



Collection of possible decarbonisation barriers

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Executive summary

This 'Collection of possible decarbonisation barriers' report (D1.5) aims to give a comprehensive overview of all major barriers to the decarbonisation process in the iron and steel industry. It does not assess the specific severity or offer possible solutions to overcome these barriers. Less serious barriers may slow down or limit the development and deployment processes; more serious barriers may block them completely.

The findings of this report are based on desk research evaluating academic and industrial publications, as well as on input provided by EU steelmakers via a scoping questionnaire.

Based on the desk research conducted, four different categories of decarbonisation barriers have been identified:

1. **technical barriers** caused either by the technological development of decarbonisation technologies or by the required mass and energy flows;
2. **organisational barriers** caused by the organisation of technology development or deployment in terms of management, administration or personnel;
3. **regulatory or societal barriers** caused by externally set framework conditions, policies or social acceptability; and
4. **financial barriers** caused by limitations to the economic operation of the iron and steel production.

For each category, four to five specific barriers have been identified and analysed in more detail. Besides the assessment of the barriers themselves, their specific relevance to the stakeholders of the EU iron and steel production is assessed through an evaluation of the consultations with steel producers covering more than 80% of the European steel industry's CO₂ emissions. The definition, background and potential impacts of these barriers can be summarised as follows.

Technical barriers

Within the technical barrier category, four specific barriers affecting the decarbonisation of the EU steel industry have been identified:

- limited availability of raw materials
- limited availability of renewable energy
- limited technical integration potential into existing plants, and
- risk of unsuccessful development.

The **main input materials** for steel production are iron ore as the primary raw material (processed into sinter or pellets), and steel scrap as the secondary raw material. A replacement of the primary raw materials (i.e. ores) by scrap would avoid the energy- and CO₂-intensive step of ironmaking; however, this is strongly limited by scrap availability and product quality issues due to residual impurities from scrap. Additionally, the higher costs of scrap are extremely relevant; the price is expected to further increase as the demand for high quality scrap rises. A shift towards direct reduction plants (to replace the blast furnace-basic oxygen furnace [BF-BOF] route) would result in a high demand for iron ore pellets. The current sintering plants, which allow the use of a wide variety of iron-bearing raw materials and the recycling of most internal residuals, probably have to be replaced in the long-term. This would need new material cycles

and new raw material supply chains. New pelletising plants would have to be built on site (causing high investments and space problems for brownfield installations) or an external pellet supply would be necessary (causing a risk of carbon leakage and decreasing flexibility).

The deployment of decarbonisation technologies results in an increased substitution of fossil energy carriers with **renewable energy sources** (including secondary biomass and waste materials). The renewable energy supply will have to be delivered mainly by electricity, which will be consumed either directly (electrification) or indirectly via hydrogen production (e.g. by water electrolysis). Only a smaller part can be supplied by secondary biomass and combustible wastes. The CO₂-free electricity demand of the EU iron and steel industry in 2050 is estimated at 400 TWh per year, corresponding to about half of today's total electricity production from renewable sources. Additionally, fluctuations in renewable electricity production should be considered. These may require, for instance, the implementation of large-scale storage systems (e.g. for electricity or gas) or new approaches to increase demand-response flexibility.

The **technical integration of a new technology into pre-existing physical plants** (brownfield sites) at industrial level requires available space for the new equipment and a connection to the existing material and energy flows. In practice, any steelworks would need comprehensive individual planning and to find room for new installations as well as for their servicing within an already limited physical space. Additionally, production would have to stop (at least partially) while the new equipment is incorporated. Longer downtimes of large parts of a plant can cause a loss of production worth several million euros. A further important aspect is the influence of the new technologies on energy flows, as currently heat and power production relies on gases generated by the processes of the plants (BF gas, BOF gas and coke oven gas) as the main energy sources.

The risk of unsuccessful development refers to failures in achieving either the technical objectives itself or in achieving an economically sound and sustainable result. While the technical functionality of a process is developed during the technical development phase, the economical operation and sustainability is developed at a later stage in the industrial deployment phase. Due to this, a risk of unsuccessful development must be considered for all stages of development and for all technologies, as in all R&D activities. In terms of decarbonisation of the iron and steel industry, due to the fluctuating quality of the raw materials and the huge size of steel production plants, the technical risks of unsuccessful development are still very present during the final stages of development.

Organisational barriers

The category of organisational barriers consists of four specific decarbonisation barriers relevant to the EU steel industry:

- limited availability of qualified staff
- administrative requirements
- issues related to the management of industrial transformation
- issues related to intellectual property management (intra- & inter-firm).

As in any large-scale production process, the planning and operation of (integrated) plants for iron and steel production require significant human resources. Thus, the **availability of qualified staff** is a precondition to pushing forward the development of decarbonisation technologies, including the necessary technical development of new technologies. In the first phase, the development and operation of new technologies need more personnel than usual commercial processes. Additional personnel is necessary when the new technology is installed in addition to the existing ones. Challenges arise with regard to the long-term perspective for the workforce, however.

Administrative requirements may also hinder the development and deployment of low-CO₂ technologies. Authorities may demand proof of compliance with relevant standards, which may be lacking at the time of first implementation. Regarding collaborative research and the funding of projects, internal and external bureaucracy could impose an additional burden.

Considering the fundamental changes of process chains, including energy and raw material supply chains, the decarbonisation of industrial production is a revolutionary **transformation process** whose different phases are extremely difficult to **manage**. It starts with the efforts and issues related to the research and demonstration of the new technologies. Managing the deployment of new technologies in the existing brownfield plants while usual production goes on might be even more important. The related effort significantly exceeds 'normal' business since the scope and time pressure of the changes are fundamentally larger than usual.

Intellectual property management refers to the management of intellectual property (IP) rights. Extraordinary intensive research and development (R&D) activities are needed within the coming decades to decarbonise the steel production. In this context, the use of exclusionary rights generates burdens and limitations for the competitors. This might lead to a delayed or altered implementation of decarbonisation technologies, possibly resulting in less CO₂ mitigation achieved or higher costs. Additionally, the information exchanged between competitors outside of the regulated environments may be decreased, leading to slower technological progress overall.

Regulatory/societal barriers

Among the regulatory or societal barriers to the decarbonisation of the EU steel industry are five specific ones:

- limited availability of permanent CO₂ storage
- limitations stemming from emissions-related legislation (e.g. pricing in EU ETS system)
- limitations associated with social acceptability and environmental protection
- burden by local taxes and fees, and
- uncertainty related to carbon contracts for difference.

For the abatement of remaining CO₂ emissions that cannot be mitigated in the process, Carbon Capture and Storage (CCS) is an option, in particular in the medium-term when not enough renewable energy sources are available yet replace all fossil energy sources. The capacities for **CO₂ storage in Europe are limited**. Current cumulative storage resources are in the range of 10,000-30,000 Gt CO₂, including 1,000 Gt in depleted oil and gas reservoirs. The main share of these capacities is restricted by national legislations due to public concern. Thus, the significance

of this barrier is highly depending on the national and regional framework conditions related to CCS.

The economic viability and competitiveness of decarbonisation technologies is subject to **emissions-related legislation** as the **carbon pricing in the EU emission trading system (ETS)**. Meanwhile, substantial increases in carbon price and/or changes in mitigation measures could ultimately result in carbon leakage. This is especially true if one considers that production costs for green steel are expected to be substantially higher than costs for conventional steel. Steel imported from third countries with less stringent climate rules than the EU could be sold at a lower price, while generating comparable or often higher carbon emissions than those linked to EU steelmaking. The magnitude of the carbon leakage challenge is increased by the global overcapacity and heavy competitive pressure from the global steel markets.

Technologies that are technically and economically viable may not be successfully implemented due to **limited social acceptability**. Such issues have already occurred to CCS and renewable energy installations (e.g. windmills or power supply lines). Other decarbonisation technologies may suffer from similar issues in the coming years (e.g. pipelines for hydrogen or CO₂).

Decarbonisation actions can be subject to additional or changing **local taxes and fees**. One example is that of feed-in tariff schemes which several member states have unilaterally changed to support renewable energy. However, in doing so, they have generated economic uncertainty and increasing investment risks. Specifically, the German Renewable Energies Act (*Erneuerbare Energien Gesetz*, EEG) plays a significant role in local electricity costs. As a matter of fact, under its provisions steelmakers may have to pay additional taxes and fees if they acquire renewable electricity externally instead of producing it internally.

The current set of **national framework conditions** is not fixed for a longer term but is subject to change in coming years. This may for instance be a barrier with respect to the currently discussed implementation of **carbon contracts for difference (CCfD)**: A 'strike price' is agreed upon between a state and a producing company over a defined period which anticipates the expected future increase of certificate prices. The aim of these contracts is to hedge the higher future prices. If the 'strike price' is higher than the market price, the state covers the difference. In the opposite case, the company covers the difference. This would guarantee producers of low-carbon steel a fixed future CO₂ emission price, decrease their investment risks and make their decarbonisation projects financially viable already in short-term. However, if national framework conditions in this respect are unknown, precarious and heterogeneous, this may become a barrier.

Financial barriers

Besides the aforementioned non-financial barriers, five specific financial decarbonisation barriers relevant to the EU steel industry have been identified:

- increased operational expenditure
- additional capital expenditure for demonstration plants
- additional capital expenditure for industrial deployment
- limited access to funding and financing, and
- unknown market conditions for clean steel.

The implementation of a technology is highly dependent on its competitiveness. Therefore, attention must be paid to the **operational expenditure (OPEX)** which includes costs for energy,

material, operation and maintenance. The OPEX related to energy and material inputs generally make up over half of the total steel production cost. The price of electrical energy is significantly higher than for thermal energy provided by fossil fuels (e.g. seven times higher for coal). It is expected that the electricity prices will significantly rise in almost every EU member state up to 2050. Additionally, new raw material demand (e.g. high quality scrap for increased scrap usage or pellets for direct reduction [DR] plants) may significantly raise the OPEX.

Most breakthrough decarbonisation technologies currently have technology readiness levels (TRLs) in the range of 7, meaning that the important step of demonstration in an operational environment still has to take place. High **capital expenditure for demonstration plants** is due to the fact that the scale of steel demonstration plants is considerable compared to process industries, with capacities ranging from 10 to 100 t per day. Usual demonstration project budgets are between 100 and 200 million euros.

Additional capital expenditure for the industrial deployment of decarbonisation technologies depends on the extent to which the new technology calls for new asset expenditure. This includes not only the investment in the decarbonisation technologies themselves, but also the effort to adapt the existing assets to integrate the new technologies into the brownfield plants. Generally, the costs must be evaluated in relation to the corresponding mitigation potential and vary among plants depending on the local conditions (e.g. investment cycles, availability of secondary biomass).

The high demand in terms of capital expenditure (CAPEX) clearly shows that the development and deployment of decarbonisation technologies need additional financial investments. Thus, the **limited access to funding** is a concern and does not encourage the desired actions. This applies not only to the high investments in demonstration plants, but also to the even more expensive industrial deployment of decarbonisation technologies.

The production of clean steel, characterised by zero or low CO₂ emissions, will go along with (significantly) higher costs, at least for the foreseeable future. To cover these additional costs, the implementation of new **markets and business models for clean steel** is a promising option. In such an approach, 'clean steel' would be characterised as a different product than conventionally produced steel (premium product), with higher pricings to cover the higher production costs. If such a market for clean steel were created, it would strongly depend on European and worldwide policies. These may include public support (currently unknown), e.g. for public procurement. Additionally, the customer acceptance of higher prices for clean steel-based end products is unknown and may need support by legislative actions.

Evaluation of the specific importance of the barriers to stakeholders

To gain insight into the significance of the identified barriers and their impacts on the overall decarbonisation process, the barriers were the subject of a scoping questionnaire in the first step of the stakeholder consultation. Stakeholders were asked to rate on a scale from 1 (not important) to 5 (very important) the importance of pre-selected barriers to the activity of their respective companies in the short term (2020-30) and in the long term (2030-50). The results presented in this report reflect the situation as of 30 August 2020, thus incorporating preliminary names and categorisation of the barriers. The evaluation is based on detailed responses from 15 stakeholders, which together account for 71% of CO₂ emissions (based on 2020 EU ETS allocations).

The results were further assessed in two different ways: as a general **average** rating and as a **CO₂-weighted** average. The CO₂-weighted average takes into account the stakeholders specific CO₂ emissions based on EU ETS data. Thus, stakeholders emitting larger amounts of CO₂ are weighted correspondingly higher. Based on these methods, the barriers were ranked to identify the main barriers to decarbonisation. In Table 1 the rankings are presented based on the short-term average (2020-30). Table 1 displays both the average and the CO₂-weighted importance ratings for both time frames (2020-30 and 2030-50). In this table, the categories were abbreviated as 'TEC' for technical barriers, 'ORG' for organisational barriers, 'FIN' for financial barriers and 'POSO' for policy or societal barriers.

It is striking that six out of the seven most significant barriers are financial ones. The only exception are the framework conditions created by national or local taxes or fees (ranking 6th) which, however, have financial implications too. Most organisational barriers can be found at the bottom of the table due to the low ranking by the stakeholders. Most rankings – for the average evaluation and the CO₂-weighted evaluation – follow the same trend.

Table 1: Ranking of decarbonisation barriers by steel producers (sorted by 2020-30 average)

1	Decarbonisation Barrier	Cat.	2020-2030		2030-2050	
			Avg.	CO ₂	Avg.	CO ₂
1	Investments for industrial deployment	FIN	4.80	3.76	4.50	4.51
2	Increase in OPEX (energy/renewable energy)	FIN	4.50	4.75	4.30	4.25
3	Unknown market conditions of clean steel	FIN	4.50	3.85	4.30	3.85
4	Investments for demonstration plants	FIN	4.40	4.59	4.11	3.11
5	Limited access to funding opportunities	FIN	4.30	4.65	4.20	4.06
6	Local taxes and fees (e.g. German EEG)	POSO	4.22	4.19	4.00	4.13
7	Other increase in OPEX (materials, CCS, CCU, etc.)	FIN	4.20	4.49	4.00	3.98
8	Availability of renewable energy	TEC	4.00	4.24	3.90	4.79
9	Bureaucracy and other administrative burdens	ORG	4.00	2.98	3.50	2.66
10	Emission-related legislation (e.g. EU ETS)	POSO	4.00	4.59	4.10	4.70
11	National implementation of other framework conditions (e.g. contract for difference)	POSO	3.63	3.17	3.50	3.17
12	Risk of unsuccessful deployment	TEC	3.60	2.00	3.40	1.90
13	Social acceptance of certain technologies	POSO	3.60	3.92	3.30	3.86
14	Integration of new technologies in existing plants	TEC	3.40	2.64	3.30	2.74
15	Information exchange with other parties, collaborative research	ORG	3.20	3.26	2.90	3.00
16	Management of industrial transformation	ORG	3.10	2.22	2.90	2.21
17	Intellectual property management	ORG	3.10	2.99	2.90	2.99
18	Availability of qualified staff	ORG	2.90	2.60	2.60	2.66
19	Issuing of CO ₂ storage permits for CCS	POSO	2.89	3.48	2.67	3.48
20	Availability of raw materials	TEC	2.40	3.28	3.10	3.98

Source: authors' own formulation based on stakeholders' consultation.

Concluding remarks regarding decarbonisation barriers

Different plants will be in different starting positions to integrate new technologies (regarding e.g. the availability of space, the possibilities for industrial symbiosis or even government permits). Therefore, it is extremely difficult to identify any single technology that could be fitted into all existing European steelworks as the best solution. Careful consideration of specific and general conditions is needed to enable the transition towards carbon neutrality. In this context, the stakeholders clearly rated the financial aspects as the biggest barrier to decarbonisation.

In more detail, especially high investment costs for industrial and demonstration plants, increasing OPEX and unknown market conditions for clean steel in particular were assessed as having the highest impact on decarbonisation for both time periods under investigation (2020-30 and 2030-50). Also limited funding opportunities and local taxes and fees had average ratings between 'high' (4) and 'very high' (5). These findings are used as basis for the more detailed impact analysis and discussion of policy options in work package 3 of the Green Steel for Europe project (refer to the Impact Assessment Report – Deliverable D3.2 of the project).