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2050

A STEEL ROADMAP FOR A LOW CARBON EUROPE 2050

2020 2030 2040 2050

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FOREWORD

The European steel industry is determined to deliver a positive contribution to a more sustainable economy in Europe by providing innovative types of steel needed for low carbon solutions in a variety of sectors and by reducing its own CO_2 emissions.

Only with a modern, innovative and profitable steel industry in Europe can the EU's targets for a sustainable, carbon-lean and competitive economy be met. EU policymakers need to provide the right framework conditions and infrastructure to enable industry to contribute effectively whilst remaining competitive on a global scale.

Success is only possible if there is a fundamental transformation of the European economy, including a total renewal and technological upgrading of the main infrastructures for transport, energy and housing. Conditions must be created to foster the growth of new and smarter industrial technologies, consumer products and all the transport fleets (air, land and water) that will operate within the new infrastructures. The job of renewal is not limited to merely a select number of economic sectors. It is a societal challenge requiring not only huge public investment in infrastructure, R&D, the demonstration and deployment of innovative technologies, as well as access to finance and risk sharing for businesses, there is also a need for broad public acceptance. Future infrastructure, technologies and transport will not only have to be environmentally-friendly to the maximum possible extent, they will also have to enable society to run more efficiently, with increased consumer satisfaction and a cost-benefit for every part of society, including the EU's industrial value chains and its workforce, which form the basis of prosperity in Europe.

The effects of human activity on the earth's climate are a global challenge and responsibility. A coordinated world-wide response is therefore essential in order to reach an acceptable degree of global greenhouse gas emission reductions in line with the recommendations of the Intergovernmental Panel on Climate Change (IPCC). In the absence of an international agreement that would provide for the necessary global reductions in greenhouse gas emissions, the EU has set its own aspirational pathway culminating in a target of 80% to 95% CO_2 emission reductions by 2050 compared to 1990 levels. Furthermore, it has set binding measures to decarbonise the EU economies, with the EU Emissions Trading Scheme as its flagship instrument.

Neither the proposed pathway nor the measures indicate how each industrial sector is to meet the objectives either from a technical perspective or in terms of the cost implications and the associated effects on international competitiveness. They are also not based on a life cycle assessment of materials and products and do not take into account the contribution sectors such as the steel industry make to emission reductions through their innovative products.

As a response to the current EU climate policy framework and the Commission Communication on a *Roadmap for moving to a competitive low carbon economy in 2050*, the EU steel industry in 2012 contracted the Boston Consulting Group together with the Steel Institute VDEh to assess the CO_2 mitigation potential of the EU27 steel industry up to the year 2050. Based on the results of that study and after comparison with existing research, the European steel industry has developed its own 'Steel Roadmap for a Low Carbon Europe 2050', which includes recommendations for policy makers.

The Steel Action Plan, presented by the European Commission in June 2013 and aimed at improving the global competitive position of the EU steel industry, acknowledges how much the steel sector is currently under pressure. In an increasingly global economy, this situation will not change any time soon. The EU must therefore refrain from unilateral climate action. Instead the EU should give the industry the means to develop the breakthrough technologies that are indispensable and at the same time until these technologies are available and affordable provide effective protection against distortions to competition. Investment is fleeing Europe. The unpredictable regulatory environment caused by repeated attempts to change the rules governing emissions is one reason for this development. But it would not take much to reverse this trend and restore a climate that encourages investment in Europe – investment in new technologies and products.

Wolfgang Eder
President of EUROFER

Gordon Moffat
Director General of EUROFER

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EUROFER would also like to thank the Boston Consulting Group and the Steel Institute VDEh for their technical contribution without which this study would not have been possible. The vivid exchanges of views in the Steering Committee meetings were an important part of the process and finally helped laying solid grounds for this very challenging work.

The authors wish to acknowledge with much appreciation the review carried out by Ecofys. Their independent review of the policy recommendations stimulated improvements and coherence throughout the study.

Last but not least, many thanks go to all organizations and individuals who contributed to this work by providing data, reviewing the study and exchanging views. The authors would like to thank in particular the following organizations for their time and attention: the European Bank for Reconstruction and Development, the European Steel Technology Platform, the International Energy Agency, the IEA Greenhouse Gas R&D Programme and the Joint Research Centre of the European Commission.

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EXECUTIVE SUMMARY

For the time being there are no economically feasible steelmaking technologies available that have the potential to meet the CO_2 reduction pathway envisaged in the Commission *Roadmap for moving to a competitive low carbon economy in 2050*. At best, a 15% decrease in the overall CO_2 intensity of the sector could be achieved between 2010 and 2050 through the widespread dissemination of technologies that could reasonably become cost-effective in the future.

However, in order to achieve radical CO_2 reductions, sweeping technological changes would be required. This is only possible if legislators create the right framework conditions with supportive EU policies that keep the EU steel industry competitive on a global scale. Such policies include continued access to high-quality raw materials and energy at globally competitive prices as well as the necessary investments in infrastructure. Furthermore, legislators need to take into account that more CO_2 emission reductions can be achieved through the development and deployment of innovative steel grades, most notably in the energy and transport sector.

Therefore a globally competitive European steel industry is key for delivering CO_2 savings not only in the steel industry itself, but also in the economy at large through widespread steel-based low carbon applications. In the right conditions, steel could be a key driver towards a competitive low carbon EU economy. The findings of this study come together with a set of recommendations for policy makers. They revolve around the need to maintain the international competitiveness of the EU's steel industry. Consequently, climate policies must be developed not only with the steel industry's specific characteristics in mind, but also with a wider perspective that takes into account other relevant aspects like restructuring needs, public acceptance of new technologies, environment protection levels, energy, labour cost, taxation and education.

TECHNICAL ECONOMIC ASSESSMENT

The principles of steelmaking have not changed fundamentally over the years. However, technological development has enabled increased control and efficiency of all the steel production processes, which in Europe have now reached a high level of optimisation. A number of studies and research programmes have already looked at how to improve energy efficiency and reduce CO_2 emissions even further in the sector.

The ULCOS[1] programme has made a major contribution to the issue. This initiative, supported by the Commission, is aimed at identifying and developing innovative low carbon steelmaking technologies. The ULCOS consortium, which includes all the major EU steel producers, was set up in 2004. It has evaluated the technical CO_2 reduction potential of over 80 existing and potential technologies. This analysis is far more extensive than anything that has been done so far in other steel producing regions and by most other industrial sectors. Four technologies were found to be promising in the long-term with emission reductions potentials of more than 50%. These technologies were selected to be investigated further through an R&D programme including pilot and demonstration plants: blast furnace with top gas recycling (BF-TGR), bath smelting, direct reduction, and, electrolysis. With the exception of electrolysis all the technologies rely on the development of carbon capture and storage (CCS) to realise their full abatement potential. To date the blast furnace with top gas recycling and bath smelting reduction technologies have reached the pilot plant phase.

In 2012 the EU's Joint Research Centre (JRC) published a study called *Prospective Scenarios on Energy Efficiency and CO_2 Emissions in the EU Iron & Steel Industry*.[2] The analysis looks into the steel sector's CO_2 savings and energy efficiency potential up to the year 2030 from a cost efficiency perspective, thereby complementing previous modelling work done under the ULCOS programme.[3] Under the assumptions used, the study concludes that the application of best available techniques and innovative technologies would lead, from 2010 to 2030, to a maximum CO_2 emission abatement of 14% to 21%, assuming the deployment of innovative technologies like BF-TGR and CCS from 2020. The modelling suggests that the carbon price would have a limited impact in the uptake of new technologies, as even under a carbon price of €200 the overall sectoral reduction in CO_2 emissions would only reach 19%. A follow-up analysis[4] using the same model shows that, with much less conservative decision-making criteria on new investments compared to that assumed in the JRC report, the reduction in energy consumption and CO_2 emissions could amount to around 18% and 65% respectively, confirming the prominent role BF-TGR should play as a mitigation technology. However as BF-TGR, and especially CCS, are unlikely to be commercially available by 2025, the expected potential would in reality be much more modest (in the case of CCS, its commercial availability at all is questionable).

EUROFER contracted the Boston Consulting Group (BCG) to assess from a techno-economic perspective the EU steel industry's options to decrease its CO_2 emissions up to 2050 (for this project, BCG teamed up with the Steel Institute VDEh). The study[5] also looks at the possible CO_2 savings in the economy stemming from the use of innovative steel grades. Both the JRC and the BCG/VDEh projects – due to their horizontal, EU-wide approach – are therefore important milestones in the identification of credible CO_2 mitigation pathways for steelmaking in Europe.

The Steel Roadmap for a Low Carbon Europe 2050 builds on these studies. It seeks to reconcile the key outcomes and findings obtained from different approaches and combines them into a report with a set of recommendations on the policies which will be required to make EU steel's contribution to the decarbonisation of Europe a success.

1 Ultra-Low CO_2 Steelmaking.
2 Pardo N., Moya J.A., Vatopoulos K. (2012): Prospective Scenarios on Energy Efficiency and CO_2 Emissions in the EU Iron & Steel Industry (JRC Scientific and Policy Reports).
3 Bellevrat E., Menanteau Ph. (La Revue de Métallurgie – CIT- 2009), Introducing Carbon Constraints in the Steel Sector : ULCOS Scenarios and Economic Modelling.
4 Moya J.A., Pardo N. (Journal of Cleaner Production - 2013), The potential for improvements in energy efficiency and CO_2 emissions in the EU27 iron and steel industry under different payback periods.
5 The Boston Consulting Group, Steel Institute VDEh (2013), Steel's Contribution to a Low-Carbon Europe 2050. Technical and economic analysis of the EU27 steel sector's CO_2 abatement potentials.

STEEL'S CONTRIBUTION TO A LOW CARBON EUROPE 2050

The BCG/VDEh study follows a holistic approach in determining CO_2 mitigation potential of the EU steel industry, taking into consideration both the emissions from steel production and the effects of the use of steel in innovative applications. It assesses the technical potential of existing or projected technologies as well as the economic viability of the retained options. The study also looks into CO_2 savings related to the use of steel in applications for which steel can be replaced by no other material.

STEEL AS A CO_2 MITIGATION ENABLER

According to BCG/VDEh case studies on eight CO_2 savings applications for which steel cannot be replaced technically or economically by any other material, the yearly savings for the EU27 of these applications alone would amount to at least 443 Mt CO_2 in 2030. This amount has to be compared to the emissions released while producing the steel grades under consideration (70 Mt CO_2) and the total EU steel industry emissions of approximately 220 Mt CO_2 in 2010. Additional significant emission reductions could be established if the scope was extended to other steel uses. It can be concluded that the application of innovative grades of steel, developed and produced in Europe, will result in an amount of CO_2 mitigation which is at least double of the CO_2 emitted by the whole sector itself. In this respect, steel can be justifiably classed as a CO_2 mitigator.

CO_2 REDUCTION POTENTIAL FROM STEELMAKING

CO_2 emissions from EU27 steel production fell by over 25% between 1990 and 2010, from 298 Mt in 1990 to 223 Mt in 2010 (direct and indirect emissions calculated down to the hot rolling process). This decrease is mainly due to a partial shift from production using virgin ores to production by recycling scrap through the electric arc furnace route (accompanied by a contraction in production volume), efficiency gains, and, the decrease of CO_2 emissions from electricity generation. Specific CO_2 emissions decreased by about 15% from 1.508 to 1.293 tonnes CO_2/tonne of steel over the same period.

As for the 2050 horizon, the BCG/VDEh study projects – based on proprietary modelling – that the EU steel market will grow by 0.8% annually, leading to EU crude steel production of 236 Mt in 2050. The amount of scrap available within the EU is projected to grow by 0.9% annually, increasing from 96 Mt in 2010 to 136 Mt in 2050.

Under these assumptions the BCG/VDEh study assessed the EU steel industry's mitigation pathways via several abatement scenarios.

The *economic scenario* involves the implementation of cost-effective incremental technologies and best-practice sharing throughout the sector. It also takes into account the projected increase in scrap availability resulting in a growing share of secondary steelmaking from 40% up to 44% in 2050[6] as well as the effect of the decrease of the CO_2 intensity of the power sector[7]. It would lead to an absolute CO_2 emission reduction of 13%, from 298 Mt CO_2 in 1990 down to 258 Mt CO_2 in 2050. Specific CO_2 emissions would in parallel decrease from 1.508 tonnes CO_2/tonne of steel in 1990 down to 1.093 tonnes CO_2/tonne of steel in 2050 (-27.5%). This represents a decrease in specific CO_2 emissions by 10% between 2010 and 2030 and by 15% between 2010 and 2050.

In the *direct reduction scenario*, the expected overall CO_2 reduction in the sector without CCS would amount to ca. 40% between 1990 and 2050. However this scenario is not economically feasible as the energy price conditions that are prevailing now are not adequate to enable the deployment of this technology. The BCG/VDEh study estimates CO_2 abatement costs pertaining to the shift from the existing BF-BOF route towards the Direct Reduced Iron – Electric Arc Furnace route (DRI-EAF) as ranging from €260/tonne of CO_2 to €710/tonne of CO_2. These figures represent the cost of abandoning existing installations for new ones with higher operating costs. The DRI-EAF route relies on natural gas and electricity which are both excessively expensive in Europe. Even under favourable natural gas and electricity prices, the technology change would incur huge investment costs which would be impossible without adequate support policies.

As under the *CCS scenario*, all iron-ore based steelmaking technologies have the same CO_2 intensity (ca. 0.7 tonne CO_2/tonne of steel), it can be concluded that the retrofit of existing blast furnaces with top gas recycling technology would be the most sensible option. Such a scenario involving full deployment of CCS would lead to a reduction of absolute CO_2 emissions of ca. 60% in 2050 compared to 1990, still falling short of the EU's 80% aspirational objective.

However to date economic viability and general applicability of CCS in Europe raises many questions and at this point its large-scale feasibility is seen as unlikely. Figures pertaining to CCS costs in the steel industry show a high sensitivity to site-specific conditions. Recent research suggests that such costs would amount to a minimum of €50 per tonne of CO_2 just for capture and without transport and storage in the case of the ULCOS blast-furnace top gas recycling.[8] These numbers come from project calculations and this technology has yet to be proven at industrial scale. In the face of public resistance to CCS in a growing number of Member States, the costs relating to CO_2 transport over long distances and storage are expected to have a high impact on steel production costs, depending on local conditions.[9]

DEEPER CO_2 CUTS IN THE STEEL SECTOR

Bringing the steel sector's emissions further down would need the deployment of technologies like HIsarna (smelting reduction) or ULCORED (direct reduction) – both connected to CCS – or hydrogen-based reduction, should they prove technically feasible. Under a fully decarbonised electricity scenario, electrolysis could also be envisaged as a potential solution. From today's perspective, it is not possible to predict which technology or combination of technologies is most likely to emerge.

CONCLUSIONS

From today's perspective – and given current energy market conditions and infrastructure – the ambitious objectives proposed in the Commission Low Carbon Roadmap for the ETS of 43-48% by 2030 and 88-92% by 2050 compared to 2005 levels is technically and economically unachievable for the steel industry unless alternative innovative steelmaking technologies combined with CCS are deployed at industrial scale and at the same time steps are taken to shield the sector's competitiveness. This is also true for the 1.74% pathway envisaged under the EU's Emission Trading Scheme (EU ETS), which results in CO_2 reductions of 37.6% by 2030 compared to 2005 levels and 70.9% by 2050.[10] In practice such levels of abatement would require as a minimum condition for their achievement yet unproven innovative or 'breakthrough' technologies and CCS to be commercially available at competitive costs for the EU steel industry.

In view of the above, the EU steel sector will need substantial support and co-operation from policy makers to shape the right framework conditions in order to maximise its contribution, especially regarding CO_2 mitigation at installation level. Furthermore, the contribution of European steel to CO_2 abatement should be evaluated and accounted for based on a holistic approach, taking into account the benefits steel production and steel products convey.

The challenges the EU steel industry is facing are many and varied. They include access to growing markets as well as to high-quality raw materials and affordable energy. With continued investment in R&D, innovation, process control and energy efficiency, the EU steel sector has managed to remain competitive despite adverse conditions in the EU compared to those of its main competitors outside the EU. These conditions need to be improved so as to enable steel to help create a sustainable Europe.

6 The modelling is based on the assumption of self-sufficiency for both the EU steel and scrap market.
7 According to IEA projections. The complete decarbonisation of the power sector by 2050 would lead to further emission decreases.

8 Hooey L., Tobiesen A., Johns J. and Santos S. (2013), Techno-Economic Evaluation of Incorporating CO_2 Capture in an Integrated Steel Mill.
9 Zero Emission Platform (2011), The Costs of CO_2 Capture, Transport and Storage, Post-demonstration CCS in the EU.
10 The 1.74% linear reduction factor would lead to CO_2 reductions of 45.5% by 2030 and 74.6% by 2050 compared to 1990 levels.

To this end, EUROFER suggests a number of policy recommendations which the reader can find in Chapter 7 of this report. These are meant to set the right conditions so as to enable the EU steel industry to decarbonise whilst retaining its competitiveness on the global scene by making the most of steel as a CO_2 mitigation enabler. These policy recommendations can be summarized as follows:

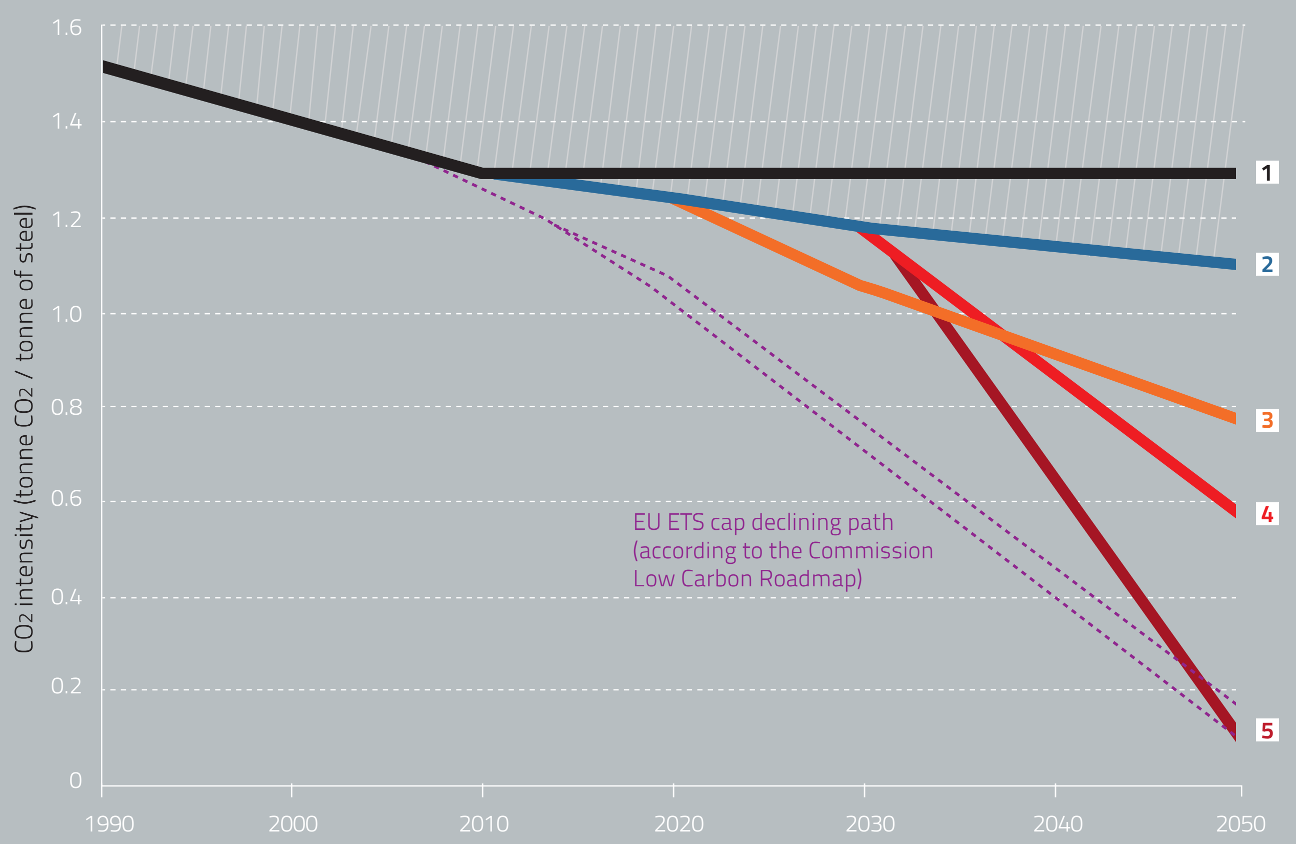
- Future policies should not damage the competitive position of the steel industry. They should provide the appropriate incentives for CO_2 mitigation as well as effective protection from distortive CO_2 costs. This necessitates taking into consideration the economic potential of improvement in the sector, what is technically achievable over time at an acceptable cost.
- Adequate support for new technologies, both for carbon-lean steel making technologies and the establishment of the infrastructures which enable these, is required to bring about radical CO_2 emission reductions in the steel industry. As already demonstrated with renewables and CCS, carbon pricing cannot bring about the emergence of breakthrough technologies. Public funding will be needed as the vast investments required will exceed the industry's financing capabilities.
- Future policies must recognise the positive role steel will play in achieving the EU's carbon abatement goals. A broadened view must be taken to incorporate and take into account the benefits of innovative steel grades and steel applications in CO_2 mitigation.
- A coherent and predictable energy and climate policy framework post 2020 is urgently needed. The EU institutions and Member States have to commit to the provision of policies and means that are consistent with the CO_2 reduction ambition and in accordance with the timeframe under consideration. In order to create a regulatory environment that stimulates investment over the long-term, they should refrain from piecemeal intervention in the policy framework.

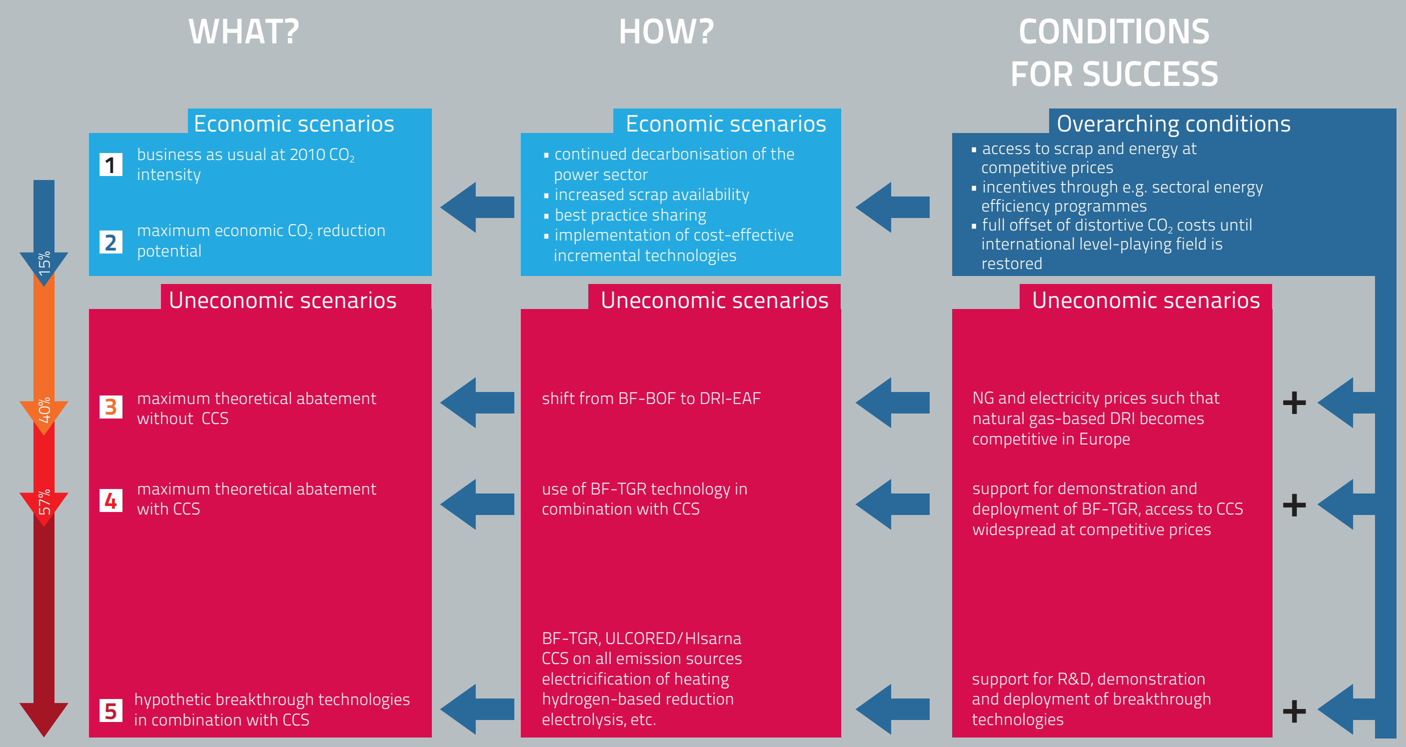
Unilateral climate action by the EU along the lines of the mitigation path suggested in the Commission Low Carbon Roadmap would have devastating effects on the EU steel industry. Mitigation targets should be in line with what the steel industry in other major economies is committing to. The EU should continue its efforts to bring as many nations as possible – including emerging economies – to agree to a meaningful, balanced global climate deal.

For illustrative purposes, the steel sector's emission reduction trajectories derived from the model developed by BCG/VDEh are shown in Figure 1.

FIGURE 1
CO_2 INTENSITY PATHWAY SCENARIOS FOR THE EU STEEL INDUSTRY UP TO 2050

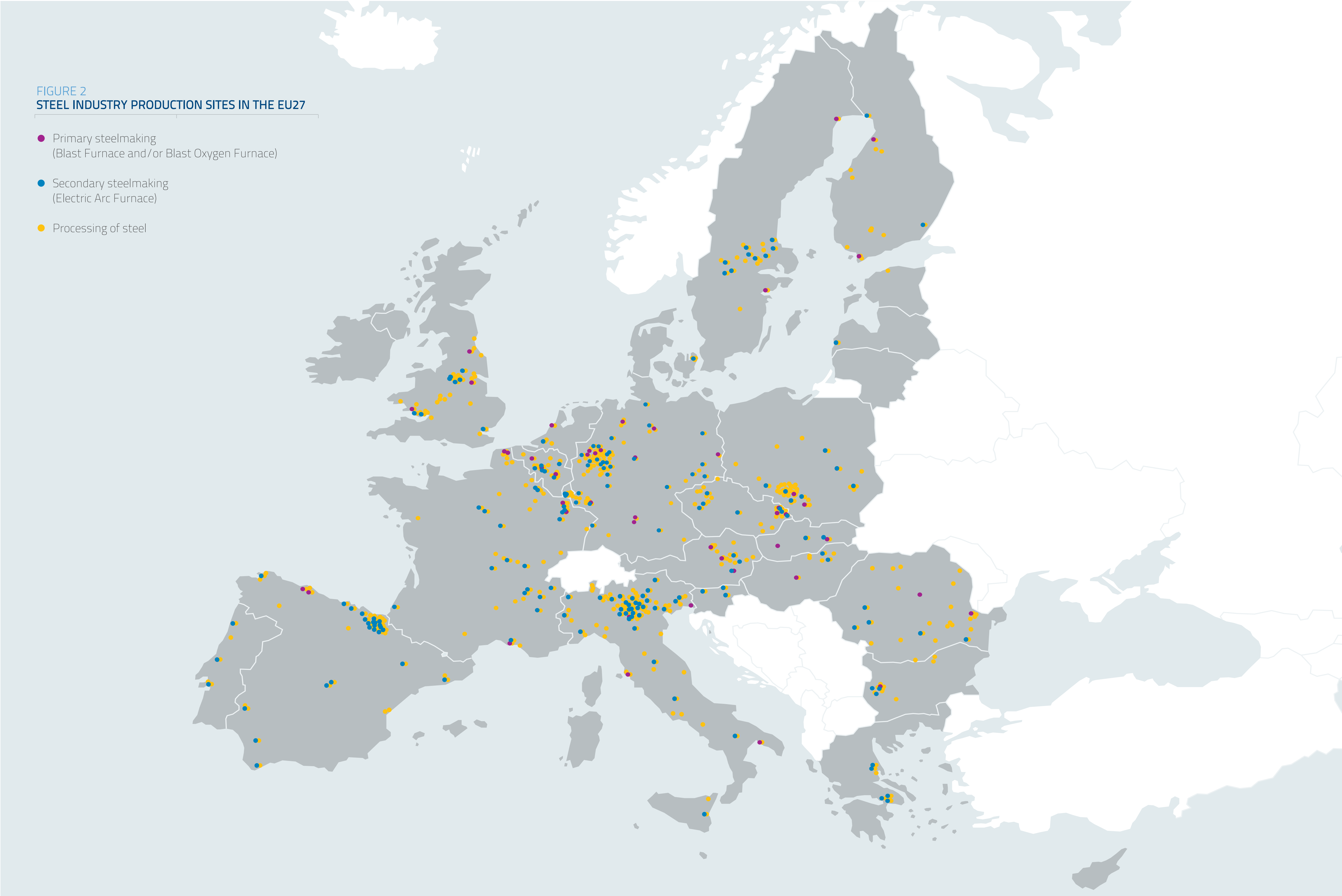
Source: BCG-VDEh, EUROFER





Emission reduction potentials are expressed in specific CO_2 emissions relatively to 2010
CCS: Carbon Capture and Storage
BF-BOF: Blast Furnace-Basic Oxygen Furnace
BF-TGR: Blast Furnace with Top Gas Recycling technology
DRI: Direct Reduction of Iron
EAF: Electric Arc Furnace
NG: natural gas

FIGURE 2
STEEL INDUSTRY PRODUCTION SITES IN THE EU27



01 STEEL FOR A MODERN, SUSTAINABLE SOCIETY

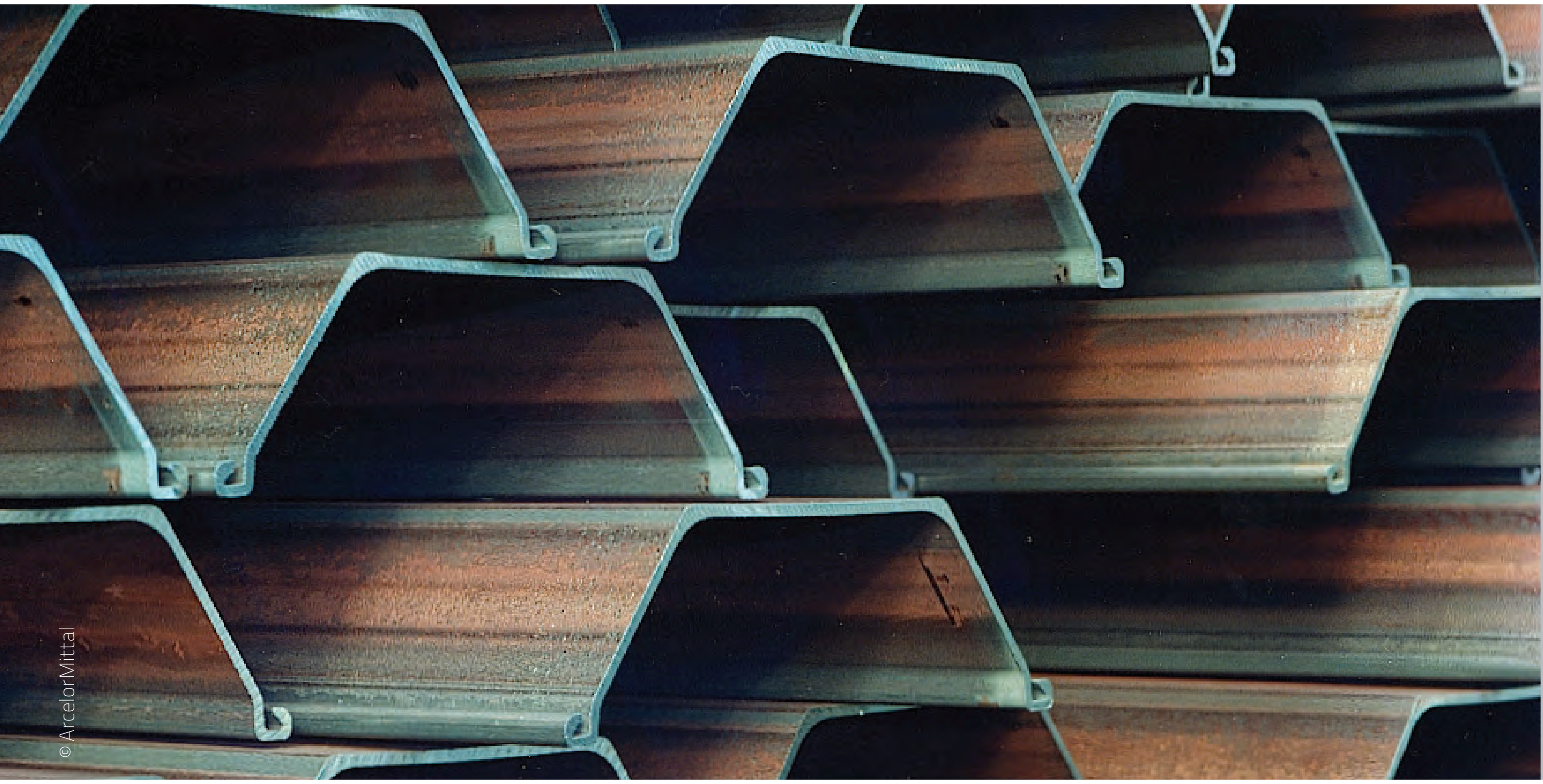


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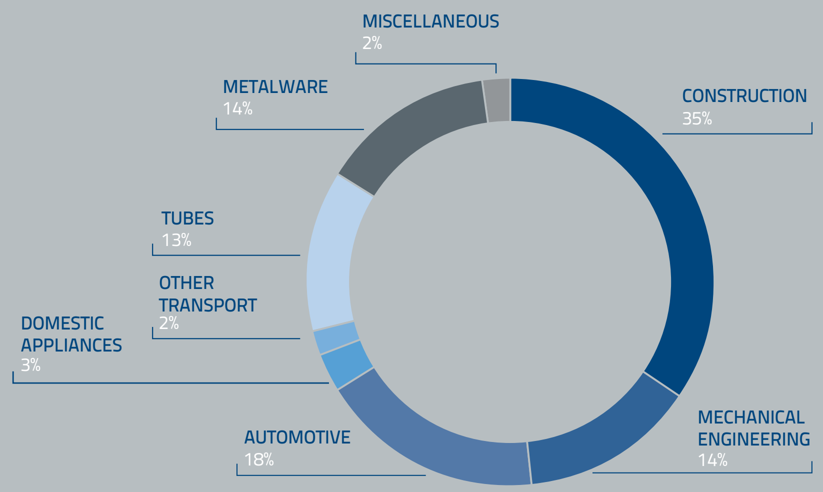
FIGURE 3
SECTOR SHARES IN TOTAL EU STEEL CONSUMPTION IN 2010

Source: EUROFER



THE EU'S STEEL INDUSTRY IS ESSENTIAL FOR INNOVATION, VALUE CREATION AND SUSTAINABILITY IN EUROPE

The European steel industry employs, at over 500 production and processing sites located in 23 EU Member States, 350.000 highly skilled people. In addition, several million more jobs are directly and indirectly dependent on steel in the value chain and service sectors.[11] It produces, on average, 170 million tonnes (Mt) of crude steel per year, of which about 60% is made via primary steelmaking (blast furnace route) and 40% via secondary steelmaking (steel scrap recycling in electric arc furnaces). In 2009 the sector generated a turnover of approximately €170 billion, 1.4% of the EU's GDP.[12]

Due to its outstanding properties in terms of strength, formability and versatility, steel is being used in countless applications. The importance of steel is therefore set to further increase as more high-grade materials will be required for the greening of the economy. European steel production has a unique role to play in providing the material base for Europe's transformation into a low carbon economy in the required qualities, quantities and at affordable prices and at the same time generating the value added needed to finance the transformation of the built environment.

European steel forms the basis of various industrial value chains and is closely connected with diverse manufacturing sectors.

The sector develops and manufactures thousands of innovative steel solutions in Europe. These provide the foundation for innovation, durability, CO_2 reductions and energy savings in applications as varied and vital as automotive, construction, machinery, brown and white goods, low carbon and renewable energies.

New, innovative technologies benefit from the strong steel R&D network in Europe which is – due to its diversity and cooperation with other sectors – unique in the world.

STEEL ENHANCES RESOURCE EFFICIENCY

The European steel industry is known for being among the most energy and resource efficient worldwide. Today, the best performing European blast furnaces (BF) and electric arc furnaces (EAF) are operating close to the technological limits. By-products from the steelmaking processes such as process gases (waste gases) and slags are used as efficiently as possible and save natural resources. Instead of being flared, waste gases are recovered for heat and electricity production. Instead of being landfilled, slags are used in the cement and construction sectors. Both thereby substitute millions of tonnes of primary raw materials and save millions of tonnes of CO_2 emissions every year. In 2010 CO_2 savings via the use of process gases totalled about 42 Mt. The recycling of slag led to about 19 Mt CO_2 savings.[13] The use of these by-products should therefore be encouraged and given due credit in EU legislation. Innovative European steel applications have the potential to save more CO_2 emissions in the EU than the emissions of the entire European steel industry (see Chapter 4).

11 For example, the employment indicator for the German steel industry is 6.5 and its production multiplier 2.7. This means that a steel demand increase of 1 euro leads to an increase of production value of 2.7 euro in the economy as a whole (Source: Rheinisch-Westfälisches Institut für Wirtschaftsforschung, Die volkswirtschaftliche Bedeutung einer Grundstoffindustrie am Beispiel der Stahlindustrie, 2011, p. 4).
12 EUROFER member survey 2010; EUROFER data collection.

13 The Boston Consulting Group, Steel Institute VDEh (2013), Steel's Contribution to a Low-Carbon Europe 2050. Technical and economic analysis of the EU27 steel sector's CO_2 abatement potentials.

STEEL IS ENDLESSLY RECYCLABLE

As it is 100% recyclable, steel contributes significantly to the long-term conservation of fundamental resources for future generations. Steel can be endlessly and easily recycled at the end of its service life without losing its properties. About 50% of total EU steel production stems from recycled steel scrap (steel scrap being fed to electric arc furnaces as well as to basic oxygen furnaces). Using steel scrap in place of virgin iron ore yields energy savings and thereby accelerates CO_2 emission reductions in the steel industry (although due to quality reasons and due to the limits of its availability, scrap cannot entirely replace iron ores).

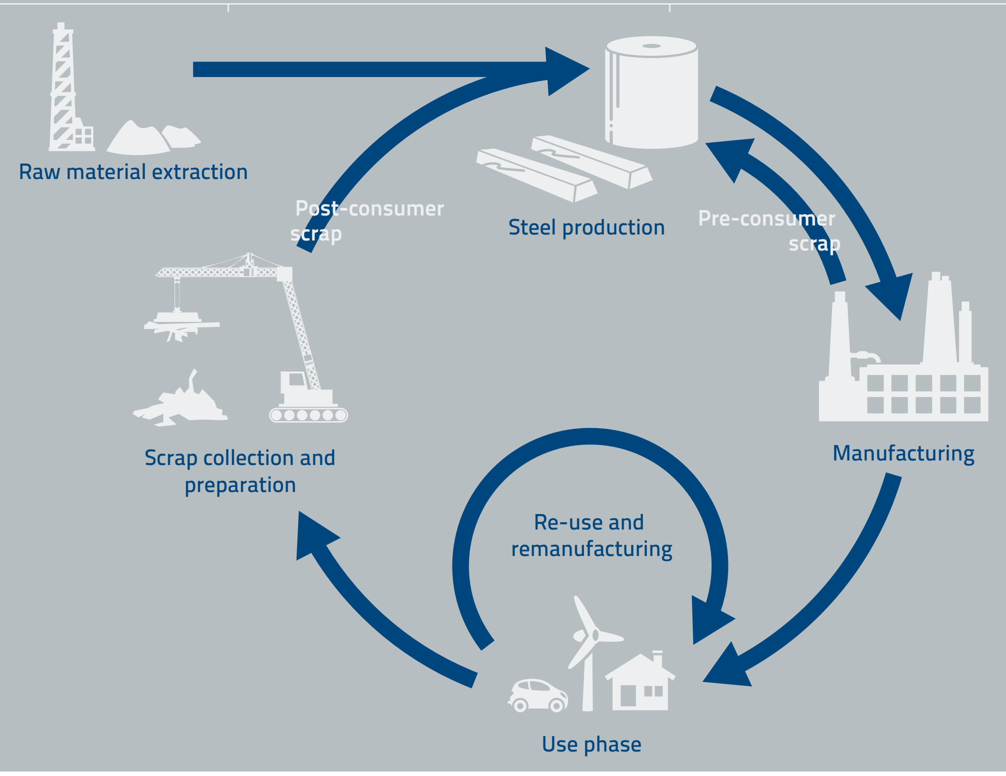
A study by the Technical University of Berlin published in 2012[14] looked into correlations of recyclability and production-related CO_2 emissions more closely. Applying a multi-recycling approach, the study delivered for the first time a holistic eco-balance for steel, evaluating all recycling processes over the complete life cycle of the material. Based on the principle that steel is infinitely recyclable without loss of quality, the modelling integrates primary steel production via the BF-BOF route and recycling of steel in the EAF route. Taking account of steel products' different lengths of life cycle lengths, it calculated an average span of 16 years between production and recycling.

On this basis the study estimates the development of CO_2 emissions related to producing one tonne of hot rolled steel, starting with primary BF-BOF production and continuing with the multiple recycling processes in the EAF route. The study covers 17 life cycles on the whole. It demonstrates that already after six recycling cycles the volume of CO_2 emissions attributable to producing steel decreased by 50% compared to primary BF-BOF production. Via the integration of primary and secondary steel production routes, the analysis demonstrates that, in a realistic scenario, production-related CO_2 emissions amount to less than 1 tonne CO_2 per tonne of hot rolled steel. Steel scrap recycling creates a win-win situation for both the environment and the economy.

14 Finkbeiner M., Neugebauer S. (2012), Resource efficiency and life cycle assessment, Multirecycling of steel.

FIGURE 4
ONCE PRODUCED, STEEL IS AN ETERNAL SOURCE FOR FUTURE GENERATIONS

Source: EUROFER



The fact that steel products have long lifecycles is one of the reasons why on a global scale there is insufficient recycled material to satisfy the growing steel demand. Virgin material has to be introduced into the supply chain. Primary and secondary steel productions are complementary routes and will continue to be so. In order for the EU to meet its sustainability objectives, it is essential to ensure enough iron and steel scrap is available within Europe at the right quality and at competitive prices. However, to date, the EU is a net exporter of steel scrap (by 16 Mt in 2012).[15]

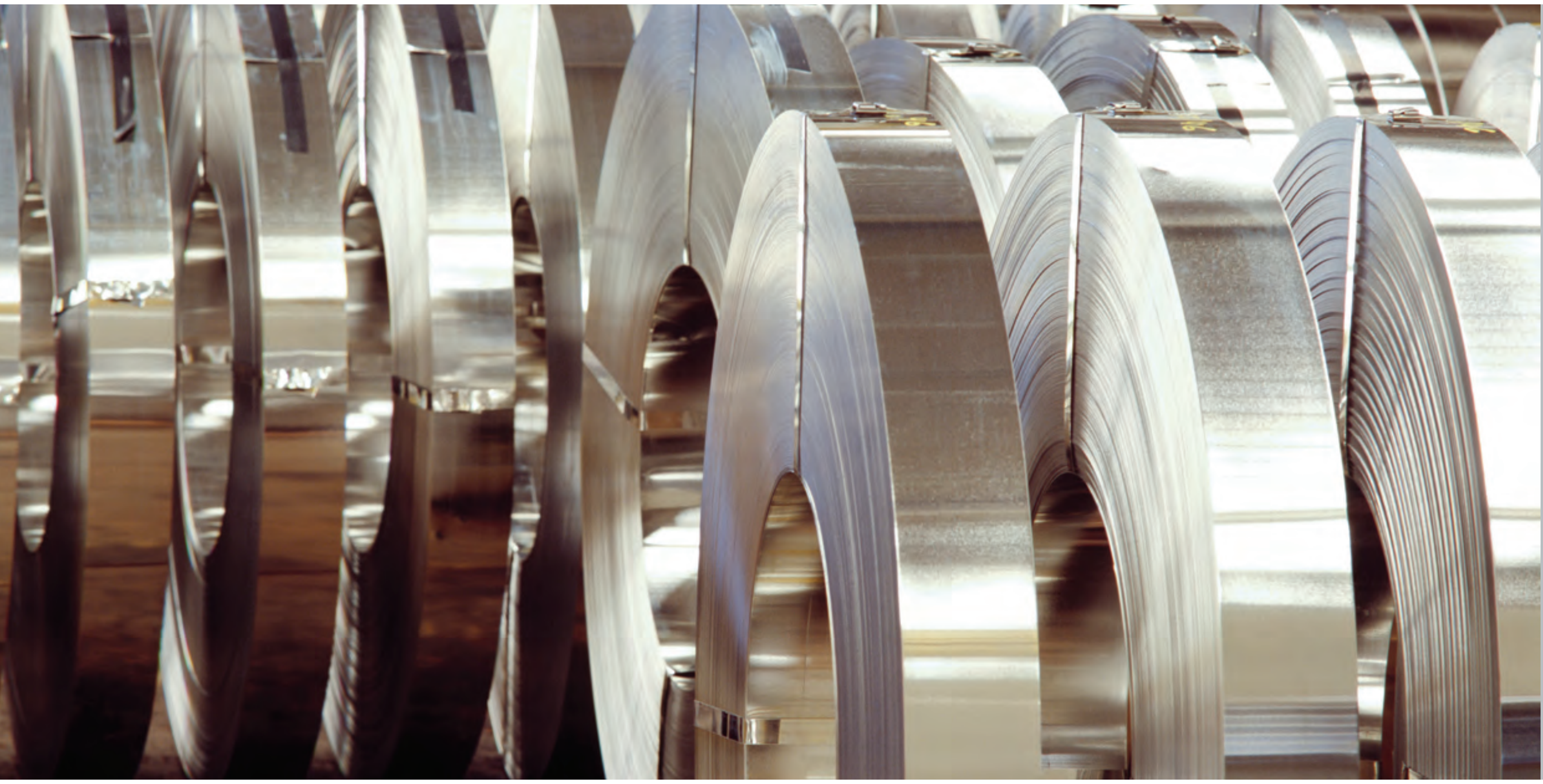
COMPETING ON GLOBAL MARKETS

EU steel makers operate in a highly competitive global market. The industry's trade intensity with third countries is above 30%. The EU27 is the second largest steel importing region in the world but also the second largest exporting one.[16] Imports in 2012 reached 21.4 Mt, the biggest import sources being Russia, Ukraine, China, Turkey and South Korea. EU steel exports for the same year totalled 31.7 Mt, the biggest markets being Turkey, the USA, Algeria, Switzerland, Russia and India.[17]

EU steel makers have remained competitive in terms of overall costs and in terms of quality, through a continuous process of investments and restructuring, and this despite energy prices and raw materials, labour and regulatory costs among the highest worldwide.

15 EUROFER data collection, scrap imports in 2012 totalled 3.4 Mt, exports totalled 19.2 Mt.
16 Worldsteel (2013), World steel in figures 2013.
17 EUROFER.

02 EU CLIMATE POLICIES FOR STEEL



THE EU'S GLOBAL CLIMATE OBJECTIVES

According to the IPCC recommendations and with a view to keeping the global temperature rise below 2°C by 2050, the European Council supports an EU objective to reduce greenhouse gas emissions by 80-95% by 2050 compared to 1990 levels, in the context of necessary reductions by developed countries as a group. The European Parliament similarly endorsed the need to set a long-term reduction target of at least 80% by 2050 for the EU and the other developed countries.

In the run-up to COP-15 in Copenhagen, the EU also offered to increase its 2020 objective from 20% to 30% emission reductions on condition that other developed countries commit themselves in a comprehensive international agreement to comparable emission reductions and that more advanced developing countries "contribute adequately according to their responsibilities and respective capabilities."[18] An international agreement by 2015 providing the necessary abatement commitments by all major economies will be crucial into stopping the continued trend in global greenhouse gas emission increases.

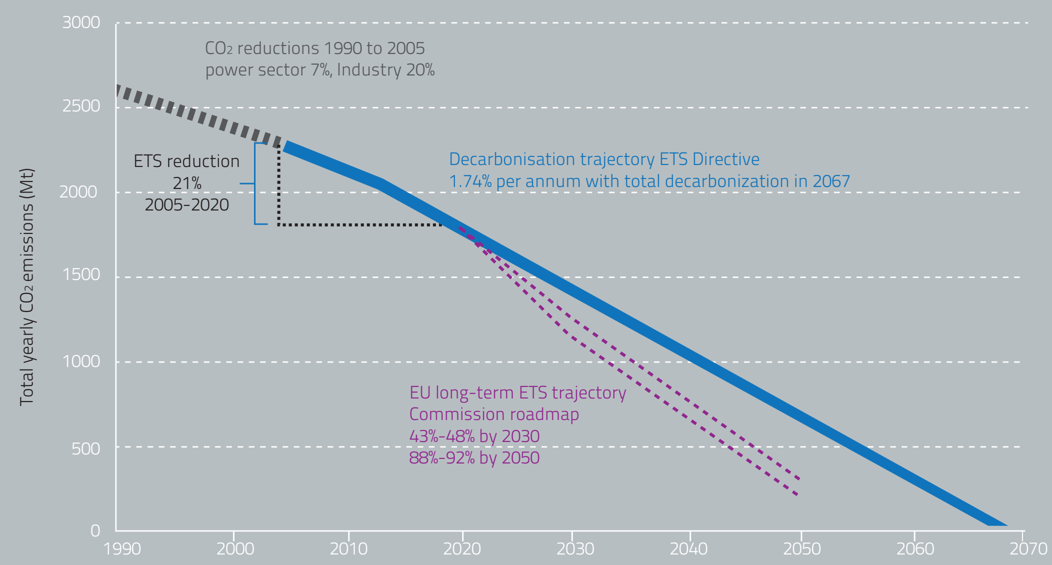
EU PATHWAY FOR CO_2 REDUCTIONS IN INDUSTRY 1990 TO 2050

In 2008 the EU revised its ETS Directive and adopted a mandatory linear CO_2 mitigation pathway of 1.74% emission reduction per annum, resulting in a 21% reduction by 2020 compared to 2005 levels (31% compared to the Kyoto reference year 1990) and leading to reductions by 37.6% in 2030, 54.3% in 2040 and 70.9% in 2050.[19] [20] Following this mandatory path, in 2068 there will be no CO_2 emissions allowed in the EU

18 Last reiterated by the Council of the European Union in its Conclusions on the Preparations for the 18th session of COP 18 to the UNFCCC and the 8th session of the Meeting of the Parties to the Kyoto Protocol (CMP 8) in Doha, Qatar, 26 November - 7 December 2012, 3194th Environment Council meeting, Luxembourg, 25 October 2012.
19 Article 9 EU ETS Directive and EUROFER calculations.
20 The 1.74% linear reduction factor would lead to CO_2 reductions of 45.5% by 2030, 60.1% by 2040 and 74.6% by 2050 compared to 1990 levels.

FIGURE 5
EU ETS CO_2 REDUCTION PATHWAY

Source: EUROFER based on the EU ETS Directive and the Commission Roadmap for moving to a competitive low carbon economy in 2050



ETS sector which will have to be either decarbonised or relocated to non-EU countries.

In order to mitigate the risk of delocalisation of steel production to non-EU countries (carbon leakage), the EU steel industry is to receive free emission allowances at the level of performance benchmarks based on the average of the 10% most efficient installations. The main benchmark for the steel industry has been set at about 10% below the CO_2 emissions of best performance because the rules failed to account all CO_2 emissions from process gases (waste gases) when setting the benchmarks. According to the current EU ETS Directive, free allocation would be limited to 25% of the benchmarks in 2021, decreasing each year by equal amounts (5%) reaching no free allocation in 2027.[21]

To avoid carbon leakage, the EU ETS Directive also allows Member States to grant compensation for CO_2 cost pass-through by the power sector to the consumer.

Such compensation is of particular importance for energy intensive industries such as steel. Considering however that under the current framework the amount of compensation available for companies hangs on each individual Member State's decision, the rules for compensation should be overhauled into a fully operative EU mechanism.

In 2011 the Commission published its 2050 Low Carbon Roadmap and suggested a further reduction of emissions under the EU ETS: 43-48% by 2030 and 88-92% by 2050 compared to 2005 levels. The Commission Roadmap assumes that the decarbonisation scenarios leading to EU domestic emission reductions by 2050 are feasible, "if sufficiently stringent carbon price incentives across sectors can be put in place". Most of the emission reductions would be enabled by changes in technology.[22]

The above conditions combined with the repeated attempts to alter the EU ETS Directive and other factors linked to bad market perspectives have resulted in a degradation of the investment environment in the EU steel industry.

21 Article 10a paragraphs 11 and 12 EU ETS Directive.
22 European Commission Communication "A Roadmap for moving to a competitive low carbon economy in 2050" (COM(2011) 112 final), Impact assessment (SEC(2011) 288 final), page 51-54.

03 STEEL FROM A GLOBAL PERSPECTIVE

FIGURE 6
MAJOR STEEL PRODUCING COUNTRIES
Source: worldsteel

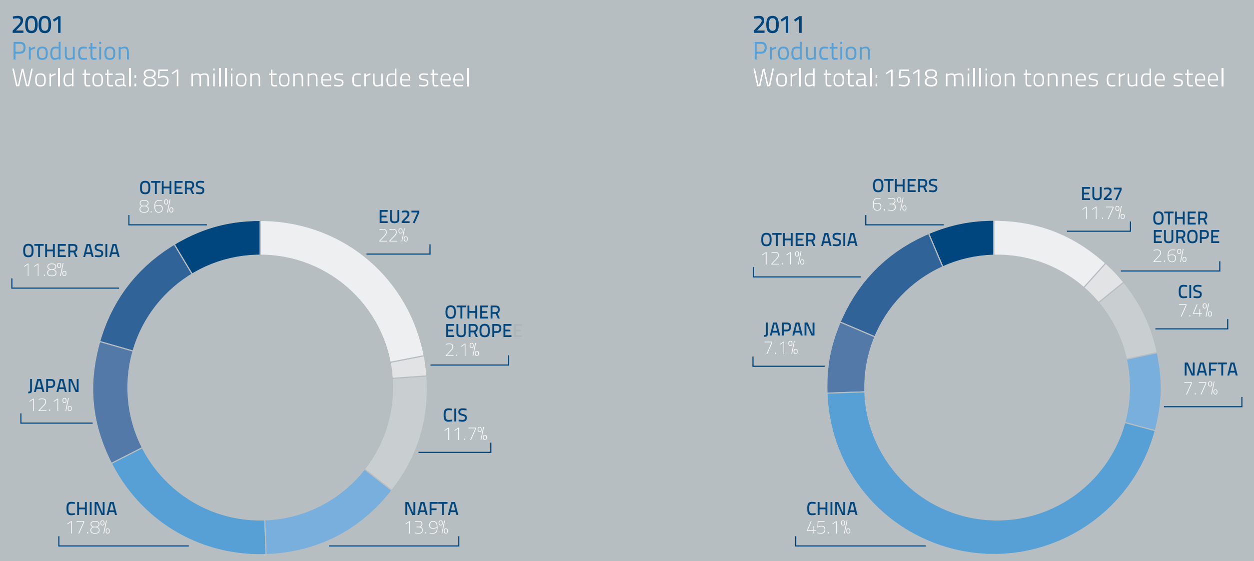
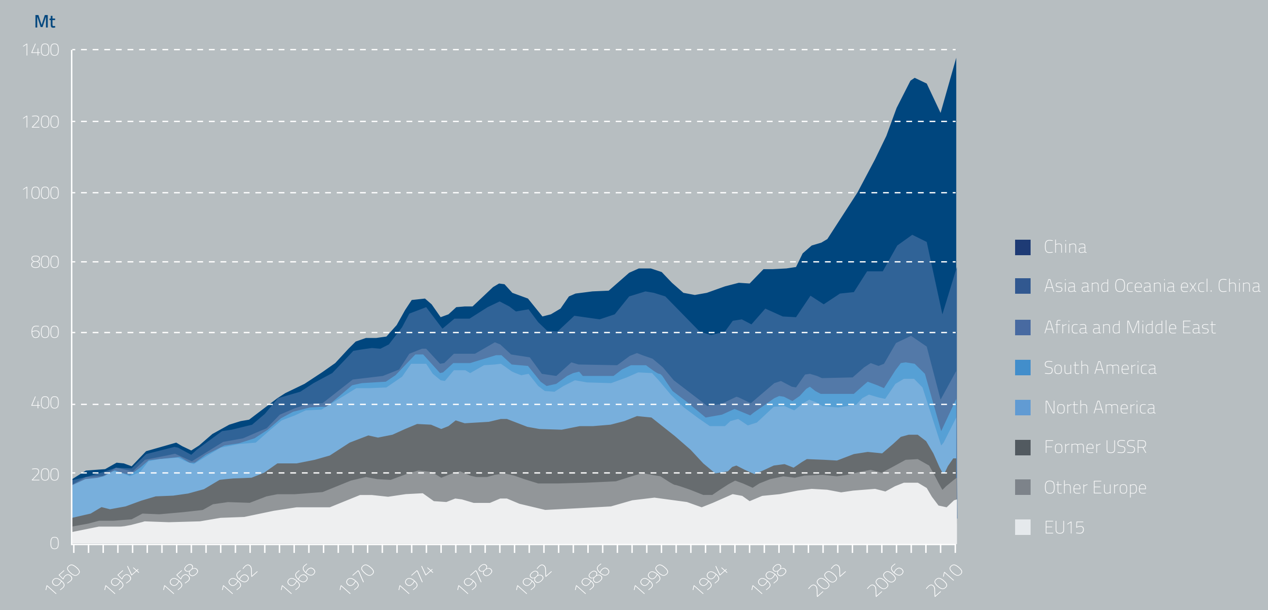


FIGURE 7
GLOBAL APPARENT CRUDE STEEL USE 1950 TO 2010
Source: worldsteel, SSY



In 2012 global crude steel production reached 1.52 billion tonnes, 11% of which was made in the EU27. Global steel consumption patterns have changed dramatically over the past decade, with China becoming a dominant player (see Figures 6 and 7). Global steel production is forecast to increase by 70% between 2010 and 2050.[23]

Global greenhouse gas emissions pertaining to steel production seem to have followed a similar trend. The CO_2 efficiency of steel production very much depends on the production route. In the EU27, about 60% of crude steel production comes from the integrated route (steel production from virgin iron ore through the BF-BOF route). The remaining 40% is produced only via the recycling of steel scrap in electric arc furnaces (EAF route, Figure 8).

As will be explained in more detail in Chapter 5, the integrated route consists of several process stages giving rise to process gases (often called waste gases) with a residual calorific value which are used to produce energy in various ways within the steel value chain, in downstream operations or in power plants, boilers, reheating furnaces, etc. The complexity of energy and product flows (waste gases can be blended in a mixing station) makes the determination of CO_2 intensity very difficult (data that is made publically available under the EU ETS Directive like in the European Transaction Log is of little help as most of the emissions stemming from waste gases are reported under the combustion category).[24]

As China's booming production of steel relies hugely on the integrated route, CO_2 emissions relating to steel production are expected to have increased over the past decade proportionally faster than total steel production.

23 Allwood J.M., Cullen J.M., et al. (2012), Sustainable Materials: with both eyes open, UIT Cambridge, England.
24 Worldsteel, the international steel association, developed a methodology for the collection and reporting of CO_2 data by steel plants, taking into consideration the issues relating to cross-boundary energy flows. This methodology has recently been accepted as an international standard:
ISO 14 404-1: Calculation method of carbon dioxide emission intensity from iron and steel production - Part 1: Steel plant with blast furnace and
ISO 14 404-2: Calculation method of carbon dioxide emission intensity from iron and steel production - Part 2: Steel plant with electric arc furnaces.

Developed countries generally have a higher share of EAF steelmaking production as they have already built their steel stock (typically two thirds of the steel stock is in buildings, the rest in infrastructure) and therefore have more steel scrap available for recycling.[25] Advanced developing countries like China and others are currently building their steel stock. If they follow a development path similar to developed countries, their steel stock will grow and their steel demand will eventually stabilise as their economies mature beyond the development stage. In parallel, the steel stock, when reaching the end of its economic life, will be available for recycling (post-consumer scrap), resulting in an increase of the share in EAF steelmaking in these countries.

In relative terms, the share of the steel industry's CO_2 emissions in global man-made CO_2 has remained more or less stable, increasing from 6% globally in 1990 to ca. 6.5% today.[26] The figure for the EU27 is about 5.3%.[27]

As shown in Figure 9, greenhouse gas emissions in the EU27 have decreased by 17.5% over the period 1990-2011. From 1990 to 2010, the EU steel sector's emissions fell by 25% (see Chapter 5). The EU – which represents ca. 15% of the world's GHG emissions (Figure 10) – is on its way to meet its objective under the second commitment period under the Kyoto Protocol. However, trade patterns analysis suggests that the stabilization of emissions in developed countries is in part due to growing imports in carbon-intensive products from developing countries.

25 Allwood J.M., Cullen J.M., et al. (2012), Sustainable Materials: with both eyes open, UIT Cambridge, England.
26 Worldsteel, including indirect CO_2 emissions.
27 EUROFER calculations (2010).

FIGURE 8
CRUDE STEEL PRODUCTION OUTPUT BY PROCESS (2011, Mt)

Source: worldsteel

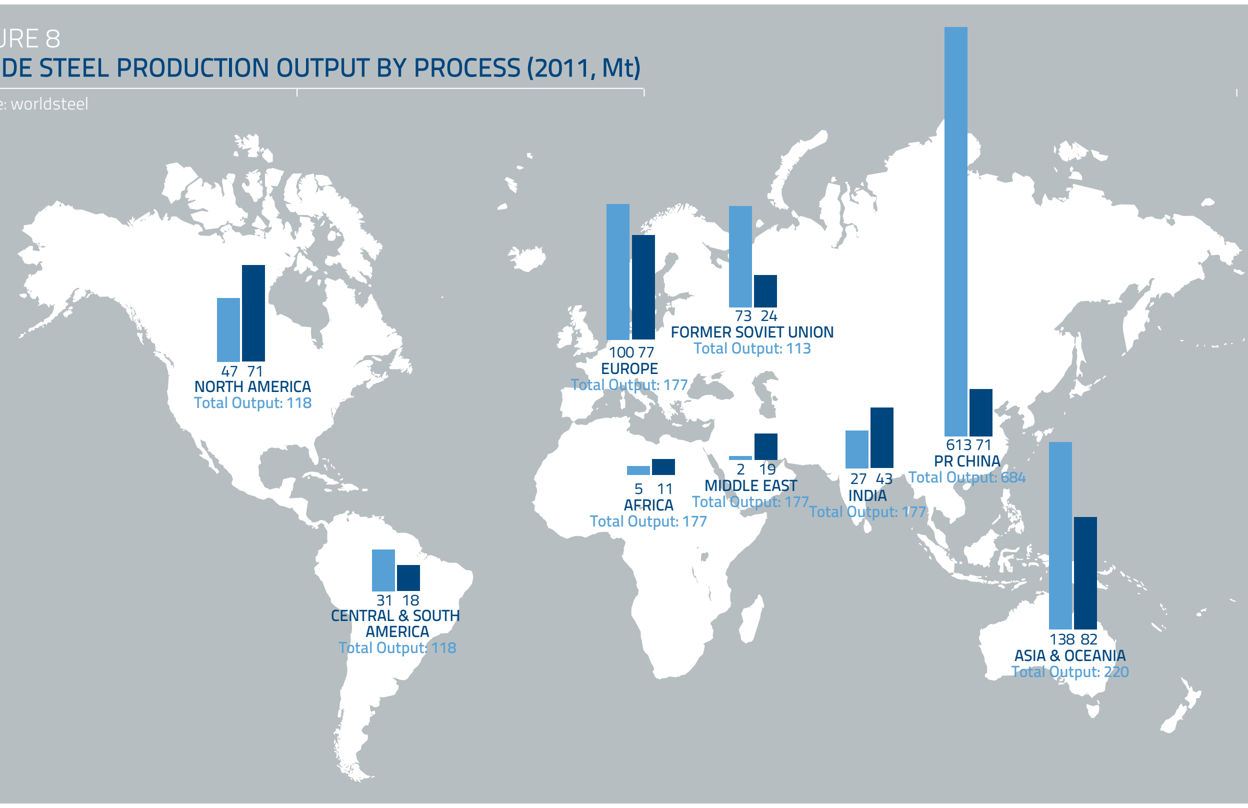
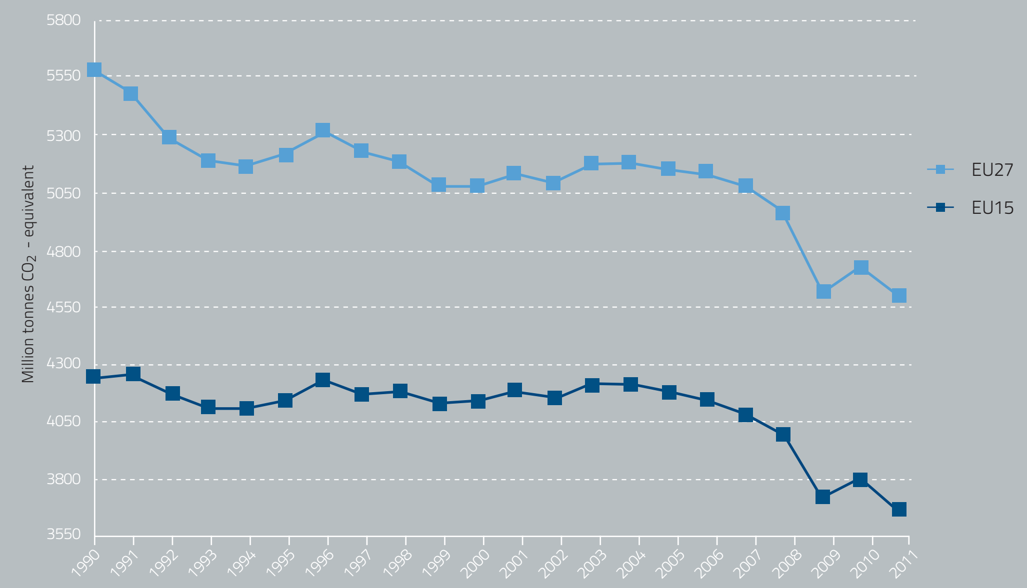


FIGURE 9
TRENDS IN GHG EMISSIONS IN THE EU15 AND EU27

Source: EEA



Recent studies[28] have tried to quantify the effect by looking into carbon emissions 'consumed' within countries or regions i.e. emissions embedded within traded goods and services, and to compare these with CO_2 emissions at the stack. They show that carbon emissions consumed by the EU have risen significantly since 1990, and particularly since 2002. This contrasts with the decreasing CO_2 emissions trend reported in the EU27.

The EU's apparent CO_2 emission reduction – the reduction in EU domestic emissions – has been more than offset by CO_2 consumption: CO_2 consumption rose by 47% between 1990 and 2006[29] because of the steep increase in international trade, and in particular imports into the EU. About a third of total consumption-based emissions were as a result of net imports of carbon, up from only 3% in 1990. In terms of sector contributions, 40% of the emissions from the production of traded products at the global level are because of energy-intensive industries. The EU is not an exception, as most developed countries have increased their consumption-based emissions faster than their territorial emissions (Figure 11).

The net emission transfers via international trade from developing to developed countries increased from 0.4 Gt CO_2 in 1990 to 1.6 Gt CO_2 in 2008, which exceeds the Kyoto Protocol emission reductions.

The fact that rapidly growing economies are emitting an increasing amount of CO_2 and exporting part of it to the EU demonstrates the relocation of substantial segments of the European manufacturing industry's value chain, pointing unambiguously to a form of carbon leakage from the EU towards the developing world. These strong signs of relocation of production to developing countries are evidence of a growing competitive disadvantage faced by the EU industry. Future climate and energy policies, if not devised properly, may exacerbate this effect. As steel production is highly regulated in the EU, not only in terms of CO_2 emissions but also from a more general environmental perspective, the relocation of steel production and employment from the EU to other countries is bound to have harmful environmental effects.

This is even more compelling for climate change, a global issue which can only be successfully tackled through a global approach.

FIGURE 10
CUMULATIVE CO_2 EMISSIONS BY REGION IN Gt

Source: EIA (2011), International Energy Outlook 2011

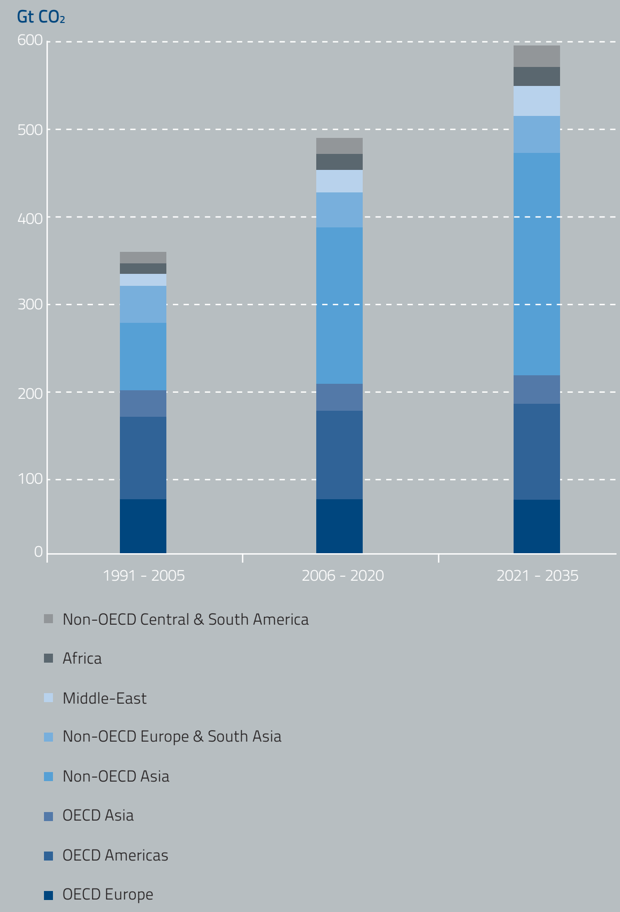
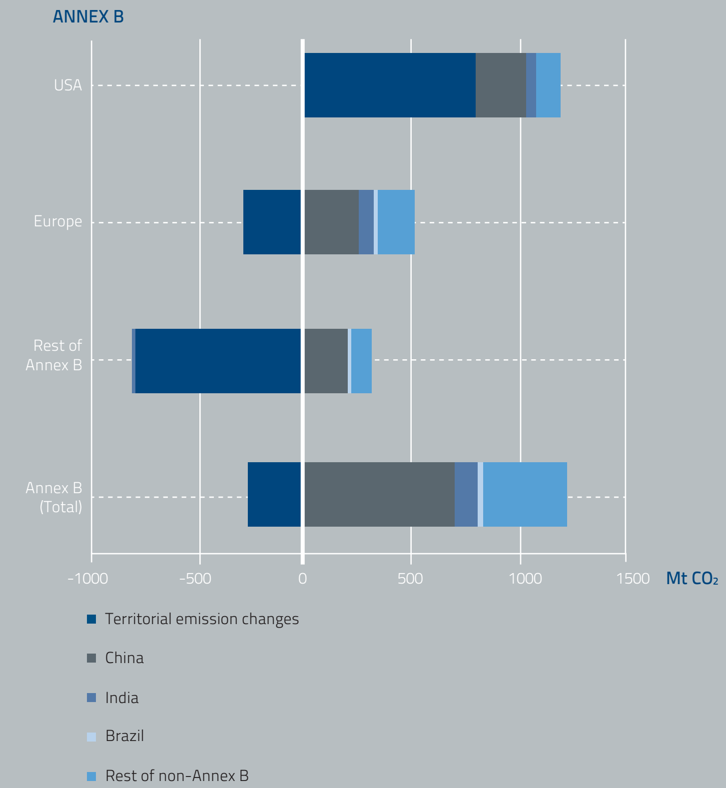


FIGURE 11
CHANGE IN EMISSION TRANSFER AND TERRITORIAL CO_2 EMISSIONS 1990-2008 IN Mt

Source: Peters et al.



Annex B refers to Annex B of the Kyoto Protocol to the United Nations Framework Convention on Climate Change which lists the quantified emission limitation and reduction commitments of the Parties in Annex I of the convention

28 Andrew Brinkley, Simon Less (2010), Carbon Omissions – Consumption-based accounting for international carbon emissions, Policy Exchange; Peters et al. (2011), Growth in emission transfers via international trade from 1990 to 2008.
29 From Carbon Omissions, page 8 (based on EU6: France, Germany, Italy, The Netherlands, Spain, United Kingdom).

04 STEEL AS CO_2 MITIGATION ENABLER

ASSESSING THE ROLE STEEL PLAYS IN TERMS OF CO_2 AND ENERGY SAVINGS

The current EU climate policy regulates CO_2 at the stack. That 'tailpipe emission' approach focuses on emissions stemming from the production of materials and overlooks the contribution they can bring to the fight against climate change. This could potentially lead to counterproductive outcomes where for example the cost of CO_2 regulation would lead to the relocation outside Europe of facilities producing products which are essential in enabling the EU to meet its climate objectives. A more coherent approach implies looking at a product's CO_2 balance from a holistic perspective, hence taking not only the production but also the use phase into account. Applied to steelmaking and steel use in Europe, such an approach shows that steel can save six times as much CO_2 where it is used than is emitted in production. It also makes it clear that the European Union's climate targets cannot be reached without innovative steel solutions.

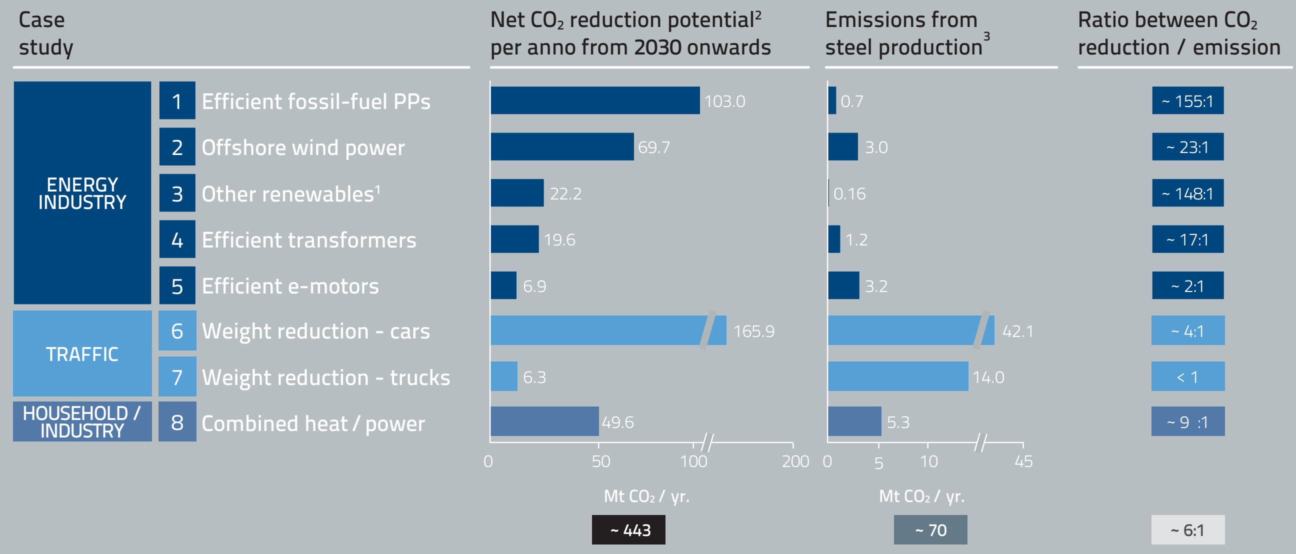
The BCG/VDEh looked into eight applications to prove this point.[30] The analysis concentrates on CO_2 mitigation potential that is directly influenced by steel. Therefore, applications were selected in which steel cannot be substituted by alternative materials. For the same reason, applications with a complex mix of materials and possible reciprocal effects were excluded from the study. The selection focused on applications with a relevant level of abatement potential within the EU27 economies i.e. above a threshold of 5 Mt annual abatement potential at least. The analysis covers the period from 2010 to 2030, for which the expansion of the applications under scrutiny can be forecast with a decent level of confidence. Any extrapolation beyond 2030 would not be usable because of the lack of reliable forecasts.

The BCG/VDEh analysis relies on external data collected and published by renowned research institutes.

30 The Boston Consulting Group, Steel Institute VDEh (2013), Steel's Contribution to a Low-Carbon Europe 2050. Technical and economic analysis of the EU27 steel sector's CO_2 abatement potentials.

FIGURE 12
CASE STUDIES FOR EU27 RESULT IN CO_2 SAVINGS

Source: BCG/VDEh



Source: Steel Institute VDEh; Project team analysis
Note: PP = power plant
[1] Bioenergy. [2] Net reduction refers to reduction attributable to steel. [3] Refers to the emissions related to the amount of steel needed for the specific application.

General forecasts regarding the development of CO_2 emissions until 2030 are based on scenarios modelled in various scientific analyses. The study applies the same methodology as the one used in a previous work carried out in 2010 for the German steel association (Wirtschaftsvereinigung Stahl) entitled *Steel's CO_2 balance (CO_2-Bilanz Stahl)*[31] but focusing on Germany alone. Looking at steel from a life-cycle perspective, the analysis does not claim to cover every aspect of a scientific life-cycle analysis (LCA). Such an approach would also have to cover and integrate additonal climate benefits arising from the steel recycling, for instance.

Steel's contribution to the reduction potential in each application is defined according to its influence on the emissions abatement. For this, four levels of influence were defined, ranging from 100% for cases in which mitigation potential is caused by steel improvements exclusively, 90% for applications in which steel has a significant or main influence on reduction potential, and 80% for cases in which steel is part of several optimization levers. In one case study – an application for which alternative materials might theoretically substitute steel – the attribution has been reduced to 70%.

Emissions abatements thus attributed to steel are then balanced with CO_2 emissions arising from production of the steel used in the applications. Because of the high quality of the steels needed for the applications discussed in the study, the production route assumed in this calculation is the BF-BOF route.

HOW STEEL WORKS FOR CLIMATE PROTECTION

The result of the analyses is that total CO_2 mitigation potential in the eight examples alone amounts to 443 Mt CO_2 per year. This is more than six times as high as the 70 Mt CO_2 of overall yearly emissions from producing the amount of steel used in the applications.

31 The Boston Consulting Group (2010), CO_2-Bilanz Stahl, Ein Beitrag zum Klimaschutz.

These savings are also considerably higher than the average yearly emissions from steel production in the EU over the period 2010-2030, which are estimated at ca. 235 Mt CO_2. The net contribution of steel to climate protection is therefore positive.

Efficient fossil fuel-fired power plants, offshore wind power and weight reduction in cars are presented in detail here to highlight the key-features of the methodology of the investigation.

EFFICIENT FOSSIL FUEL-FIRED POWER PLANTS

With about 103 Mt CO_2 emissions saved annually up to 2030 and only 0.7 Mt CO_2 yearly emissions pertaining to the production of the steel needed for the application, efficient fossil-fuel power plants form the case that shows the best reduction/emission ratio of the eight cases looked into. The ratio is 155:1.

Innovative steels are used in many critical parts of such facilities like for example in steam and turbo generators, boilers, electronics and in numerous structural elements. New, heat resistant steels, for example, are a prerequisite for raising the temperatures and the pressures of the steam driving the generators, thus increasing energy efficiency.

The calculation of steel's CO_2 balance in this application is based on the projection of overall electricity production in the EU27 in 2030, the estimated share of fossil fuel-fired power plants in the energy mix and projected CO_2 intensity improvements up to 2030. These data are taken from the World Energy Outlook published by the International Energy Agency.

The study compared overall CO_2 emissions from electricity generation in a scenario with efficiency gains as projected as opposed to a theoretical 2030 scenario in which fossil fuel-fired power plant efficiency would remain at 2010 levels. The abatement potential visible in the comparison attributable to steel is 80%. The amount of steel to be produced for the power plants was calculated according to projections of newly installed fossil fuel capacity for 2030 accessible in the World Energy Outlook and in Platts UDI Data Directories (based on a power plant life cycle of 35 years).

OFFSHORE WIND POWER

Wind power is an example that underlines both the potential of steel for mitigating CO_2 emissions and the conservative approach of the study in defining this. Generally, steel is the most applied, key material for wind power generation. This goes for the towers of the windmills as well as for the pods or the gear units.

FIGURE 13
FOSSIL FUELS POWER PLANTS DRIVERS AND PREMISES
Source: BCG/VDEh

A Net CO_2 reduction potential[1]

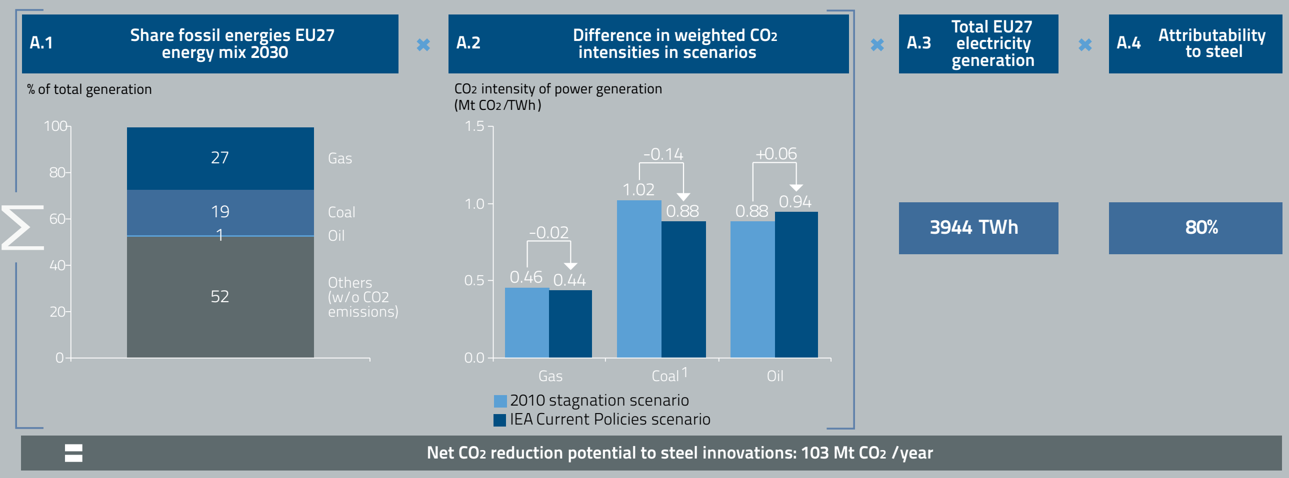
	Logic	Data Input
A.1	Share fossil energies EU27 energy mix 2030	IEA World Energy Outlook
	×	
A.2	Difference in weighted CO_2 intensity of energy mix in forecast and stagnation scenario	IEA World Energy Outlook
	×	
A.3	Total EU27 electricity generation	IEA World Energy Outlook
	×	
A.4	Attributability of efficiency gains to steel	Assessment of steel impact in reduction
	=	
	Net CO_2 reduction potential to steel innovations	

B Emissions in steel production

	Logic	Data Input
B.1	New bioenergy plants by 2030	IEA World Energy Outlook
	×	
B.2	Steel use and capacity of one bioenergy plant	Steel use in German wood biomass plant
	×	
B.3	CO_2 intensity of sheet steel	BCG/VDEh baselining
	×	
B.4	Plant lifecycle	Steel's CO_2 balance
	=	
	Emissions in steel production required for savings	

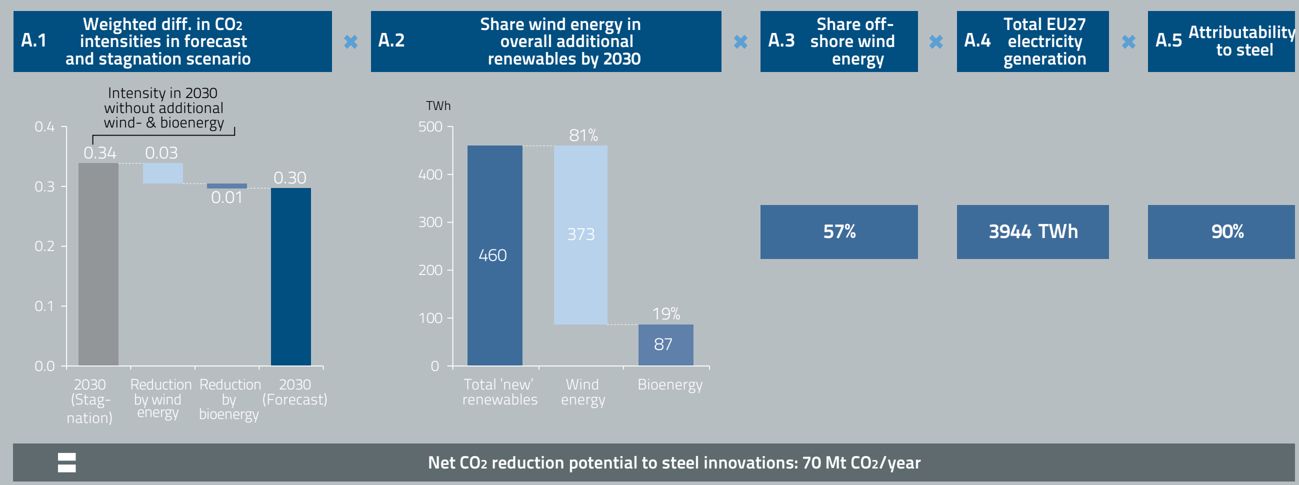
1. Net reduction refers to reduction attributable to steel
Source: IEA World Energy Outlook 2012; PLATTS UDI WPP (2011-2012); Prognos: The future role of coal in Europe (2007)

FIGURE 14
EFFICIENCY GAINS IN FOSSIL FUEL-FIRED POWER PLANTS RESULTING IN NET CO_2 REDUCTION POTENTIAL OF ABOUT 102 Mt
Source: BCG/VDEh



1. Hard coal & lignite combined
Note: Figures may differ slightly from exact results due to rounding
Source: IEA World Energy Outlook 2012 Current Policies Scenario

FIGURE 15
EFFICIENCY GAINS IN OFF-SHORE WIND POWER PLANTS RESULTING IN NET CO_2 REDUCTION POTENTIAL OF ABOUT 70 Mt
Source: BCG/VDEh

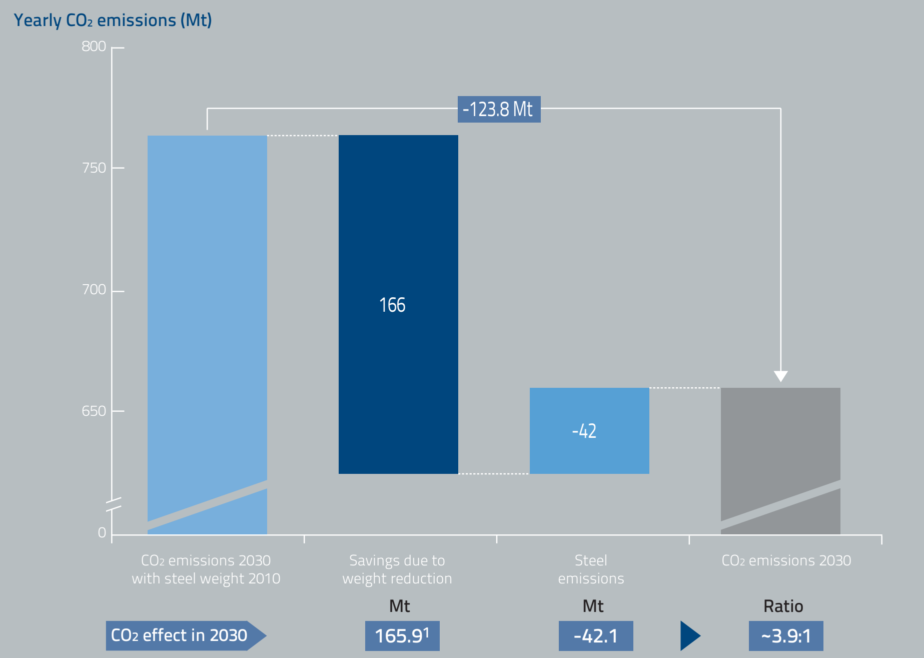


Note: Figures may differ slightly from exact results due to rounding
Source: IEA World Energy Outlook 2012; PLATTS UDI WPP (2011-2012); EWEA Wind Energy Targets for 2020 and 2030; Steel's CO_2 balance

FIGURE 16

ANNUAL EU27 CO_2 EMISSIONS REDUCED BY ABOUT 125 Mt DUE TO CAR WEIGHT REDUCTION IN 2030

Source: BCG/VDEh



1. Total savings attributable to steel (100%)
Source: iTREN 2030: Integrated transport and energy baseline until 2030; Element energy: Influences on the low carbon car market from 2020-2030; Steel's CO_2 balance

In addition, specially alloyed electrical steels are used in the generators that transform the wind power into electricity. Yet, in onshore wind farms steel might be replaced by alternative materials in certain places. The towers for example, might also be made of wood or of concrete or be realised as hybrid constructions containing steel and concrete parts. Therefore, the authors concentrated on offshore windmills because here steel really is without alternative.

Offshore wind power is expected to grow rapidly in Europe in the coming years. In many European regions there is already a lack of space for additional inland plants. Landscape preservation has to be taken into account as well as resistance of local residents to new installation.

Offshore wind farms do not have these disadvantages and, because of stronger and steadier winds at sea, they offer a significantly higher number of full load hours than inland plants. CO_2 savings from this, which are attributable to steel, amount to 70 Mt per year up to 2030. Yearly CO_2 emissions from producing the steel needed amount to 3 Mt.

CO_2 abatement potential was calculated on the basis of scenarios in the World Energy Outlook as well as projections made by the European Wind Energy Association EWEA. The methodology used takes into consideration the reduction in CO_2 intensity in the EU27's 2030 energy mix, the share of wind energy in overall additional renewable energy capacity by 2030 as well as projections of the share of offshore wind installations in wind energy capacity for 2030.

Steel's share in these emissions savings is estimated to be 90%. Annual emissions from steel production for this application were calculated according to projections for newly installed offshore plants until 2030 and according to a wind farm life cycle of 20 years.

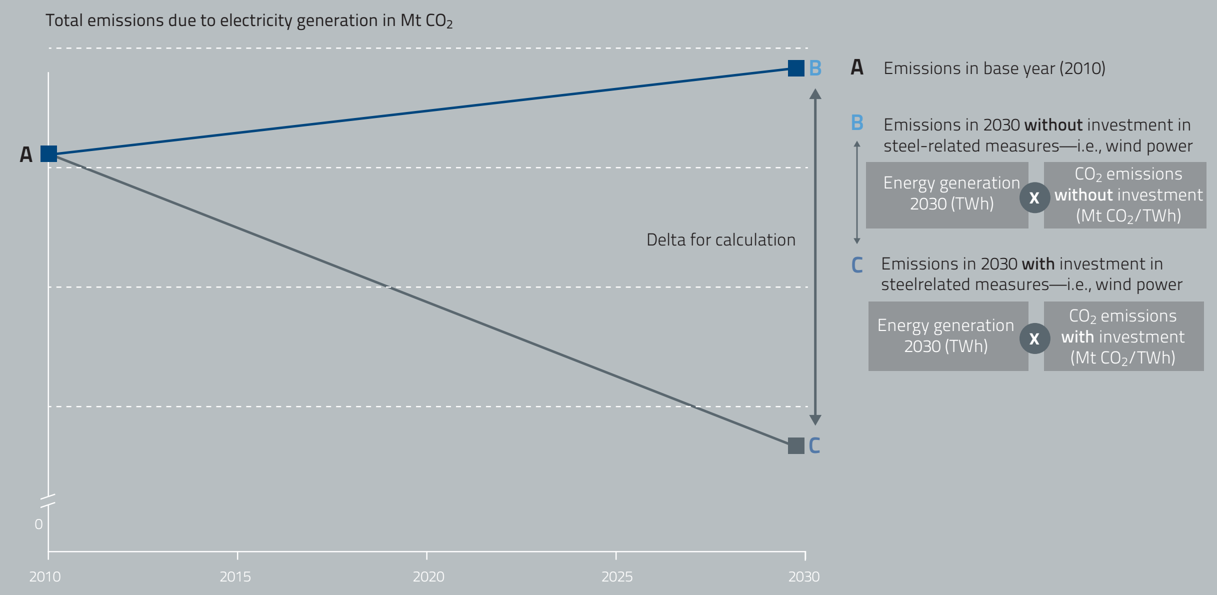
WEIGHT REDUCTION IN CARS

Weight reduction in cars is responsible for the highest absolute emissions savings among the applications analysed in the report. It amounts to ca. 166 Mt annually while CO_2 emissions from producing the steel employed are about 42 Mt. Steel is by far the most important material used in vehicle production. About two thirds of a modern car is made of steel. The BCG/VDEh analysis focuses on car components that can only be made of steel, such as axles or chassis parts.

FIGURE 17

CALCULATION LOGIC OF STEEL-INDUCED CO_2 SAVINGS

Source: BCG/VDEh



Sources: IEA World Energy Outlook 2012; Steel Institute VDEh; Project team analysis.

Reducing weight in vehicles means less fuel consumption and, therefore, fewer CO_2 emissions. The steel industry has developed special high-strength steels that can take up to 40% of the weight out of car components. Because of their increased strength these steel grades make it possible to use less material in a car part while still meeting all the functional and, in particular, safety requirements. Modern high-strength steels have been the most successful lightweight materials used in car production over the past ten years. Furthermore steel is the best automotive material in terms of design flexibility, cost effectiveness, low emissions during manufacture and recyclability. Steel use is therefore particularly praised in the compact and midsize segments that account for about 75% of the cars produced in Europe.

To calculate steel related emissions savings, projections for passenger transport activity from 2010 to 2030 (passenger-kilometers, pkm), estimated improvements in CO_2 intensity from 2010 to 2030 (tonnes/1,000 pkm) and forecasts about steel weight reduction in cars over the same period were considered. Transport activity data as well as information on CO_2 intensity were taken from the European Commission's iTren 2030 research project. Information on the development of steel weight in passenger cars was gathered by BCG in the course of preparing the CO_2-Bilanz Stahl study.

Attribution of the mitigation potential to steel is 100% since only steel parts were investigated. Yearly production related emissions were calculated according to a passenger car life cycle of eight years.

CONCLUSIONS

The BCG/VDEh study shows through the use of a simplified methodology how much steel will be essential for the EU to meet its sustainability objectives. As the current EU policy framework focuses on tailpipe emissions only, it fails to capture this fundamental aspect. In order to promote policies which truly reduce CO_2 emissions and support materials providing lean-carbon solutions, CO_2 emissions would be best regulated by using a life cycle assessment approach (LCA), taking into account all of the emissions created during the life of a product from raw material production to product end-of-life. Such an approach would also acknowledge the fact that steel can be recycled indefinitely into new steel.

05 STEEL TECHNOLOGY PATHWAYS
ABATEMENT POTENTIALS AND ECONOMIC VIABILITY

FIGURE 18
MODERN STEELMAKING PROCESSES
Source: BCG-VDEh

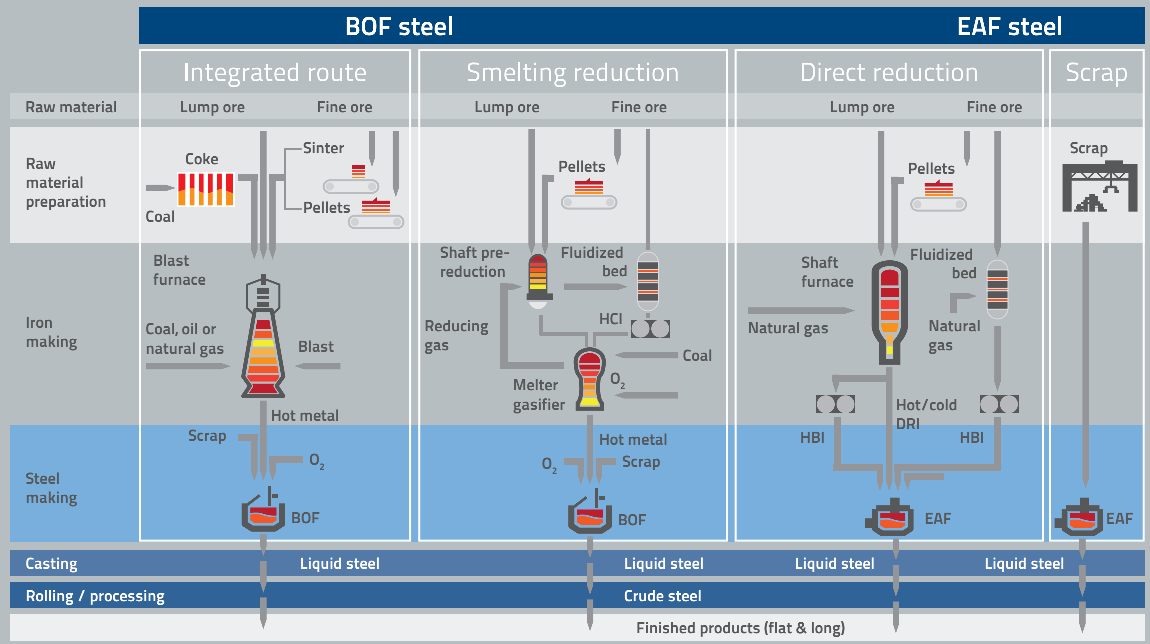
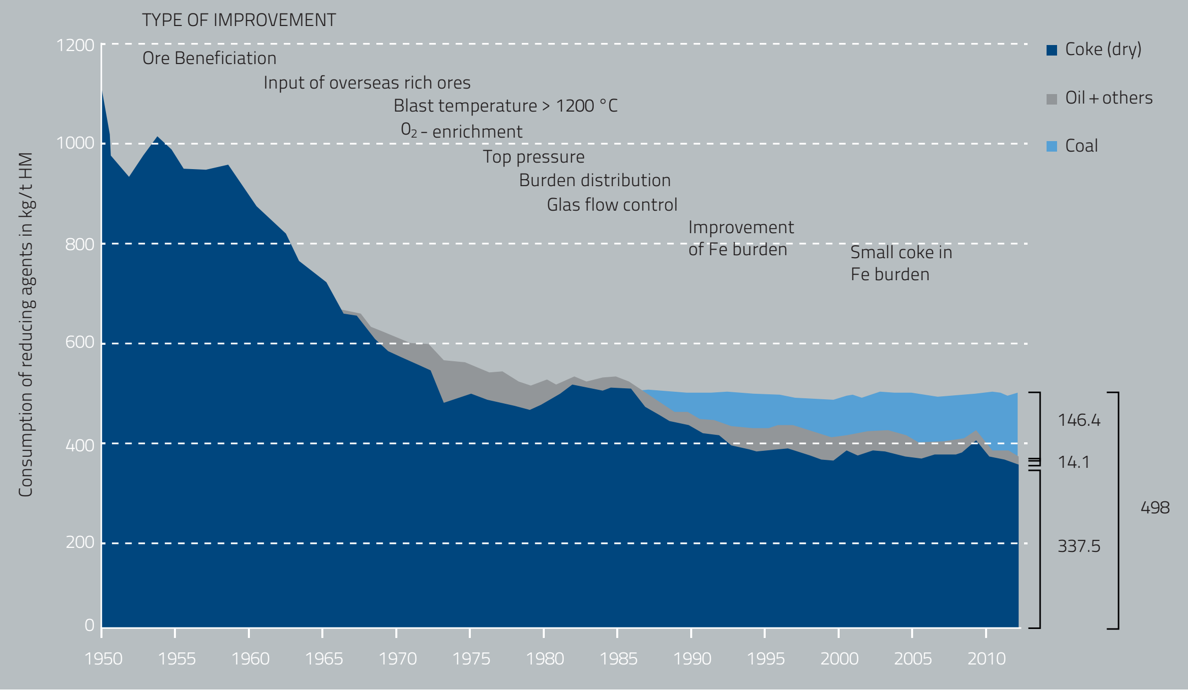


FIGURE 19
USE OF REDUCING AGENTS IN THE BLAST FURNACE IN GERMANY
Source: VDEh Blast Furnace Committee



MODERN STEELMAKING

Two main steelmaking processes can be distinguished. Primary steelmaking converts virgin iron ores into crude steel. Secondary steelmaking consists of the recycling of iron and steel scrap in an electric arc furnace (EAF route). Primary steelmaking in Europe is almost exclusively carried out in integrated steel plants where the reduction of iron ores into iron takes place in blast furnaces (BF route). There are two other steelmaking routes in use, namely smelting reduction and direct reduction (DRI route). In 2011 380,000 tonnes of DRI were produced in the EU27. This amounts to 0.2% of the European steel output for the same year. There is no smelting reduction plant in the EU.

PRIMARY STEELMAKING

Blast Furnace route

In the Blast Furnace route, steel production takes place at an integrated steel plant including one or more blast furnaces where iron ores are reduced into liquid iron (hot metal) through the use of reducing agents such as coke (which on average accounts for about 80% of the total reducing agents employed in the blast furnace), pulverized coal and to a lesser extent natural gas, coke oven gas or oil. Iron ores are fed into the blast furnaces in the form of sinter, lump ore or pellets. Sinter is produced on-site in the sinter plant, where iron ore fines are agglomerated with fluxes (the energy demand of this process is met through the addition of coke breeze). Pellets are either procured from external sources or produced in an on-site pelletisation plant.

Hot metal is converted into steel by oxygen injection in a basic oxygen furnace (BOF). The conversion of hot metal into steel is an exothermic process. Scrap, iron ore and other coolants have therefore to be fed into the BOF to keep the temperature at a reasonable level. Liquid steel then goes through a metallurgical treatment (secondary metallurgy) before being cast in various shapes and dimensions. About 60% of EU crude steel production is produced via the BF route. Coke plants, blast furnaces and basic oxygen furnaces generate process gases with a residual calorific value. These gases – often called waste gases – are mostly recovered and used to produce steam and electricity in boilers and power plants. They are also used for heating purposes, e.g. in ovens and stoves, as a substitute for natural gas. On average, integrated steel plants import additional energy (natural gas, electricity) to close the energy balance.

The amount of imported energy is relatively small, though, compared to the total energy demand, which is mostly satisfied by the waste gases recycled internally.

The operations taking place in an integrated steel site are deeply intertwined and over the years have undergone a process of optimisation in terms of material as well as energy flows.

The CO_2 intensity of integrated steelmaking decreased from 1.968 tonnes CO_2/tonne of steel in 1990 to 1.888 tonnes CO_2/tonne of steel in 2010. This reduction may seem modest, but it must be noted that most of the EU steel industry's efficiency improvement took place between the 1950s and the 1980s, as illustrated in Figure 19.

Direct reduction-based technologies

Direct reduction consists of the reduction of iron ores into solid primary iron. The solid product is called direct reduced iron (DRI) and is mainly used as feedstock in electric arc furnaces (EAF). It can also substitute scrap in a basic oxygen furnace (BOF).

Usually reformed natural gas (rich in CO and H2) is used as a reducing agent.

As the direct reduction process does not allow the separation of iron from the gangue in the reduction facility, high-grade ores or concentrates (68% Fe and a gangue content below 7%) have to be used.

Typically DRI has a metallisation rate above 92% and a carbon content below 2%. Direct reduced iron is normally used as feedstock for EAFs, together with scrap. DRI's low level of metallisation and high gangue content significantly increase the specific power consumption in the EAF.

Because it may pose a fire hazard (DRI is highly pyrophoric and needs careful handling over long distances), DRI is often hot-compacted into briquettes (hot briquetted iron - HBI) in order to be stored and transported safely.

The first commercial DRI plants were built in the late 1960s. Because the leading direct reduction processes require cheap natural gas and electricity, most plants are situated in the oil and gas-rich belt around the equator.

The only direct reduction facility in Europe is located in Hamburg, Germany. The plant started up in 1971 and was the first MIDREX unit in the world to be built. Because of the steady increase in energy prices following the first oil shock, DRI technology never took off in Europe, no other DRI plant having ever been erected in Europe since then. The DRI plant in Hamburg feeds an EAF producing high quality steel. DRI is used as a complement to steel scrap in order to keep the quality of the feedstock at a high level by diluting impurities introduced through the use of scrap. The DRI feed to the EAF is therefore adjusted according to the quality of the scrap being used.

Global direct reduced iron production grew from 0.8 to 70 million tonnes between 1970 and 2010. DRI capacity increased fastest in regions that are short in scrap or where the demand is insufficient to justify the construction of an integrated steel plant, but where low natural gas and electricity prices are available. In this regard, the flexibility of DRI plants can be a significant additional advantage.

Because of its relatively high electricity consumption, the CO_2 intensity of the DRI-EAF process depends to a high degree on the CO_2 emissions associated with the procured electricity. Contrary to integrated steelmaking, direct reduction does not produce granulated slag, which leads to CO_2 savings in the cement sector (in 2010 the production of granulated BF slag in the EU amounted to 215 kg per tonne of hot metal). When taking into consideration this side effect as part of a holistic approach, the CO_2 intensity of DRI-EAF steelmaking is today some 20% below the CO_2 intensity of the blast furnace route.[32]

Hot charging DRI to the EAF somewhat decreases the specific energy consumption at the melting stage (EAF).

Smelting reduction

In this two-step process, iron ores are heated and pre-reduced by the off-gas coming from the smelter-gasifier. Pre-reduced iron ores are then fed into the smelter-gasifier where they are melted. The smelter-gasifier uses oxygen and coal as a reducing agent (instead of coke). This process produces hot metal which has then to be converted into liquid steel in a BOF. As with a BF, this process generates slag that can be granulated for further use.

In 2011, hot metal produced from smelting reduction technologies amounted to ca. 6.8 million tonnes worldwide. Only the FINEX and COREX technologies have reached medium size industrial applications. The use of the smelting reduction technology is driven by the necessity to replace coke by coal. It is therefore used primarily in regions without sufficient primary energy sources (the surplus of waste gases being provided to public heating systems).

A typical smelting reduction unit has a CO_2 intensity about 25% higher than the blast furnace route.

32 IEAGHG, 'Overview of the current state and development of CO_2 capture technologies in the ironmaking process', 2013/TR3, April 2013.

SECONDARY STEELMAKING

Electric Arc Furnace route

This route consists in melting iron-bearing material in an Electric Arc Furnace (EAF). The major feedstock to the EAF is ferrous scrap, which can be home scrap (scrap arising within the steel mill), pre-consumer scrap (scrap arising in steel using industries) or obsolete scrap (scrap coming from steel products at the end of their life). Cast iron and DRI (HBI) can also be fed into the EAF.

The EAF process uses electricity as its main source of energy. Other sources of energy are often used in combination to varying degrees (e.g. natural gas, coal, coke). Fluxes and oxygen are also fed into the process. Liquid steel poured from the EAF then goes through a metallurgical treatment process (secondary metallurgy) before being cast in various shapes and dimensions. About 40% of EU crude steel production is produced via the EAF route. The expansion of the EAF route in Europe is driven by scrap availability and scrap quality considerations. Besides, extensive use of scrap tends to introduce impurities into steel, many of which cannot be got rid of. EAF steel therefore tends to be used more for making products that are less sensitive to the presence of impurities such as reinforcing bars for concrete, although stainless steel in Europe is also produced via the EAF route as it enables the recycling of stainless steel scrap.

The CO_2 intensity of EAF steelmaking depends to a high degree on CO_2 emissions associated with the procured electricity. The CO_2 intensity of EAF steelmaking decreased from 0.667 tonne CO_2/tonne of steel in 1990 to 0.455 tonne CO_2/tonne of steel in 2010. Most of the improvement comes from energy efficiency gains. The effect of the decrease of the CO_2 intensity of the power sector is rather limited (accounting to ca. 10% of the improvement, see Figure 25).

SUMMARY AND ECONOMIC VIABILITY ASSESSMENT

In terms of CO_2 mitigation, the EAF route has by far the lowest CO_2 intensity. It could be decreased further in the years up to 2050 along with the decarbonisation of the power sector. However, as already pointed out, increasing the share of EAF steel is constrained by the availability of scrap and the quality requirements steel grades have to meet.

All in all, EAF steel has usually been cheaper than BF-BOF steel in Europe and NAFTA, especially at times when markets were weak.[33] EU's steady 'scrap mine' combined with a higher flexibility and lower capital requirements of the EAF technology explain its success over time (Figure 20). However, recent developments in the scrap market have substantially deteriorated the margin of the EAF sector. Ever increasing electricity and gas prices and the inability of the EU to keep them at sustainable levels are likely to squeeze the EAF margins further. It is worth stressing in this respect that US shale gas poses new challenges to EU EAF steelmakers. Should the pressure to export scrap continue to increase over the coming decades as well as electricity and gas prices, the EAF route is unlikely to expand much beyond the current levels as its competitiveness would be significantly threatened.

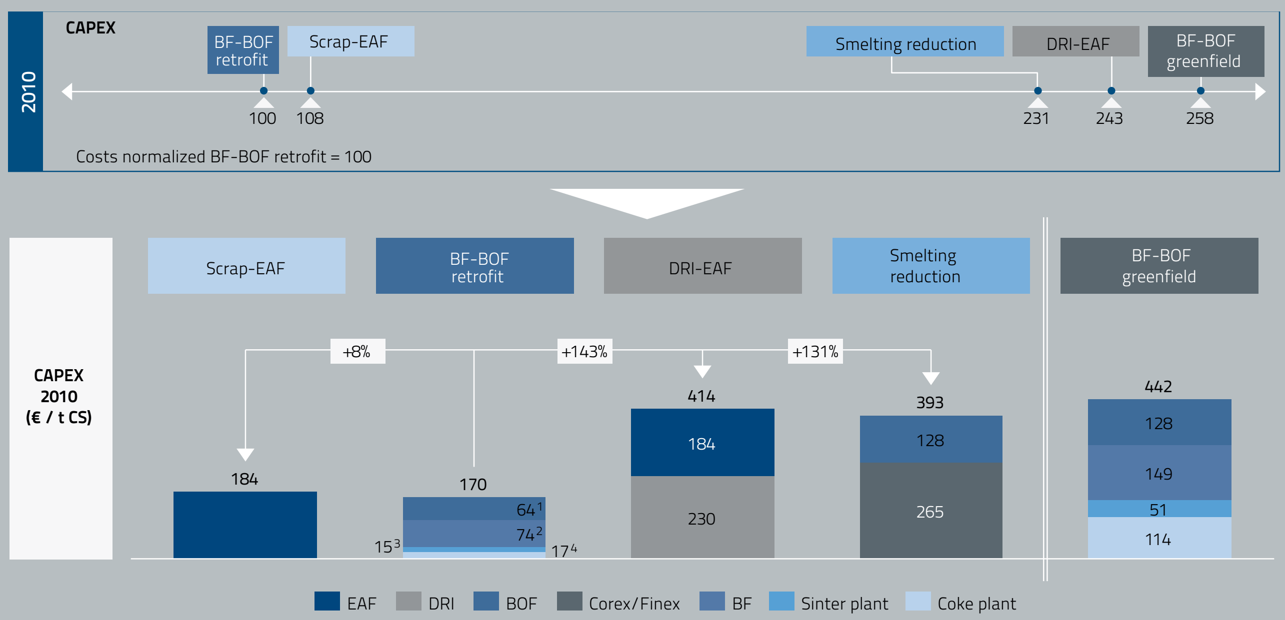
Direct reduction-based technologies have the potential to reduce specific steel production emissions by 20%[34] compared to modern integrated steelmaking. According to the analysis carried out by BCG/VDEh, the investment costs for a greenfield DRI-EAF plant are lower than for an equivalent greenfield integrated steel plant, but still much higher when compared to an existing integrated plant. Furthermore, as suggested by Figure 19, the process's operating costs are also prohibitively high in Europe because of the comparatively higher natural gas and electricity prices. For these reasons and despite the advantage of higher operational flexibility, the DRI/EAF route cannot compete with the BF-BOF route in Europe. BCG/VDEh evaluated the CO_2 abatement costs of shifting from an existing BF-BOF plant to a new DRI-EAF plant at between €260 and €710 per tonne of CO_2. This figure does not include the unavoidable decommissioning costs.

33 Laplace Conseil (2013), The future of steel: how will the industry evolve?

34 This figure assumes that for the integrated route CO_2 savings relating to the use of granulated BF slag in the cement industry are taken into consideration.

FIGURE 20
COMPARISON OF CAPEX OF ALTERNATIVE STEELMAKING

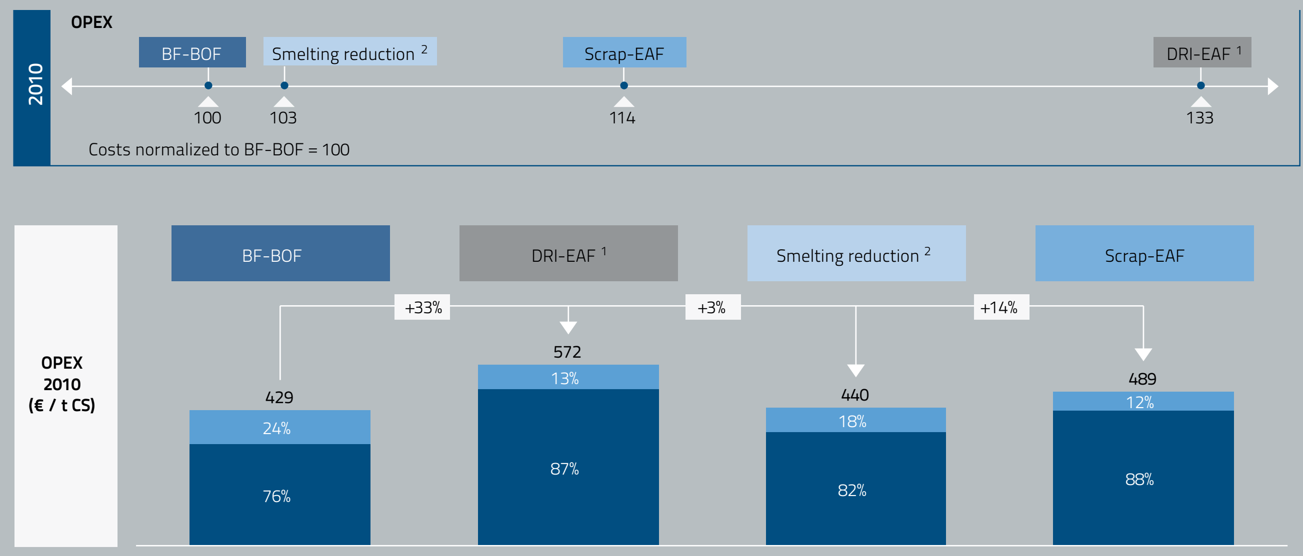
Source: BCG-VDEh



Sources: Diemer et. al., 2011; Steel Institute VDEh; Project team analysis.
Note: CS = crude steel
1. BOF: 50 percent of greenfield investment. 2. BF: 50 percent of greenfield investment. 3. Sinter: 30 percent of greenfield investment. 4. Coke: 15 percent of greenfield investment.

FIGURE 21
COMPARISON OF OPEX OF ALTERNATIVE STEELMAKING TECHNOLOGIES

Source: BCG-VDEh



Sources: Steel Institute VDEh; Project team analysis.
Note: CS = crude steel
1. Based on Midrex direct reduction technology . 2. Based on Finex smelting reduction technology.

In a scenario with lower natural gas and power prices, new DRI-EAF route capacity could become competitive in primary steelmaking in Europe. However, the current steelmaking overcapacities in Europe would be sufficient to cover the most optimistic steel demand projections out to 2050. New capacity in primary steelmaking is therefore not expected. If demand does outstrip supply, additional DRI-EAF or DRI stand-alone capacity is likely to be built but only outside the EU, in regions with lower natural gas and electricity prices. Recent DRI projects in the USA (Nucor, Voestalpine) tend to confirm the role played by the shale gas revolution and resulting low gas and electricity price perspectives as a potential game changer in the US steel sector.

DEVELOPMENT OF CO_2 CAPTURE TECHNOLOGIES IN IRON AND STEEL PRODUCTION

CARBON CAPTURE AND STORAGE, CARBON CAPTURE AND USAGE

Carbon Capture and Storage (CCS) is a process whereby the CO_2 stream is captured from the off-gas and stored virtually forever in a geological site.

This can be:
- an oil or gas field, nearing the end of its life or already depleted,
- a deep saline aquifer isolated from the surface and not communicating with sub-surface aquifers containing drinkable water,
- coal seams, containing methane, that will never be mined or have already been mined.

The site can be on-shore or off-shore, underneath the sea floor. CO_2 is injected under pressure, either in a gaseous or supercritical phase, depending on local conditions. When using aquifers, CO_2 replaces water and slowly dissolves in it until geochemical reactions occur with the embedding rock and minerals precipitate.

The concentrated stream of CO_2, with a purity of 95% or more, is produced by separating the gas out of the flue gas or process gas (the top gas of a blast furnace in the case of steelmaking) by using chemical or physical technologies (adsorption, absorption, membrane separation, cryogenic separation, etc.) The CO_2 stream is transported to the storage site in a pipeline or in boats, barges or sea vessels.

For the time being, the process of capturing and transporting CO_2 is highly energy-intensive which in turn decreases the overall efficiency of the system the CCS technology is applied to. This results in high operating costs, on top of the huge initial investment costs.

Should these issues be resolved, CCS could play an important role in mitigating CO_2 emissions in the future – up to 19% of global emissions by 2050 according to the IEA.[35] Today, only six large-scale storage sites (with a capacity of over 1 Mt CO_2 per year) are in operation in the world[36] and the inventory of candidate sites and their capacities is still sketchy in Europe and around in the world, as geostorage requires a complex validation and permitting process on a case by case basis.

Although there are currently no fully integrated, commercial-scale CCS power projects in operation, the technologies that make up CCS (CO_2 capture, transportation and storage) have been in commercial use for decades.

In the face of strong public opposition in many EU countries, storage sites might not be available throughout the EU. While sufficient storage capacity probably exists in Europe, steel producers could face being without enough nearby storage capacity, given the huge volumes of CO_2 involved (ca. 10 to 15 Mt CO_2 per year per integrated steel site).

Despite the fact that the necessity of CCS is recognised in both the Commission's *Energy Roadmap* and the *Roadmap for moving to a competitive low carbon economy in 2050*, the technology has not really taken off in the EU. The fact that no CCS projects were selected in the first call of the NER300 is not encouraging. The development of CCS requires the stepping up of efforts to secure the financing needed in each of the areas of capture technology, CO_2 infrastructure and geological storage capabilities as soon as possible. In March 2013, the Commission published a consultation paper[37] on CCS aimed at spurring the discussion on options to foster the demonstration and deployment of CCS in a timely fashion.

35 IEA (2012), Energy Technology Perspectives 2012, OECD/IEA, Paris. The 4DS (4°C Scenario) takes into account pledges made by countries by 2012 to limit emissions. The food and drink and biofuels sectors are not included here due to their low contribution.
36 http://www.zeroco2.no/projects/list-projects/
37 COM(2013)180, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions on the Future of Carbon Capture and Storage in Europe.

As an alternative to storing captured CO_2 in geological formations, using CO_2 either directly (e.g. in the food industry) or as a feedstock in chemical processes that produce valuable carbon containing products or fuels could be a possible option in the future. New biological processes currently under development make it possible to convert CO_2, CO and H_2 contained in steelmaking waste gases into fuels with a lower CO_2 intensity per unit of energy relatively to fossil fuels. This group of processes is known as Carbon Capture and Use (CCU). However this alternative to the geological storage of CO_2 is unlikely to have a sufficient sequestration potential. The unfavourable economics and the rather limited range of applications suggest that the corresponding abatement opportunities will remain modest. In particular, CO_2 use would lead to small or even negative net savings, as the energy that is available in the hydrocarbon resource is missing in the CO_2 feedstock, unless the balance is supplied by a carbon-free source of energy.

It has to be noted that CCS is a technology concept defined by its ends rather than by its means (a so-called 'end of pipe technology'), and thus is embodied in quite different technologies, both for capture and storage, depending on how industrial sectors want to make use of it. For example CCS as included in the ULCOS processes is quite different from pre-, post- or oxy-combustion capture in the power sector: it should actually rather be called 'in-process' capture.

CCS IN IRON AND STEELMAKING

For the time being, only FINEX and HYL-Energiron can be connected to a CO_2 capture unit without major changes to the process. The application of CCS to these technologies today would lead in their configuration to a CO_2 reduction of about 25 to 35%.[38] In the Blast Furnace route, it is thought that the application of CCS to a waste gases-fired power plant would lead to a reduction of about 25% in the site's total CO_2 emissions.[39]

Apart from its technical limitations in terms of accessibility and storage capacity, CCS technology will be expensive. Costs are expected to be in the range of €30-€100 per tonne of CO_2 stored.[40] Such additional costs will lead to distortions to competition, endangering the position of the EU steel industry on the global scene. As steel is a globally traded commodity, costs of this magnitude cannot be passed on through higher steel prices, making such an investment unaffordable.

Should competition issues be properly addressed and fully taken into account, the reduction levels involved would in any case fall short of making a significant contribution to climate protection. Innovative technologies are needed to really make a difference.

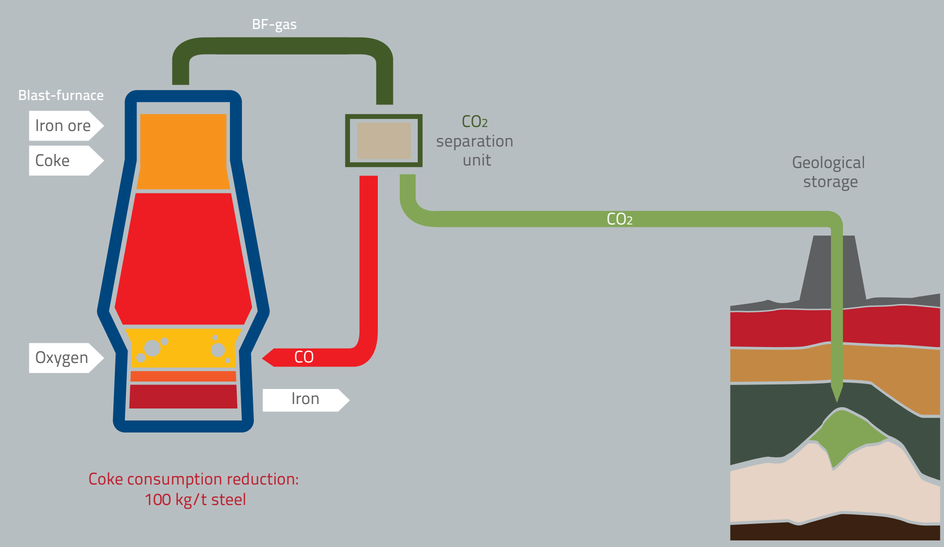
POTENTIALLY INNOVATIVE STEELMAKING TECHNOLOGIES[41 42]

The level of reduction in GHG emissions that would be necessary to mitigate Climate Change down to a manageable threat (maximum increase of 2°C by 2050 compared to pre-industrial levels) is much larger than what can be obtained by spreading the use of the lowest carbon technologies and by implementing more energy savings. This is even truer for the steel sector in light of the steep increase in global steel demand and the corresponding increase in production to meet it. Therefore, breakthrough technologies are indispensable.

Several programmes were launched in the early 2000s to tackle this extremely formidable challenge. They were organised regionally and mirrored, to some extent, the regional ambitions in terms of mitigation effort. The largest, most advanced and most ambitious programme is the European programme called ULCOS (Ultra Low CO_2 Steelmaking). There are other regional programmes in America, Asia and Australia. All exchange information within a Worldsteel platform called The CO_2 Breakthrough Programme.

38 IEAGHG, 'Overview of the current state and development of CO_2 capture technologies in the ironmaking process', 2013/TR3, April 2013.
39 Birat J.-P, Lorrain J.-P, de Lassat Y. (2009), The "CO_2 Tool": CO_2 emissions & Energy consumption of existing & breakthrough steelmaking routes (La Revue de Métallurgie – CIT).
40 European Commission, Consultative Communication on the future of Carbon Capture and Storage in Europe (Référence: MEMO/13/276, 27 March 2013).
41 Jean-Pierre Birat, Jean Borlée, Hervé Lavelaine, Dominique Sert, Patrick Négro, Koen Meijer, Jan van der Stel, Peter Sikstrom, ULCOS PROGRAMME: AN UPDATE IN 2012, 4th International Conference on Process Development in Iron and Steelmaking, 10-13 June 2012, Luleå, Sweden.
42 J.-P. Birat, Steel sectoral report, Contribution to the UNIDO roadmap on CCS, "Global Technology Roadmap for CCS in Industry" sectoral workshop, Abu Dhabi, 30 June-1 July 2010; http://www.unido.org/fileadmin/user_media/Services/Energy_and_Climate_Change/Energy_Efficiency/CCS/Stee_sectoral_%20report.pdf

FIGURE 22
PRINCIPLE OF THE ULCOS-BF PROCESS



ULCOS

The ULCOS programme was launched in 2004 with the support of the EU provided by the 6th Framework and the Research Fund for Coal and Steel programmes.

Its first phase, called ULCOS I, ran until 2011, with a €75 million budget and EU support at the level of 40% through four different coordinated projects, the remainder being financed directly by the project partners. These partners have been organised in a Consortium of 48 organisations, including 10 steel and mining companies which constitute its Board and have been providing financing beyond their own in-kind contributions; the Board is chaired by ArcelorMittal and comprises Tata Steel, ThyssenKrupp Steel, Riva, Saarstahl, Dillinger Hütte, Voestalpine, SSAB, LKAB and Ruukki, all of which constitute the ULCOS core member consortium.

The first objective of the ULCOS programme was to identify steel production process routes, which could robustly deliver cuts in CO_2 emissions of more than 50% per tonne of steel. This meant that the breakthrough routes should be worked out and demonstrated at a scale deemed sufficient for eventual commercial deployment.

ULCOS I investigated a panel of more than 80 process routes that could a priori answer the programme's objectives. After benchmarking, modelling, laboratory, bench scale and pilot tests, four routes were selected in a final shortlist. Three of them rely on the use of carbon in coal, coke or natural gas, and thus also on Carbon Capture and Storage (CCS), in a way that has been tailored to the needs of steel production; a fourth process uses electricity directly and thus no direct carbon. All of these routes are described below.
A second phase, ULCOS II, is now under way and should eventually lead to the development of all of these processes to commercial scale, if technical success materialises and if economic conditions are right.

Blast Furnace with Top Gas Recycling (ULCOS-BF)

The first ULCOS solution is based on the Blast Furnace (BF) process route, which today is the major way to produce steel from virgin ores, and is called ULCOS-BF (Figure 22). The process incorporates a CO_2 capture system that separates the CO_2 from the BF top gas and thus also produces a reducing gas, which is reinjected (recycled back) hot into the reactor at two levels of injectors including the tuyeres; pure oxygen, rather than hot blast, is used to avoid nitrogen getting trapped in the recycling loop.

FIGURE 23
PRINCIPLE OF THE HISARNA SMELTING REDUCTION PROCESS

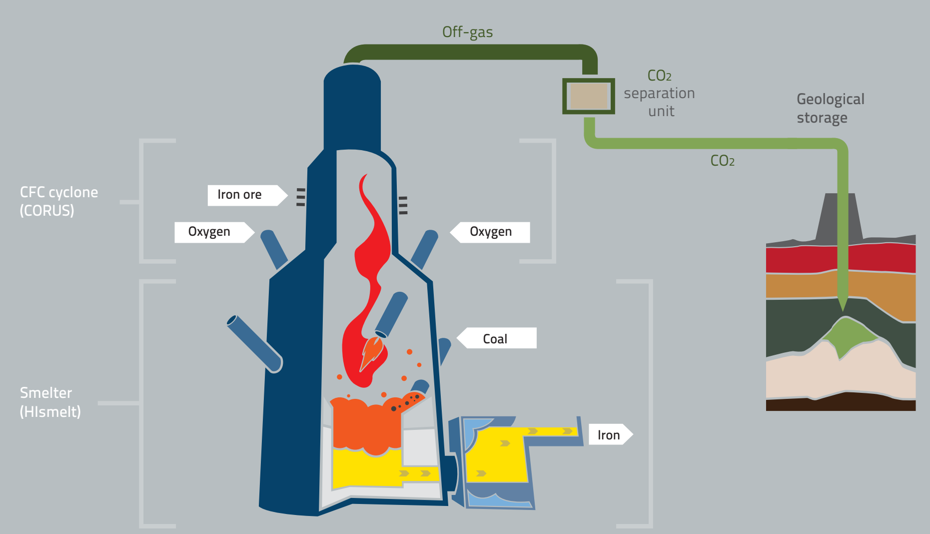
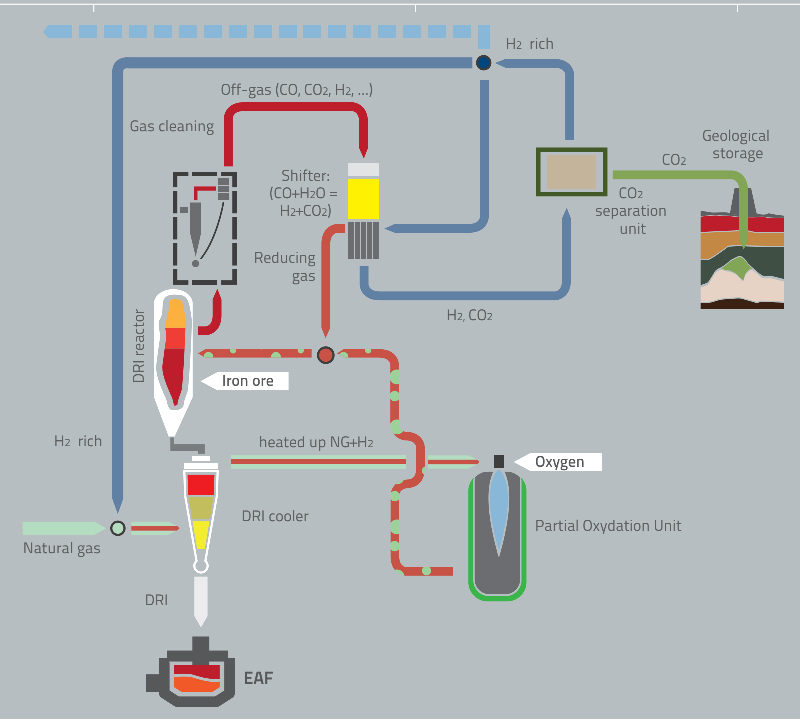


FIGURE 24
PRINCIPLE OF THE ULCORED PROCESS



The ULCOS-BF process has been tested in three campaigns on the Experimental Blast Furnace (EBF) of LKAB (one in 2008 and two campaigns in 2010; the furnace has a hearth diameter of 1.2 metres). Given their positive results and the close match with the extensive modelling that preceded the tests, the scale-up to a demonstrator on a commercial BF (with a hearth diameter above 10 metres) with integrated transport and storage of CO_2 should be the next step. The ULCOS-BF is seen as the quickest ULCOS route to be implemented in the EU steel industry, because of its relative maturity and because it is a retrofit on existing facilities: switching a BF over to ULCOS-BF operation requires no more than a major furnace relining, where the BF is made 'capture ready' by introducing a CO_2 washer on the top gas and switching over to pure oxygen operation at the tuyeres. All this has nonetheless to be confirmed in a demonstration plant test.

Bath smelting (HIsarna)

HIsarna is a Smelting Reduction process concept (based on carbon like the BF), incorporating a cyclone for heating and melting iron ore and a bath smelter, akin to the SRV of HIsmelt. The process is a joint development of ULCOS and Rio Tinto (Figure 23).

It has been redesigned to produce CO_2-rich off-gas, by using pure oxygen rather than enriched air; the gas is expected to be stored, with a very limited amount of separation/concentration. HIsarna has been designed up to the erection of an 8 tonnes per hour pilot plant (with a hearth diameter of 2.7 metres), which is a necessary step in the validation of the process concept before a full demonstrator (6 metre diameter hearth) can be planned. A first campaign on the pilot plant, erected at Tata Steel's IJmuiden steel works, took place in 2011 and 2012 and, after hot commissioning tests, has been able to operate for a sufficient length of time to validate most of the key concepts supporting the process, short of the demonstration of the industrial robustness of the technology, which will be explored in future campaigns.

HIsarna would probably be a preferred process for a greenfield steel mill site, once its viability has been demonstrated at pilot and then demonstrator scales, which will take 10 years or more.

Direct reduction (ULCORED)

ULCORED[43] is the ULCOS solution for making iron based on natural gas rather than coal (Figure 24). The concept involves separating CO_2 out of the process gas, and is therefore also dependent on CCS with a similar in-process capture. ULCORED proposes solutions fit for taking over the area occupied today by direct reduction – a technology not very much used in Europe but more in countries with access to cheap natural gas.[44] With ULCORED the objective is to reduce the natural gas consumption needed to produce DRI. This is partly achieved by replacing the traditional technology, reforming, by partial oxidation of the natural gas (as in HYL/Energiron). This will also substantially reduce capital expenditure.

ULCORED needs to be pilot tested first, a step that might use the opportunity of the EDRP (Experimental Direct Reduction Pilot) furnace, which LKAB is planning to erect in coming years as a complement to its EBF in Luleå. ULCORED would probably be a candidate to retrofitting existing direct reduction plants, once its viability has been demonstrated at pilot and then demonstrator scales, which would also take 10 to 15 years or more.

Electrolysis (ULCOWIN)

Electrolysis of iron ore is a breakthrough process concept that proposes to reduce iron oxides electrochemically, without using any direct carbon. ULCOWIN is the more mature embodiment, based on room-temperature electrowinning of an alkaline solution in which ore particles are dispersed.

The process has been developed from scratch during the ULCOS project and has reached the scale of a small-scale laboratory pilot plant that can produce 4 kg samples of pure iron. The process is currently being debugged and scaled up so it can become a candidate for large-scale production, mimicking what is done in non-ferrous metal production, like aluminium or magnesium, as part of two research projects that are part of ULCOS II. Ten years of work will still probably be necessary before a pilot at a scale commensurate to those implemented for the previously analysed process routes can be designed, erected and tested.

ULCOWIN would therefore become a candidate process route at about the time when the price of carbon-free electricity becomes competitive, if this ever happens.

43 Knop, K., Hallin, M. and Burström, E., ULCORED SP 12, Concept for minimized CO_2 emission, La Revue de Métallurgie-CIT, Sept. 2009 & Oct. Revue de Métallurgie, Number 10, October 2009, 419 – 421, Selected papers from 4th ULCOS SEMINAR (Part 2).
44 http://www.ulcos.org/fr/research/advanced_direct_reduction.php

Another process, tackling the more challenging concept of producing liquid iron directly, in a way similar to what is done in a Héroult cell, is under investigation under the name of ULCOLYSIS. Samples of iron have been produced in the liquid state, but the development path is going to be longer than for ULCOWIN.

Summary and economic viability assessment

The ULCOS process routes exhibit a number of interesting features, which have been built into them during the ULCOS I research work or came about fortuitously:

- specific CO_2 emissions are indeed reduced by 50% or more, as shown in Table 1 .
- energy consumption is reduced by 10% to 20%, taking on board the fact that the energy balance of the whole integrated steel mill is deeply modified (the ULCOS-BF does not produce any BF gas for further use in the steel mill). This is quite remarkable, as CCS in other sectors on the contrary increases energy consumption !
- all fossil-fuel based processes are expected to demonstrate higher productivity than their conventional counterpart, of 20% for ULCOS-BF and possibly more for HIsarna, for example. This will need demonstrator-scale experiments to be validated.
- the cost of avoided CO_2 associated with these same routes is about half what it would have been from applying CCS as an end-of-pipe technology, as is done in the power sector in post-combustion capture.

In terms of capital and operating costs, the situation is somewhat more complex, as there is not enough experience today to make any clear statement. What seems likely though is that the ULCOS processes are adding to the standard iron or steelmaking process functions that are not fully balanced in terms of cost by energy savings and productivity improvements.

The first three ULCOS technologies will have to be run with Carbon Capture and Storage (CCS) in order to get to specific CO_2 reductions above 50%. CCS is a precondition for these technologies, which otherwise will already at the time of their introduction be incompatible with the decarbonisation objective. Furthermore, not only are these technologies capital-intensive but they also increase heavily operational costs (CCS on the blast furnace alone would need ca. 0.15 MWh per tonne of steel).[45]

TABLE 1
ABATEMENT POTENTIALS OF THE ULCOS TECHNOLOGIES

Technology	Expected potentials for direct CO_2 mitigation effects	Soonest expectations (from a purely technical perspective)
Top Gas Recycling Blast Furnace (ULCOS-BF)	15% without CCS 60% with CCS	Laboratory: done Pilot: done Demonstrator: tbc Deployment: > 2020 onwards
Bath smelting (HIsarna)	20% without CCS 80 % with CCS	Laboratory: done Pilot: 2011-2013 Demonstrator: 2020 Deployment: > 2030
Direct reduction (ULCORED)	5% without CCS 80% with CCS	Laboratory: done Pilot: 2013 Demonstrator: 2020 Deployment: > 2030
Electrolysis (ULCOWIN)	30% with today's electricity generation mix 98% with CO_2 free electricity generation	Laboratory: ongoing Pilot: 2020 Demonstrator: 2030 Deployment: > 2040

45 Lawrence Hooey, Andrew Tobiesen, Jeremy Johns and Stanley Santos (2013): Techno-Economic Evaluation of Incorporating CO_2 Capture in an Integrated Steel Mill.

They add more costs but would endanger the competiveness of EU steel if proper mitigating policies are not implemented.

Electrolysis is still in the laboratory phase. If successful, it could be available after 2040. It is worth stressing that the power demand for this technology to substitute a mid-sized blast-furnace can be estimated at about 1 GW (one nuclear reactor).

Beyond the ULCOS solutions, other directions have potential for radical change, but their development has not been considered as likely in the short or middle term by the ULCOS consortium.

They include the direct use of hydrogen, an excellent reducing agent that compares favourably with coal, but which, however, has to be produced from natural gas or water at considerable expense of energy and, possibly, with associated GHG emissions: hydrogen can be used in a shaft furnace similar to a Midrex furnace, or in other reactors.

Another interesting concept is based on the use of biomass. The most straightforward kind of biomass for making steel is charcoal, which was used for iron and steel production over millennia before coal was used and is still a major carbon source in countries like Brazil. Using charcoal at a very large scale would involve sweeping changes in land use in tropical countries and massive international trade of the fragile and pyrothermic material, which would involve a major paradigm shift in the international organisation of agriculture and trade.

There is also a number of combinations of new and existing processes for which CO_2 abatement can be optimized (e.g. use of coke oven gas instead of natural gas for direct reduction in an integrated plant).[46]

OTHER EUROPEAN & NON-EUROPEAN INITIATIVES

As already mentioned, there are also other international programmes addressing the challenge of a drastic reduction in CO_2 emissions related to steel production, although they are not as advanced as ULCOS and would deliver results possibly many years later.

Japan has a large national programme led by the Japanese Iron and Steel Federation (JISF) called COURSE 50 for 'CO_2 Ultimate Reduction in Steelmaking process by innovative technology for cool Earth 2050'. Two research areas are being investigated:

1. Development of technologies to reduce CO_2 emissions from the blast furnace. The main intention is to control reactions for reducing iron ore with a reducing agent such as hydrogen, with a view to decreasing coke consumption in the BF. Hydrogen would come from reformed coke oven gas, amplifying its H_2 content.
2. Development of technologies to capture, separate and recover CO_2 from blast furnace gas. This targets the development of new chemical absorbents like high performance amine compounds, aiming at reducing energy consumption for CO_2 separation by absorption.

For both research areas, a pilot phase on a mini-BF is planned by 2015-2020, followed by a demonstration phase (partly industrial) by 2020-2030. Final industrialisation should be possible from 2030 on.

POSCO in Korea runs its own programme, with various dimensions including the adaptation of CCS to the COREX/FINEX process (smelting reduction) and the development of an ammonia-based scrubbing technology. So far POSCO has set up a 1.5-Mt per year FINEX unit, which is operating stably and a new FINEX plant scaled-up to 2.0-Mt per year is being progressed. Because FINEX uses pure oxygen for coal gasification and has an in-situ CO_2 removal system, POSCO claims that CO_2 can be quite easily separated and stored using FINEX.

46 Diemer P, Killich H-J, Knop K, Lüngen H-B, Reinke M and Schmöle P (2004), 'Potentials for utilization of coke oven gas in integrated iron and steel works', 2nd International meeting on ironmaking/1st International symposium on iron ore. Vitoria, Espirito Santo, Brazil.

The American Iron and Steel Institute (AISI) programme covers three areas:

1. Molten Oxide Electrolysis (MOE). Electrolysis is carried out with an electrolyte consisting of a molten slag in which iron oxide is fed and dissolved, a concept parallel to ULCOLYSIS. The MIT team has produced metal and oxygen gas at laboratory scale. There are plans to launch a pilot unit with a capacity of 4,000 Ampere to produce liquid iron at a rate of 73 kg per day.

2. Hydrogen Flash Smelting (HFS). Hydrogen is used to replace carbon as a reducing agent. Iron ore concentrates would be sprayed directly into a furnace chamber. This promising process concept was tested in the laboratory at Utah University. There are plans to move from basic research to process work with a true flash smelter presently under design, expected to be commissioned in the near future.

3. Paired Straight Hearth Furnace (PSHF). AISI members together with the US Department of Energy are developing the PSHF, a high-productivity, low-energy ironmaking unit than can process pelletised steel plant wastes as well as virgin iron materials. After preliminary tests a detailed engineering design phase is in progress for the construction of a 42,000-tonnes capacity demonstration furnace.

The Brazilian steel industry continues its development of a biomass steel production route based on sustainable plantations of eucalyptus trees, production of charcoal and small charcoal blast furnaces. The annual production range of these 160 existing small BFs is 70,000 to 500,000 tonnes per year and per BF. Seventy out of 160 BF are running so far, producing a total of 6 Mt per year. The Brazilian steel industry envisages an operating model that uses 66% imported energy (coke and mineral coal) and 34% national and renewable energy (biomass). This model would also use charcoal fines injection in coke-based blast furnace tuyeres.

A Canadian programme run by the Canadian Steel Producers Association (CSPA) has a strong focus on the use of biomass in iron and steelmaking as a substitute for fossil fuels, as biomass per capita is important in this large country. In the short term, the target is to replace PCI (pulverised coal injection) with charcoal injection, which can reduce the GHG emissions by 23%; experimental work is promising. In the long term, a bio-ironmaking process based solely on bio-carbon will be developed. Research is being conducted into areas such as bio-cokemaking, using a coal blend mixed with charcoal.

The rationale of all these programmes is similar to that of ULCOS. Nevertheless, considering the fact that the ULCOS approach has now moved to the pilot plant phase, all these programmes are less advanced down the path of making breakthrough technologies available.

Process developments are also underway related to near-net-shape casting. European equipment manufacturers are at the forefront of more conventional thin slab casting technology. Albeit quite significant in terms of energy optimisation and minimization at the casting/rolling interface, such technologies have a very limited impact at the scale of the steel mill, where CO_2 emissions are overwhelmingly related to ironmaking.

LOW CARBON STEEL ROADMAP 2050

Various studies have striven to model the CO_2 emissions of the steel sector in relation to abatement technologies and climate policies. In particular, the EU's Joint Research Centre (JRC) developed the ISIM model[47], a global simulation model able to analyse the evolution of the industry out to 2030, focusing on steel production, demand, trade, energy consumption, CO_2 emissions, technology dynamics, and retrofitting options.

This model has also been used in the context of the ULCOS programme to project the emergence of ULCOS technologies under different scenarios.[48] To this end, existing steelmaking technologies as well as the innovative technologies investigated under the programme were analysed and compared in terms of capital expense, operating costs[49] and CO_2 emissions.[50] Since steelmaking involves electricity and fuel consumption, either purchased from outside or retrieved from waste gases, CO_2 performance will be heavily influenced by the system boundaries and the assumptions pertaining to the CO_2 intensity of the purchased electricity. In light of this, it was necessary as a first step to provide an appropriate accounting framework for a fair comparison between technologies and then feed the results into simulation models.

47 I. Hidalgo, L. Szabo, J-C Ciscar, A Soria - (2005) - Technological prospects and CO_2 Emission Trading Analyses in the Iron and Steel Industry: A Global Model.
48 E. Bellevrat, Ph. Menanteau (La Revue de Métallurgie – CIT- 2009), Introducing Carbon Constraints in the Steel Sector : ULCOS Scenarios and Economic Modelling.

Although these models to some extent capture important aspects of potential responses to the global and regional carbon constraints, they follow a 'top-down' approach and as a consequence their results lack legibility in the context of an in-depth analysis of the technical-economical CO_2 mitigation potentials in the EU steel industry. Instead, 'bottom-up' approaches should be privileged so as to identify precisely what the EU steel sector is likely to achieve in terms of CO_2 reductions by 2050, the related costs, their impact on global competitiveness, and, how to get the conditions right to make the move to carbon-leaner technologies a success.

Following a series of publications on the topic, the JRC published in November 2012 a study on the Prospective Scenarios on Energy Efficiency and CO_2 Emissions in the EU Iron & Steel Industry.[51] The study analyses the impact of technology innovation and diffusion on the EU steel sector's energy and carbon efficiency. It models the EU steel industry so as to identify potential improvements up to 2030 from a cost-effectiveness point of view, following a 'bottom-up' approach which can be regarded as the first of its kind.

In parallel, EUROFER contracted the Boston Consulting Group to complete the picture out to 2050. BCG teamed up with the Steel Institute VDEh to determine the possible mitigation potential of CO_2 emissions resulting from the production of steel in the EU. The potential of existing or projected abatement technologies (so-called innovative or 'breakthrough' technologies) were investigated from a technical as well as from an economic point of view. Albeit being built on different sets of assumptions and data and looking at different time horizons, these two studies lead to conclusions consistent with each other.

THE 2030 MILESTONE: FINDINGS OF THE JRC STUDY

In summary, the study models the cost-effectiveness of the market roll-out of abatement technologies applicable to the main steelmaking processes. These are divided into two categories: best available technologies (BAT[52]) and innovative technologies.

The analysis considers well-established alternative steelmaking technologies like pre-reduction in the innovative technologies category. It also assumes CCS will be available from 2020.

As regards the development of the EU steel market, the study assumes that the EU will become self-sufficient in steel by 2030, with an annual growth rate of EU finished steel production of 1.8%. An increase in scrap availability would drive the share of EAF steel up to 47% in 2030. In the light of the assumptions derived from the BCG Steel Consumption and Scrap Model, these figures must be considered as rather optimistic. Each year the model makes a cost-benefit analysis for each facility of all possible best available and innovative technologies. Based on historical data, the annual number of retrofits is limited to six.

Different scenarios are defined, including three different developments for the carbon price. The baseline scenario considers that the CO_2 emission price rises from €11/tonne of CO_2 in 2010 to €25 in 2020 and €39 in 2030. In the alternative CO_2 scenarios, it would reach €100 and €200 per tonne of CO_2 in 2030.

The main findings of the study are described below.

49 J-P Birat, J-P Lorrain (La Revue de Métallurgie – CIT – 2009), The "Cost Tool": operating and capital costs of existing breakthrough routes in a future studies framework.
50 J-P Birat, J-P Lorrain, Yann de Lassat (La Revue de Métallurgie – CIT – 2009), The "CO_2 Tool": CO_2 emissions & Energy consumption of existing & breakthrough steelmaking routes.
51 N. Pardo, J.A. Moya, K. Vatopoulos (2012), Propspective Scenarios on Energy Efficiency and CO_2 Emissions in the EU Iron & Steel Industry (JRC Scientific and Policy Reports).
52 The notion of BAT in this report refers to existing technologies which under certain circumstances can lead to CO_2 savings.

Primary steel production route

The reduction from 2010 to 2030 would amount to respectively 11% and 14% for specific energy consumption and specific CO_2 emissions in the baseline scenario (with an allowance price of €39 in 2030). This scenario involves the uptake of CCS applied to power plants and the Top Gas Recycling technology (ULCOS-BF) as from 2021. It relies on very optimistic assumptions, given the current state of the development of these technologies.

In the €100 scenario the reduction would be respectively 8% and 15% for energy consumption and CO_2 emissions,

In the €200 scenario the reduction would be respectively 7% and 19% for energy consumption and CO_2 emissions.

Secondary steel production route

The reduction between 2010 and 2030 would amount in the case of the baseline scenario to respectively 6% and 11% for specific energy consumption and specific CO_2 emissions. No further improvements are attained with either the €100 or €200 carbon price scenarios.

The study also analyses the increase in fuel prices through two alternative scenarios in which the cost of fuels would respectively double and increase fivefold in 2030 compared to the baseline scenario. This leads to a modest penetration of direct reduction, which is at odds with the BCG/VDEh findings and rather counter-intuitive, as the direct reduction process is based on natural gas and electricity and is therefore only cost-effective with low natural gas and electricity prices. This is probably due to the fact that the model seems to ignore the costs pertaining to the investments needed in new EAF to melt the DRI production.

The study concludes that, as expected, higher energy prices and higher allowance prices lead to a higher CO_2 emission reduction. It is noteworthy, however, that allowance prices at the level of €100 or €200 don't bring about much more CO_2 reduction than the baseline scenario. The rather limited abatement potential of the steel industry and technical constraints render carbon pricing ineffective.

However it has to be noted that such carbon prices are more than enough to drive the sector out of the market. On average, a tonne of steel costs about €500.

An abatement cost of €25 would add marginal costs at a level close to the net operating margin. Under the EU ETS, this would be enough to push steel makers to reduce their production and abandon market share to foreign competitors as such costs cannot be passed on through higher sales prices because of international competition. Abatement costs of the order of magnitude of those used by the study are not sustainable in the context of unilateral climate action by the EU.

This does not mean that carbon pricing does not work for other sectors, but rather points out that the implementation of the most effective best available technologies and the most promising innovative technologies would lead to disproportionate costs in the steel industry, putting the industry at risk of relocation.

A follow-up analysis[53] with the model used in the JRC report, shows that, using the same values than in the baseline scenario, but removing the constraint that limited the number of retrofits and changing the value of the decision-making criterion about new investments, the reductions in energy consumption and CO_2 emissions feasible could amount up to 18% and 65%, respectively. However, these values include the same optimistic assumptions than the JRC report about the early market roll-out CCS and Top Gas Recycling technology (BF-TGR).

Remarks

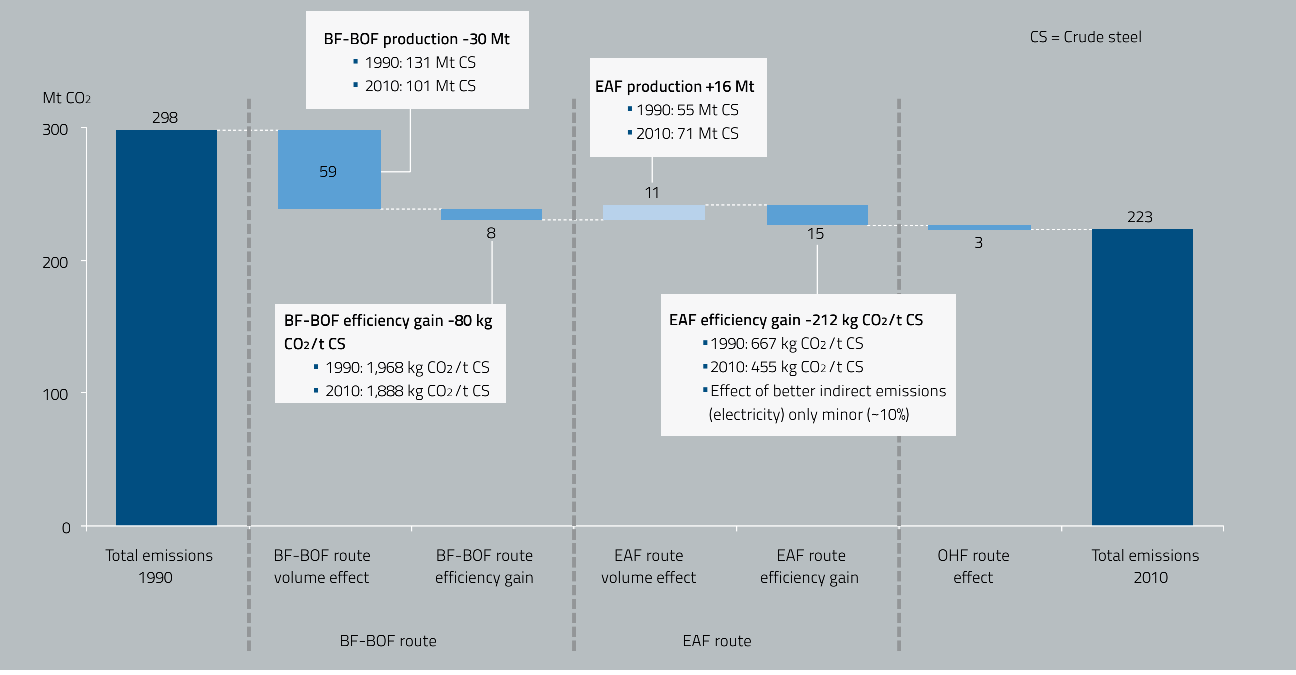
As previously pointed out, the JRC study horizon is not in line with the expected development of technologies such as CCS and TGR. This tends to overestimate the abatement potentials of the sector up to 2030. Similarly the estimated reduction in specific CO_2 emissions of BAT technologies often gives very optimistic figures. On the other hand the assumptions in terms of payback time and number of retrofits could be seen as rather conservative as these parameters usually depend on the size of the investment.

53 J.A. Moya, N. Pardo (Journal of Cleaner Production - 2013), The potential for improvements in energy efficiency and CO_2 emissions in the EU27 iron and steel industry under different payback periods.

FIGURE 25

EU27 STEEL CO_2 EMISSIONS FOR THE BASELINE YEARS 1990 AND 2010

Source: BCG-VDEh



Against this background and in order to best assess how much CO_2 savings BAT and innovative technologies can deliver and under what conditions, it is necessary to follow a slightly different approach by building up technology scenarios first and then analysing them from an economic perspective. This approach would be complementary to the JRC study and broaden the scope of the investigation. It is described in the following section.

THE 2050 HORIZON: THE BCG/VDEH APPROACH

For their study, BCG/VDEh established as a first step a technology roadmap based on a number of scenarios. The second step was to analyse what the various technology scenarios mean from an economic perspective. It can be concluded from the findings of the study that the EU steel industry, under certain conditions, is able to make significant further contributions to CO_2 mitigation in Europe and worldwide.

Establishing a baseline

The study uses two reference years: 1990 (Kyoto reference year) and 2010. The system boundaries cover ironmaking, steelmaking and hot rolling.

As for primary steelmaking, system boundaries also include CO_2 emissions pertaining to waste gases, irrespective of how they are being used. This relies on the assumption that integrated plants are self-sufficient in electricity. In reality, overall primary steelmaking in Europe is a net importer of electricity. However this approximation can be considered as realistic for the system boundaries considered in the study. It also enables circumventing the problem of the lack of detailed data on waste gas usage.

As regards secondary steelmaking and CO_2 pertaining to electricity purchased from the grid, the CO_2 factor of the national grid is used.

The following other indirect emissions related to steelmaking are included in the scope: oxygen and lime production, purchased coke and pellets.

CO_2 emissions from EU27 steel production fell by over 25% between 1990 and 2010, from 298 Mt in 1990 to 223 Mt in 2010. This was mainly due to a partial shift from primary to secondary steelmaking (accompanied by a contraction of output), efficiency gains and, to a lesser extent, to the decrease of specific CO_2 emissions from electricity generation (Figure 25). Over the same period, specific CO_2 emissions decreased by about 15% from 1.508 to 1.293 tonnes CO_2/tonne of steel.

Technical CO_2 emission reduction potential up to 2050

As for the 2050 horizon, the BCG/VDEh study projects that the EU steel market will grow by 0.8% annually leading to EU crude steel production of 236 Mt in 2050. As in the JRC study, this is based on the assumption that the EU steel market will reach self-sufficiency by 2030 (EU steel consumption=EU steel production, this assumption 'neutralizes' variations in trade flows). However, according to the annual market growth rate forecast by BCG/VDEh, steel lies significantly below the JRC projections. The stock of scrap available within the EU is projected to increase from 96 Mt in 2010 to 136 Mt in 2050, the share of secondary steelmaking (Electric Arc Furnace Route) rising to 44% by 2050. Here again the scrap model used by BCG/VDEh gives less optimistic values than those put forward in the JRC study.

Under these assumptions, BCG/VDEh conducted a technology review in order to identify the most relevant potential CO_2 abatement scenarios in the industry. The review was carried out on different levels:

- decarbonisation of the power sector;[54]
- best-practice sharing;
- implementation of incremental technologies (mainly process optimisation and retrofits);
- shift to alternative technologies (this concerns in particular primary steelmaking);
- application of innovative technologies (in combination with CCS or not).

Incremental technologies were subject to a cost-benefit analysis under different energy price scenarios.

The take-up of new technologies was modelled through the use of S-shaped curves. This modelling exercise led to a number of abatement scenarios:

- Baseline scenario: this scenario assumes for 2050 the same split between the BF-BOF and Scrap-EAF routes and the same CO_2 intensities as in 2010 (including for the power sector). This scenario leads to 305 Mt CO_2 emissions in 2050.
- Implementation of best-practice sharing and increasing scrap availability: this scenario leads to 271 Mt CO_2 emissions in 2050, the share of Scrap-EAF steel production reaching 44% in 2050. This includes the effect of the decrease of the CO_2 intensity of the power sector.
- Maximum theoretical abatement without carbon capture, use and storage (CCS): the partial shift from the conventional BF-BOF to DRI-EAF route leads to 184 Mt CO_2 emissions in 2050. This scenario also assumes the implementation of the incremental technologies deemed as economically viable.
- Maximum theoretical abatement with CCS: considering full deployment of CCS in primary steelmaking, the implementation of best-practice sharing and incremental technologies as well as the partial decarbonisation of the power sector, the steel sector's emissions would amount to approximately 130 Mt CO_2 in 2050.

As under the CCS scenario, all iron-ore based steelmaking technologies have the same CO_2 intensity (ca. 0.7 tonne CO_2/tonne of steel), it can be concluded that the retrofit of the existing blast furnaces with the top gas recycling technology (TGR) is the most sensible option, should CCS become widely available at competitive prices across the EU. In this context it is worth pointing out that full deployment of CCS would lead to a theoretical reduction of ca. 60% in 2050 compared to 1990, still falling short of the EU's 80% aspirational objective.

Economic CO_2 emission reduction potential up to 2050

The analysis carried out further by BCG/VDEh on both maximum theoretical abatement scenarios leads to the conclusion that, unless the legislative and economic conditions prevailing today change radically, they are neither realistic nor economically feasible.

The shift from the conventional BF-BOF route to DRI-EAF would entail CO_2 abatement costs in the range of €260-€710/tonne of CO_2 (without considering decommissioning costs). This figure is unsurprisingly high as it supposes abandoning existing installations for new ones with higher operating costs (the DRI-EAF route is particularly intensive in natural gas and electricity, both input factors being comparatively costly in Europe).

Furthermore, the TGR technology has only been applied in a pilot plant so far. The benefits have yet to be demonstrated at industrial scale. According to project data, the corresponding abatement costs are expected to amount to at least €50/tonne of CO_2, subject to validation in demonstration-scale tests.

54 The BCG/VDEh study envisages a decarbonisation path along the lines of the IEA projections (IEA Outlook 2012).

The numbers show a high contingency (ca. 100%) and are highly sensitive to site-specific conditions.[55] This technology doesn't lead to any competitive advantage in the absence of carbon costs. High coking coal prices may however have an alleviating effect on the economics.

As regards CCS the study also points to a number of difficulties, in particular public acceptance and the subsequent limited geological storage capacity (integrated sites would have to store about 2 to 8 Mt CO_2 annually), CO_2 transport and storage costs.[56]

To sum up, these scenarios would make steel wholly uncompetitive unless the current and reasonably foreseeable conditions change radically over coming decades.

The economic scenario identified by BCG/VDEh gives projected steel sector's emissions for 2050 of about 258 Mt CO_2[57] (-13% compared to 1990). The drivers of the reduction are:

- continued decarbonisation of the power sector;
- increased scrap availability;
- best-practice sharing;
- implementation of cost-effective incremental technologies.

The economic scenario means a 10% reduction in CO_2 intensity by 2030 and 15% by 2050 compared to 2010. This shows that the remaining potential for improvement is low because of the already high level of optimization of existing processes.

The impact of the scenarios investigated in the study on EU steel's CO_2 intensity is summarized in Table 2.

It should be noted that under the economic scenario, the CO_2 savings up to 2030 are offset by the effect of production growth. As a consequence, the total emissions of the sector in 2030 would be 7% higher than in 2010. This has to be compared with the more positive findings of the JRC, which estimate the improvement over the same period at 14%. This is partly explained by the rather optimistic technology development assumptions of the JRC study. It assumes that the TGR and CCS technologies will be available from 2020 and that there is higher overall mitigation potential for a number of 'incremental technologies' compared to the technology review carried out by BCG/VDEh.

DEEPER CO_2 CUTS

Going beyond the maximum 60% emission reduction projected in the BCG/VDEh study would require another level of technological development.

In the BF-TGR scenario, further CO_2 abatement could be envisaged at the level of the heating units (stoves, oven, reheating furnaces). These units are currently mostly fired with natural gas (or LPG) or alternatively with waste gases in integrated plants. Applying the CCS technology to each single stack is in principle imaginable (with some adaptation of the heating process e.g. increase of the oxygen rate).

TABLE 2
STEELMAKING CO_2 INTENSITY PATHWAYS UP TO 2050 (COMPARED TO 1990)
Source: BCG-VDEh

CO_2 intensity reduction compared to 1990	2030	2050
Implementation of best-practice sharing and increasing scrap availability scenario	-19%	-24%
Maximum theoretical abatement without CCS	-31%	-48%
Maximum theoretical abatement with CCS	-22%[1]	-63%
Economic scenario	**-22%**	**-28%**

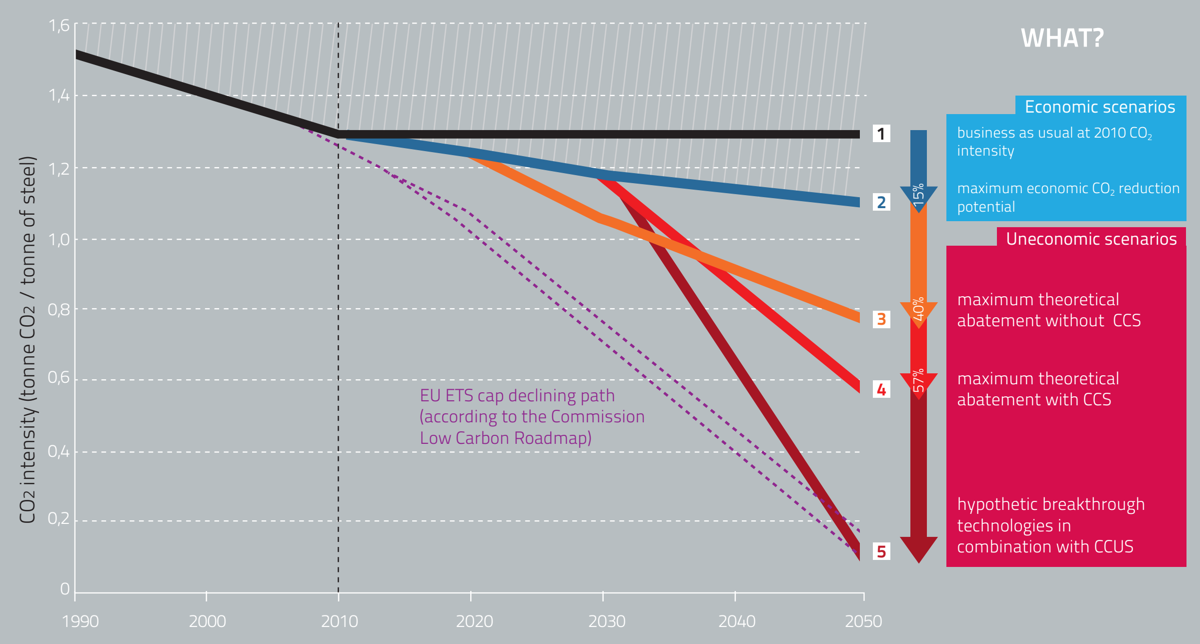
1 This scenario assumes CCS will be available only after 2030

55 Lawrence Hooey, Andrew Tobiesen, Jeremy Johns and Stanley Santos (2013): Techno-Economic Evaluation of Incorporating CO_2 Capture in an Integrated Steel Mill.
56 Typically storage costs vary from €1-7/tonne of CO_2 for on-shore storage and €6-20/tonne of CO_2 for off-shore storage. Transport costs amount to ca. €0.030/tonne CO_2 km for pipeline transportation (source: Zero Emission Platform, 2011, The Costs of CO_2 Transport, Post-demonstration CCS in the EU, and The Costs of CO_2 storage). Access to CCS will be unaffordable for companies which don't have a nearby storage site.
57 This figure corresponds to about 0.7% of the current global emissions.

FIGURE 26

TECHNICAL CO_2 INTENSITY PATHWAYS UP TO 2050

Source: BCG-VDEh, EUROFER

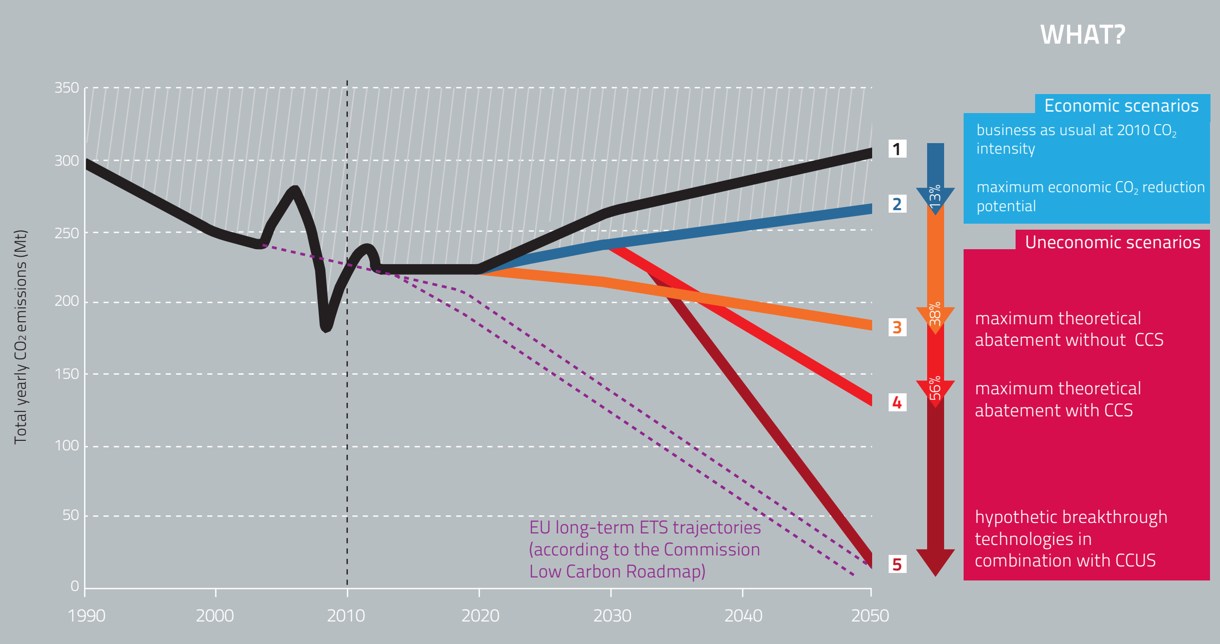


Emission reduction potentials are expressed in specific CO_2 emissions relatively to 2010

FIGURE 27

STEEL INDUSTRY CO_2 REDUCTION PATHWAYS UP TO 2050

Source: BCG-VDEh, EUROFER



Emission reduction potentials are expressed in absolute CO_2 emissions relatively to 1990

This would lead to disproportionate abatement costs given the relatively low CO_2 volumes (as most of the emissions pertain to steelmaking) spread over a large number of emission sources.

It's also worth pointing out that the application of the BF-TGR technology reduces the volume of waste gases available, as all the blast furnace gas is captured and recycled in the blast furnace. As a consequence, the recovery and use of the remaining waste gases (coke oven gas and basic oxygen furnace gas) for heating purposes becomes even more crucial, leaving little room for deployment of electrification of the heating systems in integrated steel plants.

The use of biogas or syngas (resulting from the gasification of biomass) could to some extent provide an alternative. However, sustainability issues raised by the use of biomass would have to be addressed, particularly in view of the huge quantity of energy involved.

Several projects are underway involving the use of hydrogen as the main reducing agent in primary steel production (injection into the blast furnace or direct reduction process). Maximum CO_2 savings can be achieved through the use of CO_2 free hydrogen (hydrogen obtained from electrolysis), but at the expense of huge amounts of energy.

Technologies such as HIsarna or ULCORED, subject to the outcome of the demonstration phase, could potentially lead to CO_2 savings of about 80% when combined with CCS.

The full decarbonisation of the power sector would also lead to further CO_2 cuts, in particular at the level of the EAF. Under this kind of scenario, another option would be steelmaking via electrolysis (ULCOWIN). The electrification of heating devices could also be considered. This technology is currently used to process small batches of steel in short series (in induction or resistance furnaces). For the time being, technical limitations make these technologies incompatible with the productivity requirements of the sector.

CONCLUSIONS: LOW CARBON STEEL ROADMAP 2050

Depending on the assumptions, the scenarios and the models used, the steel sector's CO_2 emissions pathway through to 2050 will have various profiles. Future energy prices and climate and energy policies at the global or regional level, because of their potentially very high distortive effect, will impact trade patterns and play a prominent role in technology choice. The best example is the shale gas revolution in the United States, which is already attracting investment in new direct reduction capacity. This will give a significant advantage to the US steel industry and at the same time lead to a decrease of its CO_2 emissions independently from any regulatory initiative.

Equally, the steel industry in Europe would in future look totally different under a well-balanced international climate agreement than it will look under a very strict unilateral EU carbon policy.

Beyond the complications inherent to the setting of assumptions, all studies converge towards the following key drivers for the future EU steel CO_2 footprint:

- more scrap will be available in the future and will lead to an increasing share of secondary steelmaking, thereby contributing to CO_2 savings in the steel industry;
- the continuing decarbonisation of the power sector will also lead to significant CO_2 savings in the industry, along with the increase of secondary steelmaking;
- incremental technologies could, to a relatively modest extent, contribute to the reduction of emissions, in particular as regards the BF-BOF route;
- more ambitious CO_2 cuts require a change of technology in primary steelmaking e.g. resorting either to direct reduction or retrofitting the existing BF fleet with top gas recycling technology; BF-TGR retrofit shows more favourable economics than the DRI-EAF route;
- combining these technologies with CCS would bring the sector's specific CO_2 emissions down further to a level of about 60% below 2050 compared to 2010.

Bringing the steel sector's emissions down further would need the deployment of technologies like HIsarna (smelting reduction), ULCORED (direct reduction) both connected to CCS or hydrogen-based reduction, should they prove technically feasible. Under a fully decarbonised electricity scenario, electrolysis could also be envisaged as a potential solution. From today's perspective, it is not possible to predict which technology or combination of technologies is most likely to emerge.

For illustrative purposes, the steel sector's emission reduction trajectories derived from the model developed by BCG/VDEh are shown in Figures 26 and 27.

According to the BCG/VDEh model, direct reduction technology could bring about an emission reduction of about 38% by 2050 compared to 1990. However as it needs a lot of natural gas and electricity, it has to be regarded as economically unviable if the current sustained price trend for these commodities continues. Furthermore the technology would require the replacement of the existing well-functioning and optimized integrated installations. In this context, it is also worth stressing that the sector is currently facing and will face in the future substantial costs to adapt installations in accordance with the Industrial Emissions Directive (IED). Such investments also have a long life cycle. They would become meaningless in such a scenario.
The maximum CO_2 emission reduction achievable by the EU steel industry by 2050 compared to 1990 levels would be about 60%. This, however, would require the retrofitting of all existing blast furnaces with TGR and CCS, hence implying that both technologies are confirmed as technically feasible on large-scale blast furnaces and commercially available across the EU at competitive prices. If not, such a scenario would raise dramatic competitiveness concerns because of the costs involved, a situation that would be exacerbated, if the EU pursues its unilateral climate policy. This level of abatement could also be achievable by applying CCS technology to direct reduction. However this option would be far more costly than retrofitting the existing BF plants.[58]

In the economic scenario which pertains to the maximum CO_2 saving potential achievable in a cost-effective way, the steel sector's emissions would decrease by about 13% in 2050 compared to 1990. This scenario is particularly relevant for the 2030 milestone, as the CCS and TGR technologies are unlikely to be in widespread use by then (in any case it is fair to assume that CCS application at industrial scale will be applied in priority to the power sector). It leads to a 10% reduction in CO_2 intensity by 2030 and 15% by 2050 compared to 2010.

The economic scenario could in principle also give rise to competitiveness issues because, as with the two theoretical maximum abatement scenarios, it implies the decarbonisation of the power sector. This, in itself, as experienced today, could lead to distortions of competition vis-à-vis competitors in energy markets not subject to such constraints since power prices would rise abnormally. Steel is a globally traded commodity and CO_2 abatement costs borne by the EU industry alone would only weaken it further.

In summary, even if the necessary technologies were available in good time, their deployment would not be affordable in the absence of an international agreement providing a level-playing field. As a consequence, if future EU climate policies impose a uniform carbon price across the economy regardless of the CO_2 reduction potential that is technically and economically achievable by the steel industry, the pressure on EU steel production would be such that Europe's steel industry and, as a consequence, large parts of the entire manufacturing value chain would gradually be forced out of Europe.

58 The BF-TGR technology would also lead to a sharp increase in hot metal productivity. Not all the exiting BF would be needed to meet the expected demand over the coming decades.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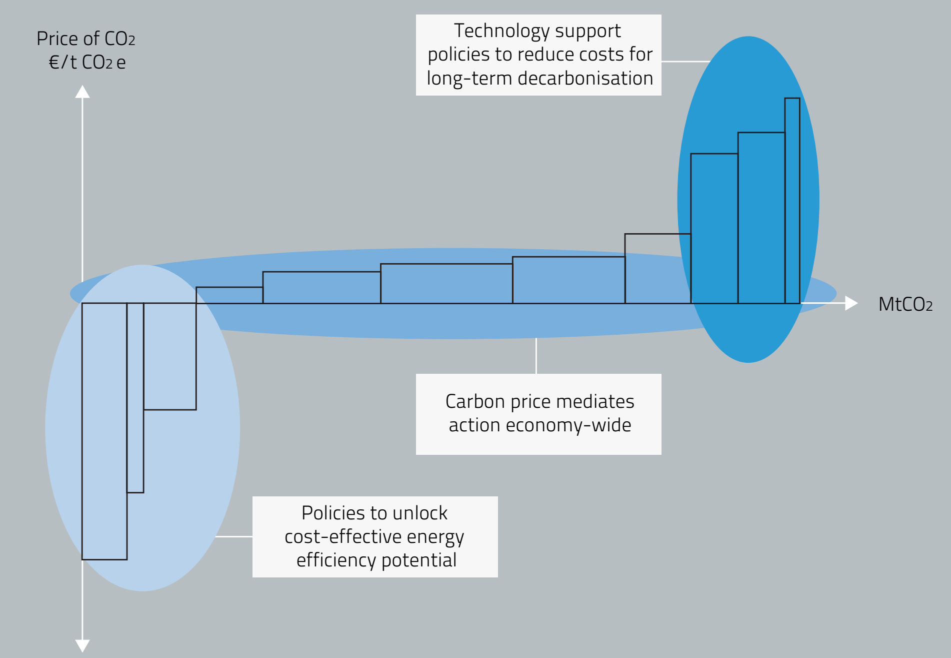
06 THE ROAD TO 2050: CHALLENGES, OPPORTUNITIES AND CONDITIONS FOR SUCCESS

FIGURE 28
THE CORE POLICY MIX: CARBON PRICE, ENERGY EFFICIENCY AND TECHNOLOGY POLICIES

Source: IEA (2011), Summing up the Parts: Combining Policy Instruments for Least-Cost Climate Mitigation Strategies.



REFLECTIONS ON THE EU CLIMATE STRATEGY

The steel roadmap strives to identify the maximum level of CO_2 abatement that the steel sector would be able to deliver in the 2050 horizon on the basis of what can reasonably be expected in terms of technological development. The outcome of this 'bottom-up' approach is at odds with the conclusions of the European Commission *Roadmap for moving to a competitive low carbon economy in 2050*: there is no cost-effective path for the steel industry to reduce its emissions by 80% to 95% by 2050 compared to 1990. A number of technologies could help make partial progress towards the goal. Some of them have yet to be proven technically feasible or go through the demonstration phase. None of them is cost-effective. This shows how important it is that each industrial sector develops its own 2050 roadmaps in order to find a way to reconcile the abatement technically achievable with the top-down 80-95% reduction objective.

The EU ETS is being given a central role in the decarbonisation of the EU. It provides a harmonised framework to reach a predefined CO_2 reduction target. It is technology-neutral and lets the market decide on the abatement techniques. It has yet to be demonstrated how it can deliver sweeping technological changes.

A parallel can be made with the deployment of renewable energies and CCS. Renewables are costly and encouraging them through the EU ETS would have required placing the cap at a dangerously low level that would have resulted in the destruction of most of the economy before the first erg of renewable energy had entered the market. Instead a renewable target was set outside the scope of the EU ETS. The same can be said for CCS. The use of CCS implies abatement costs which are not compatible with the current CO_2 objective. CCS is an option for the longer term and needs specific treatment.

The development of breakthrough technologies for steelmaking will not be triggered by a carbon price. The uncertainty affecting the carbon price – which is inherent to all markets – is not compatible with the development and deployment of breakthrough technologies. For that to happen, a different set of policies and incentives has to be set up, over a time frame consistent with the long lead times characterising such technologies.

The EU ETS has to co-exist with other policies, all must be fit for purpose and inevitable overlaps need to be addressed consistently.

Ambitious long-term objectives require a drastic change of philosophy and the reconsideration – sector-wise – of the place of the EU ETS in the EU's climate and energy arsenal.

In the long term the additional cost of carbon pricing may reduce the ability of companies to cover their capital costs, particularly in the case of overambitious CO_2 reduction targets.

RENEWABLES

The Renewable Energy Directive adopted in 2009 sets binding targets for renewable energy generation. The objective is to reach a 20% share of renewable energy in the EU's overall energy consumption by 2020. Member States have to reach individual targets for the overall share of renewable energy in energy consumption. The adoption of the current policy framework of legally binding targets has resulted in the strong growth of renewable energy.

By increasing the rate of renewable energy, the EU is diversifying its energy supply and decreasing its dependency on fossil fuels, thereby increasing its resilience to energy price shocks. However, as these energy sources are expensive, it is not clear whether their deployment can be achieved at competitive energy – and, more specifically, – power-prices over the long-term. The evidence so far is that support for renewables has increased energy bills for consumers. The amount of the cost increase not only depends on the type of renewable energy source supported, but also on the accompanying administrative burden, the need to maintain conventional capacity as back-up and particularly on how the support scheme is designed, as it can lead to overcompensation.

Furthermore the benefits from the expansion of renewable energy in other areas like employment are not clearly established. The money spent by tax-payers and energy users in renewable energy support schemes is money that cannot be allocated to other parts of the economy. In some cases inadequate support schemes can lead to abnormally high returns for investors demonstrating that this money could be better spent elsewhere. In addition subsidies have attracted investors into the market, but not only EU-based investors, which has sometimes had very detrimental consequences for EU producers unable to cope with cut-throat competition. The benefits of renewable deployment for the EU economy, in particular in terms of job creation, have been widely exaggerated.

On the other hand, support for renewables is needed to foster the maturing of the technologies and to allow them to reach grid parity. Renewables are also likely to put downward pressure on energy wholesale prices. As CO_2 emissions avoided by the renewable energy target are widely captured by the EU ETS, the increase in the share of renewable energy also pushes the price of EU carbon allowances down.

As energy policy is governed by the Member States, the overall Renewable Energy Strategy lacks clarity and coherence. Inefficiencies stemming from the multiplication of inadequate support schemes and the overlaps with the EU ETS have to be addressed.

As an ultimate objective, renewables should be able to compete on the market and support schemes should be phased out as soon as possible. Having a fully functioning energy market would in principle facilitate the integration of renewables and reduce the level of support necessary, thereby also reducing distortions within the single energy market and making support schemes converge.

More cooperation between Member States is needed with a view to making renewable policies transparent and cost-effective. Renewable support schemes should be designed so as to give an appropriate level of support reflecting the true costs of generation and avoiding creating windfall profits.

As long as the EU Renewable Energy Strategy leads to additional costs that impair the competitiveness of energy-intensive industries exposed to global competition, exemptions from energy taxes or other renewable support mechanisms should continue to be allowed.

ENERGY EFFICIENCY

Energy-efficiency is a key to competitiveness.

The 'one-size-fits-all' approach of the Energy Efficiency directive, which imposes a pre-defined level of energy savings to be achieved among a pool of users, is not fit for purpose for heavy industries like steel. First of all, fuel and power usage in the steel industry is covered directly or indirectly by the EU ETS directive. The fact that investments in energy efficiency have to respond to two sets of obligations creates confusion and hinders participants from making optimal investment decisions. The conflicting rules could eventually lead to investments in energy efficiency which are not the cheapest on the market but dictated by the application of the energy efficiency obligation schemes. It's also worth stressing that the Eco-design directive also has a bearing on energy efficiency to some degree. To rectify this situation the EU's energy efficiency policy should be focused on tapping energy efficiency potentials which are not captured by the EU ETS. It should focus not only on energy use not regulated by the EU ETS (e.g. transport and households), but also on measures within the EU ETS relating to limited savings potentials and for which the economics are often unclear. Carbon pricing – which is inherently volatile – does not provide the right incentive for this type of investment because the main objective of the EU ETS is to reduce CO_2 emissions in absolute terms, not decrease the specific energy consumption of an industrial process. Therefore improving the sector's competitiveness by reducing energy consumption through cost-effective investments in energy efficiency requires specific incentives.

In this regard, voluntary agreements have been relatively successful and could be used as basis to address more focused energy efficiency issues. Voluntary agreements should be promoted with bespoke incentive schemes aimed at overcoming the technical and economic hurdles to energy conservation and energy recovery. Steelmaking sites strive to make the most out of energy flows. However, there is still untapped potential due to technical and economic limitations (low temperature waste heat sources) or the unfavourable regulatory framework (conversion of waste gases into fuels).

In general, the gains from energy-efficiency investments are difficult to appraise, making the economics highly uncertain and hence leading to funding issues. Financial instruments and supporting schemes should be set up in order to provide access to capital.

Some general recommendations can be drawn from recent experiences:

- coherent policy package with no overlaps giving clear incentives, focusing on cost-effective measures;
- under certain circumstances, sector-specific incentives give better results. In the steel industry for example, CO_2 emissions do not decrease in a linear way with energy efficiency. This is due to the fact that process CO_2 emissions would occur anyway, regardless of how waste heat or waste gases are being recovered. Therefore bespoke approaches should be preferred, e.g. incentives through voluntary agreements;
- in particular, the recovery of important quantities of low grade industrial waste energy (waste gases, heat and pressure) should be promoted through incentives similar to those for renewable energy generation;
- funding remains an important issue, as in general capital is accessible for short pay-back periods and therefore for projects with big energy-saving potentials. Public funding or private-public programmes enable the financing of projects which are not eligible for regular bank loans.

CARBON CAPTURE AND STORAGE

CCS is an end-of-pipe technology. As such, it will increase operating costs. Unlike investments in energy efficiency which give a competitive advantage to companies in terms of lower energy costs, CCS will not make steel companies more competitive, especially not in the case of unilateral climate action by the EU. However, in the context of global action and in a world with no distortive carbon policies, CCS could in the future represent a relatively cheap alternative compared to other abatement techniques.

In the face of strong public acceptance concerns in many EU countries, storage sites might not be available throughout the EU. In order to avoid distortions to competition within the single market, CCS infrastructure must be such that it provides equal access to all companies, even those located in areas with no storage site nearby.

CCS faces in many aspects similar challenges to those faced by renewables and more generally by breakthrough technologies. It requires big risky upfront investments in research and development and demonstration-scale projects, as well as continued funding in the deployment phase. Carbon pricing – mainly because of the high uncertainty of the revenues it is able to generate is insufficient to lead to the widespread deployment of this technology. The absence of any demonstration-scale CCS project in the first NER300 funding round shows clearly that investors are not willing to bear the majority of the costs of such high risk investments. This is particularly true for CCS for industrial applications such as the technologies envisaged under the ULCOS programme, which will have a much more modest development, if successful, than CCS in the power sector. As a consequence, the financial risk is distributed over a limited number of players. EU Member States must secure the funds required for the demonstration and subsequent deployment of commercially viable CCS infrastructure: 100% public funding is a prerequisite for success.

Furthermore, more efforts should be made to raise public awareness about and acceptance of CCS. This is the key to gaining the support necessary to go ahead with the smooth transposition of the CCS directive and to ensure environmentally safe geological storage of CO_2.

The size of the investments and operating costs, or the level of the carbon price needed to incentivize them is simply not affordable for to the steel industry in the context of unilateral action. CO_2 costs would be fatal to the intensive iron-ore based route, while the EAF route would be hit hard by raising power prices.

In order to be successful, EU CCS policy must take into account the following aspects:

Global competition

Climate change is a global issue and must be addressed globally. Not only would unilateral action by the EU have no or little environmental benefit, but it would lead to increased direct and indirect CO_2 costs for industries exposed to global competition. Any policy aimed at promoting CCS has to be accompanied by mechanisms offsetting the costs for industries prone to carbon leakage.

Financing

At this point in time, CCS for industrial applications requires massive funding. Only through demonstration-scale projects can CCS overcome the public's concerns. Given the high uncertainty in terms of the regulatory framework, environmental and health & safety aspects as well as liability surrounding such investments, financing must come from public authorities. The supply side of CCS needs planning certainty. Carbon pricing under the EU ETS is unlikely to meet this fundamental requirement. As a global leader in the fight against climate change, the EU must provide resources which are consistent with its objectives.

Competitive access to CCS within the single market

CCS must be affordable and accessible to all, regardless of the storage locations. This is only possible via the creation of fully integrated CCS infrastructure with sufficient capacity to make it competitive.

CARBON CAPTURE AND USAGE

Gas fermentation provides a novel technological solution for the sequestration of carbon into fuels and high-value chemicals. Biological processes have successfully demonstrated the application of this process at industrial scale by using carbon-rich gas streams such as industrial flue gases from steel mills and processing plants, as a nutrient source for biomass growth and subsequent product synthesis – in effect the sequestration of carbon into new products such as chemicals and fuels.

Such processes are of value as they operate completely outside the food value chain and mitigate carbon emissions from industry without the need for direct or indirect land use change.

Unfortunately, these technologies were unknown at the time of writing biofuels legislation. Technology providers that use gases from industrial applications are also facing challenges as legislators/regulators focus primarily on the nature of the input gas stream. More generally an appropriate set of incentives should be put in place to promote the sequestration of CO_2 into products. The prospects of such technologies have first to be analysed and confirmed as meaningful in a CO_2 mitigation context.

INTERNATIONAL COMPETITIVENESS OF THE EU STEEL INDUSTRY

Climate change is a global issue which has to be addressed through a coordinated global response. The UN Climate Change Conference in Durban in 2011 clearly recognised the need for a global approach. Governments agreed in Durban to work together on a legal framework to deal with climate change for the years beyond 2020.

EUROFER welcomes the continued efforts by EU institutions and the EU Commission in particular to get other major developed and developing economies on board.

International climate negotiations

A meaningful, legally-binding global agreement with robust rules to monitor progress in CO_2 emission reduction will be instrumental in winning the fight against climate change. The rules will have to be designed so as to restore a level-playing field for industrial sectors exposed to global competition and to avoid distorting trade flows as far as possible.

Global steel consumption is set to grow by a factor of 1.7 by 2050.[59] Most of the demand increase will be concentrated in emerging countries, in line with demographic development, growing infrastructure needs and the reduction of poverty. In 2020 the EU will account for about 11% of global CO_2 emissions. Unilateral action by the EU is meaningless in terms of the fight against climate change if other developed countries and major developing countries do not commit to similar CO_2 reduction targets. On the other hand setting a firm cap on developing nations' CO_2 emissions hardly seems feasible.

Given the anticipated steady CO_2 emission growth rate in developing nations in the decades to come, there is pressing need to invest in energy efficiency and CO_2-lean infrastructure worldwide in order to meet the IPCC's maximum 2 degrees global warming objective.

Market-based instruments and more generally carbon pricing could provide effective incentives to achieve CO_2 emission abatements where they are the cheapest. They can also potentially promote the development and deployment of low carbon technologies without – if designed properly – harming the competitiveness of industry at local and international level.

However, over the long-term, carbon pricing might not be sufficient to foster the development and global deployment of the breakthrough technologies indispensable to achieving deep CO_2 cuts in the steel sector. Other policies – maybe based on sectoral approaches – will have to take over.

Until an integrated and globally effective carbon regime providing an equal footing to producers of globally traded goods is enforced, the EU should refrain from adopting unilateral climate targets. As in the case of the 2020 climate and energy package, the EU's CO_2 reduction objective should be dependent upon the conclusion of an international climate agreement and be aligned to the commitments of the other major players.

Competitive energy prices

Future EU policies should be aimed at reducing the gap with the EU's main competitors in terms of energy prices. Although the completion of the internal energy market is expected to stimulate competition within the internal market and thereby have a positive impact on prices, it is not expected to lead to globally competitive energy prices.

The fact that EU policies have led to higher energy prices has to be fully addressed. This is particularly important for the EAF route which is highly intensive in electricity and natural gas and which is set to play an ever important role in the EU steel production mix since the amount of scrap available in Europe is predicted to increase steadily over time. As the energy price gap with competing regions is widening, EU policies should be designed in such a way they do not accentuate the problem.

59 Allwood J.M., Cullen J.M., et al., 2012. Sustainable Materials: with both eyes open, UIT Cambridge, England.

Exemption from distortive taxes, levies and other add-ons to energy prices should therefore be kept in place and made general across the EU.

Addressing carbon leakage

As pointed out in Chapter 4, carbon leakage is a reality, although at current carbon prices the EU ETS alone cannot explain the eroding competitiveness of the EU industry. A number of studies have endeavoured to address the problem of the CO_2 embodied in imports into the EU through carbon border tax measures. But designing an enforceable system seems to present insuperable obstacles. This is particularly true for steel which has a relatively long value chain. Imposing a CO_2 tax on imports of crude steel would inevitably displace the problem to the next step of the value chain, namely hot rolled products, and so on down to fabricated products in which the amount of steel, its origin and carbon footprint would be almost impossible to trace back.

Furthermore recent experience in the aviation sector shows that border measures are likely to trigger retaliatory measures by trading partners.

In terms of protection against the risk of carbon leakage, free allocation (based on meaningful benchmarks to push the whole sector to best-practice) seems to be the most effective and practicable policy instrument.

STRONG EU INDUSTRIAL POLICY FOSTERING SUSTAINABLE GROWTH

A strong and competitive industrial base in Europe is crucial to making a successful transition to a sustainable economy. This requires setting a predictable policy framework aimed at developing low carbon strategies over the long-term and avoiding concentration only on the short-term political agenda. The EU is among the regions with the highest labour and regulatory costs. High energy prices compared to other regions are by themselves a very significant threat to the competitiveness of EU industry.[60]

The need to have stable and credible policies is not just to maintain competitiveness, but also to ensure that substantial financing is available to the industry at large. Without the support of the investors, including the boards of multinationals and their banks, the EU steel sector will not have the capacity to invest in decarbonisation technologies or anything else. The problem is currently being made more acute in light of the lasting economic crisis and the bleak market outlook for steel in Europe.

In a more and more globalised economy and an ever-changing competitive environment, unilateral climate action by the EU can only further damage the competitive position of the EU steel industry.

In light of this, future climate policies should hinge on a set of key principles with a view to making the EU economy more competitive:

- implement economic climate-friendly opportunities where they are the cheapest;
- use climate change revenues to enable a smooth and gradual transition;
- help sectors exposed to the impact of climate policies to remain competitive in order to avoid a potential decline in investment and employment. The appropriate safeguards should be put in place;
- design the rules so as to allow growth (capped absolute emissions should not hamper growth).

Moving to a low carbon economy will require new energy infrastructure, energy efficient buildings and lighter transport systems. This will only be possible through the use of more innovative steel grades. Steel is also a globally traded commodity with generally low profit margins. The EU must provide an appropriate environment so that the investments needed to develop innovative steel applications and lean-carbon steelmaking technologies take place in the EU. A prerequisite for this is that the activity must remain profitable.

Steel is a strategic industry for the EU. Steel as a material is instrumental in the economic development of the EU. The EU steel sector managed over the past decades to remain competitive despite adverse conditions. Globally steel is a growing market and the EU steel sector should be enabled to seize the opportunities fast-growing economies are offering. Future climate and energy policies should therefore focus on competitiveness and growth and avoid distorting trade flows.

60 IEA, Key World Energy Statistics 2012.

The risk of carbon leakage comes on top of other factors threatening the competitiveness of the EU industry. The issue therefore has to be appraised from a broader perspective. The carbon leakage assessment as laid down in the EU ETS directive is a purely technical exercise, looking only at the EU ETS costs. The reality is as often more complex. The costs of the EU ETS are adding to other costs that may or may not be related to other EU or national energy and climate policies. Even if most of the focus is on CO_2 emissions stemming from steelmaking, unilateral climate and energy policies are prone to put the whole steel value chain under pressure, upwards and downwards.

The EU steel industry relies heavily on a competitive customer base – some of it in the renewable energy industry – but also on competitive SMEs to which many activities like transport, maintenance and IT are outsourced. Retaining the steel industry's competitiveness will benefit large parts of the economy.

To date free allocation has provided a decent level of protection against the risk of carbon leakage. Over time, free allocation will decrease as the CO_2 emissions cap is reduced. The level of protection given by free allocation might not be sufficient if at some point in time the technologies that could enable the steel industry to abate its emissions at a competitive cost are not there. Other measures will have to be devised.

SUPPORT FOR INNOVATIVE LOW CARBON STEELMAKING TECHNOLOGIES

The ULCOS programme identified four potential breakthrough technologies leading to abatement levels above 50%. Two of them have reached the pilot plant stage (ULCOS-BF and HIsarna). A pilot ULCORED plant might be started up in coming years, but there are no plans currently for ULCOWIN/ULCOLYSIS plants. Given the high level of uncertainty and risk, carbon pricing will not be able to put these technologies into motion. Instead targeted support policies are needed to go to the demonstration and then deployment phases.

The deployment of breakthrough technologies on a commercial scale will not only require huge investments but also a lot of time, particularly for a sector like steel with capital-intensive production processes that have been optimised over decades, if not centuries. In this respect, long-term climate policies should foster the conditions needed for all segments of the economy to have sufficient financing and time to adapt to the low carbon future. Policy must take into account the fact that, depending on their specific situation and the level of transformation required, some sectors may need more time to adjust than others.

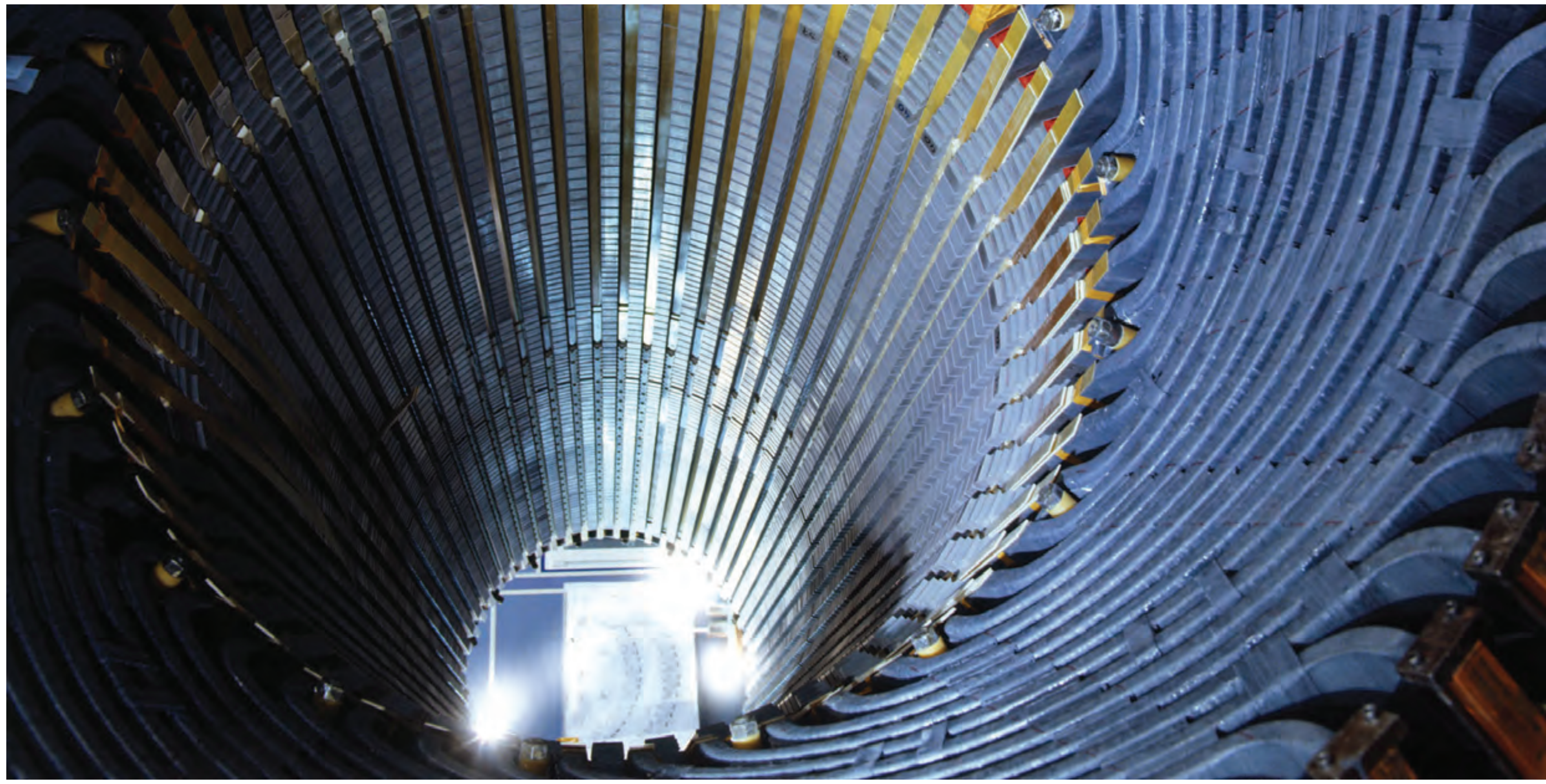
For instance, power generation can already rely on a wide range of processes and carbon-lean energy sources (nuclear, renewables), the cost of which is spread over a large part of society. But steelmaking will have to rely on technologies which are not yet proven and whose development the steel sector is not able to finance on its own.

Therefore bespoke policies to address investment risks and competition issues have to be put in place. Governments should commit public funds for demonstration-scale projects, especially in sectors like the steel industry.

The earmarking of EU ETS revenues to fund research and innovation in CO_2-lean technologies is an option that should be explored. These revenues, however, will become increasingly inadequate as the volume of allowances available for auction decreases over time. Furthermore the amount of revenues will depend on the allowance price, which may be too low (e.g. in periods of economic downturn) to provide the appropriate funding. Project funding through the NER300 suffers from the same problem and should be fixed. In parallel, research cooperation and public private partnerships (PPP) should be encouraged further.

To conclude, climate policies require the allocation of resources to research and innovation programmes which are commensurate with their ambitions and in a timely fashion. As potential breakthrough technologies involve huge investments and high financial risks, public funds are indispensable not only through the pilot and demonstration-scale phases but also to ensure the rapid roll-out of these technologies. Climate policies should therefore be aligned with EU and national budgets for research and innovation.

07 KEY-FINDINGS AND POLICY RECOMMENDATIONS



For the time being there are no economically feasible steelmaking technologies available that have the potential to meet the CO_2 reduction pathway envisaged in the Commission Roadmap for a Low Carbon Economy in 2050. Further work and research into carbon-lean technologies must be first carried out.

At best, the implementation of cost-effective CO_2 mitigation technologies could decrease the steel sector's CO_2 intensity by 15% in 2050 compared to 2010. Going beyond this level of reduction would require resorting to yet unproven technologies in combination with CCS, hence involving huge investment in infrastructure and higher operating costs. Such a scenario would lead to a reduction of absolute CO_2 emissions of ca. 60% in 2050 compared to 1990, still falling short of the EU's 80% aspirational objective. Should competing regions not be submitted to such constraints, the uptake of 'breakthrough' technologies by the EU steel industry will not be affordable.

In this context, the objectives proposed in the Commission Low Carbon Roadmap for the EU ETS of 43-48% by 2030 and 88-92% by 2050 compared to 2005 levels are not feasible for the steel industry unless legislators create the right framework conditions with supportive policies facilitating the emergence of breakthrough technologies while keeping the EU steel industry competitive on a global scale.

Nonetheless, the EU steel industry is committed to unlocking the far-reaching energy and CO_2 saving potential in Europe. The transition towards a competitive low carbon Europe requires the spread of new technologies and large investments in new infrastructure. Because of steel's contribution both to carbon-lean solutions and to the EU's economic wealth, a competitive low carbon Europe relies heavily on an economically healthy, modern, innovative and globally competitive European steel industry. A long-term European policy must clearly express this as a starting point and adopt it as a guiding principle for the development and implementation of the relevant measures and policy instruments.

In this context, the EU steel industry is committing to:

- deliver further measureable cost-efficient improvements in carbon and energy efficiency,
- implement incremental technologies (mainly process optimisation and retrofits),
- continue investing in R&D for mitigation of direct and indirect emissions from the sector,
- reinforce horizontal cooperation in best-practice sharing , energy efficiency, R&D, demonstration and pilot plant projects in relevant existing or new platforms,
- apply innovative technologies if economic viability is met,
- continue to work on the development of innovative steel grades for CO_2 mitigation and carbon-lean steel applications, together with our customers,
- actively participate in finding global solutions to mitigate CO_2 emissions in the steel sector. This includes development of international standards on CO_2 measurement and performance assessment, further refine the work initiated with this steel roadmap and find a real dialogue on this with policymakers and other stakeholders.

In order for the EU steel sector to be able to step up its efforts and in doing so overcome the associated challenging technical, economic and political barriers, a number of conditions must be met.

Firstly, ambitious climate objectives must be based on a commensurate industrial policy. This requires first and foremost sheltering the steel industry from distortive CO_2 costs and providing access to energy and raw materials at competitive prices so that steelmaking remains a profitable activity in Europe. Future EU climate and energy policies must be such that they foster growth and attract inward investments.

Second, supporting policies have to be put in place to facilitate the development and deployment of innovative technologies. The EU ETS on its own and as it is designed now is not able to bring breakthrough technologies into being in all sectors.

Thirdly, the extent to which CO_2 pricing and CO_2 targets are applied must be determined in accordance with a sector's ability to respond positively to such drivers. At the very least, this necessitates more differentiated treatment between the power sector and manufacturing sectors.

Against this background EUROFER suggests the following policy recommendations:

FUTURE POLICIES HAVE TO RETAIN THE COMPETITIVENESS OF THE STEEL INDUSTRY

1. Climate change is a global issue which requires a global response. In an ever more globalised economy, this can only be achieved through the enforcement of a comprehensive international agreement providing equal treatment for the production of globally traded goods with an effective monitoring and verification system. EU climate targets should be dependent upon comparable reduction efforts by other major economies.

2. Climate policies need to differentiate between sectors which can meet the overall target (e.g. the power sector) and those which cannot (steel). Emission reduction pathways for the steel industry should be built 'bottom-up' which means they need to be based on abatement levels which are technically and economically feasible, irrespective of the overall cap.

3. With a view to preserving the competitiveness of European industries exposed to international trade, best performers in sectors should incur no direct or indirect burdens resulting from climate policies. In the context of cap and trade, best performers need 100% of their allowances for free (no correction factor should apply) and their indirect CO_2 costs must be fully and consistently offset through an EU mechanism (based on realistic benchmarks) at least until international distortions to competition are removed.

4. Whilst globally competitive energy prices are a pre-condition for certain CO_2 abatement technologies, energy prices higher in Europe than in competing regions will not contribute to specific CO_2 reductions in the steel industry but to the industry's relocation to non-EU countries. EU energy policies must be aimed at securing globally competitive energy prices for industry. This means, among other things, deploying renewable energy in a truly cost-effective way and investigating the sustainable extraction of new forms of energy. To the same purpose, exemptions from energy taxes, network and renewables tariffs and levies have to be continued and made general.

ADEQUATE SUPPORT FOR NEW TECHNOLOGIES IS REQUIRED TO BRING ABOUT DRASTIC CO_2 EMISSION REDUCTIONS IN THE STEEL INDUSTRY

5. EU and Member States need to provide the fundamentals required for the implementation of the strategic technology path of the steel industry. This ranges from a high level of support for R&D, demonstration and deployment of new technologies, including infrastructure investments, installation, operation and access to Carbon Capture and Storage, as well as an adequate legal framework. This also includes public responsibility for the establishment of the pre-conditions for a successful implementation of new technologies.

6. To this end public funds should be provided consistent with the level of support needed. Financial support should cover all stages from research to deployment at industrial scale of the technologies and infrastructure. Funding could for instance come from the earmarking of the revenues from the EU ETS, in particular for mitigation at source and financing of related infrastructures.

7. In parallel, an appropriate set of incentives should be put in place to promote the sequestration of CO_2 into products.

8. The recovery of industrial waste energy (waste gases, heat and pressure) should be promoted through incentives similar to those available for renewable energy generation.

FUTURE POLICIES MUST RECOGNISE THE POSITIVE ROLE STEEL WILL PLAY

9. Climate policies should encourage and not hamper the production of steel as steel will play a key-role in the decarbonisation of the EU. If steel is not produced in Europe, many industrial supply chains are at risk of relocation.

10. The view should be broadened to an integrated approach so as to capitalise on the benefits of innovative steel grades and steel applications in CO_2 mitigation. This, for example, means an approach that evaluates a sector's emissions over several complete life cycles of its products and along the value adding chains it is part of. This not only entails increased use of design for recycling, recyclability and life cycle evaluations, but also the monitoring of market developments in iron and steel scrap in order to identify any adverse conditions in recycling markets, and analysing pressures on scrap flows to less emission-efficient regions.

A COHERENT AND PREDICTABLE POLICY FRAMEWORK

11. The efficiency of existing policies should be examined openly and transparently through realistic impact assessments, as should improvements or alternatives to the EU ETS to achieve cost-efficient emission reductions in the EU steel industry post 2020.

12. EU Climate policy should be designed in a way it has the potential to convince third countries to enter in a global climate agreement. This would require among others realistic benchmarks and no cap on allocation.

13. EU Energy and Climate Policies should constitute a coherent package. Overlapping policies should be avoided. The 2020 CO_2, renewables and energy efficiency targets overlap, causing confusion and hampering investment. There should be no binding targets for renewables and energy efficiency.

14. For the sake of predictability, EU institutions should refrain from constantly interfering in the agreed climate policy framework and targets. Once in place, these should remain unaffected.

LIST OF ABBREVIATIONS

BAT	Best available technology
BCG	The Boston Consulting Group
BF	Blast furnace
BF-BOF	Blast furnace-basic oxygen furnace
BF-TGR	Blast furnace with top gas recycling
BOF	Basic oxygen furnace
CAGR	Compound annual growth rate
CAPEX	Capital expenditure
CCS	Carbon capture and storage
CCU	Carbon capture and use
CDQ	Coke dry quenching
CO	Carbon monoxide
CO_2	Carbon dioxide
COG	Coke-oven gas
CS	Crude steel
DR	Direct reduction
DRI	Direct reduced iron
EAF	Electric arc furnace
EBF	Experimental Blast Furnace
EIA	US Energy Information Administration
EU ETS	European Union Emissions Trading Scheme
EU	European Union
EU15	Member states of the European Union (as of December 31, 2003)
EU27	Member states of the European Union (since January 1, 2007)
EUROFER	The European Steel Association
Fe	Ferrum, iron
GDP	Gross domestic product
GHG	Greenhouse gases
GJ	Gigajoule (one billion joule)
Gt	Gigatonne (one billion metric tonnes)
H_2	Hydrogen
HBI	Hot briquetted iron
HCI	Hot compacted iron
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
JRC	Joint Research Centre
kg	Kilogram
kWh	Kilowatt hour
LCA	Life Cycle Assessment
LULUCF	Land Use, land-use change and forestry
Mt	Megatonne (one million metric tonnes)
MWh	Megawatt hour
NG	Natural gas
O_2	Oxygen
OECD	Organisation for Economic Co-operation and Development
OHF	Open-hearth furnace
OPEX	Operational expenditure
PCI	Pulverised coal injection
PPP	Public Private Partnership
R&D	Research and Development
SR	Smelting reduction
SR-BOF	Smelting reduction-basic oxygen furnace
SRV	Smelting Reduction Vessel
TGR	Top gas recycling
TWh	Terawatt hour
TRT	Top gas recovery turbine
ULCOS	Ultra-Low CO_2 Steelmaking
UN	United Nations
VDEh	Steel Institute (Verein Deutscher Eisenhüttenleute)

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