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About Climate Strategies

Climate Strategies is an international organisation that convenes networks of leading academic experts around specific climate change policy challenges. From this it offers rigorous, independent research to governments and the full range of stakeholders, in Europe and beyond. We provide a bridge between research and international policy challenges. Our aim is to help government decision makers manage the complexities both of assessing the options, and of securing stakeholder and public consensus around them. Our reports and publications have a record of major impact with policy-makers and business.

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1. EXECUTIVE SUMMARY AND POLICY RECOMMENDATION

Analysis convened by Climate Strategies in 2007 showed that the impact of the European Emission Trading System (EU ETS) on industry dynamics and competitiveness differs across sectors.¹ This was the basis for the analysis of a variety of instruments aimed at protecting against carbon leakage.² With the economic crisis and increased focus of policy makers on unlocking investments, Climate Strategies conducted the research project “Carbon Pricing for Low Carbon Investment.”³

Now, after nine years experience with the EU ETS, Climate Strategies has engaged with the project “Carbon Control and Competitiveness Post 2020” in selected energy-intensive sectors. The first report on the cement sector was published in January 2014⁴ and is now followed by this report on the steel sector. It combines a literature review, data analyses, a legal review, in-depth interviews with selected senior managers in steel companies, extensive discussions with several CEOs, and workshops with representatives of governments, the European Commission, non-governmental organisations and industry.

The steel sector report reflects three main developments that have taken place in the area of climate policy and could influence the situation of the steel industry.

First, the preparation of the Copenhagen climate talks created expectations for globally coordinated policy action, including converging global carbon markets. Instead, policies and actions are primarily pursued by many national and regional initiatives. Thus, it has become necessary to develop instruments for leakage protection that not only can bridge a transition period, but that can also offer effective leakage protection and investment incentives should carbon prices continue to differ across regions.

Second, Kyoto emission reduction targets were formulated for the period 2008-2012 and thus focused the attention of industry and policy makers on marginal emission reductions that can be achieved in shorter time periods. Since then the emphasis in the political debate has shifted towards 2030 targets and a strategy for 2050 of moving towards a low-carbon economy. Work by Climate Strategies and others on targets in Europe needs to take into account the impacts of deep emission reductions on energy-intensive industries.

Third, the political discourse has widened from the climate protection objectives to the multiple benefits and political drivers for a low-carbon transformation. Our analysis in particular assesses the investment framework in the steel sector and

¹ Hourcade, J.-C., Neuhoﬀ, K., Demailly, D. and Sato, M., (2008) “Differentiation and dynamics of EU ETS industrial competitiveness impacts”, Climate Strategies Report.

² i.e. Droege, S., (2012) “International Industry Competitiveness, Carbon Leakage, and Approaches to Carbon Pricing”, Climate Strategies Report.

³ Neuhoﬀ, K., (2011) “Carbon Pricing for Low-Carbon Investment: Executive Summary - Final Report”, Climate Strategies Report.

⁴ Neuhoﬀ, K. et al (2014) “Carbon Control and Competitiveness Post 2020: The Cement Report”, Climate Strategies Report.

analyses the extent to which a well-designed policy framework could help to attract investment and ultimately enhance its competitiveness.

1.1. A portfolio of low-carbon opportunities for the steel sector

Climate science and macro-economic emission scenarios show that avoiding dangerous climate change requires significant emission reductions from all major emitting sectors, including not only the power but also the industry sector.⁵ Around 27% of industrial emissions in Europe originate from the steel sector, most of which are associated with primary steel production based on blast oxygen furnaces.⁶ Thus, without an effective strategy for emission reductions in sectors like steel and cement, it will be difficult and expensive to reach 2030 emission targets and impossible to achieve the deeper emission reductions thereafter.

There are a series of opportunities for manufacture and use of steel in Europe to modernize and to reduce the carbon footprint. All need to be addressed albeit over different timescales. Most well-known are the opportunities linked to (i) efficiency improvement and (ii) shifting from coal to gas as fuel type. As only 30% of emissions are linked to energy use with the remainder being process-related,⁷ additional opportunities exist that can address both fuel and process emissions, including (iii) breakthrough CCS technologies and (iv) innovative steels and efficient use of steel to deliver the same service at lower weight and carbon emissions. In addition, (v) increasing steel end of life recovery and reuse rates needs to be pursued because both energy and process-related emissions will be lower in secondary production. We discuss these mitigation options in Section II.

- (i) *Energy efficiency improvement* potentials of primary steel production with existing technologies are estimated to be in the order of 10-20% for the European installations, but are only pursued where investment costs are covered by energy cost savings within the following 2-4 years.⁸ Such short payback periods for cost saving measures are common requirements in industry and are further reduced when the industry is suffering from limited financial capacity, as is the case during a crisis. The same short payback periods are also applied to emission savings under the EU ETS. But additional factors, such as constraints in the capacity for coking coal or co-generation rules, often provide stronger drivers for efficiency improvement.

⁵ IPCC (2014) “Technical Summary, Working Group III: Mitigation of Climate Change”, p. 3, <http://report.mitigation2014.org/drafts/final-draft-postplenary/ipcc_wg3_ar5_final-draft_postplenary_technical-summary.pdf>, 25.06.2014.

⁶ IEA (2007) “Tracking Industrial Energy Efficiency and CO2 Emissions”, p. 44, <http://www.iea.org/publications/freepublications/publication/tracking_emissions.pdf>, 25 June 2014.

⁷ Gale, J., Freund, P. “Greenhouse gas abatement in energy intensive industries”, The Carbon Capture and Storage Information Source”, p. 5, <<http://ccs101.ca/assets/Documents/ghgt5.pdf>>, 25.06.2014.

⁸ Interview with industry stakeholder.

- (ii) *Fuel shifting* from coal to gas and electricity with the direct reduced iron process (DRI) combined with electric arc furnaces (EAF) reduces carbon emissions of primary steel production by 20-40%.⁹ However, the economics of DRI depend on the combination of coal, gas and carbon prices. The current combination in Europe of high gas prices with low coal and carbon prices makes DRI economically unattractive, raising the question of producing steel slabs or billets via the DRI/EAF process route in countries with access to cheap gas with only rolling to finished steel products undertaken in Europe. This would however reduce flexibility of higher value steel producers to respond to customer requests regarding the range and type of steel products. It would also create import dependency on slab instead of depending on iron ore and coke. Thus, investing in DRI facilities might not be a large scale mitigation option for Europe.
- (iii) *Break-through technologies with Carbon Capture and Sequestration (CCS)* are necessary to significantly reduce emissions of primary steel production. For reductions of 50% or more CCS technologies are necessary. Their potential has been explored as part of the European Ultra Low Carbon Steel Making (ULCOS) consortium, initiated in response to carbon constraints expected from the EU ETS. So far it resulted in three small-scale demonstration projects for different technology options funded jointly by public and private sector. Further progress has stalled since 2012 primarily because of (a) discontinuity of public funding, (b) formulation of risk allocation provisions requiring return of NER300 funding in case of technology failure, (c) the lack of a long-term business case in the absence of a robust EU ETS price, and (d) the lack of a leakage protection mechanism that would ensure incremental costs of large-scale use of CCS are born by the European consumers and not reduce the competitiveness of the European steel companies. The lack of public support for CCS in some Member States and of efforts to effectively engage a broader public to change the situation creates a further challenge.
- (iv) *Moving to higher value steel products and more efficient steel use* aim to deliver the functions of steel, like stability and strength, with less weight. This will reduce total emissions, as emissions from steel production are largely proportional to its weight. Such a shift from volume to value of steel will decrease the demand for primary steel production, but might provide higher margins and job opportunities in higher value products. So far developments differ significantly across the main applications of steel, as illustrated by the automotive and construction sectors. In the automotive sector, innovative high strength steel and forming techniques achieved

⁹ IEAGHG (2013) "Overview of the current state and development of CO2 capture technologies in the ironmaking process", p. 5, <http://ieaghg.org/docs/General_Docs/Reports/2013-TR3.pdf>, 25.06.2014

about 30-40% savings in body weight since 2005.¹⁰ In the building sector, no such progress has been made,¹¹ despite studies showing that efficient steel use in construction is possible by using tailored shapes, by supporting multiple loads with fewer structures, by aligning loads to avoid bending, and by avoiding over-specification of loads.¹²

- (v) *Increasing steel recycling rates* would lead to the substitution of primary steel with recycled steel, saving about 75% of emissions on every ton of scrap recycled.¹³ A maturing economy increasingly replaces rather than adds buildings and cars, and thus the volume of recovered scrap in Europe already equals 64% of European steel consumption.¹⁴ This rate will increase further, thus reducing the demand for primary steel production. While almost 100% of steel from the automotive sector and structural components in construction is recycled, improvement potential remains in reinforcement steel in construction, packaging and appliances. Action is required not only at the recovery stage, but also during the primary steel production and design stages in order to facilitate better separation and recovery of different materials later, thus enhancing the recyclability of the collected scrap.

Mature OECD economies collect larger volumes of scrap than emerging economies but retain large capacity for primary steel production. Hence about 20% of EU scrap is exported and replaces primary steel production in emerging economies. Thus using more scrap in Europe would in the short-run decrease carbon emissions in Europe and lead to an equivalent emission increase outside of Europe. Globally and over time, improving steel recovery and increasing recycling volumes is likely to form part of the solution to curb steel emissions whilst meeting growing steel demand, together with other strategies such as extending the life of products, diverting scrap to other uses before recycling and re-using metal components without melting them.

¹⁰ Zuidema, B.K. ArcelorMittal Presentation “On the Role of Body-in-White Weight Reduction in the Attainment of the 2012-2025 US EPA/NHTSA Fuel Economy Mandate”, Slide 5.

¹¹ Giesekam, J., Barrett, J., Taylor, P., Owen, A. (2014) “The greenhouse gas emissions and mitigation options for materials used in UK construction” *Energy and Buildings* 78 (2014) pp. 210.

¹² Allwood J. M. et al (2012), *Sustainable materials: with both eyes open*. Cambridge, UK: UIT Cambridge, p. 180.

¹³ Average CO₂ emissions in the EU: 1888 kgCO₂/tonne for the integrated steelmaking and 455 kgCO₂/tonne for secondary steel route. EUROFER (2013) “A Steel Roadmap for a Low Carbon Europe 2050”, pp. 32, 33.

¹⁴ Laplace Conseil (2012) “EAF and/or BOF. Which route is best for Europe”, p. 11, <<http://www.laplaceconseil.com/LaplaceConseil/htdocs/admin/upload//File/MarcelGenetPlatts1205.pdf>>, 13 September 2014.

1.2. Current economic challenges and policies for steel sector development

Between 2007 and 2012 the steel industry had to face a decrease in real consumption of steel products of almost 30%,¹⁵ and only some of the demand is expected to be recovered in the coming years. Also at global scale large surplus of steel production capacity exists. This results in low margins and losses that will persist until the supply-demand balance is recovered, most likely through closures. All of this is **not** linked to climate policy, but it limits re-investments and thus requires attention to not put at risk the longer-term viability of European installations. Financial challenges can furthermore distract the management from long-term strategies, thus requiring additional effort to engage the sector in the development of low-carbon roadmaps.

A set of necessary policy developments would allow industry to exploit different low-carbon opportunities at scale – as illustrated in Table 1.

Table 1: Policy framework necessary for different low-carbon opportunities in the steel sector.

| | Strengthening EU ETS | Reform of ETS leakage protection | Strengthening interactions between producers and consumers | Funding of technology innovation |
|---|----------------------|----------------------------------|--|----------------------------------|
| Unlocking efficiency potential | x | | | |
| Facilitating shift to lower carbon fuels | x | x | | |
| Advancing break-through technologies like CCS | x | x | | x |
| Higher value steel products and efficient use | x | x | x | x |
| Increasing recycling rates | | | x | |

1.2.1. Strengthening of EU ETS

The decline of the carbon price from at times 30 €/t almost to 5-10 €/t has significantly reduced the credibility of the EU ETS and virtually eliminated the incentives created through the scheme. This has been broadly recognized and is the motivation for the backloading of allowance sales in this current trading period and the EU proposal of a market stability reserve after 2020. Other Climate Strategies

¹⁵ Eurofer (2013) “2008-2012 European Steel in Figures”, p. 9, <<http://www.aceroplatea.es/docs/documento184.pdf>>, 25 June 2014.

projects are exploring the policy options in detail¹⁶ but from the perspective of the steel sector a few principles are of particular importance:

- **Long-term perspective:** Capital-intensive investments in the steel sector require long decision and investment periods, and need to ensure viable returns over more than a decade. Hence, early clarity on longer term perspectives, especially for the development of new, low carbon technologies, is essential.
- **Carbon price:** Long-term carbon constraints will only obtain credibility and impact corporate choices if they view today's carbon prices as consistent with the long-term vision. Similarly, today's efficiency investments are not informed by expectations about long-term price developments but are based on current carbon prices.
- **Flexibility:** Technology opportunities are uncertain and hence it is impossible for the industry to commit to and for the governments to prescribe, a meaningful emission trajectory for the steel sector. This points to the value that the coverage of emissions across many sectors offers – it provides a credible commitment to an overall trajectory, while offering the flexibility to respond to technology developments at sector level.

1.2.2. Structural reform of leakage protection mechanisms under the EU ETS to enable low-carbon investment

When the EU ETS was developed, the Kyoto Protocol gave confidence that similar approaches would be followed globally. For the transition period until convergence to a global carbon price, free allocation of allowances was designed to provide protection from carbon leakage. Instead of a global carbon price, national and regional policies combining regulation, investment funding and regional specific pricing are emerging. This requires a longer-term perspective on leakage protection mechanisms. This longer-term perspective must combine effective leakage protection with an economic framework for all mitigation options. We review five options for post 2020:

- *Continuation of benchmark-based allocation using historic production volumes.* Different benchmarks are defined for primary steel production and for recycling of steel with electric arc furnaces.
- *Benchmark-based allocation using recent production volumes* instead of historic production volumes (also discussed as output-based allocation or Dutch Ecofys proposal).
- *Consumption tax per ton of steel consumed* in Europe. To reflect externality costs of production of energy-intensive commodities in consumption choices, a tax would

¹⁶ i.e. Michael Mehling (2013), "Policy Options to Address Competitiveness Concerns: Lessons from the EU ETS and Other Trading Systems", Michael Grubb (2012), "Strengthening the EU ETS".

be applied to consumption of steel and other energy-intensive commodities, irrespective of production process or location.

- *Combination of output-based allocation with an inclusion of consumption into the EU ETS.* All steel produced or imported in raw form or as part of products is recorded and the transfer traced via a simple digital tracking system. A charge based on steel weight and benchmark emission rate is then levied on the final product, when steel is moved to the final consumption sphere. No charge applies for exported steel or steel containing products. Similar tracking systems for taxation purposes are already used in the EU for other products such as alcohol and tobacco. The money raised could be managed by a trust fund to support climate action. ,
- *Inclusion of imports in the EU ETS:* Imports of steel commodities would have to obtain EU ETS allowances to set them on a par with domestic production, most likely on the basis of a best available technology benchmark, and exporters would be reimbursed the cost of allowances. Thus emitters could pass carbon costs to product prices without leakage risk and free allocation could be phased down, as with the power sector.

Table 2: How leakage protection mechanisms impact investments in low-carbon opportunities (excluding effect of use of revenue from allowance auction or tax).

| | Current | Output based (OB) | Consumption tax | OB & inclusion of consumption | Inclusion of imports |
|---|---------|-------------------|-----------------|-------------------------------|----------------------|
| Incentives for efficiency | + | ++ | | ++ | +++ |
| Framework for fuel switching | + | + | | ++ | ++ |
| Business case for break-through process | + | + | | +++ | +++ |
| Moving to higher value steel and efficient use | + | | +++ | +++ | +++ |
| Additional recycling incentives | | | | | +++ |
| Credible long-term leakage protection | + | ++ | ++ | +++ | +++ |
| Political challenge | | | -- | | -- |
| Administrative effort | - | -- | -- | --- | --- |

Moving from the current mechanism in which allocation is based on historic production volumes to one in which the allocation is based on more recent output measurements would help to avoid large surplus allocations and resulting distortions between companies. Linking the free allocation to each unit of production rather than to the continuation of production at an installation level also improves protection against operational leakage and potential distortions related to new entrant and closure rules. However, for investors uncertainties remain about future leakage protection, because of the potential conflict between allocation at full benchmark level corresponding to cover all emissions and the reduced availability of allowances under a shrinking cap.

A major challenge of the free allowance allocation approach is that it fails to create a business case for higher value steels and their efficient use. It also risks undermining investment incentives for break-through technologies like CCS. The price of steel does not reflect carbon costs and does not therefore deliver incentives to shift to higher value (and thus lower weight) steels. Break through steel production processes would need to sell surplus allowances to other sectors to cover incremental costs. This would require that consumers of potentially competing products from other sectors would bear cost of mitigation efforts in the steel sector. This could create significant political opposition, reduce the regulatory credibility of the system, and does thus not constitute a credible investment framework.

A replacement of the EU ETS with a consumption tax on steel would create incentives for use higher value steel products. However a similar measure has to be applied also to competing commodities like cement, aluminium or copper in order to avoid product choice distortions. The consumption tax would, on its own, not encourage upstream emission reductions, e.g. efficiency improvements, but also not create any leakage risk. One significant challenge for the implementation would be the number of product categories that needs to be covered. Furthermore a consumption tax on steel is politically challenging, as taxation at European level requires unanimous support in the European Council.

The combination of output-based allocation with an inclusion of consumption of steel (and competing commodities) in the EU ETS creates incentives for emission reductions both upstream (efficiency) and downstream (higher value steel). It is also part of a credible business case for breakthrough technologies like CCS. Inclusion of consumption of steel in the EU ETS ensures that steel consumers pay for the carbon cost of steel. Thus distortions, that would result from only a free allocation approach, are avoided.

Inclusion of imports and exports of steel in the EU ETS (or border levelling) creates incentives and fair cost allocation for all mitigation options. As it would also be applied to scrap, it would lead to higher scrap prices in the EU and could, thus, also provide incentives to increase recycling rates.

While it could arguably be implemented without disadvantaging foreign producers and without violating WTO requirements, developing countries – drawing in part on historical experience – remain concerned at the potential for apparently objective and WTO-compatible measures to be distorted into protectionist measures. Thus, trust building measures and at least informal international cooperation would have to complement the approach.

Administrative requirements would increase with any shift from the current mechanism, both because allocation decisions of allowances are more frequent and because steel containing products would need to be traced. However, there is a trade-off between the additional administrative work required and the strength of the new incentives that would be created for innovation and decarbonisation. The key question is therefore whether this trade off is reasonable after weighing up the costs (administration) and benefits (incentives). Experience with measures that place

charges on the consumption of products in other sectors such as tobacco and alcohol suggest that such approaches are not unduly administratively burdensome for participants once they are in place. Nevertheless, for consumption taxes, inclusion of consumption and inclusion of imports, a *de-minimis* threshold would be defined such that only products where steel is a significant share of the value are covered. The benefit of the mechanism that delivers a full carbon price across the value chain is the reduction of administrative complexity linked to the large distributional implications that have dominated the political process of determining benchmarks and cross-sectoral adjustment factors for free allowance allocation under EU ETS:

Furthermore, these consumption approaches can provide co-benefits in the form of additional information and attention by decision makers on carbon embodied in products.

In summary, our analysis highlights the need for a fundamental rethinking of anti-leakage measures for the steel sector as part of the structural reform of the EU ETS post-2020. They need to provide lasting leakage protection and ensure that sectors with high carbon costs can pass these on to downstream consumers. Two policy options address these requirements: border-levelling with full auctioning, and inclusion of consumption in the EU ETS combined with output-based free allocation. These options should therefore be explored in detail for the very carbon intensive sectors for implementation in 2020. To contribute to this process, the report provides legal analysis and review of experiences with the implementation of consumption charges in other sectors.

1.2.3. Strengthening interactions between producers and consumers

Materials play a key role in a low-carbon transformation. Hence progress on the design and use of materials creates large scale opportunities for the steel sector to serve new markets of innovative and therefore higher value products. To unlock these opportunities it is essential that the links between producers and consumers are strengthened.

Consistent product labeling reflecting the full life-cycle emissions of steel and other materials in final products enhances awareness, creates lead markets to serve environmentally conscious business and households and provides information for business strategy and policy design. Shared development platforms can also facilitate progress on material and product design, as successfully demonstrated in the automotive sector.

Regulatory adjustments are also necessary to give consumers the flexibility to use new steel types or designs for example in construction. In addition, where consumer attention to choice is limited, well designed regulation can catalyze a more efficient use of steel for example through requirements tailored design and quality control. In the automotive industry, fuel efficiency standards incentivized the development of

higher value steels that reduced cars' weight by 30-40%.¹⁷ Similar regulations could also be explored in other sectors but need to build on a better understanding of sector-specific opportunities.

A low-carbon transformation comprises shifts in technology, materials and infrastructure. Adequate policy design can help to coordinate the developments, for example with targets for early stage technology development such as deployment of electric cars, to guide the investments along the supply chain.

Finally, with increasing rates of recycled steel in a maturing economy, recycled steel will also have to be used for high value applications. Therefore today's materials and product design needs to facilitate separation and sorting at end-of-life to secure the future needs and thus improve the lifecycle performance of steel.

1.2.4. Financial support for innovation

Innovation in product and process innovation has very different features with respect to scale of investment required and time-frame over which new technologies are commercially applicable. For successful product innovation the close link to consumers is essential. Where timeframes from development to market are short and there is clear product differentiation for the consumer, this can allow for largely private sector funded innovation. However, where markets are fragmented, timescales longer, risks bigger, and technology spillovers can be high, there is a strong case for public funding to complement private investments.

Innovation in low-carbon steel processes is unlikely to be consumer led, especially where the innovation will not impact the properties of the resulting steel. In addition, timeframes and investment volumes for demonstration are large – pointing to a central role for public policy to guide and support the innovation process. At the demonstration stage there is a need for a sustained public funding of process innovation to transform ideas to industrial reality. Technology progress should become the key criteria to determine continuation of funding.

Once one of the break-through technology options reaches commercial scale, investment in initial plants will still involve significant risks linked to the larger scale and the central role of the furnace for an integrated steelmaking plant. Thus risk sharing arrangements are necessary. They should involve the public both on the risks and benefits (e.g. innovation credits). Ultimately the business case for low-carbon process technologies depends on the viability of their large scale utilization. This requires that the structural reform of the EU ETS ensures sufficient stringency and sustainable leakage protection including cost allocation.

¹⁷ Zuidema, B.K.

1.2.5.A vision for industry

The European steel industry has to be highly energy efficient and innovative to have a future. It will, therefore, be important for the sector to develop a positive perspective so as to attract investment and remain among the technology leaders. The low-carbon transformation of the economy offers such a positive perspective for the sector, providing the policy framework is right. Materials are at the core of the low-carbon transition – and progress requires a dynamic industry that attracts young talents to realize the vision of less materials and more value added. Thus it can not only contribute to environmental but also to economical sustainability of the sector. Preparing a low-carbon roadmap could become a starting point for an industry vision.

With all the opportunities, there are serious challenges and risks. It will therefore require both effective policy and forward looking and innovative companies to translate any such roadmap into tangible investment and innovation. The view derived from classical economics had laid emphasis upon markets as the best way of generating efficiencies, and pricing as the most efficient policy tool for dealing with an externality. This ‘Second Domain’ economics had dominated European climate policymaking.¹⁸ However, the problems of the EU steel industry, and of climate change, are both structural and long term. At the consumer end, they involve questions of consumer choice in materials and resource efficiency – “First Domain” economics, in which many subtle factors introduce structural inefficiencies and blunt the impact of price alone. And innovation and structural change involve centrally the economics of transformation – the “Third Domain” of economics, in which industry structure and the capacity for strategic investment are crucial. The capital intensity of steel production and the relatively homogenous nature of products impede the ability of the industry on its own to advance new production processes. There is thus an unavoidable role for strategic investment led by public sector if the industry is to adapt to the demands of the future.

European climate policy embedded in the broader policy framework can thus provide a focal point for the modernization of the European steel sector. Europe covers a territory large enough to host and finance demonstration projects. Climate policy has a well-defined objective to provide clear guidance and visibility and it is based at its core on a shared climate policy objective that facilitates cooperation across EU member states and beyond.

¹⁸ Grubb, M., Hourcade, J., Neuhoff, K. (2014) *Planetary Economic. Energy, Climate Change and the Three Domains of Sustainable Development*, Routledge Chapman & Hall.

2. The current situation of the European steel sector

Before the economic crisis of 2008/2008 European Union produced annually over 200 million tons of steel.¹⁹ Steel is a vital material for a modern economy and is used in virtually every sector including automotive, rail, shipping, power generation and transmission, domestic appliances, civil engineering and building.

Steel is produced from virgin iron ore by smelting in a blast furnace to produce molten iron and then converted into steels in a basic oxygen furnace. It is a capital intensive high tech industry but produces in the EU on average almost 1.9 tonnes of CO₂ for every tonne of finished steel (BF/BOF).²⁰ Steel can also be produced by recycling end of life steel containing products in an electric arc furnace (EAF). The main emissions from this process route depend on the carbon intensity of the electricity power plant, but is typically 75% below that of the primary steel.²¹ There are hundreds of different steel types (alloys of iron), but with limited variations in carbon intensity. The carbon intensity, per tonne of steel, is dominated by the carbon emissions linked to the steel production.

Steel is produced in nearly all EU countries with the most important concentration on BF/BOF in Germany, France, Poland, The Netherlands, and the UK. Steel recycling from scrap in EAF is predominant in Spain and Italy which import scrap from Northern Europe.

The period of most rapid progress in reducing CO₂ emissions per tonne was in the 1980s and 1990s in Western Europe and after collapse of Communism in Eastern Europe.

Today steel demand is still 20% below the level of 2007.²² The period after the 2008 financial crisis was very difficult for most European steel producers. Many companies have now returned to a low level of profitability but the poor prospects for a return to former production volumes mean long-term investments in steel production are on hold.

¹⁹ World Steel Association (2010) "Steel Statistical Yearbook 2010", p. 3, <<http://www.worldsteel.org/dms/internetDocumentList/statistics-archive/yearbook-archive/Steel-statistical-yearbook-2010/document/Steel%20statistical%20yearbook%202010.pdf>>

²⁰ Eurofer (2013) "A Steel Roadmap for a Low Carbon Europe 2050", p. 32.

²¹ Ibid., p. 33.

²² Eurofer (2013) "2008-2012 European Steel in Figures", p. 9.

3. Experience with low-carbon opportunities for steel sector

3.1. Improving energy efficiency

3.1.1. Assessing potentials for improving energy efficiency

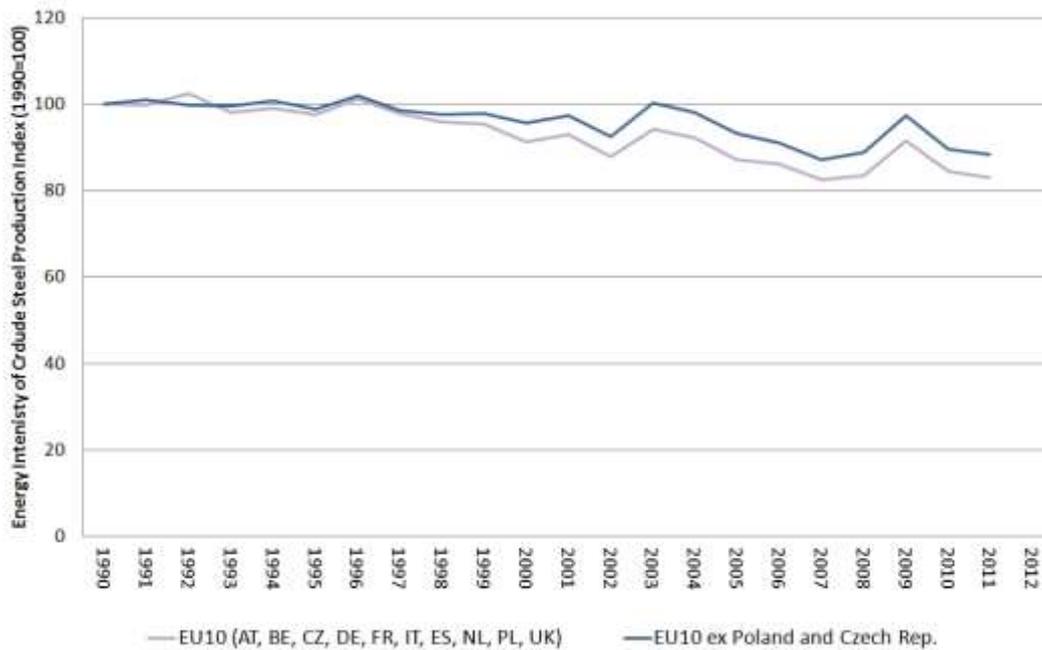
In a world of rising energy costs, and where the majority of greenfield investments in new steel production and the application of best available technologies will occur in developing countries, policies that support investments in Europe to maintain and lead world class energy and carbon efficiency can be in the long-term strategic interest of the industry. Otherwise, European steel risks falling into a situation of structurally higher energy prices, lower demand growth, as well as lower energy and material efficiency and higher CO₂ emissions. Energy efficiency is, therefore, not only strategically relevant for the sector but is also a lever for reducing CO₂ emissions.

Significant efficiency gains have been made in the EU steel sector in recent decades (Figure 1). These gains reflect a number of factors, including closure of inefficient capacity in new EU Member States, improvements in utilization rates of plants and equipment, as well as marginal increases in the use of continuous casting, which was already above 90% in most EU countries by 1990.²³ The aggregate picture is underpinned by significant variations across countries. For instance, Arens et al found that in Germany between 1991 and 2007, specific energy consumption of crude steel production improved by only 0.1% per year on average after controlling for the effects of shifts from BF-BOF to EAF on the data.²⁴

²³ Nippon Steel (1994) "Special Issue of Steelmaking". Issue 61, <<http://www.nssmc.com/en/tech/report/nsc/no61.html>> 14.09.2014.

²⁴ Arens, M., Worrell, E., Schleich, J. (2012) „Energy intensity development of the German iron and steel industry between 1991 and 2007“, *Energy* 45, pp. 786-797.

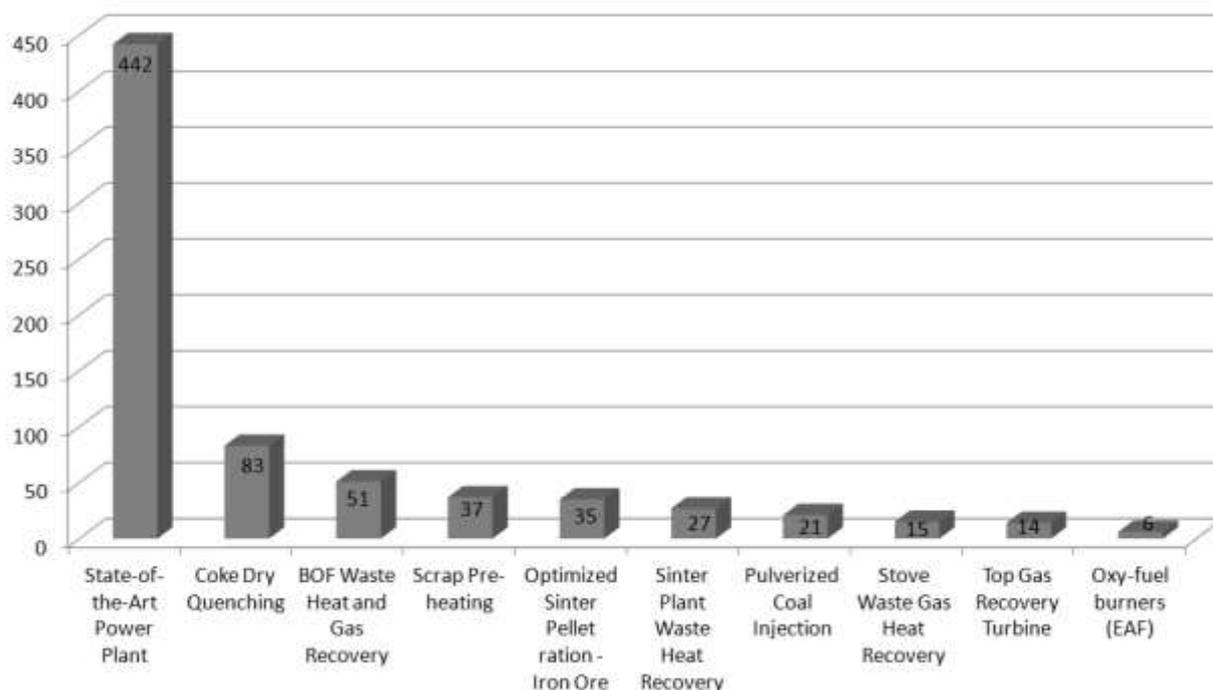
Figure 1: Energy intensity of European steel production from 1990-2012.



Source: Odyssee-mure database. Energy intensity adjusted for share of BF/BOF and respective EAF process.

In terms of physical or “hard” technologies, some of the most promising options include reducing waste gas emissions related to power generation, wider use of pulverised coal injection (PCI), greater use of EAF (a CO₂-only related measure), sinter plant waste gas recovery, as well as updating computerization and control systems for hot and cold rolling mills in order to improve material efficiency. Figure 2 below shows estimates by the European Commission’s Joint Research Council in terms of kg of CO₂ reduced per tonne of steel for several of these alternatives. Note that many of these investments do not necessarily require greenfield investment in brand new steel-making sites, since significant scope exists for “shoe-horning” best available technology into existing plants.

Figure 2: Estimated CO2 emissions reduction potential in kg/t Steel.



Source: Own compilation, based on data from Joint Research Council of the European Commission.

Views within the industry differ somewhat on the potential for the sector to deliver additional CO2 emissions reductions from these technologies. Some sources suggest that the maximum potential lies in the order of 15% below current levels.²⁵ Meanwhile, Ecofys – which did an analysis for the purposes of establishing CO2 efficiency benchmarks for Phase 3 of the EU ETS – found that the difference between theoretical technical potentials for the aggregated emissions from coke making, sintering and hot metal production and European industry averages reported to it by Eurofer for 2009 were in the order of 30-35%.²⁶ In this latter case, part of the gap appears to reflect different carbon accounting practices as well as the effect of overcapacity on plant efficiency in the year of measurement, 2009. For the case of Germany, Breun, Fröhling and Schultmann find that the best performing steel plants already use the minimum amount of coal and coke as specified in the BAT reference document, while the less-performing plants deviate by 4-8% from these levels.²⁷ With regard to CO2 emissions, deviations between the best- and least-performing plants are larger: the deviation amount to 29% for cokeries and to 35% for blast furnaces. These deviations can, for example, be explained by the use of different cogeneration gases as well as

²⁵ I.e. IEA (2013); Eurofer (2013) „A Steel Roadmap for a Low Carbon Europe 2050”, p.10.

²⁶ Ecofys, Fraunhofer, Oeko Institut (2009) “Methodology for the free allocation of emission allowances in the EU ETS post 2012. Sector report for the iron and steel industry”, <http://ec.europa.eu/clima/policies/ets/cap/allocation/docs/bm_study-iron_and_steel_en.pdf> 10.08.2014.

²⁷ Breun, Fröhling and Schultmann (2013) “Ein nichtlineares Optimierungsmodell zur Bestimmung der Stoffflüsse in der deutschen Eisen- und Stahlindustrie”, Tagungsband zum Workshop der GOR-Arbeitsgruppe OR im Umweltschutz, pp.1-16.

direct injection of reducing agents. More generally, differences in estimates may be explained by differences in the set of technologies and places in the value chain that specific sources refer to (more on this below). Nevertheless, it is clear that significant potential exists to reduce emissions and energy use at the steel plant.

Another major potential abatement lever comes from reducing emissions and improving efficiency in the power supply to plants. However, since these emissions often fall outside the immediate scope and control of many steel plants, they may not always be counted in industry emissions or abatement estimates, or be identified by steel makers as potential cost reduction options. Nevertheless, quantitatively speaking, reducing emissions from power production represents the biggest individual lever for reducing sectoral emissions and energy consumption: According to a study by Joint Research Centre, utilization of waste gases in state-of-the-art power plant would reduce CO₂ emissions by 442 kg/tSteel.²⁸

3.1.2. Drivers and barriers to improving energy efficiency

As an energy intensive industry, incentives to manage rising energy prices and control energy costs have historically been a driver for the steel industry to continuously improve its energy efficiency. However, much of the low-hanging fruits in terms of energy efficiency improvements, such as wider use of continuously casting, was exhausted in the 1970s and 1980s. Moreover, as new greenfield investments in the EU are currently uneconomical due to overcapacity, and many retrofitting possibilities for reducing energy use are mutually exclusive, the process of making improvements to energy efficiency in the steel sector has become more incremental. A consequence of this incrementalism is that the cost savings related to many of the available efficiency potentials, although positive, are relatively small. For example, in Europe, energy costs related to steel making often account for around 20-30% of variable steel-making costs.²⁹ Pursuing measures that deliver, i.e. 5% improvement in energy efficiency reduce total costs by 1-1.5% before discounting. Interviews with steel company executives revealed that such measures, which can nevertheless involve significant periods of plant shutdown and mobilization of capital, can often have payback periods that struggle to compete with other company priorities in particular the development of new or securing of existing markets.

A key barrier to improving energy and CO₂ efficiency in existing steel plants is therefore the need to develop more attractive payback periods for energy efficiency investments. Energy efficiency options must compete with alternative uses of funds – such as paying down debt, R&D, etc – and thus, projects with payback periods longer than about 2-4 years are often deemed insufficiently attractive to undertake, despite

²⁸ Pardo, N., Moja J. A., (2013), “Prospective Scenarios on energy efficiency and CO₂ emissions in the EU Iron & Steel industry”, *Energy* 54, p. 116.

²⁹ World Steel Association (2008), “Fact Sheet Energy”, p. 20.
<https://www.worldsteel.org/dms/internetDocumentList/fact-sheets/Fact-sheet_Energy/document/Fact%20sheet_Energy.pdf> 13.09.2014.

being economically rational in an absolute sense. This phenomenon is aggravated in a context of weak revenue and sector profitability. Moreover, realized gains from some energy and CO₂ efficiency measures are inherently uncertain prior to being undertaken, such as efforts to deal with low temperature waste heat flows.³⁰ In these cases, decisions to halt production and spend scarce financial resources to pursue uncertain gains may be perceived as too risky relative to the low expected reward in cost reduction.

One way of improving these payback periods could be to increase energy prices via carbon pricing. For instance, if one assumes that BOF steel making using an average of 0.4 t coking coal/t crude steel³¹, and that coking coal prices are around 100€/t, and that each tonne of coking coal contains approximately 2 tCO₂, then at carbon prices of 50€/tCO₂, coking coal costs for steel plants would double. This of course requires that carbon leakage protection measures in the EU ETS are sufficiently robust to ensure that carbon leakage would not occur.

Another possibility for improving the payback periods of energy efficiency investments is via regulation, either in “hard” or “soft” forms. Several historical examples of the effectiveness of direct (“hard”) regulation leading to efficiency improvements exist in the steel sector. For example, in the United States, energy efficiency improvements were mainly driven by requirements by the Environmental Protection Agency (US EPA) that firms meet certain environmental standards with respect to local pollutants in order to obtain operating permits. Faced with the choice between investing to improve energy efficiency in order to meet the standards or being forced to shutdown, most firms decided to invest in measures that payback calculations alone had not incentivized.³² Similarly, in 1995 as result of an agreement with government a Luxembourg steel company Arbud closed its BOF plant and replaced it by an EAF plant.³³ [2]. This example also highlights an important caveat to direct regulation as a tool for driving efficiency improvements: to be successful, there must already be an economic case – i.e. a viable economic model - for firms to shift to the new technology. Assuming that this is the case, however, past sectoral experience suggests that regulation can be an enabling device that speeds up and overcomes weak economic signals and a lack of prioritization within companies to improve efficiency and environmental performance. Use of permitting requirements for re-investment decisions to drive the highest potential technologies listed above (such as coke dry quenching) may therefore be an option that could be exploited by the EU.

An alternative involves softer regulatory approaches, which fall between purely economic incentives and binding regulatory obligations. One example is the use of emissions performance benchmarks in order to determine free allocation of emissions

³⁰ Eurofer (2013) “A Steel Roadmap for a Low Carbon Europe 2050”.

³¹ Luengen, H.B., Peter, M., Schmöle, P. (2011) “Ironmaking in Western Europe“ *Stahlindustrie VDEh*, Figure 5 <<http://metallics.org.uk/wp-content/uploads/2013/10/Ironmaking-in-Western-Europe-VDEh-May-2011.pdf>> 25.06.2014.

³² Interview with industry stakeholder.

³³ Internet Archive (n.d.) An Economic and Social History of Luxembourg <<http://web.archive.org/web/20071114213256/http://www.portrait.public.lu/en/introduction/index.html>> 25.06.2014.

allowances in the EU ETS. The benchmarking system was established with an implicit understanding that it would allow for installations to receive 100% of their free allowances on the condition that they attained the level of the best available technology. However, benchmarking also offers the potential to be more than anti-leakage measure because it provides a clear focal point for management to aim for in terms of target efficiency levels.

In practice, however, interviews with steel company executives suggest that the desired outcome of benchmarking as a focal point for industry action has been undermined by the strong political opposition that the new rules have generated within the industry. Indeed, the industry has expended significant energy and resources to challenge the legality of its benchmark, which it claims is below technically achievable levels due to the only partial inclusion of waste gases in the benchmark value. Moreover, the sector objects in principle to the application of a cross sectoral adjustment factor to its free allocations, which, in effect, renders the benchmarks below the level of BAT by 5.7% in 2013; a gap that will increase to 17.5% in 2020 before starting to narrow again. The industry's economic self-interest in preserving 100% free allocation is, of course, a factor in this opposition. However, interviews with steel executives also suggested that the level of frustration and resistance to the rules may also be distracting from their desired intent, which was to focus management attention on achieving viable efficiency levels.

It was noted earlier that process improvement and achieving best practice process within steel plants also hold potential to reduce energy use and CO2 emissions. The main barrier for many of these process improvements is that they imply or would be most effective under conditions where steel plants change their business models. Especially for long products this would require that steel companies seek out and build closer relations to their customers than they currently have.³⁴ What would be the incentive for steel companies to do this? Interestingly, this strategy would tend to be consistent with the view – expressed elsewhere in this report and increasingly in the sector –that specialized and tailor-made products that require less material and weight to deliver the same service are central for the future of European steel.³⁵ This would suggest that opportunities exist for exploiting synergies between improving energy and material efficiency at steel plants and the sectors broader competitive strategy going forward. Policy may be able to reinforce these synergies by promoting the development of downstream sectors that require higher value-added steel applications and that are also important for European decarbonisation as a whole. Light weight and electric vehicles is one obvious example.

Another barrier to improving energy efficiency within steel plants is the present overcapacity and low utilization rates. Running plants well below their intended capacity creates inefficiencies. However, steel makers are unable to directly affect the

³⁴ Interview with industry stakeholder.

³⁵ SteelConsult International (2013) "Realities of survival for European steel: Is there a future for Steel in Europe?", pp. 34-35.

demand side of the market, while political pressure is generally strong to keep unprofitable plants open which inhibits rationalisation of production.

3.1.3. Conclusions

In a world of rising energy costs, and where the majority of greenfield investments in new steel production and applying best available technology will occur in developing countries, it is in European steel's long-term strategic interest to accept policies that force it to achieve world class energy and carbon efficiency.

The lack of profitable new investment opportunities has forced the industry to focus on cost cutting and cost efficiencies. There appears to be significant scope for further improvement by the European industry but there are barriers to their full exploitation. For example, since payback periods for efficiency investments need to be short in order to gain priority with company management, there remains a role for ambitious emissions performance benchmarks as currently devised in the anti-leakage measures of the EU ETS. Stronger carbon pricing can also help to ensure that these measures are financial priorities. Stronger carbon pricing need not be inconsistent with industry profitability and competitiveness if the industry were compensated at the level of the benchmarks, or indeed if it aided rationalization of inefficient assets in the sector. A concerted approach – via which the industry accepts supporting a robust carbon market in tandem with robust leakage protection measures – is therefore necessary if the industry is to become serious about achieving world best available technology standards of energy and carbon efficiency.

At the same time, a range of evidence suggests that the potential to cut CO₂ emissions by improving energy efficiency – while still significant – is nevertheless relatively limited in terms of the larger climate objectives that are required of European industry. Moreover, incremental improvements will only cut emissions step by step, so it will take time to cut emissions substantially. Both these points ultimately make the case for more radical process innovation in the steel industry.³⁶ The European steel industry has taken the lead in developing new breakthrough technologies to cut CO₂ emissions. However, as explained below, innovation and supporting policy frameworks, such as carbon pricing and anti-leakage measures, will need to be substantially reinforced in the post-2020 climate and energy package in order to deliver on the early promise of these technologies.

³⁶ ThyssenKrupp “Annual Report 2008-2009” p. 38.

3.2. Fuel shifting from coal to gas and electricity

Iron ore is smelted in a blast furnace using coke as the main reducing agent. The resultant molten iron is converted into molten steel by blowing off the excess carbon with oxygen in a basic oxygen furnace (BOS). The direct and indirect CO₂ emissions associated with the production of a typical steel product by the BF/BOS process is almost 1.9 tonnes CO₂ per tonne of finished steel.³⁷ Over 90% of these emissions occur at the ironmaking and steelmaking stage rather than during subsequent rolling and finishing. The single most important process is the chemical reduction of iron oxide ore to iron metal.

An alternative established process for production of primary steel is the Direct Reduction furnace (**DRI**) using natural gas as the reducing agent. The pellets and briquettes produced in such a DRI furnace needs to be feed into an Electric Arc Furnace (EAF) to produce steel. The combination of DRI/EAF reduces emissions by 20-30 % compared to BF/BOS process route.³⁸

The EAF do – on their own – not allow for primary steel production, but make recycling of scrap possible. The EAF process is therefore particularly prominent in economies with mature infrastructure and transport systems with high scrap volumes and constitutes 62% of US and 42%³⁹ of European production. Many emerging economies use EAFs because of their smaller scale and lower capital costs for example Turkey and Singapore.

Carbon Capture and Sequestration from steel production is typically considered as complement to further refined or integrated BF/BOF processes. The prospect of its implementation is widely discussed. The European Commission considers CCS as a crucial ways of CO₂ abatement,⁴⁰ possibly the only option available to reduce direct emissions from industrial processes.⁴¹ Slightly less enthusiastic in this regard was the High Level Round Table, according to which the future of CCS depends on its deployment costs and public acceptance.⁴² In contrast, the European Parliament does

³⁷ Eurofer (2013) “A Steel Roadmap for a Low Carbon Europe 2050”, p. 32.

³⁸ Laplace Conseil (2012) “EAF and/or BOF. Which route is best for Europe?”, p.9. <<http://www.laplaceconseil.com/LaplaceConseil/htdocs/admin/upload//File/MarcelGenetPlatts1205.pdf>>, 13.09.2014.

³⁹ World Steel Association (2013) “Steel Statistical Yearbook 2013”, p. 2, <<http://www.worldsteel.org/dms/internetDocumentList/statistics-archive/yearbook-archive/Steel-Statistical-Yearbook-2013/document/Steel-Statistical-Yearbook-2012.pdf>> 14.09.2014.

⁴⁰ European Commission (2013) “Action Plan for a competitive and sustainable steel industry in Europe”, <http://ec.europa.eu/enterprise/sectors/metals-minerals/files/steel-action-plan_en.pdf>, 14.09.2014.

⁴¹ European Commission (2014) “Commission Staff Working Document. Impact Assessment accompanying the document Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions A policy framework for climate and energy in the period from 2020 up to 2030”.

⁴² European Commission (2013) “High-level Round Table on the future of the European Steel Industry. Recommendations”, <http://ec.europa.eu/enterprise/sectors/metals-minerals/files/high-level-roundtable-recommendations_en.pdf> 14.09.2014.

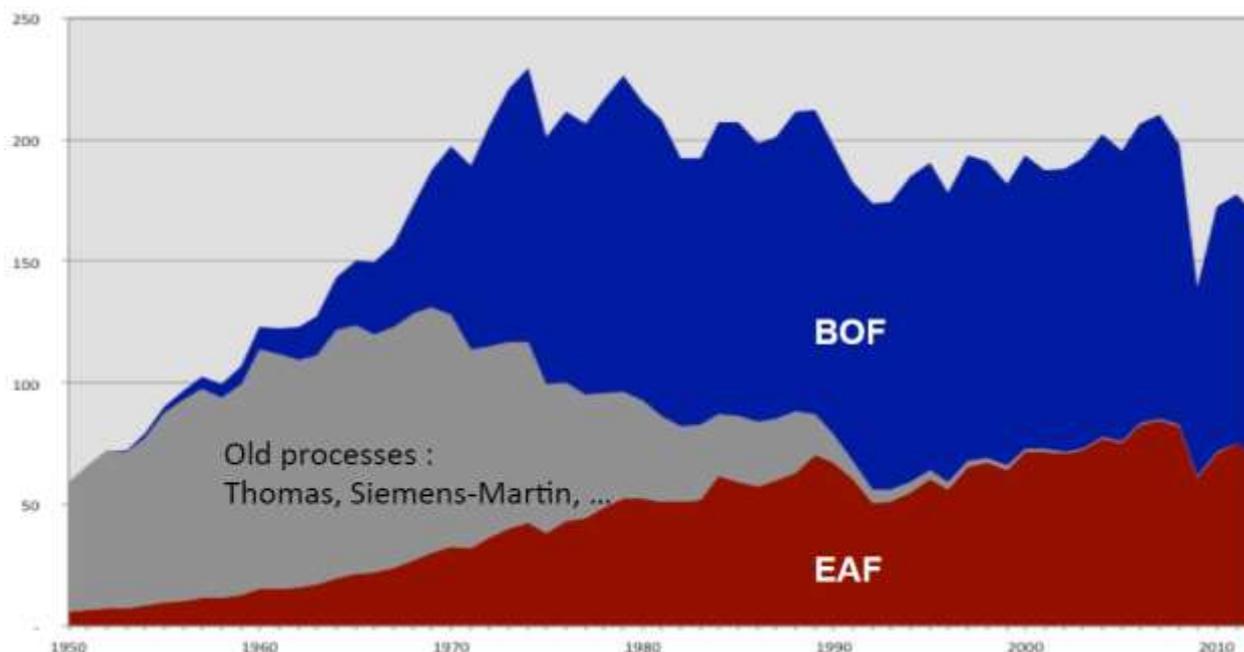
not mention CCS; only referring to the use of process gases and the waste heat as technology to be promoted.⁴³

The steel emerging from any of these processes is then continuously cast into slabs, rounds or squares (billets) and fed through a series of rolling mills, heat treatment, and coating lines to produce finished steel products.

3.2.1. Experience to date

From 1960 to 1990 the first major process change involved the replacement the previously dominant of slow and energy intensive open-hearth steelmaking by the BOS (the LD process having been developed in Austria at Linz and Donawitz). In parallel the share of EAF plants in total steel production started to increase and reached approximately 42% of European crude steel production in 2012.⁴⁴ This trend was accelerated during the economic downturn from 2008, as several integrated plants were shut down either temporarily or permanently; more so than the EAF capacity (Figure 3). The shift to EAF was not homogenous across Europe, but prominent in Southern European countries, while large integrated mills continue to dominate in North Europe (Austria, Benelux, France, Germany, Scandinavia and the UK)

Figure 3: Evolution of crude steel production by process in EU28 (Mt).



Source: Worldsteel, Laplace Conseil analysis

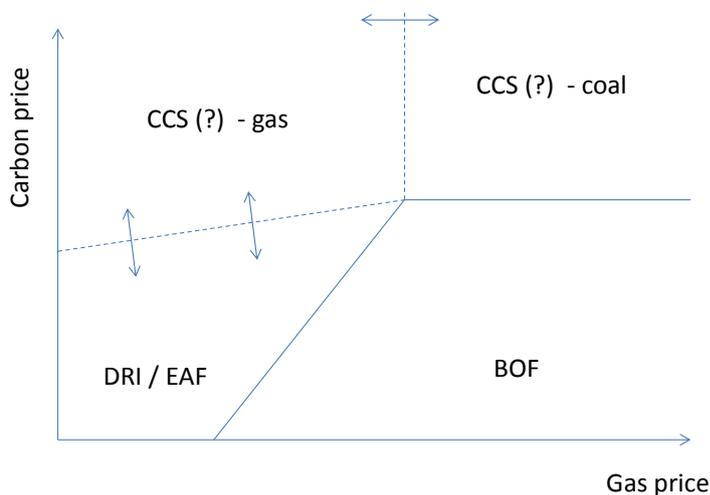
⁴³ European Parliament (2014) "Resolution on the Action Plan for a competitive and sustainable steel industry in Europe".

⁴⁴ World Steel Association (2013) "Steel Statistical Yearbook 2013", p. 2.

3.2.2. Criteria for process choices

Figure 4 below illustrates how the least cost processes for primary steel production will change with gas and carbon prices for a given coking coal price. At high gas prices, the BOF process is more profitable than the DRI/EAF process, while at low gas prices (compared to coking coal prices) the DRI/EAF process is more economical and has motivated recent investments in the USA. With increasing carbon prices, the BOF process suffers from its higher carbon intensity, resulting initially in a higher propensity to shift to the DRI/EAF process, and ultimately a point at which commercialized CCS technologies would be economically viable. For CCS in the DRI/EAF processes a first plant is under construction in Abu Dhabi also motivated by the use of captured carbon for enhanced oil recovery.⁴⁵ The development of additional steel manufacturing technologies could further increase the choice for steel investors also based on low-carbon non CCS technologies.

Figure 4: Profitability of different processes depending on gas and carbon price



Source: Authors' analysis

3.2.3. Investment cycle: Addition versus replacement

Relative costs for different processes can influence operational choices, but are of particular relevance with respect to investment. The steel production process is very capital intensive, with an integrated green field steelworks of 3-5 million tonnes per annum production capacity costing 7-10 billion euros investment cost and occupying a site of several square kilometres, while employing around 5000 people.

For the purpose of the following discussion we can differentiate between three investment types.

⁴⁵ Global CCS Institute "Abu Dhabi CCS Project" <<http://www.globalccsinstitute.com/project/esi-ccs-project>>, 14.08.2014.

New investment (“greenfield investment”) allows for a choice of most economic production processes. In principle the process choice would follow the principles established in Figure 4 (preceding section). However, investment costs and time-lines differ across processes. For example, the DRI/EAF process is less capital and labor intensive and more modular than the BOF process. Therefore a shift of investment toward DRI/EAF also happens at higher gas prices than calculated for a shift of production in existing plants. Hence new investments in the USA were focused on DRI/EAF.

Replacement of an operational plant with a new investment based on a different process would require the highest price difference for the CO₂ emissions, as the new plant needs to fully recover investment cost to make it a viable choice compared to an existing installation that could continue to operate as long as current costs are covered.

Re-investment / re-furbishment: A common phenomenon is that maintenance activities on existing sites are reduced, either due to cash-flow constraints or as a strategic choice considering the option of potential closure of a site or production process. If re-investment needs to accumulate over years the efficiency of production process declines and operation costs increase. Thus the scale of a refurbishment process that will eventually be necessary to secure continued operation of a production process increases, thus creating the option for either a process switch or closure.

With the economic crisis that started in 2007, operational margins and, consequently, available cash has declined for European steel firms. As such, expenditure on re-investments and refurbishments can be delayed by a few years. However, with increasing delays efficiency declines and necessary re-investment costs increase. Ultimately the plants with most investment backlog run the risk of closure rather than re-investment – given similar access to markets and resources.

3.2.4. The impact of iron ore and scrap availability on process choice

As European steel producers have shifted from the use of domestic iron ore toward lower cost imported iron ore, they have become more exposed to price and quality of available material. Three developments coincide:

- The volume of scrap available in OECD countries is increasing with maturing of infrastructure.
- The quality of scrap is decreasing as compound materials, for example from automotive use, reduce the purity of the scrap.
- The quality of iron available on global markets is less predictable and dependency on supply from few exporting countries is likely to persist.

These developments contribute to a persistent tendency toward EAF processes to utilize available scrap and thus reduce dependency from imported iron ore. For higher value applications of steel, scrap can be blended with higher quality slab from DRI.

3.2.5. The impact of energy endowment for process choice

BOF: Since the 1960s, cheaper and higher quality coking coal and iron ore has become available from Australia and Brazil. As a result European investment in new steelworks moved to coastal sites, following the pattern established by the Japanese steel companies. Sites seeing major developments included Taranto in Southern Italy, Ijmuiden in the Netherlands, Fos near Marseilles in France as well as Dunkerque and Ghent in Flanders and Teesside in England.

This created an expectation that further steps will involve a shift of production sites toward countries hosting these raw material resources. Such a strategy has been discredited by the large scale losses incurred by ThyssenKrupp with its greenfield plant in Brazil (which was also partially built to serve the Brazilian market).

With increasing shares of European sourced scrap used in BOF processes (min 20% required, but higher shares possible dependent on cost of scrap, coke and iron ore) the weight shifts further in favor of a European based BOF production. Most importantly, there is a globally persistent tendency to meet steel demand with regional production, reflecting an interest to

- Enhance security of steel supply as input to key production facilities. While, in principle, import dependency of primary iron ore could reflect a similar dependency as import dependency from slab, it would increase exposure to bottlenecks and strategic behavior in slab production in addition to existing exposure in iron ore mining.
- Economies of scale and innovation potentials across steel value chain creating an interest for countries (and incumbent steel companies) to maintain steel production at home.
- Energy efficiency gains of integrated production sites reducing needs to re-heat slab and allowing for use of heat and process gases from BOF.

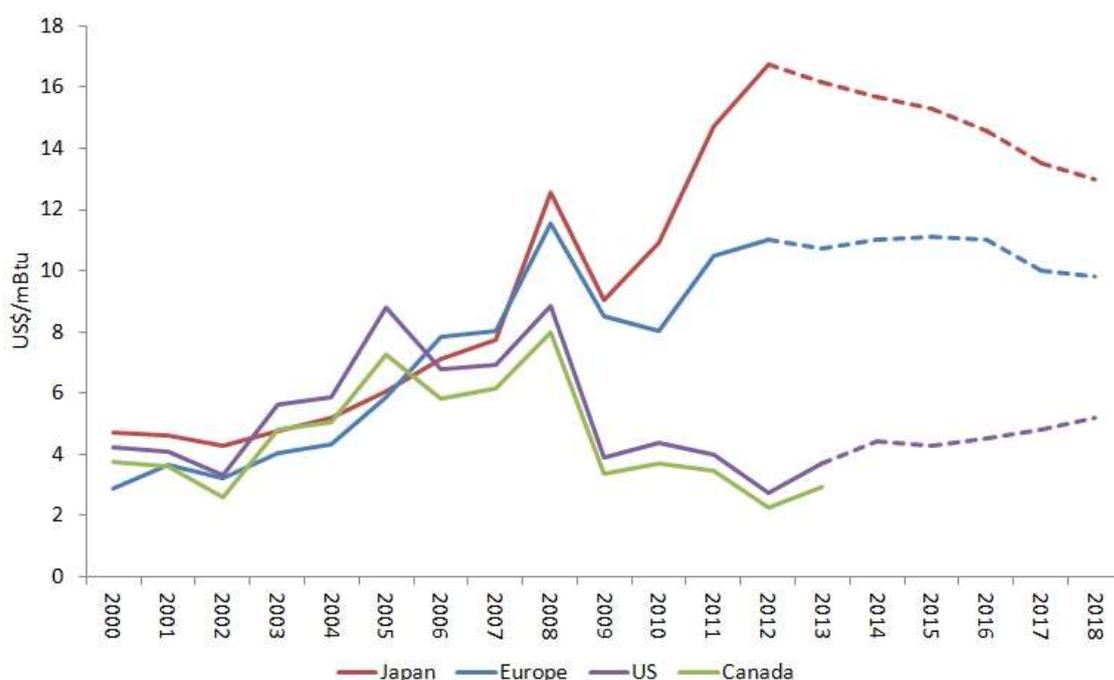
Thus the current paradigm would suggest, that BOF facilities – to the extent that they remain the process of choice – would continue to operate in Europe.

DRI: The DRI process is gas intensive and thus exposed to regional gas prices. Until 2006/07 it was expected that liquefied natural gas shipped from Gulf States or Trinidad and Tobago would provide marginal supplies around the world, thus resulting in homogeneous gas prices across OECD countries and most emerging economies. Locating DRI facilities in gas producing countries could allow for access to lower cost gas at the expense of higher country related risk factors. With the shale gas development, the USA and Canada are no longer dependent on gas imports. Figure 5 illustrates how the surplus capacity (in absence of export capacity) temporarily resulted in very low gas prices in the USA over the 2008-2014 period. By

2020 additional gas export capacity is expected to reduce this price gap to the cost of liquefaction, transport and regasification (largely energy related costs).

European shale gas resources are estimated to be smaller and linked to both more difficult sites and, due to higher population density, more difficult to access. Hence they are not expected to replace European gas imports, meaning that some of the price gap, vis-à-vis North America, will be preserved. In this situation, further DRI developments are more likely to be based in North America and the Middle East instead of the EU.

Figure 5: Differences in energy prices.



Source: Neuhoff et al. (2014) "Staying with the Leaders: Europe's Path to a Successful Low-Carbon Economy", Climate Strategies, London, UK.

EAF: The electric arc furnace process is power intensive. Power prices for very energy intensive users are in liberalized markets linked to wholesale power prices and largely exempt from additional charges. For strategic investment choices companies will consider the potential development of such wholesale prices, in particular after 2020 (or costs for on-site power generation). Recent developments in wind and solar prices suggest that these sources of energy could set the marginal cost for such power provision. Additional storage costs need to be considered, but it will be limited if a mix of technologies reduces the overall storage needs and if EAF provide some demand side flexibility. As the resource basis for wind and solar is not fundamentally different across regions, the cost of capital to finance such investments will ultimately determine the competitiveness of power in different regions. This points to the importance of investment friendly renewable remuneration mechanisms as main factor to facilitate EAF investments in a region (e.g. US tenders for long-term off-take contracts, European feed-in tariffs).

3.2.6. The role of carbon constraints

As the DRI/EAF process is less carbon intensive than BOF process, carbon prices will shift the weight towards DRI/EAF processes – however given the relatively small (20-30%) emissions savings,⁴⁶ very high carbon prices would be necessary to compensate for high European gas prices.

Once CCS becomes commercially available this might again influence the fuel choice. The capture rate that can be achieved with different technologies and the cost of transport and storage of captured carbon can impact the technology choice. So far the European research cooperation ULCOS (see the next section) has focused on demonstration projects based on coal as a fuel. This might reflect combination of the cost assessment (of the early ULCOS period) or the strategic interest of process choices that allows for production in Europe.

The location for siting new technologies can change in a carbon constrained world – even if leakage protection measures are in place or the carbon price is similar in different regions.

3.3. Break-through technologies and Carbon Capture and Sequestration

Through pricing carbon, the EU ETS has also had the effect of making executives in the steel industry think about the long-term sustainability of the industry in Europe. With rising carbon prices it became clear to the industry that it has to shift from current technologies to lower carbon options. This led to the ULCOS project, short for Ultra-Low CO₂ Steelmaking, a consortium of all major steel companies in Europe, important contractors and service providers, several power companies, as well as research institutes and universities. ArcelorMittal coordinates the projects.⁴⁷

In 2004 funding was secured under the Sixth Framework Program for six years; additional funding was obtained from the Research Fund for Coal and Steel on a project-by-project basis. The total budget for the period 2004-10 amounted to EUR 75 million. The aim was to investigate “concept process routes” that could cut CO₂ emissions by at least 50%.⁴⁸ About eighty options were screened, with potential emission cuts ranging from 20% to 100% compared to the conventional blast furnace route. In 2008 the four most promising routes were chosen (Table 3).

⁴⁶ Boston Consulting Group (2013) “Steel's Contribution to a Low-Carbon Europe 2050: Technical and Economic Analysis of the Sector's CO₂ Abatement Potential”, p. 22, <<http://www.bcg.de/documents/file154633.pdf>>.

⁴⁷ ULCOS Website, <<http://www.ulcos.org/en/index.php>>, 13.01.2014.

⁴⁸ Project details of “Ultra-Low CO₂ steelmaking” <http://cordis.europa.eu/projects/rcn/74430_en.html>, 24.01.2014.

Table 3: ULCOS technology options after 2008: An overview.

| Name | Technology | Status | Time horizon | CO2 reduced / tonne of steel | |
|--------------------------------|---|---|--------------|------------------------------|------------------|
| | | | | Directly | With CCS |
| ULCOLYSIS & ULCOWIN | Electrolysis of iron ore | Laboratory work; proposal for 5 kg/ day | Long | 100% | - |
| ULCORED | Direct reduction of iron ore with natural gas; electric arc furnace to melt solid metal intermediates | Laboratory work | Long | < 50% ⁽²⁾ | ? ⁽²⁾ |
| Hlsarna | Process intensification: omits coke and sinter/ pellet plants; integrated smelting reduction | Pilot plant; funding rejected by ERFCS but a fourth campaign to go ahead anyway | Medium | 20% | 80% |
| Top gas recycling | Separates CO2 from the off gases from the blast furnace, improves reduction and facilitates CCS | Experimental plant in Sweden. Plans for pilot plant in Eisenhüttenstadt (without CCS) and demonstration project in Florange (with CCS) floundered | Short | 25% ⁽³⁾ | 75% |

Notes:

- (1) This depends on CO2 emissions generated during the production of the required electric power.
- (2) No data reported; it is clear, however, that CCS is necessary to reach the 50% reduction aimed for in ULCOS. With CCS, the CO2 reductions would probably be in the range of Hlsarna and Top Gas Recycling processes. CO2 emissions from power production are also a factor of importance with this technology.
- (3) Direct cuts in CO2 emissions come from decreased consumption of coal and coke.

3.3.1. Electrolysis and Direct Reduction

Only ULCOLYSIS and ULCOWIN, two routes based on electrolysis of iron ore, could meet the stated aim of cutting CO2 emission by 50% without carbon capture and storage. Electrolysis is applied industrially to produce metals such as zinc and aluminum but not iron. Under the ULCOS project only laboratory scale investigations and some relatively small scale tests have been done. Moreover, large quantities of competitively priced electricity would have to be available in order for electrolysis to be economically viable, and this electricity would have to be produced with minimal CO2 emissions to make steel production sustainable.

ULCORED is a Direct Reduced Iron (DRI) process. Instead of using coal or coke as a reducing agent, DRI processes use natural gas or a coal-based gas to produce iron.

The ULCORED process uses partial oxidation of natural gas instead of the conventional reformers to manufacture a reduction gas. The process is designed in a way which allows for the extraction and storage of CO₂. The DRI step produces a solid product that is then melted using an electric arc furnace (EAF). So far, only laboratory investigations were conducted. Next to the price of CO₂, the viability of ULCORED hinges on the price and availability of natural gas and electricity. The extent to which ULCORED cuts CO₂ emissions, moreover, would also depend on the electricity source.⁴⁹

3.3.2. Hlsarna

The Hlsarna process is a step further in its development. This process uses a cyclone to introduce iron ore and oxygen, doing away with the need to produce coke and to process iron ore into the aggregates used in conventional blast furnaces. Hoogovens and British Steel, later assisted by Ilva, developed this Cyclone Converter Furnace in the late 1980s and 1990s but the technology was overtaken by the direct injection of coal and R&D was stopped. It gained new relevance, however, with the onset of the EU ETS and was incorporated into the ULCOS program. For the final reduction stage, the Hlsmelt reactor from Rio Tinto was incorporated, leading to a two-step reduction process. Hlsmelt is a smelting reduction process, an alternative to the blast furnace that is cheaper to build and run, and that can process a variety of (impure) iron ores.⁵⁰

In process development, scale up is an important but risky activity: the process may well behave differently at different volumes of production. To address these problems and understand scale related risks, pilot plants, which operate at several tonnes are a critical next step beyond laboratory investigations (which typically takes place at the scale of grams or kilograms). Pilot plants also operate under regular production conditions, or as close to those conditions as possible, so that reliability and costs can also be evaluated.

Hence, a Hlsarna pilot plant was built at Tata Steel's IJmuiden works in the Netherlands. EUR 20 million was invested in this plant, split more or less evenly between the ULCOS partners and European Union. In addition, the Dutch government supplied some additional funding. In 2011 the installation made its first run, followed by further trials in 2012 and 2013. Two final runs are planned for the Hlsarna pilot plant in 2014 and 2015, after which it should be clear if the Hlsarna process can produce steel continuously over extended periods of time. All data needed to engineer and build a full scale industrial plant will also have to be in place.

⁴⁹ Stanley Santos (2013) "Overview of the current state and development of CO₂ capture technologies in the ironmaking process" IEAGHG Report 2013/TR3, April 2013, pp. 8-9.

⁵⁰ Meijer, K., Guenther, C., Dry, R.J. (2011) "Hlsarna Pilot Plant Project". <http://www.riotintoironore.com/documents/Hlsarna_Pllot_Plant_Project_Metec_2011_Final.pdf>, 21.01.2014.

The Hlsarna Pilot Project has demonstrated that the Hlsarna process could cut CO₂ emissions by 20%. Furthermore, off gasses from the Hlsarna process are free of nitrogen, making it well-suited for CCS. With CCS, 80% reduction in emissions is possible. Essentially, Hlsarna is a form of process intensification: steel is produced in a much shorter route. Consequently, it requires less capital outlay when compared to the conventional steel production process. In the case of greenfield investments, this makes the Hlsarna process competitive with the conventional blast furnace route. Moreover, steel plants are periodically revamped. The Hlsarna process might be able to compete with conventional technologies if introduced in existing steel plants when such decisions are made. High carbon prices would further tilt the balance to the advantage of the Hlsarna process.

An application for funding of the fourth pilot plant trial was rejected by the RFCS in 2013. The rejection of the Hlsarna application also shows that no mechanism is in place to follow-up on projects once they show potential: the success of the previous trials and commitments of private sector co-funding apparently counts for little when applying for funding for a next trial. The amount of money needed for processes innovation once new processes leave the laboratory and are implemented into a pilot plant become significant and quickly outstrip EU budgets for R&D in the steel industry. Between 2003 and 2010, the RFCS spent EUR 56 million annually divided into 53 projects.⁵¹

Assuming the Hlsarna process completes the final pilot plant trials successfully, it would still need to be scaled up ten-fold for commercial application. Given the risks associated with scaling up process technologies, - a substantial risk of failure remains for any company that decides to build Hlsarna. In addition, the Hlsarna process cuts CO₂ emissions but deep cuts would require CCS. The case of CCS in the steel industry, however, is not straightforward, as the development of the Top Gas Recycling process illustrates.

3.3.3. Top Gas Recycling and CCS

In the Top Gas Recycling (TGR) process the off gases from the blast furnace are processed so that the CO₂ can be separated, transported and stored. The remaining gas is fed back into the furnace to act as a reducing agent, cutting back on coal and coke consumption. With CCS, CO₂ emissions can be reduced by 75%. A small plant was constructed at LKAB in Sweden during the first phase of the ULCOS project, showing that the process works. In 2009, ArcelorMittal, TataSteel and ThyssenKrupp took the lead to develop this technology further, in conjunction with CCS. At ArcelorMittal's site in Eisenhüttenstadt (Germany) a pilot plant will be built for EUR 50 million to develop the concept further. A large-scale demonstration project was planned at Arcelor's site in Florange (France). The companies aimed to have demonstrated by 2020 that TGR and CCS are possible on the required industrial scale.

⁵¹ European Commission (2013) "Research Fund for Coal & Steel: Assessment report". For an overview of the portfolio see "Research Fund for Coal & Steel: Monitoring report" pp. 22-26.

The investments needed were estimated between EUR 300 million and EUR 400 million.

In July 2009 the German Federal Government provided ArcelorMittal EUR 30 million to build the pilot plant. Planning for the Florange project also proceeded quickly and an ULCOS consortium, led by ArcelorMittal, applied for funding in the first round of the NER300 program, announced in November 2010.⁵² Funding was aimed at demonstration projects in carbon capture and storage and in renewable energy. The allowances were sold in two rounds; in the first round, from December 2011 to September 2012, 200 million allowances were sold, generating EUR 1.5 billion; projects were capped at EUR 337 million.⁵³

The Florange project made it through the initial selection in July 2012. The Florange site, however, performed poorly and its blast furnaces had, by that time, already been shut down. In October 2012 ArcelorMittal decided to shut down the project permanently, prompting sharp protests from the French government. In November 2012 a deal was reached to “mothball” the site, i.e. to shut it down in a way that it might be restarted later. A month later ArcelorMittal withdrew its application for the NER300 funding, citing problems in upscaling the gas recycling and storage technologies but underlining its commitment to the TGR process at the same time. Obviously, with the closure of the overall plant, it no longer made sense to demonstrate a technology that relies on operating blast furnaces at the Florange site.

Within the steel industry, the conditions of NER300 are considered prohibitive.⁵⁴ Selected projects would be funded at 50% of total costs but in relation to the volume of CO₂ actually stored, so conditionally on the basis of performance.⁵⁵ Based on these conditions, if a project were to fail to deliver the capture rates, funding would need to be paid back. For innovative projects this makes little sense: the risk of failure was the very reason steel companies were looking for public funding.

Some in the steel industry have concerns about the viability of CCS. The technology needs to be developed and demonstrated before it can be introduced on industrial scale. CCS will also add to the cost of producing steel. Estimates vary but the cost increase will be significant. Therefore the economic viability of CCS depends on high

⁵² The NER300 program is run by the European Commission and the European Investment Bank (EIB), and is funded by selling 300 million allowances from the New Entrants Reserve, a cache of free allowances in the EU ETS set aside for new entrants in certain sectors. For the planning, see: Jean-Pierre Birat (2012) “Resource issues in the Steel Industry. Industrial technologies 2012: Integrating nano, materials and production”, Aarhus, 19-21 June 2012, Slides 8-15.

⁵³ European Commission (2014) “Award Decision under the first call for proposals of the NER300 funding programme” C(2012) 9432 final <http://ec.europa.eu/clima/news/docs/c_2012_9432_en.pdf>, 2.06.2014.

⁵⁴ For a broader analysis of the NER300 program, see Lupion, M., Herzog, H. J. (2013) “NER300: Lessons learnt in attempting to secure CCS projects in Europe” *International Journal of Greenhouse Gas Control* 19, pp. 19-25.

⁵⁵ European Commission (2010) “Commission Decisions of 3 November 2010 laying down criteria and measures for the financing of commercial demonstration projects that aim at the environmentally safe capture and geological storage of CO₂ as well as demonstration projects of innovative renewable energy technologies under the scheme for greenhouse gas emission allowance trading within the Community established by Directive 2003/87/EC of the European Parliament and of the Council”, articles 11.2 and 11.4.

carbon prices. Furthermore, the social acceptability of CCS is uneven across Europe; with perhaps the only politically acceptable sites being located off shore, in the North Sea.

The opinions on CCS in the steel industry are strong, and perhaps too negative, but it is clear that the problems are significant. First, in addition to high costs the volumes to be captured and stored are much larger in the steel industry compared with the power industry. Second, there are several sources of CO₂ emissions at a steel production site (including the site's own power plant and coke ovens). Finally, steel plants are typically quite old and vary from site to site such that CCS is not a simple piece of equipment to be retrofitted to any existing plant.

3.3.4. Breakthrough technologies: Taking stock

In 2010 an ULCOS II program was rolled out and estimated to run through to 2015. Within the European steel industry, however, there are concerns about the viability of ULCOS. Some feel that the expectations raised in 2004, when ULCOS I was started, have not been met. Others point out that TGR was already a proven technology. Confidence in CCS is also fragile. Steel industry executives doubt whether the necessary political and societal support is forthcoming and whether the needed investment costs can be brought down to a manageable level.

Whether any of the ULCOS technologies are or become competitive depends to a large extent on the carbon price. As part of the ULCOS program a modelling study was undertaken and published in 2009. This study concluded that a price of EUR 500 per tonne would be needed to cut emissions by 75% and, at such price levels, ULCOS technologies would be competitive with conventional blast furnaces.⁵⁶ Obviously the low carbon price has weakened commitment to radical process innovation. The onset of the financial crisis and the weakening performance of the European steel companies further added to the loss of momentum in investment in energy and carbon efficiency.

A substantial amount of money is needed to develop ULCOS technology options to the point that they can be engineered and built, but that amount of money should not be impossible to raise. One estimate made at the start of ULCOS II put the amount of money needed to demonstrate the industrial viability of all four routes at between EUR 700 million and EUR 800 million.⁵⁷ This is about the 2012 R&D budgets of ThyssenKrupp and VoestAlpine combined. Similarly, EUR 2.2 billion has been raised by selling the 300 million NER allowances.⁵⁸ Finally, since 2009 the European Investment Bank (EIB) has lent about one billion euros to the EU steel industry under

⁵⁶ Bellevrat, E., Menanteau, P. (2008) "Introducing carbon constraint in the steel sector: ULCOS scenarios and economic modeling" *Revue de Métallurgie* 106(9), 318-324.

⁵⁷ ESTEP (2009) "New steel initiatives for a sustainable society" <<http://www.ulcos.org/en/docs/Estep%20press%20release%20March%205%20EN.doc> > 13.01.2014.

⁵⁸ Excluding costs and fees of the selling process. EIB (2014) "NER300 Monetisation: Final Monthly Report".

its Risk Sharing Finance Facility (RSFF). That money is also intended to fund R&D projects but is mostly spent on product-related innovation.⁵⁹

However, corporate R&D is not focused on innovation to cuts in CO₂ emissions during the production of steel. The EU is still an important market but growth is weak, and what growth there will be in the future will likely come from innovative specialty products. When companies invest in Europe, the case for R&D and capital expenditure on product innovations that meet market demand is much stronger than the case for the implementation of any ULCOS technology. ULCOS technologies cut CO₂ emissions, not production costs. With these technologies, companies can comply with EU regulation but they do little to maintain, let alone improve, competitive position. The competitive logic in the steel industry is relentless: low costs are essential. Globalization, i.e. trade liberalization and the growth of steel demand in China, first created a boom but has now put pressure on production sites in Europe as surpluses flow onto the world market.

At this point we should emphasize the challenge that the steel industry set itself with ULCOS. Radical process innovation in an industry such as steel is difficult and involves a fundamental trade-off between technology and economics. The steel industry is extremely large. Large amounts of capital are sunk into existing plants. Writing off these plants and building new ones is extremely expensive. Building a small plant, moreover, might be attractive from a technological point of view to sort out the teething problems of the process, but it makes no economic sense. Such an innovative small plant would still compete against established big plants and would need to conform to that level of cost - which it typically cannot. If markets were growing and if additional capacity was needed, new technologies could be built, but these conditions are not present in the EU today nor in the foreseeable future. Market niches are also difficult if not impossible to develop with process innovations.

It is easy to understand, why reducing CO₂ emissions is not high on the agenda of companies. More surprising, however, is the low priority that radical reductions of CO₂ emissions get in EU funding for R&D. The RFCS has spent only 6% of its available budget for steel R&D between 2003 and 2010 on ULCOS. In the same period, the RFCS funded EUR 135 million in coal R&D.⁶⁰ Climate change and competitiveness are not explicitly mentioned among the Fund's stated aims. Similarly, in the currently running Horizon 2020 program, only a general program, Sustainable Process Industries through Resource and Energy Efficiency (SPIRE), is intended to help industry master the challenge of sustainability. A 104 page long roadmap nicely summarizes the challenges, but seems to start from scratch: ULCOS technologies

⁵⁹ List of finance contract signed by EIB
<<http://www.eib.europa.eu/projects/loans/sectors/industry.htm>>, 18.06. 2014.

⁶⁰ Authors' calculations based on: European Commission (2013) "Research Fund for Coal & Steel: Monitoring and Assessment Report", pp. 25-26.

“are in preliminary development phases and further development can be considered.”⁶¹

The particularities of EU R&D funding are also a poor match for process development projects. In IJmuiden, first as Hoogovens, then as Corus and now as Tata Steel, companies have been working on what is now Hlsarna for decades. For the EU, however, R&D is cut up into projects with a limited time span of only a few years. Worse yet, technological progress amounts to little when applying for funding, as the Hlsarna experience underlines. This gives little chance for new technologies to develop.

It also seems doubtful whether the EU R&D funding system can cope with amounts of money necessary for process development once a technology leaves the laboratory. The funding requirements become substantial: from tens of millions for pilot plants to hundreds of millions for demonstration projects. The NER300 program could have filled this gap but did not. R&D on the TGR process had only demonstrated the possibility to separate CO₂ from blast furnace off gases in an experimental plant, not in an operating industrial plant. Nor had the project dealt with the transport and storage of the CO₂. Making funding conditional upon the performance of the technology misses the point: it leaves the costs of failure with the industry.

There is still a long way to go before any of the technologies investigated in the framework of the ULCOS program are ready for industrial scale application. But this should not be a surprising conclusion. ULCOS was a relatively small project aiming to scope options; now we have these options and they need to be further developed.

3.4. Moving to higher value steel

3.4.1. Potentials for greater efficiency in use via lightweighting

Additional opportunities for deep emissions cuts derive from material efficiency and related product innovation. Innovation in light-weight design can take various forms. In construction, for example, the use of structural steel can be reduced by applying alternative designs of beams, avoiding over specification of loads or upgrading the type of steel to higher strength steel. Allwood et al. identify six options, including lightweighting, to use less new steel to provide a given service in the steel sector:

- increasing light weight design,
- improving yield ratios along the supply chain,
- diverting manufacturing scrap to avoid high melting of energy of recycling,
- re-using steel components without recycling,
- delaying end-of life by using building and products longer
- using products more intensively.⁶²

⁶¹ SPIRE (2013), “SPIRE Roadmap”, p. 27, <http://www.spire2030.eu/uploads/Modules/Publications/spire-roadmap_december_2013_pbp.pdf>, 13.09.2014.

This study surveys a range of steel applications and estimates potential aggregate reductions of materials on the order of 20-25% using combinations of the above six approaches. Similarly, Carruth et al estimate that many products made of steel could be according to technical assessments, 25-30% lighter.⁶³

Developing some of these materially more efficient products would also appear to offer a potential opportunity for the steel industry (and their downstream customers) to market these and their final products as higher value-added products. The potential policy supports required for this are discussed below.

3.4.2. Barriers to uptake

Nevertheless, there are several barriers to exploiting the full potential of greater material efficiency, many of which need to be overcome with dedicated policy tools. One such barrier relates to the nature of the downstream sectors that make use of steel. Demand for steel stems mainly from construction (~35-50% of steel use), followed by vehicles and equipment (25%) and other products including packaging.⁶⁴ Some of these sectors lend themselves more easily to the uptake of material efficient products than others because of the different degree of concentration of end-users in the sectors concerned. For example, one interviewee reported that they work closely with car manufacturers to develop solutions in 2 years (at times also 5-10 years), thus allowing them to compete with light materials such as plastics and aluminum.⁶⁵

Similarly, the late 1990's UltraLight Steel Auto Body (ULSAB)⁶⁶ programme is an example of a private sector initiative. The main motivation for this project was a combination of increased safety standards, which had begun making vehicles heavier, and the introduction of new vehicle fuel economy standards, which threatened heavier vehicles with penalties for non-compliance. In the 1990s, 35 steel companies pulled together in a large global consortium under the umbrella of the World Steel Association to develop lighter steel auto body structures by using high-strength steels, tailored blanked parts and sandwich steel materials. ULSAB allowed for 25% mass reduction compared to mid-sized four door sedans (benchmarked by Porsche Engineering Services, Inc.), with the vast majority of its recommended innovations ultimately being adopted by the industry.⁶⁷

Interviews with actors involved in the initial ULSAB indicated that the global reach of the consortium as well as the ability to coordinate directly with specific, large-scale

⁶² Allwood J. M. et al (2012).

⁶³ Carruth, M.A., Allwood, J.M., Moynihan, M.C. (2011) "The technical potential for reducing metal requirements through lightweight product design" *Resources Conservation Recycling*, 57, pp. 48-60.

⁶⁴ Carruth, M.A. (2011)

⁶⁵ Interview with industry stakeholder.

⁶⁶ World Auto Steel (1998) "UltraLight Steel Auto Body (ULSAB). Overview Report", <<http://www.worldautosteel.org/projects/ulsab/ultralight-steel-auto-body-ulsab-programme>> 13.09.2014.

⁶⁷ Follow-up initiatives are the ULSAB-Advanced Vehicle Concepts and the Ultralight Steel Auto Closure (ULSAC) to develop lightweight designs for doors, hoods, decklids and hatches of cars.

manufacturers was a key to the uptake of its innovations. However, other steel-intensive sectors, such as construction, do not exhibit the same degree of sectoral or global coordination. On the contrary, the construction market is dominated by small firms, with limited capacity for engagement with the steel sector on product innovations and material efficiencies. A Carbon Trust study shows that car manufacturers in general use flat steel with specific requirements and thus of higher value. Accordingly, the industry tends to source its flat steel from specific suppliers. In contrast, construction firms use less specialized, low value long steel.⁶⁸ This suggests that improving material efficiencies and product innovation in these sectors would need to be driven by alternative approaches, such as direct regulation on material use, and not industry initiative or price-based approaches.

Another barrier to the uptake of some of the above-listed material efficiencies concerns the fact that not all of these options are considered economically viable at present. Indeed, some of them may require significantly greater resource scarcity, or much larger economies of scale, in order to become economically viable. For this reason it is also important not to exaggerate the short-term potential of some of these measures. However, generating economies of scale may help bring down costs over time.

A further potential barrier to efficiently reducing CO₂ emissions by improving light weight design of steel products is that regulations may have blind spots that lead to perverse outcomes. In the automotive industry, for example, alternative materials such as aluminum, plastic, carbon fiber compete with steel for fabricating various parts of vehicles. This report does not take a view on which material is optimal from an environmental perspective. However, interviews with sector experts indicated that certain forms of regulation – such regulations on tail-pipe emissions of vehicles – run the risk of favoring less emissions friendly materials if they are not accompanied by a broader framework for creating a level playing field. A focus purely on vehicle fuel economy may therefore lead to car designers picking lighter products over those that have the lowest emissions footprint.

Such concerns have led the industry to call for mandatory life cycle assessments (LCAs) in meeting any given efficiency standard. In fact, most European car manufacturers complete LCAs of their cars and require suppliers of components to provide information on emissions intensity of their products. This practice shows that LCA tools can and are used in the auto industry. At the same time, current practice is limited in at least three ways. Firstly, car-makers are not necessarily bound to use the least CO₂ intensive materials on a life-cycle basis. Secondly, LCA information about the life cycle CO₂ intensity of different cars is not forwarded to the customer. Therefore, car customers are left with only the information about end of pipe (fuel efficiency) emissions. In a sector where innovation is strongly driven by creating value for consumers, the failure to pass on such information hinders the ability for customers to drive innovation by demanding more efficiently produced vehicles.

⁶⁸ Carbon Trust (2011) “International carbon flows. Steel.”
<<http://www.carbontrust.com/media/38362/ctc791-international-carbon-flows-steel.pdf>> 14.9.2014.

Passing on CO2 LCA information to consumers of end use steel products would also appear to take on greater importance when one considers that price-based approaches to driving consumer demand for material efficient and lower carbon products are likely to be quite marginal. Table 4 below shows estimates of the cost of CO2 for an average car assuming different CO2 prices and steel CO2 efficiencies. The results of the final row demonstrate that at a carbon price of 100€/tCO2, the incremental carbon cost increase is on the order of 173€. Similarly, structural steel products represent an extremely small share of construction costs. It is therefore questionable whether price alone can act as a fundamental driver of consumer-driven choices that encourage industry to seek lightweight design and greater material efficiency.

However, it is important not to underestimate the importance of prices as a barrier to innovative designs and material efficiency. Prices might not be the driver toward lower carbon steel from the consumer side, but from the manufacturer’s perspective, it is likely that choices toward more efficient/innovative steel use are not economical without a carbon price reflected in steel (Table 4). Given that manufacturers are focused on minimizing production costs to secure margins, they are unlikely to choose products that are not competitive - hence price signals are necessary. While carbon costs may reflect a small share of the overall value of a car or building, these items are made via value chains producing different components. Therefore, carbon prices and price-pass-through are likely to be important to the producers of carbon-cost intensive components of final products and are, thus, complementary to labeling and consumer engagement.

Table 4: Automotive - carbon cost of average car.

| Unit | Scenario 1 | Scenario 2 | Scenario 3 | Scenario 4 | Scenario 5 |
|------------------|------------|------------|------------|------------|------------|
| tCO2/t of steel | 1.80 | 1.80 | 1.80 | 1.30 | 2.30 |
| t of steel / car | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 |
| tCO2/ car | 1.73 | 1.73 | 1.73 | 1.25 | 2.21 |
| EUR/ tCO2 | 5 | 20 | 100 | 100 | 100 |
| EUR / car | 9 | 35 | 173 | 125 | 221 |

Source: Calculations by authors, based on data from World Steel Association (2014) “Steel’s contribution to a low carbon future”, Carbon Trust (2011) “International carbon flows. Steel.”, Allwood et al (2012) “Sustainable materials: with both eyes open”.

3.4.3. Potential drivers of greater material and end use efficiency

An exhaustive list of the drivers of all of greater material efficiency in all sectors is beyond the scope of this report. Nevertheless, the interviews conducted with industry actors for this study allow for the identification of a number of broad themes. The first theme is that downstream regulation has tended to be a more powerful driver of product innovation and improved material efficiency than price. This is amply illustrated by the example of ULSAB in the late 1990s – early 2000s, provided above. A key question for policy makers is therefore how to design regulations that can

similarly serve as attractors for industry innovation across key downstream steel sectors.

At the same time, however, interviews revealed that cost remains a significant consideration for manufacturers of steel intensive products and component parts. Prices – carbon prices in particular – are, therefore, an essential, albeit perhaps insufficient, driver to greater efficiency and innovations in materials use. For example, life cycle assessments are unlikely to have their implications fully followed by steel companies if they increase costs. And regulations are dangerous and likely to be politically difficult to implement if they are not economical to implement for the sector.

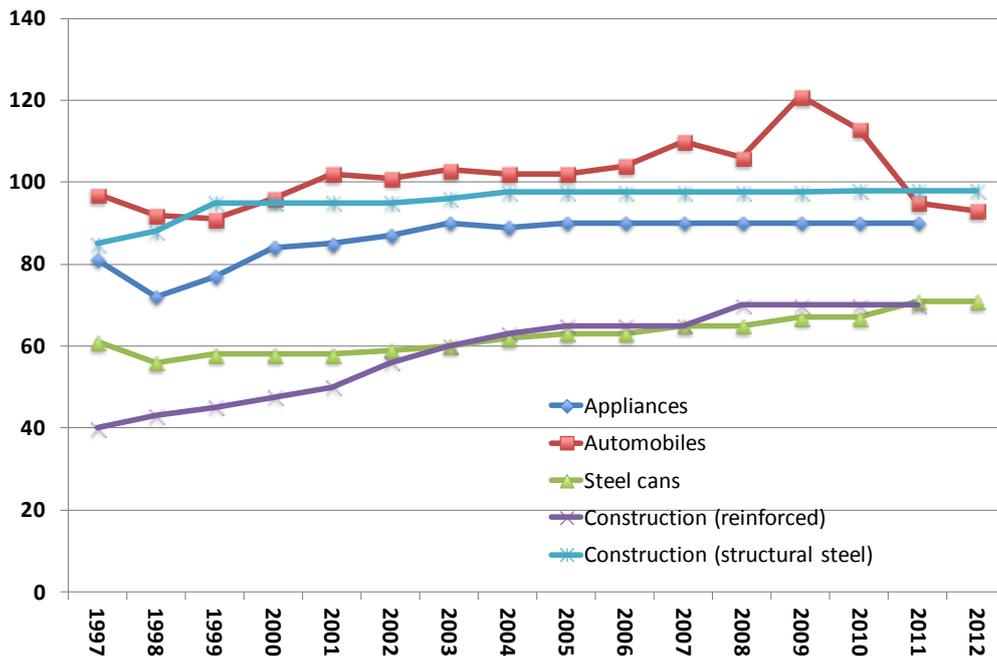
Another key theme is that customer engagement is important as a driver of innovation. This is evidenced by the ULSAB experience (where car manufacturers demanded innovation from steel makers) but also from one of its successor programs - the Steel Future Vehicle Program. The latter was a project led by World Auto Steel that developed a set of 4 advanced car models, which combined elements of electrification and hybridization with new advanced high strength steels (AHSS). The program found that with limited cost increases, car body weight could be decreased by a further 30%, with life cycle emissions reduction by 70%. These cars were designed with a view to marketing them by 2015-2020.⁶⁹ At present, however, the innovations flowing from this project have not yet been taken up.

3.5. Increasing steel recycling rates

Almost 100% of steel in used automobiles is recycled. High shares of scrap steel are recycled from household appliances and structural steel in construction (Figure 6 below). In contrast, retrieving in construction rebar from reinforced concrete is difficult and costly, therefore recovery rates are low. There is also considerable scope for improvement of recycling rates from packaging (e.g. drink and aerosol cans).

⁶⁹ ULSAB: Working High-Strength Steel into Automotive Design, <<http://www.autosteel.org/Global/Document%20Types/News/2006%20and%20Before/ULSAB%20-%20Working%20High-Strength%20Steel%20into%20Automotive%20Design.aspx>>. 18.08.2014.

Figure 6: Recycling rates in the USA by steel type.



Source: Steel Recycling Institute (2013). Appliances include washing machines, water heaters, air conditioners, refrigerators and dryers.

Recycling steel with EAF is cheaper than primary steel production and this has provided incentives to use scrap over the last 150 years⁷⁰. Every tonne of recycled steel saves 1134 kg of iron ore, 635 kg of coking coal and 54 kg of limestone, compared to smelting iron in a blast furnace⁷¹. The EU Steel Action Plan advocates increasing recycling, primarily on the grounds of **reducing import dependency** of raw materials (iron ore and coking coal) that are scarce in Europe, and hence the trade balance⁷². More broadly, increasing recycling is central to policies that promote the shift to a “circular economy.”⁷³ Every tonne of recycled steel saves 1.3 tonne of solid waste, 1.3-1.6 tonnes of CO₂ and generates 86% less general air pollutants, 76% less water pollution and 40% less water use.⁷⁴ While primary steel production in the

⁷⁰ Eurofer (2014), “Steel Recycling: scrap is a valuable raw material”, <<http://www.Eurofer.org/Sustainable%20Steel/Steel%20Recycling.fhtml>>. 15.08.2014.

⁷¹ Emery et al (2002) in Söderholm, P. & Ejdemo, T. (2008). “Steel scrap markets in Europe and the USA”. *Minerals & Energy - Raw Materials Report*, 23(2), 57–73.

⁷² European Commission (2013), “Action Plan for a competitive and sustainable steel industry in Europe”.

⁷³ The concept of circular economy originates in the field of industrial ecology, which envisions a form of material symbiosis between otherwise very different companies and production processes. Industrial ecology emphasises the benefits of recycling residual waste materials and by-products through the development of complex interlinkages. In more general terms, it promotes resource minimisation and the adoption of cleaner technologies: Andersen, M. S. (2007). An introductory note on the environmental economics of the circular economy” *Sustainability Science*, 2(1), pp. 133–140. Pauliuk et al (2013) find that per capita in-use stocks in many industrialized countries show saturation or signs of saturation in the range of 11–16 tons, including Australia, Canada, the former Czechoslovakia, Finland, France, Benelux, Germany, Japan, Norway, Sweden, Switzerland, the UK, and the U.S. Pauliuk, S., Wang, T., & Müller, D. B. (2013) “Steel all over the world: Estimating in-use stocks of iron for 200 countries”. *Resources, Conservation and Recycling*, 71, pp. 22–30.

⁷⁴ Emery et al (2002).

BF/BOF sector is more labour intensive than operating an EAF based on recycled steel (310,000 full time jobs in BOF for 98Mt annually and 100,000 full time jobs in EAF producing 70Mt), the scrap sector additionally provides 300,000 full time jobs in Europe⁷⁵.

3.5.1. Increasing recycling rates

Improvements in recycling rates to date were driven both by higher value and prices of scrap and public policies. In Europe the Extended Producer Responsibility (EPR) Programme, the Packaging and Packaging Waste Directive and the End of Life Vehicles Directive and landfill taxes have contributed to higher recycling rates.

The EU, the Eco-Design Directive allows for the possibility to set out requirements on the on the recyclability, dismantling of products in a cost-effective way, which could contribute to ensuring better access to high-grade scrap metals⁷⁶. The establishment of **end-of-waste criteria** for iron and steel has helped boost demand for recycled steel by giving confidence in the quality specification of scrap.⁷⁷ The Commission's **raw materials strategy** sets out a strategy to pursue the objective of encouraging greater recycling in steel⁷⁸.

3.5.2. Improving quality of scrap

As economies are maturing the volume of available scrap is increasing, thus also increasing the share of steel that can be produced from this scrap. But at a time when compound materials and other impurities in scrap are reducing the quality of available scrap the quality requirements on scrap to meet requirements for higher value steel increase. In response steel producers aim to mix scrap with primary steel of higher quality to produce almost the entire range of steel grades,⁷⁹ but in the future the quality of scrap will be of increasing importance.

Additional policies considering the product value chain and product life cycle may be necessary to avoid creating complex product where metals are stuck and difficult to

⁷⁵ Laplace Conseil (2013a) "Evaluating the implications of the EU Steel Action Plan on steel scrap production and trade." Presentation held during the World Recycling Convention in Warsaw on October 28, 2013 in Warsaw.

<<http://www.laplaceconseil.com/LaplaceConseil/htdocs/admin/upload//File/BIR%20World%20Recycling%20Convention%20Warsaw.pdf>>, 14.09.2014.

⁷⁶ European Council (2009) "Directive 2009/125/ec of the European Parliament and of the Council of 21 October 2009 establishing a framework for the setting of ecodesign requirements for energy-related products". *Official Journal of the European Union* L 285/10.

⁷⁷ European Commission (2011) "Council Regulation No 333/2011 of 31 March 2011 establishing criteria determining when certain types of scrap metal cease to be waste under Directive 2008/98/EC of the European Parliament and of the Council". *Official Journal of the European Union* L 94/2.

⁷⁸ European Commission (2014) "Report of the Ad hoc Working Group on defining critical raw materials", <http://ec.europa.eu/enterprise/policies/raw-materials/files/docs/crm-report-on-critical-raw-materials_en.pdf> 14.08.2014.

⁷⁹ Laplace Conseil (2013a).

recover. For example requirements to properly grade steel and to provide incentives for steel makers to consider the recovery and recycling of the steel could help addressing these problems and need to ultimately cover as large share of global steel producers as possible. Policies to support technological innovation and better governance to improve the rate of recovery and reuse may reduce the uncertainty around scrap supply in the future and thus facilitate recycling in the longer run.⁸⁰

In parallel, technologies allowing use of scrap of inferior quality need to be developed to meet the demand of the downstream sector for higher quality products. Improved recovery technology to separate material from one another will provide better quality scrap. As demonstrated by the success of Nucor in the USA, specialization in steel recovery and recycling can go hand in hand with greater safety and technological innovation. In Europe, there is hope that “the potential of new sorting technologies and innovative systems, markets and business models in further developing scrap recycling is particularly promising in terms of improving competitiveness and reducing environmental impact and emissions”.⁸¹

3.5.3. Should Europe use more scrap domestically?

Scrap is a globally traded product. Mature economies have larger scrap volumes due to the big historic asset base. Emerging economies have, in contrast, younger infrastructure and thus less scrap volumes from recycling. This difference creates a natural starting point for scrap trade, as efficient operation also of primary steel production with BF/BOF processes is often combined with the use of 20% scrap. In addition, some countries like Spain or Turkey invested directly in EAF for scrap recycling rather than in BF/BOF process turning these countries to large net importers scrap. This is mirrored by mature economies with large existing BF/BOF plants that export scrap rather than reduce production of primary steel.⁸²

Overall, net European scrap exports to outside of Europe have increased from 4Mt in 2000, 5Mt in 2005 and 17Mt in 2012. Internal EU scrap trade has also grown from 20Mt in 2000 to 25Mt in 2005 and 28Mt in 2012.⁸³ The Bureau of International Recycling estimates that the total world steel scrap use reached 580 Mt in 2013, about a third of the volume of world crude steel production for that year (Figure 7).⁸⁴

⁸⁰ Allwood, J.M. et al (2012).

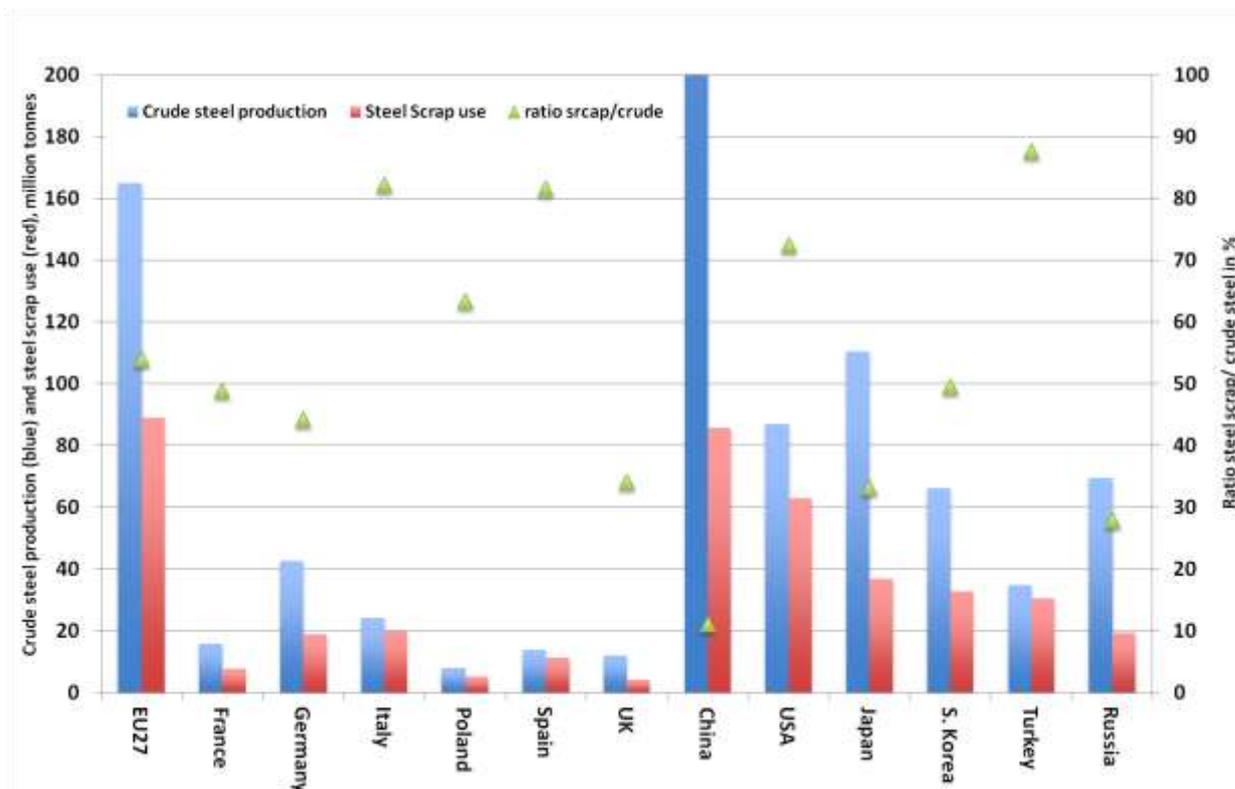
⁸¹ European Commission (2013), “Action Plan for a competitive and sustainable steel industry in Europe”, p.19.

⁸² Laplace Conseil (2013a).

⁸³ Source: UN Comtrade accessed via World Integrated Trade Solution

⁸⁴ Bureau of International Recycling, <<http://www.bir.org/>> 15.07.2014.

Figure 7: Volumes of crude steel production and steel scrap use by country (bars and left axis) and Ratio of steel scrap use to crude steel production (marker, right axis) in 2013.



Source: Bureau of International Recycling, Ferrous Division (2014). *World steel recycling in figures 2009-2013: Steel scrap - a raw material for steelmaking*. BIR report.

The large volumes of scrap exports from Europe sometimes raise the question whether the price of scrap is discouraging the European steel companies from increasing the share of scrap in steel production. For example, EU Steel Action Plan mentions a possibility to monitor or restrict scrap exports: “Given the reduced amount of CO₂ in the production of scrap in Europe, non-discriminatory measures justified on environmental grounds could be envisaged, if necessary to address carbon leakage to non EU countries, provided that they do not result directly or indirectly in export restrictions”.⁸⁵

However, such restrictions do not seem warranted as the global scrap market is well integrated. In addition, a multitude of actors are both selling and buying. Therefore the global scrap markets can be considered well-functioning and competitive.⁸⁶ Scrap prices in different regions are closely linked, and the overall price trend of scrap can be well explained by competitive factors. Scrap prices tend to move in sync with iron

⁸⁵ European Commission (2013), “Action Plan for a competitive and sustainable steel industry in Europe”, p. 11.

⁸⁶ Fenton, M.D. (2004) “Iron and Steel Scrap”, U.S. Geological Survey Minerals Yearbook 2004, <<http://minerals.usgs.gov/minerals/pubs/commodity/iron & steel scrap/fescrmyb04.pdf>> 15.06.2014.

ore and coal price, which are in turn set by the global supply and demand balance. In Europe, although scrap prices have been higher than iron ore prices to reflect greater value, EAF costs have, on average, been lower than BOF costs, especially in weaker markets.⁸⁷ Scrap demand is derived demand, thus fluctuates with the demand for steel and ultimately for the final consumer goods made of steel, which are, in turn, highly income elastic (demand increases with income and is highly cyclical). Studies show that scrap demand is price-inelastic in the short run⁸⁸ but more price elastic in the longer run. Supply is also considered own-price inelastic. For new scrap, supply is predominantly determined by the current level of metal consumption. New scrap is easy and inexpensive to recycle, hence most of it tends to get recycled, and as a result the supply curve tends to be flat during low demand, although it becomes steeper as demand increases toward the supply constraint.⁸⁹

If EU scrap use as share of overall steel production would be strongly affected by scrap prices, we would expect high net scrap exports during high price periods, and low exports during low price periods; if one assume that foreign demand remains the same. However, net EU exports of scrap have steadily increased and show little correlation with scrap price. Thus scrap prices appear not to pose an immediate constraint to increasing European scrap use. This further argues against the use of export constraints on scrap to reduce scrap prices. Such export restrictions could instead reduce profits of the EU scrap sector, lead to loss of jobs and may also increase uncertainty for buyers of scrap internationally, and discouraging investment in EAF globally.⁹⁰

3.5.4. The role of EU electricity prices for scrap utilization

While electricity prices affect BOF producers only to a small extent – in part because BOF producers generate their own electricity from waste gases – electricity prices are the largest variable cost category for EAF producers. Hence, the access to a stable supply of low-cost electricity is a crucial locational factor for minimills⁹¹. That EU electricity prices are too high to favor EAF expansion was also expressed in interviews.⁹² Still others were relatively less concerned about electricity price, stating that the price of scrap will respond to changes of electricity prices.⁹³ Under the EU ETS and renewables programmes, few electricity-intensive industries have, so far, had to bear these costs, as most (but not all) Member States have placed the burden of paying for renewables onto retail consumers, whereas electro-intensive activities tend

⁸⁷ Laplace Conseil (2012). The future of steel: how will the industry evolve? Technical Report DSTI/SU/SC(2012)21, OECD Directorate for Science, Technology and Industry.

⁸⁸ Blomberg, J., Hellmer, S. (2000) "Short-run Demand and Supply Elasticities in the Western European Market for Secondary Aluminium", *Resources Policy*, Vol. 26, pp. 329-350.

⁸⁹ Söderholm, P. & Ejdemo, T. (2008) "Steel scrap markets in Europe and the USA" *Minerals & Energy - Raw Materials Report*, 23(2), pp. 57-73.

⁹⁰ Laplace Conseil (2012), "EAF and/or BOF. Which route is best for Europe?"

⁹¹ Egenhofer, C. et al (2013) „The Steel Industry in the European Union: Composition and drivers of energy prices and costs" *CEPS Special Report*, p. 8.

⁹² Interview with industry stakeholder.

⁹³ Interview with industry stakeholder.

to pay wholesale power prices.⁹⁴ State aid guidelines on renewables have been recently published, with exemptions for primary and secondary steel becoming more widely possible.

3.6. Summary: What can we learn from progress to date - and what is missing?

The discussion presented in this section identifies a number of relevant opportunities, drivers, and barriers linked to deeper decarbonisation of the European steel sector. Specifically, it outlines key potentials to reduce CO₂ emissions related to production technologies, to process technologies and downstream at the level of the final product. While some of these potentials are larger than others – for example, breakthrough technologies currently hold much greater potential for deep decarbonisation than further energy efficiency improvements (~10-15%) – each of these potentials are individually significant and justify further attention.

However, the main drivers of and barriers to emissions reductions vary among these different mitigation options. For example, improvements in energy efficiency through increased use of best available technologies require sufficiently short payback periods to compete with other company priorities. Improvements in process and material efficiency require greater engagement with customers than existing business models of European steel companies sometimes allow for. This in turn calls into question how business strategy and policy frameworks can help establish these links, how greater material efficiency be integrated with sectoral strategies for future competitiveness, and what opportunities and barriers climate and energy policy presents to the steel sector to developing these links.

Meanwhile, breakthrough innovations in ultra-low-carbon steel technologies require the development of longer-term planning by business and government, as well as more stable and secure medium term funding arrangements in order to overcome the “valley of death” problems that are currently inhibiting research programs such as ULCOS. They also require clearer signals from policy-makers that there is an economically viable model for the technologies to be integrated into EU steel making in the medium term. Current anti-leakage measures and weak carbon price from the EU ETS appear to not have yet provided a sufficiently credible framework.

As the main drivers and barriers are different in each of the key areas for abatement, policy settings for unlocking the potential in each of these areas will also need to be more holistic, nuanced and differentiated. For instance, carbon pricing and market-based instruments, while necessary to create a viable economic model for certain innovations and technologies, do not address all of the barriers relating to the different mitigation levers. Similarly, greater public funding for breakthrough

⁹⁴ Sartor, O., Colombier, M., Spencer, T., (2014) “Addressing industrial competitiveness concerns in the 2030 EU Climate and Energy Package”, IDDRI Policy Briefs, n°3, IDDRI, Paris, <<http://www.iddri.org/Publications/Addressing-industrial-competitiveness-concerns-in-the-2030-EU-Climate-and-Energy-Package>> 25.06.2014.

innovations such as CCS, while necessary, overlooks many mitigation potentials, not to mention the need to develop the economic conditions under which commercialization of such technologies is feasible. A mix of policies and approaches will therefore be required.

In the interest of further exploring the key elements which an effective and efficient policy mix would involve in the steel sector, the following section sets out a number of policy implications and recommendations based on the sectoral analysis presented above.

4. Policy implications

The preceding chapter highlights a number of issues for designing an effective climate and energy policy around the steel sector in the EU. These issues are perhaps best understood by examining the areas where possible synergies between climate policy and steel sector strategies may exist or diverge and which merit further investigation.

4.1. Strengthening the EU ETS

The EU ETS can play an important role in driving low-carbon investment by lending credibility to the EU energy and climate targets until 2020 and beyond, and by delivering a carbon price that makes more low-carbon options viable.⁹⁵ According to several executives interviewed, the EU ETS has not been a driver of low-carbon investments in the recent years.⁹⁶ Instead price increases of other inputs, like coal in 2010/11, have influenced investment in the modernisation of plants.⁹⁷ However, climate policy and CO₂ pricing, in particular, have been identified as crucial drivers for encouraging investment in breakthrough technologies promoted under ULCOS programme.⁹⁸

The decline of the carbon price, which remains at a low level, has however significantly reduced credibility of the EU ETS and virtually eliminated the incentives to invest in energy efficiency and breakthrough technologies created initially through the scheme. This has been broadly recognized and is the motivation for the backloading of allowance sales and the EU proposal of a market stability reserve after 2020. From the perspective of the steel sector a few principles are important:

- **Long-term perspective:** Capital intensive investments in the steel sector require long decision and investment periods, and need to ensure viable returns over more than a decade. Hence early clarity on longer-term perspectives is essential.

⁹⁵ Neuhoff, K. (2011). "Carbon Pricing for Low-Carbon Investment. Executive summary." Report prepared as part of the Carbon Pricing for Low Carbon Investment Project. Climate Strategies.

⁹⁶ Interview with industry stakeholder.

⁹⁷ Interview with industry stakeholder.

⁹⁸ Interview with industry stakeholder.

- **Carbon price:** Long-term carbon constraints will only obtain credibility and impact corporate choices if they today's carbon prices consistent with the long-term vision. Similarly, today's efficiency investments will not be only informed by expectation about long-term price developments but also be informed by current carbon prices.
- **Flexibility:** Technology opportunities are uncertain and hence it is impossible for the industry to commit or for government to prescribe a meaningful emission trajectory for the steel sector. This points to the value that the coverage of emissions across many sectors offers – it provides a credible commitment to an overall trajectory while offering flexibility to respond to technology developments at sector level.

4.2. Structural reform of leakage protection mechanism under the EU ETS

In a world of uneven climate policies, carbon pricing within the European Union raises concerns regarding the competitiveness of carbon intensive industry and of carbon leakage. When the EU ETS was developed the Kyoto Protocol gave confidence that similar approaches would be followed globally. For the transitional period, until convergence to a global carbon price happens, free allocation of allowances was designed to provide protection from carbon leakage. But instead of a global carbon price, national and regional policies combining regulation, investment funding and regional specific pricing are emerging. This requires a longer-term perspective on leakage protection mechanisms. In its resolution from January 2014 the European Parliament stressed that best performers should have no direct or indirect additional costs resulting from climate policies also post 2020. At the same time, it will be necessary to create a suitable economic framework for all mitigation options by:

- Creating extra margin for low-carbon production process with lower carbon cost.
- Creating market opportunities for low carbon substitutes.
- Creating incentives and business case for efficient use of steel use.

Against these objectives different options for a post 2020 approach can be identified:

- *Continuation of benchmark based allocation based on historic production volumes.* Different benchmarks would be defined for primary steel production and for recycling of steel in electric arc furnaces and. These benchmarks would be periodically updated. The EU Commission considers this approach in its impact assessment as a suitable tool.⁹⁹
- *Introduction of benchmark based allocation based on recent production volumes* instead of historic production volumes (also discussed as output based allocation or Dutch Ecofys proposal)

⁹⁹ European Commission (2014) "Commission Staff Working Document. Impact Assessment...", p. 113.

- *Consumption tax per tonne of steel consumed in the EU:* To reflect external costs of production of energy intensive commodities in consumption choices, a tax would be applied to consumption of steel and other energy intensive commodities, irrespective of production process or location.
- *Combination of output based allocation with inclusion of consumption in EU ETS.* All steel produced or imported in raw form or as part of products would be recorded and the transfer traced. A charge based on steel weight and benchmark emission rate would be levied by a climate action trust fund when steel is moved to consumption sphere, while no charge would apply for exported steel or steel containing products.
- *Inclusion of imports in EU ETS:* All imports would be charged a tariff based on the best available technology benchmark. Thus emitters could pass carbon costs to product prices without leakage risk and no free allowance allocation would be required.

Table 5 summarizes to what extent the different approaches create economic conditions to pursue the five types of mitigation options in the steel sector.

Table 5: How leakage protection mechanisms impact investments in low-carbon opportunities (excluding effect of use of revenue from allowance auction or tax).

| | Current | Output based (OB) | Consumption tax | OB & inclusion of consumption | Inclusion of imports |
|---|---------|-------------------|-----------------|-------------------------------|----------------------|
| Incentives for efficiency | + | ++ | | ++ | +++ |
| Framework for fuel switching | + | + | | ++ | ++ |
| Business case for break-through process | + | + | | +++ | +++ |
| Moving to higher value steel and efficient use | + | | +++ | +++ | +++ |
| Additional recycling incentives | | | | | +++ |
| Credible long-term leakage protection | + | ++ | ++ | +++ | +++ |
| Political challenge | | | -- | | -- |
| Administrative effort | -- | -- | -- | -- | -- |

Output based allocation: Replacing the current allocation method that is based on historic production volumes by an allocation based output measurements for example in the preceding year would help to avoid large surplus allocations and resulting distortions between companies. Linking the free allocation to each unit of production rather than to the continuation of production at an installation level would also improve protection against operational leakage. For investors uncertainties remain about future leakage protection because of the potential conflict between allocation at full benchmark level corresponding to cover all emissions and reduced availability of allowances under a shrinking cap.

A Consumption tax could be levied on steel products when purchased by European consumers, irrespective of the steel's origin. If this would replace the coverage of the respective sectors under the EU ETS, it would create incentives for a shift to higher value steel products that have lower weight and thus fewer taxes. A similar measure would have to be applied also to competing commodities like cement, aluminium and copper in order to avoid product choice distortions. However, the consumption tax would, on its own, not encourage upstream emission reductions, e.g. efficiency improvements, but it also would also not create any leakage risk.

Combination of output based allocation with an Inclusion of Consumption of steel (and competing commodities) in the EU ETS. Firstly producers of steel would remain within the EU ETS and receive free allocation of allowances based on recent production volumes and a best available technology benchmark.

Secondly, the application of the EU ETS would be extended to carbon embedded in consumed goods. As the participation of each consumer in the trading scheme would not be feasible, an indirect consumption-based charge¹⁰⁰ would be added to the emission trading directive, which reflects the carbon embedded in the consumed goods. The charge would be assigned to national trust funds at the time of the release of the product for consumption within the territory of the European Union, irrespective of the origin of the product. A product not released for consumption within the territory of the community but destined for export would not bear the charge.

A direct link to the EU ETS would be established by linking the charge to the EU ETS allowance price, applying the same emission benchmark used in EU ETS for free allowance allocation for steel producers and by using part of the money raised through the charge for the acquisition of allowances.

The number of allowances acquired and retired by the trusts would reflect the carbon embedded in European Union consumption that is not already covered by allowances surrendered by producers or embedded in exported steel products. The remaining funds reflect revenue that would have been raised through auctions of allowances, had they not have been allocated for free at the upstream level. Thus it should be – in line with the earmarking envisaged in the EU ETS directive – used for climate action, including low-carbon technology development.

The combination of both components creates incentives for emission reductions both upstream (efficiency) and downstream (higher value steel). It would also be a basis for a credible business case for CCS technologies. Free allowance allocation on its own, in principle, already provides surplus allowances that can be sold to cover incremental costs of carbon capture and sequestration. But these allowances need to be sold to emitters in other sectors. While costs of products in other sectors increase, the price of steel would be cross-subsidised and stay constant. This creates distortions in product choices and would likely trigger significant political opposition, reduce the regulatory credibility of the system, and thus does not constitute a robust

¹⁰⁰ In comparison to a tax, a parafiscal charge is not given to the national budget and not usable for general government expenditures. Moreover, a parafiscal charge does not require unanimous agreement of all EU member states.

investment framework. Inclusion of Consumption of steel in the EU ETS ensures that steel consumers bear the charge for the carbon cost of steel and would thus avoid such distortions.

Inclusion of imports and exports of steel in EU ETS (or border levelling) would be combined with full auctioning of allowances to European installations. This creates incentives and fair cost allocation for all mitigation options. If also applied to scrap, it would lead to higher scrap prices in the EU and can thus also provide incentives to increase recycling rates. Generally, under the WTO border levelling must ensure the national treatment requirement set under Art. III GATT is met, meaning, that there is no discrimination against imported products. Furthermore, any border levelling must demonstrate that the measures have been implemented to achieve a specific purpose, such as climate protection, in the least trade restrictive manner.¹⁰¹ Hence, trust building measures and at least informal international cooperation would have to complement the approach.

4.2.1. The opportunities and constraints of the different options

Consumption tax on steel is politically very challenging because the Treaties of the European Union (TFEU) require unanimous decision in the Council for “provisions primarily of a fiscal nature” (Art. 192 para 2 lit. a TFEU). This voting rule was in the 1990s one major reason for the failure of the Commission’s proposal to introduce a carbon tax. Also, inclusion of imports or other border related measures are politically challenging. While it could arguably be implemented without disadvantaging foreign producers and without violating WTO requirements, developed countries have a bad track-record of discriminating against poorer countries with border measures. Thus border levelling may reduce trust between countries, affecting prospects for future international climate cooperation. Trust building measures and international cooperation would have to complement the approach.

Administrative requirements would increase with any shift from the current mechanism, both because allocation decisions of allowances are more frequent and because steel containing products would need to be traced. However, there is a trade-off between the additional administrative work required and the strength of the new incentives that would be created for innovation and decarbonisation. The key question is therefore whether this trade off is reasonable after weighing up the costs (administration) and benefits (incentives). Experience with measures that place charges on the consumption of products in other sectors such as tobacco and alcohol suggest that such approaches are not unduly administratively burdensome for participants once they are in place. Nevertheless, for consumption taxes, inclusion of consumption and inclusion of imports, a *de-minimis* threshold would be defined such that only products where steel is a significant share of the value are covered. The

¹⁰¹ See for example Susanne Dröge et al., Tackling Leakage in a World of Unequal Carbon Prices, Climate Strategies 2009; Roland Ismer and Karsten Neuhoff, Border tax adjustment: a feasible way to support stringent emission trading, Eur J Law Econ (2007) 24.

benefit of the mechanism that delivers a full carbon price across the value chain is the reduction of administrative complexity linked to the large distributional implications that have dominated the political process of determining benchmarks and cross-sectoral adjustment factors for free allowance allocation under EU ETS:

Furthermore, the consumption approaches can provide co-benefits in the form of additional information about and attention by decision makers on carbon embodied in products.

In summary, our analysis points to significant benefits – albeit at some additional administrative costs – of combining an output based allocation with inclusion of consumption of steel in EU ETS. Hence we now summarize additional analysis of legal and administrative aspects of this option, with further detail provided in an accompanying working paper.

4.2.2. Political and legal aspects of output based allocation with inclusion of consumption

Unlike border levelling and consumption based taxes, Inclusion of Consumption is compatible with the current European political debate. Being designed as an indirect consumption-based charge and following the principle of destination, the approach is internationally neutral, non-discriminatory and in line with the national treatment requirement set under World Trade Law. Steel, irrespective of its origin is subject to the same charge.

In addition, the approach does not constitute “provisions primarily of a fiscal nature.” Such provisions comprise of taxes that can be easily adjusted by governments and contribute to the general fiscal budgets, but require unanimous support. In contrast, parafiscal charges have the following features: earmarking of revenues; assigned to a body governed by public law; and no inflow to the national budget. According to European law, parafiscal charges can be based on Art. 192 para 1 TFEU and implemented with a qualified majority rather than a unanimous vote.

European Court of Justice decisions provide evidence that the Inclusion of Consumption should not be considered “provisions primarily of a fiscal nature” but rather non-fiscal in nature. For example, in its ATA decision, the European Court of Justice ruled that the inclusion of aviation into the EU ETS “is not intended to generate revenue for the public authorities, does not in any way enable the establishment, applying a basis of assessment and a rate defined in advance, of an amount that must be payable...” and thus does not give rise to a tax, fee, charge or duty.¹⁰² These findings of the Court can be generalized and applied to the EU ETS as a whole. Hence, the inclusion of consumption into the EU ETS by itself would be qualified as not being fiscal in nature. Accordingly, it could be implemented through majority, rather than unanimous, voting.

¹⁰² European Court of Justice (2011) “Case C-366/10 ATA v Secretary of State for Energy and Climate Change”, para 143.

This result should not be expected to change if consumers, retailers or wholesalers are, on grounds of feasibility, not directly included in the EU ETS. This is because the charge payable to the trust funds is a parafiscal charge not a tax. First, the income raised is not assigned to national budgets but to national trust funds (bodies governed by public law). Second, the money raised is used for the acquisition of allowances and for climate action. Third, the charge imposed is only implemented to make the overall emission trading mechanism effective and feasible. Finally, several aspects result in a close linkage to the environmental regulation EU ETS – the (variable) carbon price, the use of revenue to retire allowances for net-imports of embedded carbon, and the integration with the leakage protection mechanism under the EU ETS.

4.2.2.1. Administering the Inclusion of Consumption

Consumption charges are not new. Charges on tobacco, alcohol and fuel are long established, widely implemented consumption charges, which provide excellent insights as to how a carbon based consumption charge can be implemented, administered and controlled. In recognition of this, the European excise administration and control system has been assessed, to understand what insights can be drawn for administering the Inclusion of Consumption. The research was informed via case studies with businesses that produce excisable goods as well as interviews with public authorities, academics and excise administration experts. Importantly, the intent is not to design an all-encompassing administrative framework, but rather to demonstrate how such a system may function.

Drawing on experience from excise, administering the inclusion of consumption should meet the following requirements:

- allow duty suspension arrangements;
- a system of licencing and registration;
- monitoring, reporting and verification;
- allow for exemptions; and
- compliance and enforcement efforts.

These issues are briefly discussed in the following sections.

4.2.2.2. Duty suspension arrangements

Under existing European consumption charge schemes, the liability is created when a good is produced or imported.¹⁰³ However, the charge is only due at the time, and in the Member State, that the good is released for consumption. As long as no release

¹⁰³ See Art. 2 of Directive 2008/118/EC and Art. 7 para 1 of Directive 2008/118/EC for excise arrangements within the European Union.

for consumption has taken place, excise is not due. Such provisions were considered highly valuable by industry experts and participants. Specifically, those entities that are involved in the production but not distribution of goods or produce goods for the external market avoid the need to pay excise duties in advance. In addition, for those entities that do participate in the excise scheme, deferred payment allows for the management of cash flows over the reporting period.

4.2.2.3. Licensing and registration

Duty suspension requires those entities dealing in the production, transportation and storage of goods to be licenced. Licensing and registration is necessary to ensure that mechanisms are in place to control the stock and movement of goods, to avoid tax evasion, and to differentiate between the consumption and production spheres. Under the European excise scheme, European legislation only lays down a limited range of requirements and leaves discretion up to Member States to establish additional conditions necessary for licencing purposes. However, drawing on experience with the excise approach, common licencing requirements include:

- the creation and maintenance of business records to a specific standard;
- full access of the relevant agency to business records, the licenced premise, or other relevant business apparatus;
- notification of changes to business activities or structure; and
- lodgement of a form of security related to the size of the liability.¹⁰⁴

Furthermore, under the excise approach, all registered entities receive an individual excise registration number that is stored in an open access electronic database. This database is made available to all participants of the excise scheme in order to gain information about the status of trade partners and check whether excise goods can be moved under suspension arrangements.

Discussions with stakeholders revealed a number of key lessons with regards to the licencing and registration procedures within the excise sector. Firstly, registration and licensing are a systemic necessity to ensure the effective control of consumption charges. However, the requirements, which have to be met for registration purposes, should not be overly onerous. As a general rule, striking this balance requires stricter licencing requirements for those entities which produce or manage larger liabilities. Furthermore, access to assistance in completing the registration process, either through online forms, helps desks, tutorials etc., can reduce the administrative cost of licencing for smaller businesses.

¹⁰⁴ Preece, R. (2008) "Key Controls in the Administration of Excise Duties", *World Customs Journal*, Vol. 2 No. 1.

4.2.2.4. Monitoring, reporting and verification

The aim of reporting is to ensure that the created liabilities appear correctly in the licensee's records. This requires tracking the liability as it moves through registered participants at each stage of the supply chain.

Within the excise sector, monitoring of movement is done via IT based reporting systems, which essentially introduces an electronic form of double bookkeeping. Such an approach has proven to be effective and has gained acceptance from industry. Applied to the Inclusion of Consumption, it would first be necessary to establish a European wide database similar to SEED, which contains all licenced entities in the scheme. A unique carbon identification number would be assigned to each licenced entity. The creation and movement of goods by or between entities is then tracked and liabilities deducted or added to the license's accounts. Being electronic, transactions can be monitored by the relevant authority with discrepancies highlighted and investigated.

Steel movement as it enters and departs registered entities and stocks are recorded electronically, such that the liability can easily be calculated at the end of the reporting period. These records are then audited periodically by the relevant authorities. If any discrepancies are detected, then appropriate action is taken.

Recording on production levels, sales and transportation of goods are an essential component of long established protocols. Therefore, it appears as though reporting requirements in many cases are only marginally additional to those activities already carried out under standard business reporting. Hence, in developing a consumption charge, reporting arrangements should align to or build on existing practices.

4.2.2.5. Exemptions

The *de minimis* principle reflects a trade-off between losses in economic efficiency from preferential treatment of low value goods and gains in economic efficiency from reducing the administrative and compliance costs for governments and business. Within excise, *de minimis* thresholds have proven an effective means of avoiding high administrative costs associated with the control of small liabilities. *De minimis* can be applied to outright exemptions, reduced licencing requirements, and reduced reporting procedures. Therefore, under the proposed Inclusion of Consumption scheme, following the example provided by European Excise, *de minimis* thresholds should be considered to ensure a balance between scheme coverage and administrative cost.

4.2.2.6. Compliance and enforcement efforts

For a number of reasons, higher compliance rates could be expected with the Inclusion of Consumption compared to other consumption based charges. Firstly, unlike excise goods, the consumption charge would only make up a minor proportion of the final value of the steel product. Secondly, as the charge would largely be determined by the carbon price, it would be consistent across states. Hence, there would not be the incentive for illegal movement of goods between member states to exploit excise rate differences. That said, policies are only effective when correctly administered and enforced. The relevant authority, working with the industry, would need to find an enforcement strategy that increases compliance without excessive costs.

4.3. Strengthening interactions between producers and consumers

Materials play a key role in low-carbon transformations. Therefore progress on the design and use of materials creates opportunities for the steel sector to serve new, innovative and high value product markets. To unlock these opportunities, it is essential that the links between producers and consumers are strengthened through information and regulation. Since not all steel customer requirements are alike, approaches will need to vary depending on the downstream sector being engaged.

4.3.1. Sharing information about environmental performance

Engaging final consumers can create demand that facilitates innovation and diffusion of new products linked to carbon intensive commodities, as well as contributes to improvements of recycling rates. Both the decisions of private actors (see section on consumer engagement) and the design of regulation depends on information. Therefore, the availability, quality, and credibility of information are essential. So far consumers have very limited awareness and information about life-cycle emissions and environmental performance of commodities. This inhibits not only the opportunity to develop lead markets for progressive consumers that value and are prepared to pay more for low-carbon options but it also reduces the capacity of companies, e.g. under Corporate Social Responsibility principles, and of public and private buyers to single out products with particularly bad life-cycle performance.

Better engagement of consumers, in example through labels informing about carbon footprints, can provide the necessary information and trigger awareness. Of particular concern in the steel sector is that for a comparison across different products, all stages of the life-cycle (including the high rate and low environmental impact of recycling at the end of life) should be considered. Such comprehensive information should also be the basis for the design of regulatory requirements. The multitude of different labels limits comparability, hence standardisation efforts are important.

4.3.2. Creating a shared perspective on technology development

In the transport sector, past examples, such as the ULSAB project of the 1990s-2000s, as well as the recent introduction of the new CAFE standards in the United States, show the strong potential of regulation on downstream customers to drive coordination between steel and auto producers in order to achieve greater material and CO2 efficiency. Moreover, the results of the Future Steel Vehicle program recently carried out by World Auto Steel suggest that significant further potential exists to increase material efficiency in the auto sector.

In the buildings and construction sector it is unlikely that individual construction firms – which are often small companies – will have the institutional capacity to perform life-cycle assessments on their construction. In addition, given the innate conservatism of the construction industry in adopting new and “unproven” products, the arrival of new “higher value” steel products on the market would take time to be accepted.

A fragmented value chain and many small actors have limited exploration of improvement and innovation opportunities. A shared platform on the use of materials in construction sector might create an opportunity to replicate the success in the automotive sector and could draw on earlier experience, like e.g. of British steel’s efforts to increase the proportion of large beams instead of re-bar in construction.

4.3.3. The role of regulation

Regulations and standards will be decisive for the ability of the steel sector to realize low-carbon opportunities. They can incentivize progress and facilitate the provision of information to private and public decision makers, but they equally can create barriers to change if not well designed.

Existing standards and regulations that set minimum rather than target requirements and thus lock-in current practices often constitute a barrier for progress. This is part of the explanation of why the construction sector’s use of steel for structural purposes has not changed significantly over the last decades. In many applications generous steel use is less expensive than investing in tailored design and quality control.

The situation in the automotive industry looks very different. There most progress has been achieved with innovative high strength steel and forming techniques, which led to 30-40% savings in body weight.¹⁰⁵ The main drivers of the development were fuel efficiency standards that require lower weight cars and competition with lower weight materials, especially aluminium.¹⁰⁶

¹⁰⁵ Zuidema, B.K.

¹⁰⁶ As noted earlier, approaches to reducing material-related emissions from transport will require moving beyond a focus on tail-pipe emissions. Such approaches risk creating distortive signals regarding CO2 emissions on a life cycle basis. At present, all large EU auto companies perform life cycle analysis of the CO2 footprint of their vehicles. However, under a free allocation system – even

It is an open question of whether and how this experience could be translated to other sectors. For example, in the construction sector, better tailoring steel beam specifications to maximum loads represents a shift from volume to weight, and thus also reduces carbon emissions that are, in first order, linked to volume. This approach requires that steel companies produce beams that closer match load specifications. At present, it is often not considered economical to do so, since beams are often commodity products. However, stronger regulation concerning material use in the building sector may be one option to force greater process innovation within the EU steel sector in order to adapt their models to allow for more interaction between consumers demands and steel company output. In principle, such regulations could also create advantages in the commodity steel space for the European steel industry, insofar as it would create a leading market for new tailor-made steel beams, in which it would benefit from first mover advantage.

As an alternative to requirements limiting the material use, existing regulation on rebar strength standards could be updated with either higher strength and/or mandating use of large beams. The latter option has already been pursued by the British government. Carruth et al estimate that globally up to 51 Mt steel, which is around 3% of world's annual production, could be saved globally by increasing steel strengths to >500 MPa.¹⁰⁷

Economy wide decarbonization objectives also require more structural decarbonization of the transport sector, including large-scale electrification of the vehicle fleet. Such developments create opportunities for the steel sector to serve the new demand for new and higher value added steel products. Specific targets for electric, hybrid and fuel efficient vehicle penetration, supported by credible policy frameworks, could provide investment visibility and thus mobilize the sector and provide focal points around which actors can plan. A stronger push on the transformation of transport infrastructure in the EU to accommodate low-carbon vehicles could therefore provide European steel-making industry with new market opportunities and support it in continuing with the transforming its business model from low value-added (and increasingly uncompetitive products) to higher value, tailor-made steel products.

In the coming decades the demand for high quality (pure) scrap will increase, because increasing scrap volumes reduces the use of primary steel that would otherwise provide high quality material. It is unlikely that private decision makers will consider this in today's design of products and buildings unless mandated. Requirements on – for example – proper grading of steel and design that facilitates

with inclusion of consumption (cf. above) – there will be little to no economic incentive for car manufacturers to reduce material consumption in order to reduce costs. Obligating car manufacturers to produce cars with minimum CO₂ emissions on a life cycle basis via regulations may ultimately be too challenging and administratively intensive. However, an intermediate solution, which consisted of obligating car manufacturers to pass on information via labeling to consumers about the life cycle emissions of different cars may be a second best approach while life cycle analyses are improved. Certain technical barriers – such as the treatment of recycled material – need not be resolved fully in order for such information to be useful and sufficiently reliable.

¹⁰⁷ Carruth et al (2011).

separation of steel at the end of product or construction life should therefore be explored.

4.4. Financial support for innovation

Investment in product and process innovation has very different features with respect to scale of investment required and timeframe over which new technologies are commercially applicable. Hence also the financial requirements vary significantly especially between investment in product innovation and process innovation.

4.4.1. Product innovation

As discussed in previous sections, through close interactions with steel consumers, the steel sector can be more active and successful in product innovation like higher strength steel in circumstances with corresponding customer demand. In the automotive sector such demand had been created through fuel efficiency regulation. In other steel applications, like for example in the building sector, steel product innovation is low and concerns mainly materials for building surfaces as opposed to structural use. This reflects a combination of a lack of interactions with customers and limited capacity of the construction sector to participate and invest in innovation. Hence in sectors like the construction sector additional financial support for innovative low-carbon products might be warranted. It will still be important to ensure that any such support is targeted toward current or emerging consumer needs and preferably be industry led.

4.4.2. Process innovation

Process innovation is facing a very different situation. Innovative production processes for low-carbon steel are delivering a product of similar quality. Hence innovation is unlikely to be led by changing demand and there might instead be a stronger role for public policy to structure the innovation process. Replacing current BOF processes with alternative low carbon technologies processes requires a strategy for three consecutive steps of technology development: (i) funding for demonstration projects at increasing scale, (ii) risks sharing for maturing of commercial scale processes, and (iii) business case for large scale use of (successful) technology.

4.4.2.1. Funding for demonstration projects at increasing scale

While significant public R&D funding goes to the steel sector, few public resources are dedicated to *process innovation in the EU steel industry*. Given the expected timeframe from one to two decades between invention and commercial roll out, large potential

for technology spill-over in engineering technologies, and in addition the currently challenging financial situation of the EU steel industry, most financial resources have to come from the public sector.

There is a need for *sustained* public funding of process innovation to transform ideas into industrial reality. For steel technologies the scale of efficient processes is huge, requiring increasing scale demonstration processes with corresponding scales of financial requirements. This requires a clear policy strategy to secure funding at a scale that will increase significantly with an increasing scale of investment in breakthrough technologies and will require commitment on continuity. Especially the latter factor needs to be underlined. The EU and member states already fund R&D in the steel industry but this money achieves little. Radical process innovations take years to develop, particularly in an extremely large scale and capital intensive industry such as steel. Instead of the current R&D program Horizon 2020, a longer-term oriented program would be necessary that would provide investment perspectives particularly in line with technology development time-frames. Currently funding is provided ad-hoc, project-per-project, and there is a constant risk that the funding stops, threatening the life of the project as it would then have to compete for corporate resources with other projects that have immediate effects on the business.

Technological progress should be a key criterion for public funding of R&D and lack of progress should lead to project termination. Long-term solutions are necessary but most of the potential solutions of today will fail for technological or commercial reasons. Creating an innovation funnel and a stage-gate innovation process could be an answer to this problem. Stage-gate processes are in ample use in industry to manage R&D portfolios. It has the key advantage that the best options can be selected incrementally over time: in the development from laboratory idea to full scale commercial technology, clear conditions are set periodically and in sync with the particular phase in the innovation process so that the options with low chance of success can be weeded out. The process can be organized as a form of open innovation, explicitly sourcing ideas from outside of the industry, and monitored by industry executives, academics and policy makers - very similar as to how EU funding for *product* innovation in the steel industry currently works. Organizing a stage gate process, however, focuses innovation funding on reducing CO2 emissions, and in such a way that this issue might actually be tackled.

Currently, only the Risk Sharing Financing Facility of the EIB and the NER300 program is able to provide financing at the necessary scale. The Risk Sharing Facility, however, is a debt driven program and the money provided must be paid back with interest. The conditions of the NER300 program also make it unattractive for innovation. Changing the conditions of NER300, however, could create an innovation credit facility for cutting CO2 emissions: when a project is *successful*, part or the benefit from the new technology, or part of the funding would have to be paid back over a period of time. The risk of failure is shouldered by the EU - a condition that would trigger more R&D in the steel industry.

4.4.2.2. Risks sharing for maturing of commercial scale processes

Assuming that by the early 2020s demonstration plants have reached commercial scale, the commercial application of a low-carbon production process will still face a set of risks compared to the established technologies with long track record. The risks are particularly large because blast furnaces are not modular – which would allow for gradual replacement – but are so large that typically only one to three furnaces are located on the premises of a large steel mill. If a furnace will not deliver the envisaged slab volumes, this can jeopardize the entire value chain. The scale of furnaces is matched by their capital intensity. Hence the business case for the investment in a low-carbon steel furnace would likely require that an existing furnace is at the stage of large-scale re-investment or replacement.

If the risks associated with investing in a maturing process technology rests fully with the steel company, then investors might invest in the traditional technology. The traditional technology would involve less technology risks, and even regulatory risks might be limited as long as absence of large scale demonstration of a new technology will inhibit regulators to significantly tighten environmental regulation.

This points to the need or an integrated approach to risk management and competition policy to overcome market entry barriers for a new technologies. They are particularly challenging for a sector in which incumbent integrated steel makers, rather than new entrants, are the likely investors in new technologies. Therefore the policy framework to support early investors in commercial scale low-carbon steel making is necessary. This might be addressed through risk sharing arrangements that reduce the risk or costs for the steel makers that deploy the initial low-carbon steel production. The concept of an *innovation credit facility* offers a promising perspective; as argued above, the NER300 program could be adapted as such.

4.4.2.3. Business case for large scale use of successful technology.

Without credible long-term business case for technology, companies will not devote the necessary attention and resources to a break-through technology. This points to the importance of early clarity and stringency of the EU ETS and the leakage protection strategy.

5. Summary: A vision for the industry?

The European steel industry is currently struggling with surplus capacity and low margins – also creating risks of limited re-investment and discontinued improvement of existing facilities. This can create the risk of a downward spiral – without investments, the efficiency of European installation falls behind global competitors, reducing the competitiveness and capacity to invest and innovate. As bulk producers of large volumes with limited value added, the European steel sector with limited coal and iron ore resource base cannot compete.

The European steel industry therefore has to become highly energy efficient and innovative to have a future. It will therefore be important for the sector to develop a positive perspective so as to attract investment and remain among the technology leaders. The low-carbon transformation of the economy offers such a positive perspective for the sector. Materials are at the core of the low-carbon transition – and their progress requires a dynamic industry that attracts young talent to realize the vision of less materials and more value added. Thus it can not only contribute to environmental but also to economical sustainability of the sector. Preparing a low-carbon roadmap for the industry could become a starting point for an industry vision and allow for the development of a joint strategy to unlock portfolio of mitigation opportunities.

Cutting emissions from the steel sector is difficult – so the focus of the further development of the roadmap should be on all the opportunities that are linked to reducing emissions from the use of materials – and not just on process emissions. Ultimately it will require both effective policy and forward looking and innovative companies to translate any such roadmap into tangible investment and innovation.

Climate policy can provide such a focal point for the European steel sector. It covers a territory large enough to host and finance demonstration projects, it has a well-defined objective to provide clear guidance and visibility, and it has a shared motivation that facilitates cooperation across EU member states and beyond – rather than risking a purely nationalistic focus that is sometimes driving industrial policy.

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