Horizon 2020 Societal challenge 5: Climate action, environment, resource efficiency and raw materials

PUTTING INDUSTRIAL TRANSFORMATION AT THE HEART OF THE EUROPEAN GREEN DEAL

Objective: Making the case for a comprehensive EU Industrial Decarbonization Mission based on key project results related to the decarbonization of heavy industries, in particular steel making.

POLICY PAPER

NOVEMBER 2019

KEY MESSAGES

◗ Decarbonization of emission intensive industries is a key challenge for achieving the objectives of the Paris Agreement, both for the EU and globally. The European Commission should include an 'Industrial Decarbonization Mission' under the European Green Deal.

◗ A coherent industrial decarbonization strategy should provide long-term clarity for the direction of innovation, integrate different policy priorities, use the full range of innovation instruments and coordinate among different governance levels.

◗ A transnational steel sector decarbonization club could help the EU achieve several objectives at a time: advance domestic decarbonization and renew its role as a leader in international climate diplomacy. A club could also be an ideal testbed to pilot the introduction of border carbon adjustments.

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A "European Green Deal" is at the core of the new European Commission's political agenda and will define and shape policy making in the coming legislative period of the European Parliament. Ursula von der Leyen, President of the European Commission for the 2019-2024 period, has called for Europe to become the first climate-neutral continent. She aims to achieve this by, *inter alia*, extending the EU Emissions Trading System (EU ETS), and introduce Border Carbon Adjustments (BCAs) to enable more stringent domestic climate policies whilst reducing the risk of carbon leakage, whereby industries relocate to jurisdictions with fewer or less stringent regulatory requirements and associated costs, to maintain cost competitiveness.

Institutionally, this is to be achieved by placing the various policy pillars contributing to this broad mission under the auspices of the Executive Vice-President for the European Green Deal, Frans Timmermans. Also von der Leyen's mission letter to the Commissioner for the internal market contains a clear mandate that "all parts of European industry should contribute fully to

This Policy Paper draws on the following reports

- Rayner, Tim, Sebastian Oberthür, Lukas Hermwille, Gauri Khandekar, Wolfgang Obergassel, Bianca Kretschmer, Tomas Wyns, et al. 2018. 'Evaluating the Adequacy of the Outcome of COP21 in the Context of the Development of the Broader International Climate Regime Complex'. Deliverable 4.2. COP21 RIPPLES Project (Horizon2020). *https://www.cop21ripples.eu/wp-content/uploads/2018/07/RIPPLES_D4.2-Final.pdf*.
- Wyns, Tomas, Gauri Khandekar, and Lisanne Groen. 2019. 'International Technology and Innovation Governance for Addressing Climate Change: Options for the EU'. Deliverable D4.3b. COP21 RIPPLES Project (Horizon2020). *https://www.cop21ripples.eu/resources/deliverable-4-3/*.
- Hermwille, Lukas. 2019. 'Exploring the Prospects for a Sectoral Decarbonization Club in the Steel Industry'. Deliverable D4.3d. COP21 RIPPLES Project (Horizon2020). *https://www.cop21ripples.eu/resources/deliverable-4-3/*.
- Parrado, Ramiro, Maciej Bukowski, and Aleksander Śniegocki. 2019. 'Report on Competitiveness, Trade, and Industrial Implications of the INDCs and 2°C /1.5°C Mitigation Pathways'. Deliverable 3.4. Paris: COP21 RIPPLES Project (Horizon2020). *https://www.cop21ripples.eu/resources/deliverable-3-4/*.
- Sluisveld, Mariësse van, Harmen-Sytze de Boer, Andries Hof, Detlef van Vuuren, Clemens Schneider, and Stefan Lechtenböhmer. 2018. 'EU Decarbonisation Scenarios for Industry'. Deliverable 4.2. The Hague, Wuppertal: REINVENT Project (Horizon 2020). *https://www.reinvent-project.eu/s/D42-EU-decarbonisation-scenarios-for-industry.pdf*.
- Lechtenböhmer, Stefan, Clemens Schneider, Valentin Vogl, and Cordelia Pätz. 2018. 'Climate Innovations in the Steel Industry'. Deliverable 2.2. Wuppertal, Lund: REINVENT Project (Horizon 2020). *https://www.reinvent-project.eu/s/D22-Climate-innovations-in-the-steel-industry.pdf*.

the objective of a climate-neutral economy by 2050" and including a requirement to establish a 'Circular Economy Action Plan' as part of the Commission's general industrial strategy. Yet, curiously, **a coherent mission for industry decarbonization is not part of the European Green Deal portfolio.**

Drawing on research from the EU Horizon 2020 funded COP21 RIPPLES research project, as well as adjacent research activities of the consortium partners, this Policy Brief argues why **industrial transformation is at the heart of the decarbonization challenge, and must be addressed with a coherent and ambitious industrial policy and innovation strategy.** The Brief specifically outlines how the EU can support the transformation of emission-intensive industry[1] through **effective technology, innovation and infrastructure governance as well as enhanced international cooperation,** thereby addressing several priorities of the new European Commission simultaneously including the decarbonization of the domestic industry as well as achieving renewed leadership in international climate diplomacy.

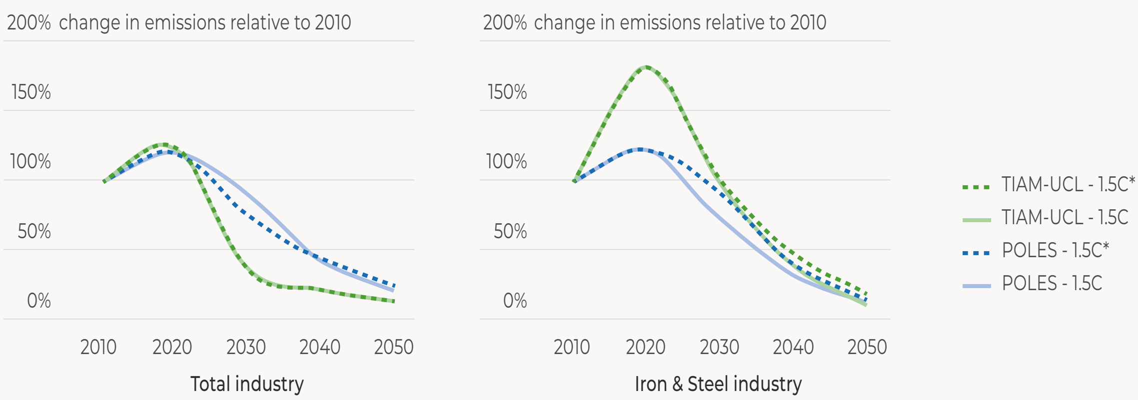
1 In this Brief we focus on the iron and steel sector, but most of the findings and recommendations are similarly applicable to other emission-intensive industries in Europe.

Outlining the Transformation Challenge

Achieving deep decarbonization in the industrial sector is a daunting challenge, as reliable and scalable low-carbon production processes are not yet commercially available. Modelling results from the COP21 RIPPLES project shows that by 2050, CO_2 emissions from global industrial energy consumption must reduce by 77%-87%, below 2010 levels. For the iron and steel sector, this value is 82%-89% for direct CO_2 emissions from energy consumption (see **Figure 1** below). Indeed, von der Leyen has stated that "all parts of European industry should contribute fully to the objective of a climate-neutral economy by 2050". In practice, this means that **conventional CO_2-emitting primary steel production must be phased out altogether by 2050. This means that no new investments in conventional blast furnaces should be made after 2030.**

But what are the main barriers and challenges to decarbonization in the sector? According to COP21 RIPPLES research, the main, inter-related

Figure 1. Global emission pathways (relative to 2010 levels) for total industry and iron & steel industry for various Paris-compatible scenarios developed under the COP21 RIPPLES project



Note: Total industry comprises all CO_2 emissions. Iron & Steel comprises energy-related CO_2 emissions ex-cluding emissions from electricity generation. 1.5C scenarios feature reduced energy demand.*

Source: Wuppertal Institute, COP21 RIPPLES.

impediments for deep decarbonisation of emission intensive industries are:

- ***Technological inertia and R&D mismatch:*** Large production installations mostly see incremental improvements in energy efficiency and CO_2 intensity. Since basic material production sectors use large (and costly) process installations the investment cycles are long. This prevents an accelerated take-up of new breakthrough technologies. Furthermore, the basic materials industries (with the exception of chemicals) exhibit low R&D expenditure compared to their revenues in comparison to other industrial sectors.

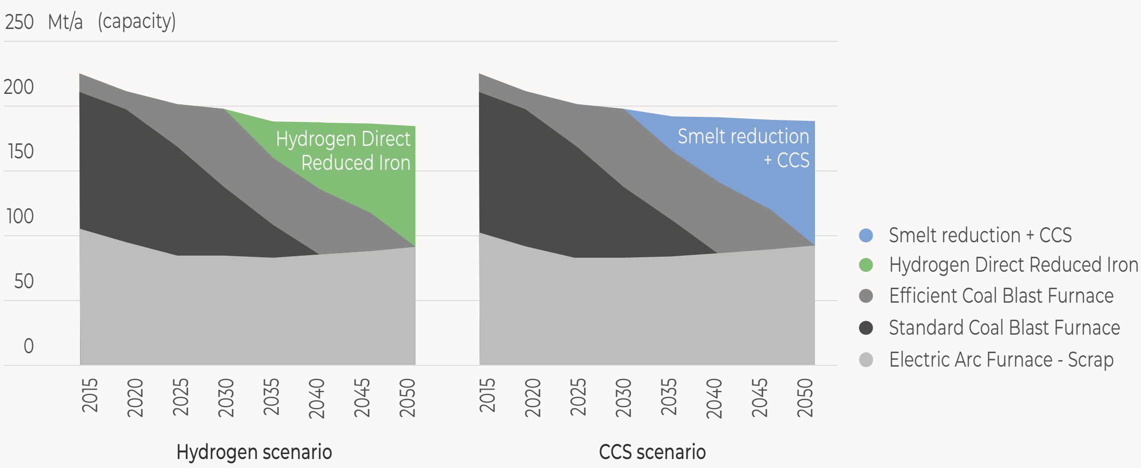
- ***High CAPEX and technology risk of new breakthrough process technologies:*** Further to the above, large-scale pilot and demonstration of a new technology, the final steps towards commercialisation, requires substantial capital expenditure, with significant uncertainty around the eventual technical or economic viability of the technology.

- ***Differentiated requirements and competitiveness concerns:*** Across the world large parts of the industrial sectors oppose stringent mitigation policies that would increase production costs. Incumbent producers fear that a high(er) price on CO_2 emissions in one jurisdiction (such as the EU) would, in the absence of similar measures elsewhere, lead to so called 'investment leakage', where sectors invest in new production plants in jurisdictions where productions costs are lower.

- ***Global complex value chains:*** Deep decarbonisation in industrial sectors will require attention across global value and supply chains, from low- and near? zero-emission production processes, through end-use efficiency and material recycling. However, with policy to encourage these actions instituted largely at national level (and in some cases at the supranational level, in the EU), a coherent approach across global value and supply chains requires a highly co-ordinated effort across jurisdictions.

Above and beyond these challenges, deep decarbonization of the steel industry comprises a massive infrastructure challenge. By 2030 significant new infrastructure needs to be in place to enable the use of low- and zero-emission primary steelmaking technologies. Modelling results from the REINVENT project demonstrate that

Figure 2. Projected technologies in steel making. Modelling results from the WISEE model with hydrogen scenario and CCS scenario developed under the REINVENT project



Sources: Wuppertal Institute, REINVENT project.

in order to decarbonize, a significant amount of production capacity will have to be converted to either the large-scale application of carbon capture technology or hydrogen-based steel making (see **Figure 2**). Each of these technologies requires not only massive investments in new production plants but also the enabling infrastructure. Currently, neither hydrogen nor CCS infrastructure is anywhere near where it needs to be to enable the large-scale application of those technologies. Planning and building the required infrastructure may take decades in many cases. Therefore, for the EU to maintain a steel industry compatible with its aim of climate-neutrality by 2050, **planning and investing in the required hydrogen and CCS infrastructure is a matter of urgency.** Such infrastructure developments could take advantage of existing (natural gas) infrastructures near industrial clusters. E.g. North-West European steel and other industrial clusters are partly located close to the shore with short distance to potential carbon storage sites in depleted offshore gas fields. In this region there will also be natural gas pipelines becoming obsolete in the near future which could potentially be converted to carry hydrogen to supply steel, chemicals and other industries in the region.

Ambitious climate policy can increase competitiveness

Despite the challenges outlined above, if implemented in the right way, ambitious climate policy may actually increase competitiveness of some emission-intensive industries in the EU. COP21 RIPPLES analysed two policy options to address competitiveness concerns: Border Carbon Adjustments (BCA) and Output Based Rebates (OBR)[2]. Results from model-based analysis suggest that with globally differentiated decarbonisation efforts (modelled using differentiated carbon prices), BCAs and OBRs show an increase of iron & steel output compared to the reference scenario for the EU28 collectively and for most EU15 countries individually (France, Germany, Italy, and UK), but for OBRs the effect is slightly stronger. Since OBRs are

2 Under an output based rebate scheme the revenues generated by the carbon pricing instrument (e.g. ETS) are refunded back to the participants in proportion to their output, effectively constituting a production subsidy.

Table 1. Overview of scenarios applied to assess the competitiveness effects of ambitious climate policies

Scenario ***NDC+***

This reference scenario represents a proportionate acceleration of NDC global ambition in the short-term before 2030 in order to achieve a Paris-compatible global carbon budget. The adoption of energy efficiency measures, more efficient capital, renewable energy deployment, and electrification of the economy are intensified before 2030. Emission reductions are achieved by means of a domestic effort with differentiated regional and country carbon prices.

Scenario ***NDC+ EU BCA***

Same as NDC+ scenario with the EU imposing a Border Carbon Adjustment in the form of an import tariff based on the carbon content of all imported commodities. The scenario does not include compensation measures for exports.

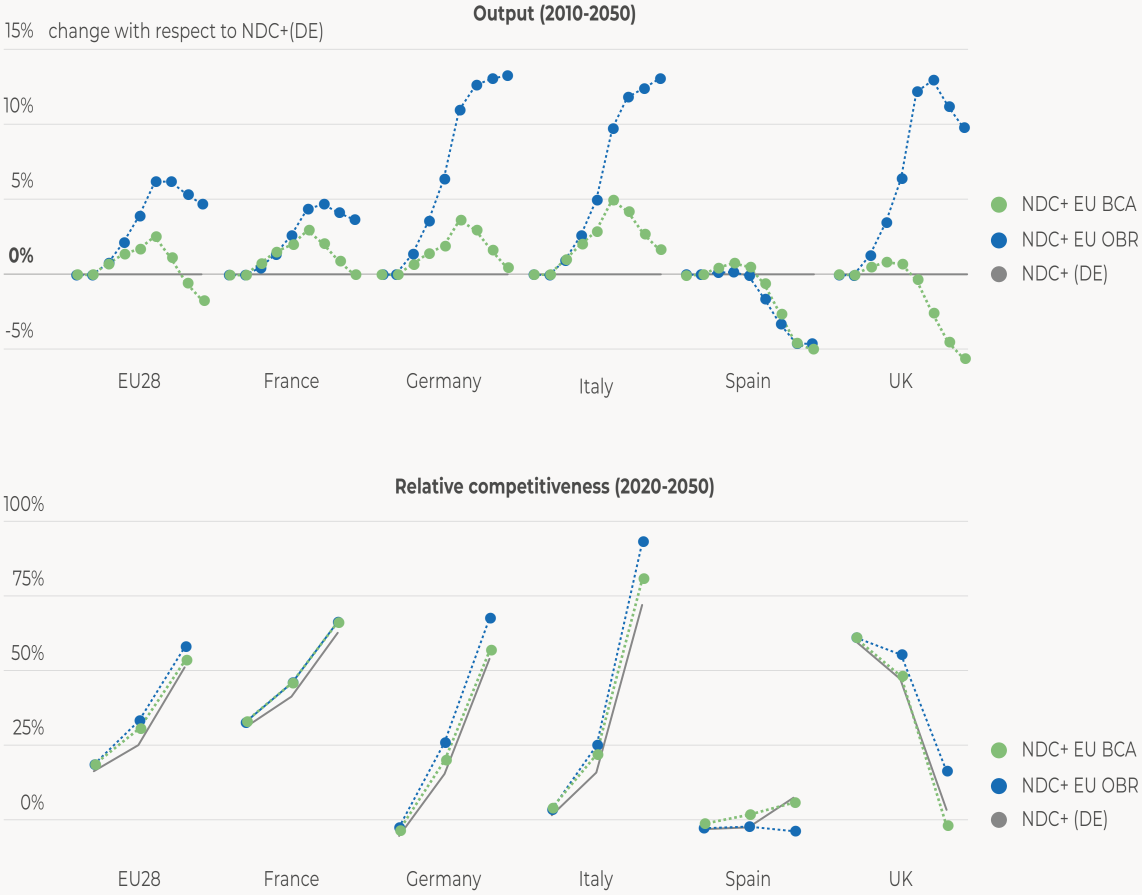
Scenario ***NDC+ EU OBR***

Same as NDC+ scenario with the EU implementing an Output Based Rebate of the carbon cost for emission intensive trade exposed industries only. The carbon cost rebate is implemented as an output subsidy equivalent to the carbon price paid by each emission-intensive trade exposed industry.

implemented as an output subsidy the industry can use the value of the rebate to invest in new and more efficient capital which will increase output in the long term more than in the BTA scenario. With decreasing carbon intensity of both imported products as well as domestic production the positive effect diminishes after 2030/2035 (see **Figure 3**). In a context where all countries in the world increase the ambition of current NDCs to 2030 in line with the Paris Agreement long term goals (NDC+ scenario), with differentiated regional carbon prices, the European Iron & Steel industry would improve its relative competitiveness compared to current values.[3] As with output, OBRs are more effective in improving competitiveness while BCAs have lower positive effects in the EU28, France, Germany and Italy. However, there are some countries like Spain and the United Kingdom that would not get an improvement of competitiveness in this industry. It is important to note that the improvements in competitiveness are also the result of the implementation of the three pillars of decarbonization (energy efficiency, electrification of the economy, and decarbonization of power generation) which should be at the base of the industrial transformation.

3 Competitiveness effects are analysed based on the Revealed Competitiveness (RC) Indicator by comparing the relative export and import advantages of a specific sector. If the RC indicator is positive then it denotes a comparative advantage while if it is negative it implies a comparative disadvantage. See Vollrath, Thomas L. 1991. '*A. Weltwirtschaftliches Archiv* 127 (2): 265–80. *https://doi.org/10.1007/BF02707986.*

Figure 3. Iron & Steel sector: Effects of BCA and OBR on output (top panel) and relative competitiveness (bottom panel) for EU28 and by country



Source: CMCC, COP21 RIPPLES.

Ways and Means to Improve Technology and Innovation Governance in the EU

The EU's main innovation-related priorities are: (i) accelerating the deployment and incremental innovation of mature technologies, (ii) enabling key technologies to cross the 'valley of death' towards demonstration and commercialisation, and (iii) aligning supply- and demand-side innovations to enable systemic changes. Achieving these priorities will require the EU to move beyond correcting 'market failures' that hinder technological development and adoption, to include a 'market-shaping' and 'mission-oriented' innovation framework.

Providing long-term clarity of direction and ambition

The public sector can provide a clear direction in which the actors involved in innovation should move. This can be achieved by fixing medium or long-term targets but also by defining innovation 'missions' (e.g. climate-neutral steel production by 2050). This commitment by the public sector provides a framework in and around which other public (e.g. policy) and private (e.g. investment) action may fit and be oriented. Moreover, setting those policy priorities in an integrated way is important to cover the broader innovation chain and to avoid policy conflicts. For instance, electrification of industrial processes will need to be integrated or coupled with the transition to renewable energy sources. Developing international supply and trade routes for green energy e.g. based on renewably sourced hydrogen or synthetic fuels should also be considered. Finally, other policy areas that are often at the core of greenhouse gas mitigation can be integrated and streamlined further from an industrial policy perspective. This can for instance be integration of enhancing industrial competitiveness with climate and trade e.g. as part of future free trade and investment agreements.

Using a broader set of innovation instruments

While supporting basic R&D has been an important role of the public sector, a large-scale economic transition such as drastically reducing greenhouse gas emissions will require innovation policies beyond but aligned with basic research. This can include innovation instruments for financing and sharing the risks of large-scale demonstration installations. Instruments such as the new EU ETS Innovation Fund or the European Investment Bank's (EIB) 'Innovfin' that help innovations bridge the 'valley of death' towards large scale demonstration and commercialization but the volume provided may still not suffice. Another quite promising instrument for commercialisation of new production facilities could by so called Carbon Contracts for Difference (CFDs) that grant the necessary CO_2-price to the investor in a way that the public will reimburse for the difference between an agreed necessary carbon price for the investment to the actual price in the EU ETS over a period of e.g. 20 years.[4] Equally important is ensuring a streamlined innovation system that covers the whole innovation process from invention to market. In this context it will be important to also develop or use market-pull innovation instruments that allow the creation of lead markets for climate friendly processes and products e.g. through public procurement of low-carbon products or services or the use of quotas or standards (or adjustment of existing standards to allow new products market entry).

Providing infrastructure for transformational technologies and practices

Embedding sectoral innovations will need a public investment programme that finances or facilitates financing for supporting infrastructure. Hence, the EU and its member states will need to link sectoral innovation with infrastructure needs, map these and introduce a

4 See Sartor, Oliver, and Chris Bataille. 2019. 'Decarbonising Basic Materials in Europe: How Carbon Contracts-for-Difference Could Help Bring Breakthrough Technologies to Market'. Study 6/19. Paris: IDDRI - Institut du développement durable et des relations internationales. https://www.iddri.org/sites/default/files/PDF/Publications/Catalogue%20Iddri/Etude/201910-ST0619-CCfDs_0.pdf.

long-term programme to roll them out. This will require the mission-oriented use of existing EU wide (and national) financing institutions such as the EIB as well as European Structural and Investment Funds.

Induce the creation of new value chains for materials efficiency and circularity

The supply- and demand-side innovations must be linked by implementing climate-friendly innovations along the value chains. Particularly in the iron & steel sector key mitigation strategies include the increase of steel recycling towards a more circular economy (which mainly means increasing the quality of the recycled steel by improved sorting practises to prevent mixing it with unwanted materials such as copper) and material efficiency through more environmentally lenient product designs and production processes across the value chain. Excluding the value chains from climate-friendly innovations risks leaving the necessary technological breakthroughs solely with incumbent primary materials producers which can lead to a lock-in into existing processes using more expensive mitigation technologies as opposed to value chain innovations which can use a broader spectrum of actions.

Accelerating coordination with local and national authorities

Innovation and industrial policies are not a unique EU competence. These areas are also covered by national (and subnational) competences and instruments (e.g. R&D tax breaks). It is hence important for the EU to align its innovation missions and implementing actions with those of the national and local authorities. This can include technical and regulatory assistance and knowledge and best practice sharing. Furthermore, the early stage design of new EU innovation frameworks should be coordinated and aligned with national innovation systems as to allow for different programmes to maximise possible synergies. After all, the required infrastructures, symbiotic effects between different industries (e.g. in carbon capture of steel sector emissions for reuse in the chemical industry), as well as employment effects play out mostly on the regional level and hence should be addressed there as well.

Develop an integrated governance system

Given that the previous elements touch upon much more than pure innovation instruments (e.g. finance, regulation, infrastructure), and upon competences shared between the EU and its Member States, it is necessary to provide more integrated and coherent governance for an industrial decarbonization mission. This would allow for fostering collaboration between different levels of governance and pooling of resources through co-financing. It will also help coordination of different competences beyond innovation but necessary to successfully bring innovations to the market and enhance the consistency and effectiveness of instruments. New monitoring instruments such as innovation dashboards that use metrics to assess the state of innovation missions and broader (socio-economic and environmental) goals that are set out. These can help with timely adjustments of instruments that are underperforming. Finally, it may require to compromise the objectives of decarbonization with long-standing issues of competition policy, to reconcile short-term interests of protecting consumers from higher prices with long-term objectives of becoming the first climate neutral continent.

A challenge beyond the European Union

Most future growth in steel production (and notably demand), especially primary production from iron ore, is expected to be in developing countries. A global roadmap acceptable to developing countries will have to consider how low-carbon production technologies may be equitably established in these countries. But it is not only a question of equity, more importantly it is a matter of unlocking the transformation at global scale. In this section we highlight this argument from a South African perspective.

Steel is crucial for new buildings and infrastructure in rapidly-urbanising Africa. 'In-use steel stock' in South Africa, for example is 2t per capita (and around 1t per capita in most of Africa), whereas in China and the EU this value is 5.5t and 10-14t per capita, respectively. A substantial growth in the primary production of steel will be required to meet increasing demand in Africa as the economy develops.[5]

Current African primary steel production is around 14Mt per year (mostly in Egypt and South Africa), and consumption around 40Mt per year. While it is unlikely that Africa will be able to meet its increasing needs from local production there is clearly huge scope for those African countries that have the capacity to supply regional demand. However, realities of steel markets and especially the global primary steel production glut is making development of local primary steel production impossible for domestic producers in Africa. Regional production has fallen by 5Mt (nearly 30%) since 2006 and is under existential threat.

South Africa has a low-cost iron ore reserve of 650Mt, a previously competitive primary steel sector and large downstream steel-based manufacturing sector. It also has amongst the highest solar radiation resources in the world. South Africa could thus be a least-cost production location. With the right support, South Africa could host ultra-low emissions primary steel production via renewable hydrogen based direct reduction technology in commercial plants by 2030-2035. This would mean to apply emerging technologies, with industrial scale pilot plants under construction in the EU. Given the advantageous circumstances, the low carbon steel produced would be relatively economic compared to other production but most like would incur a substantial cost premium compared to conventional (imported) steel. Further, the use of domestic coal would be abandoned in favour of solar electricity based hydrogen.

Integrating future evolution of South African primary steel production into a global roadmap could be facilitated by Europe. ArcelorMittal, for example, has proposed to be carbon neutral in Europe by 2050 and is constructing a low-emissions hydrogen-based direct reduction primary steel demonstration plant in Hamburg. But ArcelorMittal also owns the bulk of South African primary steel production. Bringing this technology to the African continent would certainly facilitate the global transformation of the sector and might prevent Africa from locking in into incumbent high-carbon development.

Yet, given the current situation of the global steel market, intra-company competition for investments in new production facilities, the declining South African production and the country's limited political influence in global trade means that arguably South Africa cannot, on its own, setup low-carbon steel production and protect it with duties – but in the context of international cooperation between the EU and South Africa it potentially could. If the EU were to create a lead market for low- and zero-emission steel through labelling and/or public procurement, through establishing a level playing field using GHG standards or BCAs, through providing sustainable finance for technology development and production facilities, including South Africa in such a scheme would enable the country to develop low-carbon steel production. In the short term that industry would supply primarily European lead markets at relatively competitive prices, but in the medium to long term would substitute current domestic steel production and ultimately cater to the strong demand for primary steel across Africa.

5 A ball park figure would be that an African population of 2bn (UN population projections for 2050) with 3t/cap of in-use steel stock (a very moderate aim) would require some 200Mt p.a. average steel production from 2020-2050.

A Steel Sector Decarbonization Club

Global governance can and should support the transformation of the global steel industry by

- providing a clear **signal** to investors e.g. in form of a credible and authoritative sectoral decarbonization roadmap;
- **setting rules and standards** e.g. with respect to minimizing the risk of carbon leakage which would undermine stringent climate policy in the sector;
- supplying **transparency and accountability** through monitoring of emissions to enable and support cooperation;
- leveraging **means of implementation** especially with respect to transfer of low carbon technology corresponding financial means for developing countries esp. in Africa;
- facilitating **knowledge creation and diffusion** e.g. through coordinated R&D and diffusion of technical knowledge.

Yet, COP21 RIPPLES research has highlighted a dearth of international institutions specifically focusing on the transformation of heavy industries. The number of institutions directly addressing the iron & steel sector remains notably limited especially when compared to other sectors. None of the above mentioned potential functions of global governance is sufficiently being supplied to effectively drive the sector toward decarbonisation.

A transnational 'decarbonization club' comprising national and subnational governments, as well as (multinational) companies, has significant potential to close some of those governance gaps. **We define a transnational 'decarbonization club' as a limited grouping that comprises at least three country, non-state, or subnational actors from more than one country as members; that is formalised in terms of membership, dues, regular meetings, and tracking action; that delivers a club good or benefit (exclusively) to its members; and that significantly contributes to decarbonisation.**

We suggest that the overarching objective of a steel sector decarbonization club should be **to phase out process and energy-related carbon emissions of primary steel production by 2050 and to establish a moratorium on investments in unabated conventional blast furnaces by 2025** (industrialized countries) **or 2030** (developing countries). The club can contribute to achieving this objective by addressing three fundamental uncertainties: political uncertainty, uncertainty about zero-emission technologies, and uncertainty about markets for zero-emission steel:

- ***Political uncertainty:*** Industry needs certainty to invest and policy makers need certainty that industry is able to comply with stringent climate policy. A steel sector decarbonization club can help coordinate in this regard. Process innovation is usually motivated by anticipation of lower production cost or higher product quality. But in the case of low-carbon innovation in the steel industry this is not applicable. Instead, what motivates innovation leaders in the industry are normative objectives to contribute a fair share to the goals of the Paris Agreement as well as the anticipation of much more stringent future climate policy. A sectoral decarbonization club could support and reward this motivation.

- ***Technological uncertainty:*** Decarbonization of the steel industry requires a large scale experiment with competing technological avenues: carbon capture, hydrogen, or other less developed potential breakthroughs. A club could coordinate these experiments by means of coordinated public private partnerships sharing investment risks and managing access to intellectual property rights. It can also help to coordinate the build-up of required infrastructure, e.g. for the international supply of green hydrogen.

- ***Uncertain markets:*** zero emission steel will require substantial CAPEX but will also have higher operating expenditures and consequently requires a market premium to be financially viable. Our analysis shows that a carbon price of as low as €40-60 per tonne could suffice for zero emission steel to break even. A club could establish a credible labelling/certification scheme for low emission steel and establish a lead market through public procurement and/or via establishment of a club of large steel buyers e.g. from automobile or buildings and construction industries. A club setup would also be an ideal test bed to explore BCAs. While implementing BCAs would certainly increase incentives to join the club, there is no need to consider them an essential pre-condition. Anticipated geo-political challenges of implementing BCAs should not delay the foundation of the club.

Corresponding to those uncertainties, the club should provide club benefits from three complementary components. The **innovation component** should focus on supporting the development of demonstration and industrial-scale production plants. This could be achieved, for example, through a series of public-private partnerships where public club members (national or subnational governments) engage as co-investors assuming some of the risks and ensuring access to the successful technologies under pre-determined conditions for other members of the club. The **infrastructure component** should coordinate the build-up of required infrastructure, whether that is hydrogen infrastructure, CCUS infrastructure or enhanced electricity infrastructure. While most of this coordination will need to happen on the regional level global coordination may be required regarding e.g. international hydrogen supply. Regional coordination could happen e.g. in the form of regional initiatives under the club which mutually exchange experiences and lessons learned. Finally, the club should include a **market component**. It should establish a credible label for zero emission steel and create a reliably growing lead market of low-carbon steel. This could be achieved e.g. through public procurement, a complementary commitment of large private buyers such as car manufacturers, carbon-based contracts for difference or even standards/quotas for the use of low carbon steel in consumer products. In the long run, a protected market within the club could be created through BCAs or a materials consumption charge with exemptions for zero-emission steel.

Another key recommendation is to conceptualize the club with a clear pathway to membership. This is required to avoid the accusation that the club is a means to protect and unduly support European industry at the expense of international competition, but to encourage a growing membership for a cooperative approach motivated by the need to mitigate climate change. For initial membership, we propose to target steel companies leading in low-carbon innovation, and a mix of national governments, subnational governments from major industrial centres (including China). However, this may prove challenging from the point of few of participating companies who might rather want to use the club to gain a competitive edge over their Chinese competitors. Meanwhile as discussed above, South Africa could be an ideal partner to engage. Also India could be a strategic partner in founding a steel sector decarbonization club, not least because of the prominent role of Tata Steel and ArcelorMittal but also because India can be expected to become major centre of future steel demand.

Figure 4. Key features of a steel sector decarbonization club

Objectives	Phase out process and energy-related carbon emissions from primary steel making by 2050 Moratorium on conventional unabated blast furnaces by 2050/30		
Club benefits	**Innovation component** Support development of demonstration plants through public private partnerships IPR Hub: enable access to sustainable technologies on pre-determined conditions	**Infrastructure component** Coordinate and facilitate build-up of hydrogen, carbon capture, and electric infrastructure for large-scale employment of breakthrough technologies	**Market component** Establish a label for zero emission steel Create lead market (e.g. through public procurement) Explore border carbon adjustments
Modalities	Open club with clear pathway to membership		

Sources: Wuppertal Institute, COP21 RIPPLES.

Conclusions and Recommendations for the EU

The research conducted under the COP21 RIPPLES project clearly indicates the central role of energy intensive industries in delivering a transition to climate-neutrality both in the EU and globally. To address the sectoral challenges, the EU should develop a clear and ambitious decarbonisation strategy and develop adequate (international) governance arrangements for the sector. Specifically we recommend that the **European Commission includes an 'Industrial Decarbonization' mission under the European Green Deal portfolio**. This mission could build on the following priorities:

- ***Provide long-term clarity for the direction of innovation*** by committing to a decarbonization of emission-intensive industries by 2050 and – as an example – for the steel sector commit to a moratorium on conventional unabated blast furnaces by 2025 in the EU.
- ***Work towards the integration of policy priorities*** including the integration of the expected electrification of industrial policies with the objectives of the Energy Union.
- ***Use the full range of innovation instruments*** including financing instruments and PPP arrangements for investment in demonstration plants as well as creating lead markets for low-carbon raw materials to 'pull' innovation into the market.
- ***Improve coordination among different governance levels*** and align EU funding instruments such as the European Structural Investment Funds to accelerate the planning and build-up of hydrogen, CCS and enhanced electricity infrastructure to enable the switch towards zero-emission production processes when the technologies are sufficiently matured (no later than 2030).

We propose the use of sector-specific 'decarbonization clubs' to offer a vehicle to advance those elements and at the same time link them to the international context. By pursuing such a club, the EU could advance its own domestic decarbonization and at the same time engage proactively and constructively with international partners, furthering and renewing its role as a leader in international climate diplomacy. Finally, such clubs provide a meaningful context to seriously explore and experiment with the introduction of BCAs.

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The COP21 RIPPLES project

"COP21: Results and Implications for Pathways and Policies for Low Emissions European Societies" aims to analyse the transformations in the energy systems, and in the wider economy, that are required in order to implement the Paris Agreement (NDCs), and investigate what steps are needed to attain deeper, more ambitious decarbonisation targets, as well as the socio-economic consequences that this transition will trigger.

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