapping further CO2 mitigation and energy savings. **Figure 17. Main current low-carbon technological paths in the EU** shows the main low-carbon projects and initiatives currently under way in the industry, structured according to these principles.

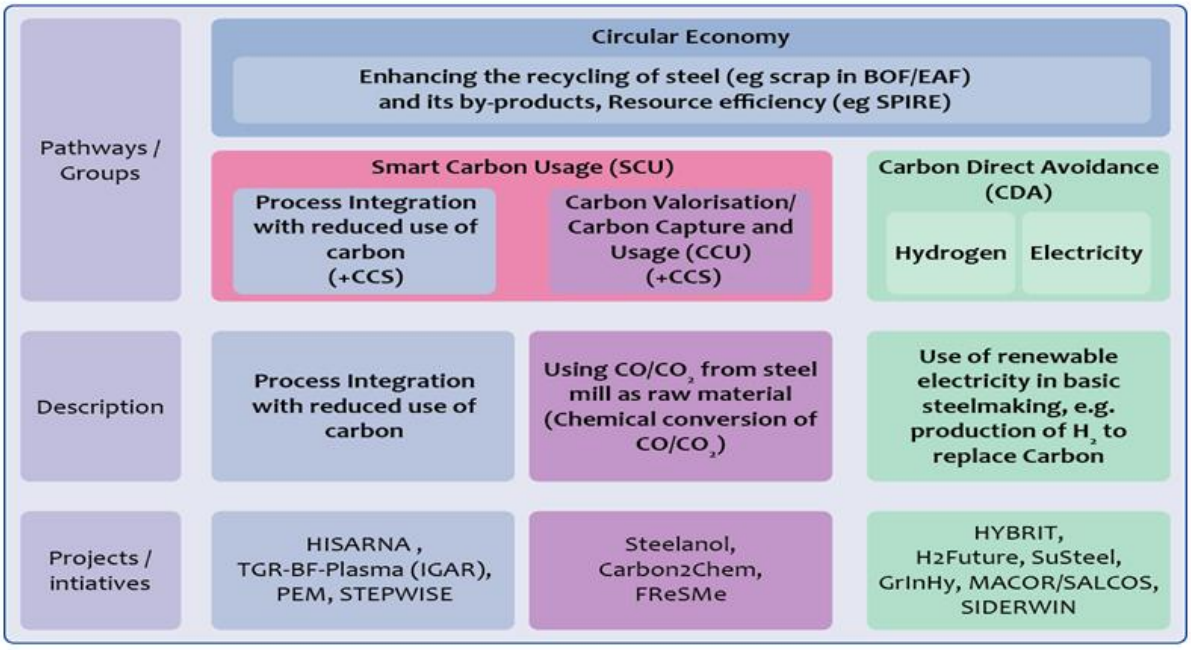


Figure 17. Main current low-carbon technological paths in the EU

The estimated potentials for CO2 reduction (with the assumption of external green power being available) are:

- 82 % with 100 % electrical power-based iron reduction (hydrogen or direct electrolysis)
- 80 % with smart carbon combined with CCS : 80 % or more (if the CO2 from lime, sinter/pellet plant is also captured)
- 70 % with smart carbon with external hydrogen to maximise synergies with chemicals
- 50 % smart carbon without external hydrogen
- 30 % EAF/DRI based on natural gas

A technical agenda is necessary, but not sufficient; as noted above, it needs to be situated within a wider framework covering policy and regulation. Mr Croon and Mr Peters called for a Masterplan led by the European Commission. The objectives of this plan would be:

- To identify: the most salient facts and underlying trends in production, CO2 emissions and energy consumption in the EU global steel industries
- To produce: an overview of key R&D&I activities and trends in the EU steel sector
- To set out: the broad lines for a European Big Scale Initiative that reflects the interaction between the steel industry and other sectors
- To outline: the necessary legislative and competition policy framework to make technological research and implementation possible.

EUROFER has already kicked off this debate with a draft of a Discussion Paper entitled "Towards an EU Masterplan for a low-carbon, competitive European Steel Value Chain[24]. This is intended as a "living document" serving to align the interests of, and to stimulate commitment from, the European steel industry, the EU institutions, member states and other relevant stakeholders on an overall EU approach. A detailed review of the technological and economic details in the form of a roadmap for low-carbon to 2050 was prepared by EUROFER in 2013, but it now needs updating and extending with a schedule of work towards specific targets for key performance indicators and clear milestones. This work is proceeding and will be supported by an Accompanying Measure "Low-Carbon Future" under RFCS that starting in Spring 2018; it will be completed in 2019 and will define the scope of a future Joint Initiative.

[24] Discussion paper: Towards an EU Masterplan for a low-carbon, competitive European Steel Value Chain, draft. EUROFER, 2018.

Cooperation within and across the EU

This ambitious proposal for an EU Masterplan was followed by a panel comprising Mr Fabio Donato from the Italian Permanent Representation, Mr Peter Handley from DG GROW and Mark van Stiphout from DG ENER, chaired by Mr Hervé Martin from DG RTD.

Mr Donato briefed the seminar on progress within the Council. On the 1st December 2017 the Council adopted conclusions on "From Interim Evaluation of Horizon 2020 towards the ninth Framework Programme". These conclusions offer guidance in the design and basic principles of "POST HORIZON 2020" programme. The Council encouraged a greater linking of research and innovation with other sectoral policies at EU, national and regional level and noted with concern that better integration with EU policies and coherence with other EU funding programmes is impeded by different non-complementary intervention logics and the complexity of the funding rules and various other regulations.

Mr Donato informed the meeting that the Council had clearly articulated in its conclusions the principles that would guide "Post Horizon 2020" programme. The Italian position on "Post Horizon 2020" programme was to push for a programme based on European value added and cooperation. These ideas are strongly apparent in the conclusions that assert cooperation, excellence, impact and openness to be the fundamental principles of "Post Horizon 2020" programme and that stress EU added value should be the major driver for implementation. The Council is pushing to rationalise the funding landscape that has become too complex, in part because of the proliferation of partnership instruments (including PPPs).

The Council called on the Commission to explore the recommendation of the Lamy report to develop a strategic, interdisciplinary mission-oriented approach to address common challenges with a European dimension. It wants better coordination with national research policies and proposes the establishment of a strategic programming process as part of the implementation of "Post Horizon 2020" programme to develop priorities at an early stage, including those of future missions. It highlights the contribution of key enabling technologies to industrial competitiveness and wants support to be continued in "Post Horizon 2020" programme. The Council recognised also that competitiveness requires skilled people and it recommended strong links between the successor programmes to Erasmus+ and Horizon 2020 to work more effectively together.

The Italian delegation had argued for a stronger cross-sectoral and inter-disciplinary approach. This is reflected in the importance given in the conclusions to improved synergies and complementarity between the Framework Programme and other funding instruments. Mr Donato concluded that he looked forward to a proposal from the Commission on the design and implementation of the European Innovation Council (EIC) under "Post Horizon 2020" programme, which is at present operating as a pilot project. In the view of the Council the EIC should be an important element of support offered by the EU to close-to-market innovations, but should clearly bring added value and develop synergies with national programmes. There was much of Mr Donato's explanation that is relevant to the proposal for an EU Masterplan for steel and much for participants to ponder upon.

Mr Martin observed that Parliament had indicated that it would support an initiative on the steel industry if the Commission would work together on the surrounding legislation and regulation; he asked the representatives from DG GROW and DG ENER for their thoughts on how that might be done.

Mr Handley from DG GROW argued that the key challenge was accelerate the transition to the low-carbon and circular economy and to develop a first-mover advantage without undermining the EU's competitive position. A steel mission was one possibility, but it might be a vehicle with a broader remit, covering a range of energy-intensive industries. All the industries in transition to a low-carbon future need identify the critical obstacles, e.g. access to non-energy raw materials or to clean electricity. DG GROW was ready to cooperate with the energy-intensive industries in analysing the system-wide implications of managing industrial transformation, and this would be discussed on 28 February at the High Level Group on Energy-Intensive Industries. The investment challenge was significant, as highlighted in the recently published final report of the High Level Expert Group on Sustainable Financing. The Commission would shortly come forward with its sustainable financing proposal.

Van Stiphout of DG ENER also expressed his desire to cooperate. ENER is preparing a clean energy package to ensure that renewable energies are well-integrated into the energy market. This initiative should go some way towards reassuring participants about the volume and quality of green electricity in the future. He agreed with the observation of DG GROW that the objective is to decarbonise whilst remaining competitive. The package aims at a deep reform of the market to cope with a high percentage of renewable energy and to make the market work with more flexibility. The exercise will demand a very large investment in electrical networks and this should

be done as efficiently as possible. DG ENER hopes to finalise the package over the summer and certainly before the end of 2018.

A joint approach by Directorate Generals implies a joint rationalisation of instruments. Generally, within the Commission there is a shared view that the various instruments should be aligned and coordinated as much as possible.

Within the framework of the SET Plan, DG ENER is conducting a dialogue with the steel industry and others to see how the Commission can profit from the lessons and ideas of the SET Plan to align the priorities of member states and the Commission in other areas with the intent to maximise the impact of the research and innovation budgets at European and national levels. The types of innovations that the SET Plan is now addressing do not focus just on energy, but rather comprise technologies that cross industries, for example the use of hydrogen in process industries or technologies that integrate processes in different industries. It is important to demonstrate how these ideas work in practice and from that experience to derive the policy implications. DG ENER is trying to promote work in such cross-cutting applications within "Post Horizon 2020" programme and this ambition obliges cooperation with DG GROW and DG RTD.

Moving Forward

Mr Dröll closed the seminar. He noted that the community had made a big step forward since the previous event one year ago. The presentations and discussion were indicative of how the EU steel industry is fully committed to ambitious and appropriate action that has been to some extent formulated in the Strategic Research Agenda of ESTEP[25] and the steel industry discussion paper on a Master Plan[26]. But there is still far to go and many gaps and open questions remain in terms of clear schedules of work, key performance indicators and milestones. The RFCS Accompanying Measure will provide some answers, but Mr Dröll suggested considering crowd sourcing of ideas for the Master Plan to uncover new opportunities for breakthrough innovation.

[25] Strategic Research Agenda (SRA), ESTEP, 2017.

[26] Discussion paper: Towards an EU Masterplan for a low-carbon, competitive European Steel Value Chain, draft. EUROFER, 2018.

European Steel: The Wind of Change

European Commission, DG RTD, Place Rogier 16, Auditorium Nowotny (25th floor)
Brussels, Wednesday 31 January 2018

9:15 **Welcome and introduction**
Peter Dröll, Director, Industrial Technologies, DG RTD, European Commission
Reinhard Bütikofer, Member of the European Parliament

9:30 **Research Fund for Coal and Steel (RFCS), Horizon 2020 and Innovation Fund**
Hervé Martin, Domenico Rossetti and Roman Doubrava, European Commission

Session I: Energy in Future Steelmaking

10:00 **Energy supply, consumption and efficiency in the steel sector**
Jean Theo Ghenda, VDEh Stahlinstitut and Helén Axelsson, Swedish Steel Association

10:30 **The hydrogen and electrical technological paths**
Johann Prammer, voestalpine and Katharina Rechberger, K1-MET

11:00 Coffee break

Session II: Steel in the Energy Market Applications

11:30 **Steel for the development of renewable energy technologies**
Pietro Gimondo, Research manager, Centro Sviluppo Materiali (CSM)

11:50 **Steel as a key component of the EU energy security of supply**
Marion Erdelen-Peppler, Head of European Pipeline Research Group (EPRG)

Session III: Greening European Steel

12:10 **European Joint Initiative**
Klaus Peters, Secretary General of European Steel Technology Platform (ESTEP)
Dany Croon, Director, European Steel Association (EUROFER)

12:40 **Panel Discussion**

Karina Angelieva, Bulgarian Presidency of the Council
Fabio Donato, Italian Permanent Representation
Peter Handley, DG GROW and Mark Van Stiphout, DG ENER

13.20 **Next steps and conclusions**
Artur Runge-Metzger, Director, Climate Strategy, DG CLIMA, European Commission
Peter Dröll, Director, Industrial Technologies, DG RTD, European Commission

13:30 Networking lunch

14:00 **Steel and Society - The inverted pyramid** offered by *Abbas Armut, Chef d'Atelier, Athénée Royal de la Rive Gauche* and presented (in French) by *Edouard Martin, MEP*



Seminar 'European Steel: The Wind of Change'
Brussels, 31 January 2018
Participant List

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ACRONYMS AND ABBREVIATIONS

BF	Blast Furnace
BOF	Basic Oxygen Furnace
CCU	Carbon Capture and Use
CDA	Carbon Direct Avoidance
CO2	Carbon Dioxide
CO2	Carbon Monoxide
DG CLIMA	Directorate-General for Climate Action
DG ENER	Directorate-General for Energy
DG GROW	Directorate-General Internal Market, Industry, Entrepreneurship and SME
DG RTD	Directorate-General for Research and Innovation
EAF	Electric Arc Furnace
ECSC	European Coal and Steel Community
EEB	Energy Efficiency in Buildings
EIB	European Investment Bank
EIC	European Innovation Council
ESIF	European Structural and Investment Fund
ESTEP	European Steel Platform
ETS	Emissions Trading System
EUROFER	European Steel Association
FCH2JU	Fuel Cells and Hydrogen 2 Joint Undertaking
FP	Framework Programme
GHG	Green House Gas
HBI	Hot Briquetted Iron
IEA	International Energy Agency
IGAR	Injection de Gaz Réformé
LEIT	Leadership in Enabling and Industrial Technologies
LNG	Liquefied Natural Gas
MEP	Member of the European Parliament
PEM	Proton Exchange Membrane
PPP	Public Private Partnership
RFCS	Research Fund for Coal and Steel
SCU	Smart Carbon Usage
SET	Strategic Energy Technology
SPIRE	Sustainable Process Industry through Resource and Energy Efficiency

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Steel is strategic for the future of European industry. And industry has always been a cornerstone of economic prosperity in Europe as reminded in the Commission 'Industrial Policy Strategy'. Efforts are needed to reinforce industrial leadership in the age of globalisation, sustainability challenges and rapid technological change.

The Seminar 'European steel – The wind of change' underlined the energy questions for the future European steelmaking. It tackled the issues of hydrogen and electrical technological paths, of energy efficiency as well as the energy applications largely based on steel, stemming from renewable energy technologies to gas pipelines.

This publication sheds light on the need for a large European innovation joint public and private initiative to ensure long-term competitiveness and sustainability of European Steel.

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