IMPACT ASSESSMENT REPORT

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List of acronyms and abbreviations

BAT	Best available techniques
BECCS	Bioenergy with CCS
BF	Blast furnace
BNEF	BloombergNEF
BOF	Blast oxygen furnace
BREF	Best available techniques reference document
CAPEX	Capital expenditure
CBA	Carbon border adjustment
CBAM	Carbon border adjustment mechanism
CCfD	Carbon contract for difference
CCS	Carbon capture and storage
CCU	Carbon capture and utilisation
CCUS	Carbon capture utilisation and storage
CDA	Carbon direct avoidance
CEF	Connecting Europe facility
CF	Cohesion fund
CO	Carbon monoxide
CO_2	Carbon dioxide
CSP	Clean steel partnership
DACCS	Direct air capture with CCS
DSO	Distribution system operator
EAF	Electric arc furnace
EBGL	European Commission's guideline on electricity balancing
EC	European Commission
ECB	European central bank
EEA	European economic area
EEAG	EU state aid guidelines for environmental protection and energy
EFSI	European fund for strategic investment
EIB	European investment bank
ELV	End-of-life vehicles
ENTSO-E	European network of transmission system operators for electricity
EOR	Enhanced oil recovery

ERDF	European regional development fund
ESIF	European structural and investment fund
ETNSO-E	European network of transmission system operators for electricity
ETS	Emissions trading system
EU	European Union
EUA	European Union allowance
DG COMP	Directorate-General for competition of the European Commission
DG ENER	Directorate-General for energy of the European Commission
DSR	Demand-response measures
FOAK	First-of-a-kind
GDP	Gross domestic product
GHG	Greenhouse gas
GO	Guarantees of origin
GPP	Green public procurement
GREENSTEEL	Green Steel for Europe
GW	Gigawatt
H2020	Horizon 2020
HEU	Horizon Europe
IEA	International energy agency
IED	Industrial emission directive
IF	Innovation fund
IPCC	Intergovernmental panel on climate change
IPCEI	Important project for common interest
KW	Kilowatt
kWel	Kilowatt electric
LCOE	Levelized cost of electricity
MRV	Monitoring, reporting and verification
MSR	Market stability reserve
Mt	Million tonnes
MW	Megawatt
MWh	Megawatt-hour
NECPs	National energy and climate plans
NE	Northern Europe
NER	New entrants' reserves

OECD	Organization for economic co-operation and development
OIES	Oxford institute for energy studies
OPEX	Operating expense
PCI	Project of common interest
PEM	Polymer electrolyte membrane
PPA	Power purchase agreements
PV	Photovoltaic
R&D	Research and development
R&D&I	Research, development, and innovation
RE	Renewable energy
REDII	Renewable energy directive
RES	Renewable energy source
RES-E	Renewable electricity
RFCS	Research fund for coal and steel
RRF	Recovery and resilience facility
ROI	Return on investment
SCU	Smart carbon use
SE	Southern Europe
SMR	Steam methane reforming
SOEC	Solid oxide electrolyser cell
t	Tonne
tCS	Tonne of crude steel
TEN-E	Trans-European energy networks
TEU	Treaty on European Union
TFEU	Treaty on the functioning of the European Union
TRL	Technology readiness level
TSO	Transmission system operator
TWh	Terawatt-hour
UK	United Kingdom
WSR	Waste shipments regulation
WTO	World trade organisation

Executive summary

Green steel can be achieved through various technological pathways, some of which may be more suitable for specific producers and regions, depending on local factors related to energy infrastructure and demand. EU policy has an important role to play in the decarbonisation of the steel industry. Nevertheless, member state environmental, energy and industrial policies can also affect the prospects for certain industrial decarbonisation pathways. In the long term, some decarbonisation technologies may end up being more successful and competitive than others. This summary examines some of the most promising policy options that can support the technological pathways[1] and leverage the funding opportunities[2] identified in the project.

It includes policy options directly linked to specific technologies, such as green hydrogen, CCUS, renewables and scraps, but also options related to specific policy strategies such as carbon pricing – which is strengthened by the EU's Fit-for-55 package – and funding, which applies horizontally across the policy areas. Some options aim to address specific problems related to the individual technologies, while others could support industrial decarbonisation or emission reductions more generally. A number of cross-cutting policy options that can contribute to all policy areas have also been identified.

Below, the **six policy areas (funding, carbon pricing, renewable electricity, green hydrogen, CCUS, scraps)** are discussed separately, covering the specific policy problems, policy objectives, and policy options as well as the expected results from the most promising options.

1. **Funding**

The general problem for funding is the limited amount of funding flowing towards decarbonisation technologies in the steel industry. This does not necessarily mean there is an insufficient amount of potential funding, but rather that the business case for individual transformational investments in (costlier) green steelmaking production capacity is still missing.

Specifically, the funding challenges of green steel are also rooted in the – as of yet – higher costs of green steelmaking, both with regard to CAPEX and OPEX. In addition, green steelmaking technologies are unproven at scale (although there is rapid progress in some technologies, such as hydrogen-based steelmaking) and therefore carry greater risk. While some public funding is available to be invested in emission reduction technologies for the industrial sectors, they are not sufficient considering the transformational investment needs. Moreover, funding is especially required to fill the gap between R&D and commercial deployment at scale. Investments will also depend on there being a market for green steel specifically.

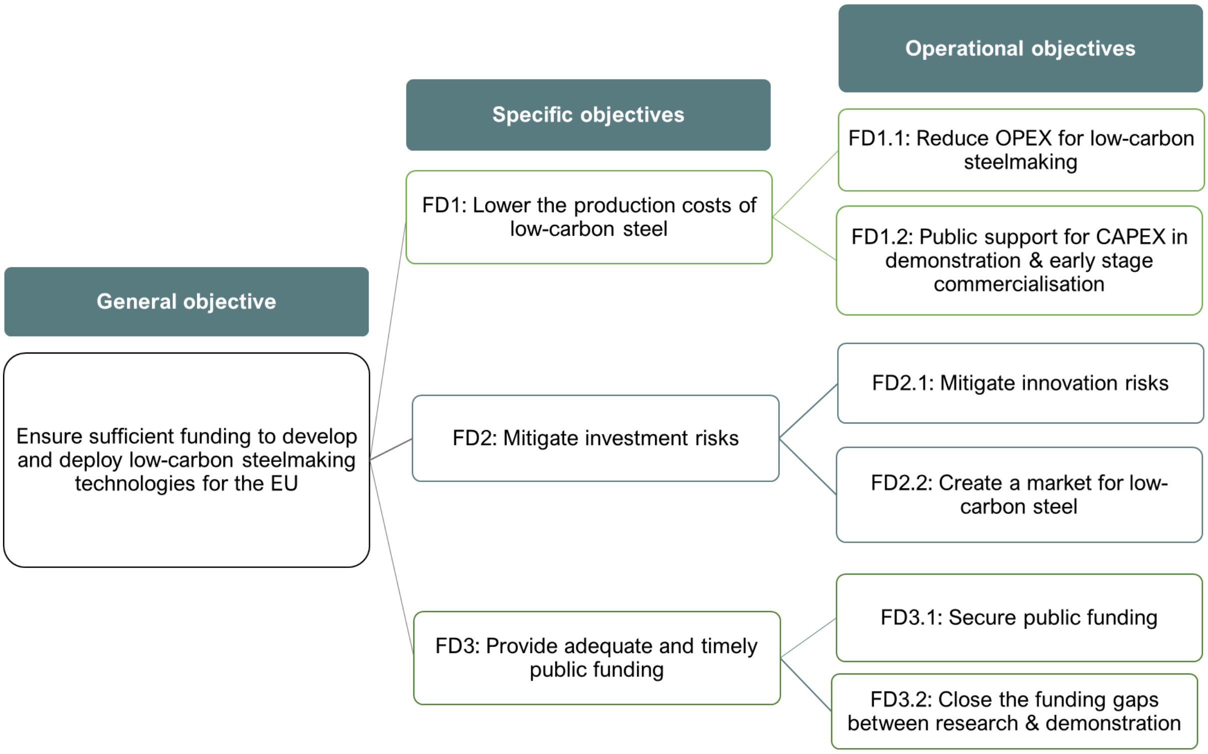
Green steel funding should, therefore, cover a wide range of drivers that lead to an increase in costs and investment needs. This includes new low-carbon production plants that replace existing blast furnaces, as well as low-carbon energy sources and infrastructure (e.g. hydrogen and CCUS). While public funding is inevitable to a degree, private funding would ideally constitute the

[1] See Work Package 1 of GreenSteel
[2] See Work Package 2 of GreenSteel

biggest share of green steel investments. However, the market conditions for green steel will be a key driver for such private investment. The risk of carbon leakage can negatively impact it all. Competition from non-EU producers that face lower carbon costs can deter investments in green steel. Policy interventions aimed at creating a market – for example through green public procurement (GPP) – can, nevertheless, improve the business case for such green steel investments. However, knowledge about green steel, and demand for it, should be present throughout the whole steel value chain.

There are also several challenges related to combining various public and private funding mechanisms to ensure that their impact is maximalised. It is not always possible to blend different sources of funding, even if that would increase the impact. Furthermore, steel investments have long lead times and require lengthy financial commitments, even if some funding instruments operate on shorter-term project bases. Furthermore, in the wake of the Covid-19 pandemic, the capacity of member states to provide funding (i.e. State aid) may be constrained due to budgetary pressure.

Figure 1: Policy objectives of funding (FD) for decarbonisation technologies in the steel industry



Source: Authors' own composition.

The objectives of funding policies are threefold in light of the above problems: the production costs of green steel need to decrease (specific objective FD1), investment risks should be mitigated (specific objective FD2), and funding should be aligned with the needs of the steel industry in terms of timing and scale (specific objective FD3) (see Figure 1). Some problems require specific and dedicated solutions.

- To address the greater OPEX costs of green steel, the use of EU funding programmes such as the ETS innovation fund is recommended. The large CAPEX requirement cannot be fully covered with public funds, it therefore requires the mobilisation of private funds (see specific objective FD1).

- Public support could also go beyond direct funding, using tools such as risk mitigation instruments and loan guarantees to lower capital costs. Besides 'technology-push' measures, policies that result in 'demand-pull' for green steel are also important. These measures, such as GPP, green labels and standards, are not classic funding instruments but can nevertheless address some of the gaps in the current steel investment landscape. In fact, these three policy tools can often address multiple policy objectives at once, going beyond funding goals. They are therefore also reviewed separately as cross-cutting policy options, together with the impact of higher carbon prices and carbon contracts for differences (CCfDs) (see specific objective FD2).
- Finally, synergies between funding instruments are important. Initiatives such as the Clean Steel Partnership (CSP) can play an important role here, as well as coordination instruments such as the Important Projects of Common European Interests (PCEIs), as they could target technologies that enable green steelmaking (as is already happening with hydrogen) or the steel value chain as a whole (see specific objective FD3).

Table 1: Overview of policy solutions[3] – Funding

	Effectiveness	**Efficiency**	**Feasibility**	**Coherence**
Option FD1: promoting the use EU funding programmes to finance OPEX of low-carbon steel				
Option FD2: mobilising private funding to support CAPEX of decarbonisation technologies				
Option FD3: ensuring public support for CAPEX beyond direct public funding				
Option FD4: introducing risk mitigation and loan guarantee instruments for investments in decarbonisation technologies				
Option FD8: ensuring that EU resources will support the green transition in the steel industry				
Option FD9: identifying pathways (2030 & 2050) for decarbonisation technology routes and ensuring that EU & national policy makers account for them				
Option FD10: creating synergies in EU level funding via the Clean Steel Partnership				
Option FD11: creating additional synergies in EU level funding via blending & sequencing of different opportunities				
Option FD12: establishing an IPCEI for low-carbon steel				

Note: This table presents the policy options in the funding area that would support the decarbonisation of the EU steel industry. The options are assessed based on the four criteria under the Better Regulation guidelines: their effectiveness, efficiency, feasibility and coherence. Colour legend: orange - low, yellow – moderate, green – high. For instance, a policy option that has a green cell in the Effectiveness column is considered to be "highly" effective. Source: authors' own composition

[3] Policy options FD3-5 have not been included in this overview as these options are assessed in the cross-cutting policy chapter

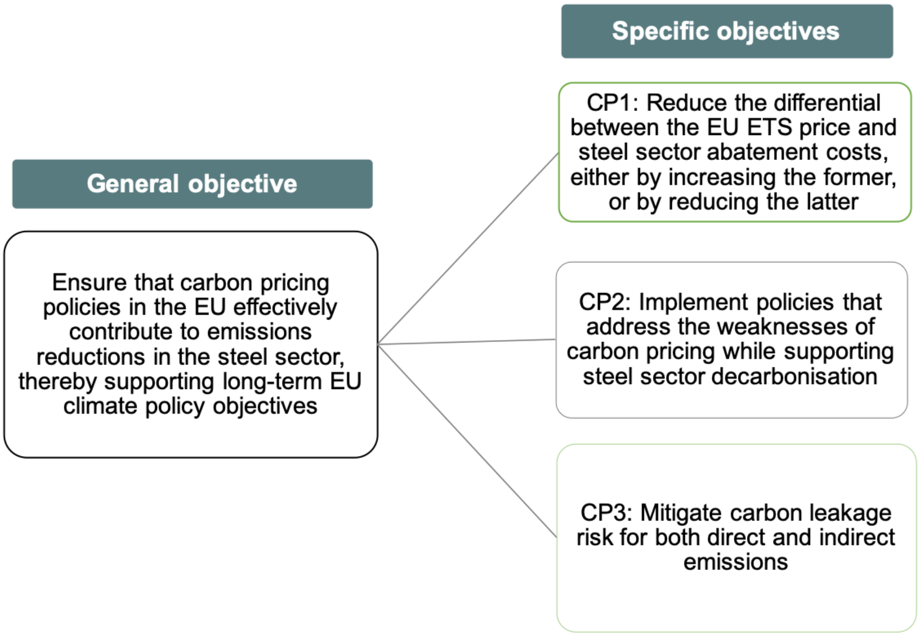
2. Carbon pricing

The EU's main carbon pricing policy – the EU ETS – also applies to steel sector emissions. However, the EU ETS is insufficient, on its own, to fully decarbonise the sector. This is partly because carbon prices are too low compared to the abatement costs in the steel sector, but also because there are other economic and non-economic barriers to the deep decarbonisation of energy-intensive industries that make carbon pricing on its own insufficient. In addition, the steel sector is considered at risk of carbon leakage, which may deter private investment in climate-neutral technology.

Several specific issues hinder the ability of the EU ETS to contribute to the decarbonisation of the steel sector. The supply of allowances in the ETS is relatively rigid, even if it has become more responsive to fluctuations in demand after the introduction of the Market Stability Reserve. Demand is more volatile, however, which has led to supply-demand imbalances in the ETS, and with it, to carbon price volatility. This volatility undermines predictability and deters investment. While the ETS price increasingly reflects future scarcity, this is insufficient, in the short term, to drive the investments the steel sector requires. The long lead times of the steel sector's investments exacerbates this issue. Furthermore, so long as the market for green steel remains limited, private investments may likewise lag.

The risk of carbon leakage can hinder the effectiveness of carbon pricing not just because of the purported threat to competitiveness, but also because of the measures that are taken to mitigate said carbon leakage risk. Free allocation can support the bottom line of steel companies, but it also dampens the carbon price signal. The suggested alternative, i.e. the carbon border adjustment mechanism (CBAM), can have many different designs, each with significant impacts on investment signals and competitiveness. Beyond direct carbon costs, the carbon leakage risk may also arise through indirect costs, i.e. higher energy prices (mostly for electricity) due to the pass-through of the carbon price in energy prices. Finally, the competitiveness of the steel industry is affected by many more (global) factors beyond climate policy. This too, will affect the capacity and willingness to invest in green steelmaking.

Figure 2: Policy objectives on carbon pricing (CP) to decarbonise the EU steel sector



Source: Authors' own composition.

The general objective of policy interventions should be to make carbon pricing contribute effectively to the steel sector's decarbonisation. To achieve that, the carbon pricing instruments themselves could be strengthened, but, as an alternative, policies that reduce abatement costs in the steel sector could be implemented instead. Once abatement costs are lower and green steelmaking is more competitive, the impact of a carbon price signal increases. Some additional policies that address the inherent weaknesses of carbon pricing are nevertheless recommended. This includes, for example, demand-side policies that can support an increased market for green steel. Finally, the carbon leakage risk should be mitigated for both direct and indirect carbon costs. However, mitigating carbon leakage risk is not always the same as supporting industrial competitiveness, and vice versa.

The most promising policy option is the introduction of CCfDs. CCfDs specifically address a key weakness of current carbon pricing policies in the EU: carbon prices are too volatile and too low to trigger investments in green steel. By agreeing on a 'strike price' that would enable a producer to invest in green steelmaking capacity, a variable subsidy could be agreed. CCfDs work in tandem with the EU ETS: if the carbon price gets closer to the agreed strike price, the subsidy payments can be lowered.

In general, policies (such as public investments) aimed to lower the steel sector's abatement costs would be effective, as the ETS price level at which carbon-intensive steelmaking would be discouraged and made less competitive will decrease as well. The CBAM can also make investments in green steelmaking more attractive, although much depends on the design of the mechanism and what happens to existing free allocation.

Table 2: Overview of policy solutions[4] – Carbon pricing

	Effectiveness	Efficiency	Feasibility	Coherence
Option CP1: adopting a hybrid MSR design				
Option CP2: reducing steel sector abatement costs				
Option CP5: introducing CCfDs				
Option CP6: implementing a CBAM				
Option CP7: introducing a separate industrial competitiveness policy for the steel industry				

Note: This table presents the policy options in the carbon pricing area that would support the decarbonisation of the EU steel industry. The options are assessed based on the four criteria under the Better Regulation guidelines: their effectiveness, efficiency, feasibility and coherence. Colour legend: orange - low, yellow – moderate, green – high. For instance, a policy option that has a green cell in the Effectiveness column is considered to be "highly" effective. Source: authors' own composition.

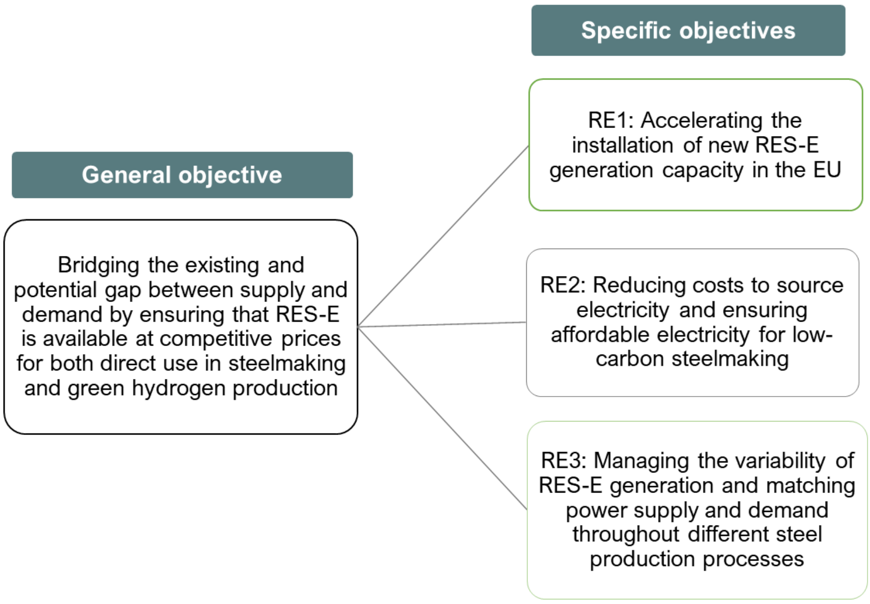
3. Renewable electricity

Renewables can contribute to the decarbonisation of the steel industry in two ways: directly, using electricity to power electric arc furnaces; or indirectly, due to electrification through hydrogen-based steelmaking. In both cases, vast additional volumes of renewables are needed, ranging up to 400TWh by 2050 (up from 55TWh today – which is a little more than Romania's total annual electricity demand). The general problem is therefore the gap between demand and supply of renewable electricity (RES-E) for the steel industry. There are three specific reasons for this gap:

- the first is the insufficient installed capacity of renewables – a challenge for the whole economy, as electrification and renewables are the preferred decarbonisation option in many sectors. Volatile and occasionally low electricity prices can, nonetheless, deter further investment in renewables deployment. In addition, the deployment of some RES-E projects is sometimes hindered by administrative or local barriers;
- the second is increasing network costs and unharmonized rules on RES-levies for the industry, which affect industrial power prices and can also deter investment. Furthermore, indirect carbon costs are compensated unequally, while Power Purchase Agreements (PPA) may also have divergent rules across MS;
- the third is the inherent variability of renewable electricity, which is a challenge per se. To this end, increased investments in electricity storage and balancing, or in demand-side responses are needed.

[4] Policy options CP3 and CP4 have not been included in this overview as these options are assessed in the cross-cutting policy chapter

Figure 3: Policy objectives on the availability of RES-E (RE) to decarbonise the EU steel sector



Source: Authors' own composition.

The EU's policy interventions to bridge the gap between RES-E supply and demand from the steel sector can be supported by: (i) accelerating the installation of new RES-E generation capacity; (ii) reducing costs to source electricity and ensuring affordable electricity for green steelmaking, and (iii) managing the variability of RES-E generation and matching power supply and demand in steelmaking.

The proposed policy options would affect the availability of RES-E for the steel industry by facilitating RES-E investments (through funding, better permitting rules, better rules on PPAs) and addressing the variability of RES-E supply (through an increase in RES-E storage capacity and better balancing services). EU policies can also lead to lower energy costs for the EU steel industry through a lower levelized cost of electricity (LCOE) of RES-E, improved mechanisms for indirect carbon costs, updated rules on demand-response measures and PPAs. The most promising policy interventions are to continue to financially support RES-E technologies, support PPAs and green energy offers (e.g. a reformed guarantees of origin system), and to improve the availability of energy storage solutions.

Table 3: ***Overview of policy solutions – Renewable electricity***

	Effectiveness	Efficiency	Feasibility	Coherence
Option RE1: EU funding for RE technologies				
Option RE2: EU guidelines on permitting process for RE projects				
Option RE3: compensation of indirect emission costs				
Option RE4: EU guidelines on demand-response measures				
Option RE5: PPAs or green energy offers				
Option RE6: balancing and shaping costs in national markets				
Option RE7: policies on energy storage				

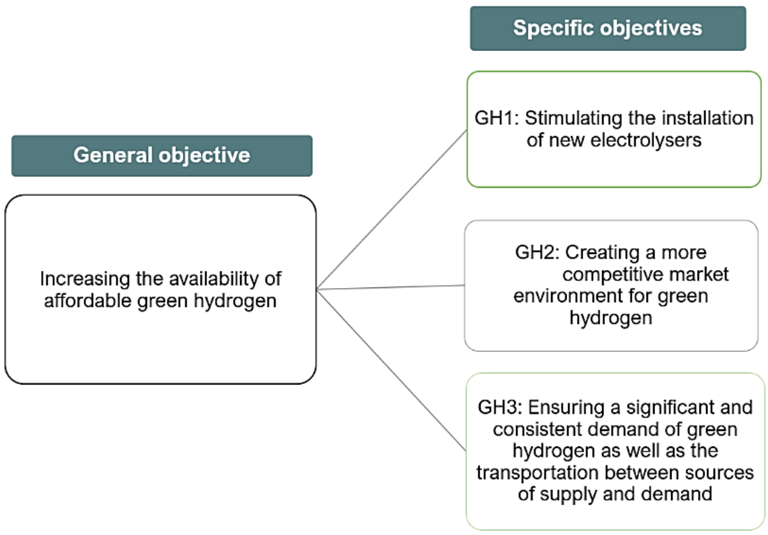
Note: This table presents the policy options in the energy area that would support the decarbonisation of the EU steel industry. The options are assessed based on the four criteria under the Better Regulation guidelines: their effectiveness, efficiency, feasibility and coherence. Colour legend: orange - low, yellow – moderate, green – high. For instance, a policy option that has a green cell in the Effectiveness column is considered to be "highly" effective. Source: authors' own composition.

4. Green hydrogen

Green hydrogen – i.e. hydrogen produced through electrolysis powered by RES-E – can be used in certain green steelmaking pathways. Today, however, there is only limited availability of green hydrogen, nor is it competitively priced. This limited availability of green hydrogen is driven by a limited production capacity, i.e. lack of installed electrolyser capacity. The technological readiness of electrolysers running on variable electricity is still improving, therefore funding and projects may be risky and low in number. In addition, green hydrogen is not the only type of hydrogen, nor even the only type of hydrogen that can deliver significant emissions reductions. Green hydrogen, therefore, needs to compete with these other hydrogen types such as blue and grey hydrogen[5], which for now are more cost-competitive. Finally, there is a poor link between the supply and demand for green hydrogen. The use of green hydrogen in the steel industry requires significant capital investments in production facilities that can produce steel this way. Furthermore, infrastructure is required to match supply and demand.

[5] Grey hydrogen is hydrogen produced through the steam methane reforming of natural gas without carbon capture

Figure 4: Policy objectives on availability of green hydrogen (GH) to decarbonise the EU steel sector



Source: Authors' own composition.

To increase the availability and competitiveness of green hydrogen, EU policies should foster the installation of new electrolyser capacity, create a more competitive market environment for green hydrogen specifically and support a wider demand for green hydrogen as well as the infrastructure to transport it.

The most promising policy options to support green hydrogen availability are a more widespread availability of CCfDs to green hydrogen producers and a wider support to MS initiatives – in particular through State aid guidelines. EU funding support for electrolysis and investment in transport infrastructure can also be worthwhile options.

***Table 4:* Overview of policy solutions – Green hydrogen**

	Effectiveness	Efficiency	Feasibility	Coherence
Option GH1: supporting MS initiatives				
Option GH2: providing financing for electrolysers at EU level				
Option GH3: improving the GOs framework				
Option GH4: offering a premium such as CCfDs				
Option GH5: financial support for hydrogen transport infrastructure				

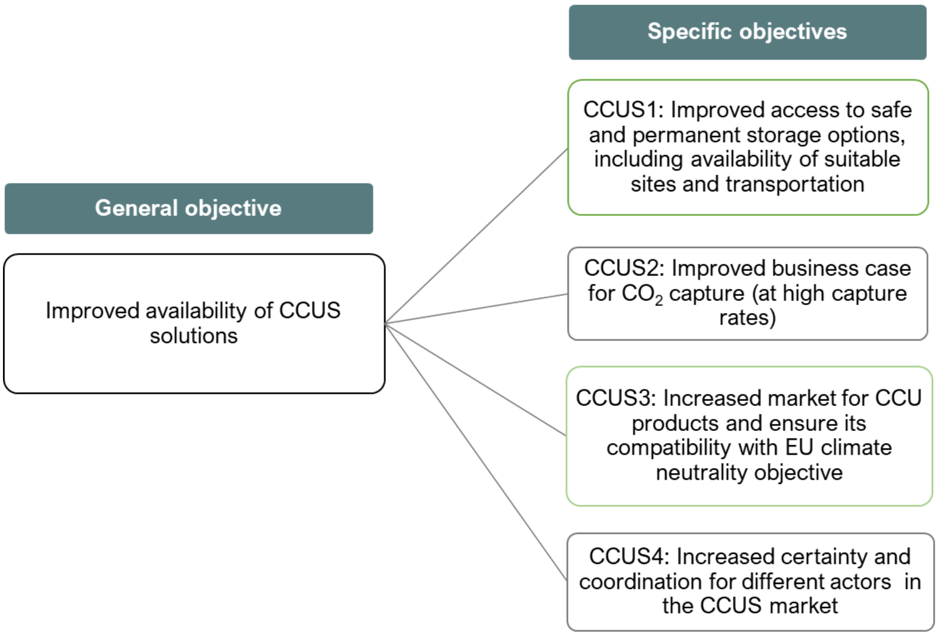
Note: This table presents the policy options in the green hydrogen area that would support the decarbonisation of the EU steel industry. The options are assessed based on the four criteria under the Better Regulation guidelines: their effectiveness, efficiency, feasibility and coherence. Colour legend: orange - low, yellow – moderate, green – high. For instance, a policy option that has a green cell in the Effectiveness column is considered to be "highly" effective. Source: authors' own composition

5. Carbon capture and use or storage (CCUS)

CCUS provides another technological pathway for the steel sector's decarbonisation. While CCUS has been deployed at small scale throughout the world, there is not yet widespread deployment of CCUS infrastructure, especially as part of industrial clusters. The specific reasons for this limited availability of CCUS solutions for the steel industry are related to the individual parts of the CCUS value chain: (i) CO2 storage sites are not yet available; (ii) CO2 capture is energy-intensive, faces challenges with capture rates and is costly, and (iii) many use-cases for CO2 (CCU) are incompatible with climate neutrality. In addition, there are also cross-chain issues, such as the underinvestment in CO2 transport infrastructure so long as CO2 capture and storage remain limited.

The different parts of the CCUS value chain are often interdependent, which raises coordination challenges. CO_2 purity levels, expected volumes, or the availability of other low-carbon infrastructures may all affect the choices of other decision-makers in the value chain. To improve the availability of CCUS solutions for the steel industry, EU policies should: (i) target an improved access to safe CO_2 storage sites; (ii) improve the business case for CO_2 capture at high capture rates; (iii) develop a market for CCU products that is compatible with climate neutrality, and (iv) support coordination efforts along the value chain.

Figure 5: Policy objectives on availability of CCUS solutions to decarbonise the EU steel sector



Source: Authors' own composition.

The most promising policy options are to provide increased public funding for R&D to optimise CO_2 capture rates; foster the use of climate-neutral CCU applications under the EU ETS; provide a coordination platform; and focus public support on entire industrial clusters, as CCUS solutions could provide decarbonisation options for (industrial) sectors beyond the steel sector, thereby increasing the efficiency of decarbonisation efforts.

Table 5: Overview of policy solutions[6] – CCUS

	Effectiveness	Efficiency	Feasibility	Coherence
Option CCUS2: supporting other CO_2transport methods beyond pipelines, as well as recognising and promoting negative emissions technologies in ETS				
Option CCUS3: providing funding (CAPEX and OPEX) for CO_2 storage and transport infrastructure				
Option CCUS5: providing increased public support and funding for R&D&I to optimise capture at high rates				
Option CCUS6: promoting the use of climate-neutral CO_2				
Option CCUS7: providing a platform where different actors in the value chain meet and coordinate				
Option CCUS8: supporting clusters/industrial symbiosis				

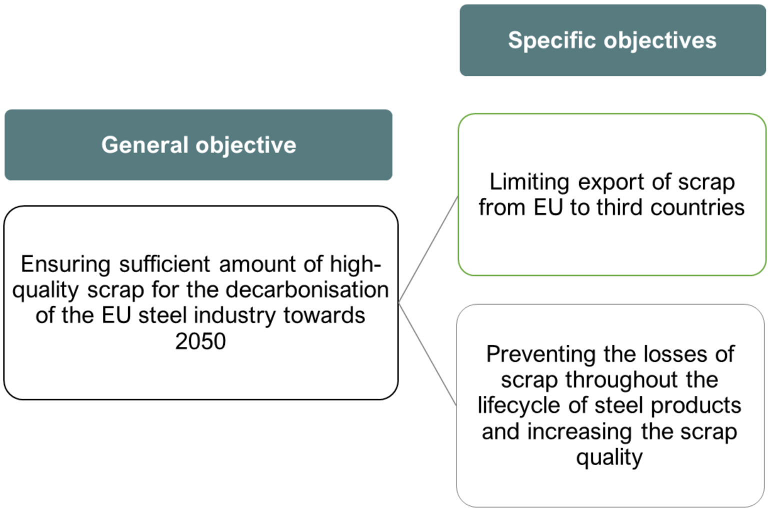
Note: This table presents the policy options in the CCUS area that would support the decarbonisation of the EU steel industry. The options are assessed based on the four criteria under the Better Regulation guidelines: their effectiveness, efficiency, feasibility and coherence. Colour legend: orange - low, yellow – moderate, green – high. For instance, a policy option that has a green cell in the Effectiveness column is considered to be "highly" effective. Source: authors' own composition.

6. Iron and steel scraps

Increasing the reuse of ferrous scrap in steel production is effective in reducing CO2 emissions from steelmaking. However, the EU steel industry can count on only limited amounts of steel scrap, particularly high-quality scrap for steelmaking with electric arc furnaces (the EAF route). There are two reasons for this: the first one is that a large share of steel scrap generated in the EU is exported to third countries, first of all because scrap processing in third countries costs less, and secondly because scrap prices there are high enough to cover transport costs. The second reason is that steel scrap is lost during the steel's life cycle and end-of-life scrap contains high level of impurities that reduce the quality of steel produced in the EAF route.

[6] Options CCUS1 and CCUS4 have not been included in this overview as these options are assessed in the cross-cutting policy chapter

Figure 6: Policy objectives on the availability of steel scrap in the EU



Source: Authors' own composition.

Policy measures should therefore ensure the availability of a sufficient amount of high-quality scrap in Europe, either through limiting the export of scrap to non-EU countries or preventing the loss of steel throughout the use cycle and increasing the scrap quality. The most promising policy options could have positive impacts on increasing the quality of steel scrap for EU steelmakers through promoting the use of best available technologies (BATs) and fostering innovation of scrap refining solutions. Reducing illegal scrap export, or increasing the recyclability of steel-contained products, can also be useful means to increase the availability of steel scrap in the EU.

Table 6 ***Overview of policy solutions – Iron and steel scrap***

	Effectiveness	Efficiency	Feasibility	Coherence
Option SC1: revision of the EU regulatory framework on scrap exports				
Option SC2: improving the quality of scrap available in the EU				
Option SC3: ensuring that final products are recyclable				

Note: This table presents the policy options linked to steel scrap that would support the decarbonisation of the EU steel industry. The options are assessed based on the four criteria under the Better Regulation guidelines: their effectiveness, efficiency, feasibility and coherence. Colour legend: orange - low, yellow – moderate, green – high. For instance, a policy option that has a green cell in the Effectiveness column is considered to be "highly" effective. Source: authors' own composition.

7. Cross-cutting policy options

Several policy options were identified separately in the individual chapters and are considered to have the potential to contribute to many different problem areas at the same time. These include GPP, labels for green steel, CCfDs, increased ETS scarcity and low-carbon standards. These options also represent policy approaches that could be applied to other industrial sectors as well – which often face similar decarbonisation challenges as the steel industry. As such, these options could constitute a particularly coherent set of policy measures to support the industrial dimension of the European Green Deal.

Increased ETS scarcity is a given with the Fit-for-55 package. A higher ETS price will further deter carbon-intensive steel production, and it may also support other policy proposals. A higher ETS price would reduce the subsidy payments made through CCfDs, while the latter could still provide crucial funding for specific green steel investments. The EU carbon price can also be used in GPP projects as a guiding factor for investments. Green labels could also support a market for green steel by making it easier for steel customers to choose climate-neutral products. Longer term, low-carbon standards could harmonise the playing field and protect EU producers of green steel, as such standards would apply to both domestic producers and importers.

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1. Introduction

The Green Steel for Europe project (GREENSTEEL) supports the European Union (EU) towards achieving the 2030 climate and energy targets and implementing the 2050 long-term strategy for a climate-neutral Europe with effective solutions for clean steelmaking. Through its innovative approach consisting of the combined assessment of promising technologies, industrial transformation scenarios, and policy options and impacts, GREENSTEEL will effectively contribute to the sustainable decarbonisation of the EU steel industry. The project helps position the EU as a leading provider of low-carbon products, services and advanced technologies in steelmaking, it supports the green transition and the fight against climate change on a global scale.

The steel industry is one of the most important industrial sectors discussed under the European Green Deal. It is the largest emitter in the EU ETS outside of electricity generation. Its importance as a sector is due to both its primary production and the production of intermediate products used in other industries. The ubiquity of steel and steel products in industrialised societies, however, makes it paramount to focus also on demand reduction through increased circularity and resource efficiency.

The key actions to be implemented under the Green Deal contain several measures that directly affect the steel industry, and many more that do so indirectly. With the EU's updated target of a 55% reduction in carbon emissions by 2030, cuts will need to move beyond the power system, where most of the reductions have been realised up to today. The 160 million tonnes of CO_2[7] of the steel industry will need to be addressed too. The Green Deal, to this end, contains several proposals aimed to support the steel industry in becoming more circular and climate-neutral.

Tools such as a CBAM can mitigate the carbon leakage risk for EU producers facing competition from importers that do not pay similar carbon costs. If this new mechanism replaces (part of) the ETS free allocation (which is a political decision), then more auction revenues to support the EU's new industrial strategy may be available. One way this could be done is through initiatives that stimulate lead markets for climate neutral and circular industrial products. Some of the options, like CCFDs and GPP, are examined in this impact assessment. Policy options that complement the EU ETS – while making use of its strengths – are specifically analysed in Chapter 4 on carbon pricing.

On the energy supply side, the EU has increasingly focused on clean hydrogen. Hydrogen-based steelmaking represents one of the main decarbonisation routes analysed in this study. For this impact assessment, we focussed specifically on green hydrogen, as it has the most transformational potential and it can be integrated in an electricity system with a very high share of renewables. Due to the importance of renewables and electrification (both direct and indirect), Chapter 5 of this impact assessment is dedicated exclusively to how the renewables capacity can be further expanded in the EU.

Another decarbonisation route assessed is based on carbon capture and use or storage (CCUS). While the use of CO_2 is an example of circular economy, storing CO_2 in geological formations can

[7] Data from the EU Transaction Log

be a solution for multiple hard-to-abate industries. Both EU industrial policies and support to MS initiatives can help CCUS to develop further in the EU.

Given the large-scale investment needs identified in the Work Package 2 of the GREENSTEEL project, funding remains one of the most critical policy challenges for the steel industry. In this impact assessment, we review several measures, including EU instruments and facilities, that support both private and MS funding. In contrast to the other chapters, funding is remarkably and explicitly horizontal in nature. As such, Chapter 3 not only offers a review of all available measures, but it also analyses their impact on other policy areas related to the decarbonisation of the steel industry. Some of the policy measures that have the greatest potential to affect multiple policy areas are assessed separately in Chapter 9, on cross-cutting policies. At the end of this report, a set of policy recommendations follows.

2. Methodology

This impact assessment report aims to put forward policy recommendations to foster the decarbonisation of the EU steel industry. This report includes seven main research tasks reflecting the typical methodology for impact assessments described in the Better Regulation Guidelines of the European Commission:

- identification of the policy problems to be address;
- assessment of the EU right and need to act;
- definition of the objectives of the policy intervention;
- selection of the policy options to achieve the objectives;
- assessment of the economic, social, environmental and competitiveness impacts of the selected policy options;
- comparison of the different policy options and selection of the preferred ones, and
- identification of indicators and methods to monitor the future impacts of the preferred options and their contribution to the achievement of the policy objectives.

The above tasks rely on the data and information gathered through desk research and extensive consultation activities. In total, three online surveys were conducted to gather feedback from stakeholders on (i) problems affecting the decarbonisation of the EU steel industry, (ii) the proposed policy solutions to achieve relevant objectives, and (iii) the impacts and comparison of these policy options. Besides online surveys, the study findings were reinforced by expert review and, in particular, through in-depth interviews with stakeholders representing the EU steel sector and other industries, research institutions, civil society organisations and public authorities. Further details can be found in the Synopsis Report of Consultation Activities of Work Package 3 (D3.3) of the project.

The impact assessment is structured around six policy areas affecting the decarbonisation of the EU steel industry: (i) funding, (ii) EU carbon pricing, (iii) renewable electricity, (iv) green hydrogen, (v) carbon capture, usage and storage, and (vi) iron and steel scrap. These areas were identified through the findings of the report on Collection of Possible Decarbonisation Barriers (D1.5) under the Working Package 1 and the report on Investment Needs (D2.2) of the project. They were confirmed with further desk research and stakeholder consultation. The chapters follow the structure of the Better Regulation Guidelines, starting from problem identification, going through the EU's right and need to act, the policy objectives and options, the impacts of the policy options, and finally the comparison of the options.

In addition to these six policy areas, an additional chapter is dedicated to policy options that have transversal impacts on different areas (Chapter 9 – cross-cutting policy options). This chapter's structure is different from the other six. It focuses specifically on the impacts of policy options that potentially affect, whether directly or indirectly, all policy areas. These policy options were selected due to their recurrent mentions in the stakeholder consultation process. For instance, the impacts of one of the policy options in this chapter (integrating compulsory low-carbon standards) are evaluated in all six areas – funding, renewable electricity, carbon pricing, green hydrogen, CCUS and steel scrap.

3. Funding

3.1. Problem identification

3.1.1. Background

The EU steel industry would need approximately **€11 B to bring major decarbonisation technologies to industrial deployment between 2021 and 2034** (EUROFER, 2018a, p. 2).[8] Towards 2050, the capital investments for the two main decarbonisation pathways (smart carbon use - SCU and carbon direct avoidance - CDA) are expected to be around € 52 B (Navigant 2019, p. iii). The funding to cover these investment needs has not been fully mobilised because of the unmitigated risks of low-carbon steel and the lack of available public funding to bring down the production costs and catalyse private investment. It is important to note that by 2030, around 48% of the blast furnaces in the EU steel sector will require major re-investment to remain operational and avoid carbon leakage (Agora 2020b, p. 9). The upcoming investment cycle of the steel industry, estimated to last for about 20 to 30 years (ESTEP 2020a, p. 20), opens the door for the EU to advance its economic recovery and climate neutrality transition progress.

3.1.2. General problem

Decarbonising the EU steel industry requires major investments. While part of the investment can be made directly by the steel industry, **public support is needed**, especially if one considers the high-risk profile of low-carbon steelmaking projects and the large societal benefits that can stem from the decarbonisation of the steel industry. As innovations in the steel sector take decades to develop, key investment decisions should be made as soon as possible to timely achieve the EU climate targets (ESTEP 2020a, p. 20). **Limited funding for decarbonisation technologies** is hindering to a high extent the decarbonisation of the steel sector according to the respondents to the survey conducted during the Inception phase.

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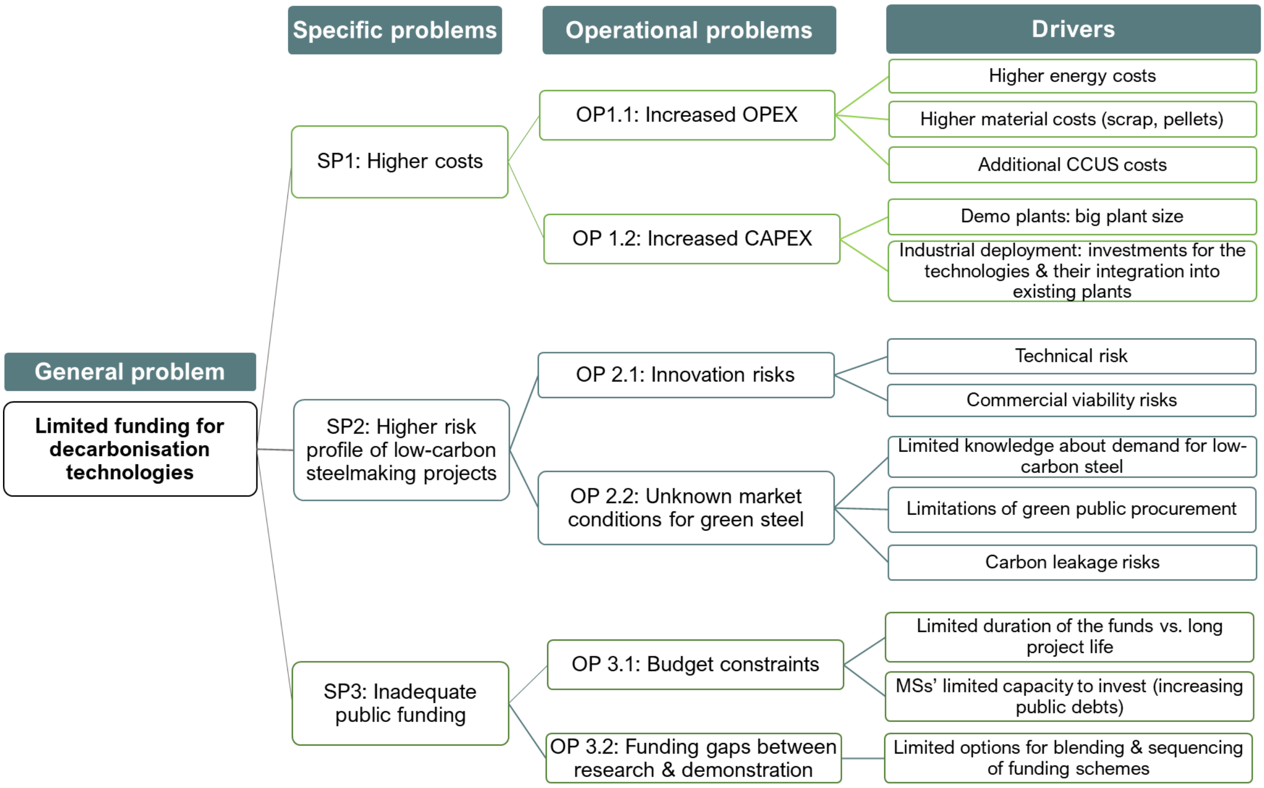
[8] This estimate applies to the demonstration of the decarbonisation technologies. For their deployment, stakeholders engaged in the interviews estimated that about EUR 1 billion is needed to change 1 million tonnes of steelmaking capacity from conventional integrated routes to low-carbon routes.

Figure 7: Problems affecting funding of decarbonisation technologies in the EU steel industry



Source: Author's composition.

3.1.3. Specific problem FD1

Low-carbon steel is expected to cost more than 'conventional' steel, at least at the earlier stage of deployment of decarbonisation technologies. Technologies with higher CO_2 abatement potential cost more and need longer time to be deployed; and the main investments for development (including demonstration) are needed before 2030, whereas most investments for industrial deployment will occur between 2030 and 2050 (GREENSTEEL 2021c, p. 10-12). The increase in production costs results from a combination of higher operating expenses (OPEX) and remarkably higher capital expenditures (CAPEX) for decarbonisation technologies compared to conventional ones (IDDRI, 2019, p. 5; EUROFER, 2018a, p. 3; OECD, 2019b, p. 13). It is estimated that production costs in low-carbon steelmaking routes would be 20-30% higher than current costs[9] (Navigant, 2019, p. iii; Wyns et al., 2019, p. 23; Vogl et al., 2019, p. 3). The expected increase in production costs affects the profitability and return on investment (ROI) of low-carbon steel plants, with negative impacts on investment decisions. Stakeholders consulted in the Inception phase agree to some extent that high production costs expected for low-carbon steel would limit funding opportunities for decarbonisation technologies.

3.1.3.1. Operational problem FD1.1

[9] Navigant (2019) estimates an increase in the EU steel's total production costs from EUR 74-91 billion for the business-as-usual production pathway to EUR 81-112 billion for the decarbonisation pathways in 2050. The projection takes into account, *inter alia*, a growth from 166 Mt of crude steel production in 2015 to 200 Mt in 2050.

Low-carbon steel is expected to face **higher OPEX** than conventional steel. In certain technology routes such as hydrogen-based direct reduction, the OPEX would increase by 80% compared to the conventional integrated route, depending on hydrogen costs (GREENSTEEL 2021c, p. 6). Together with the expected increase in CAPEX (see Operational Problem FD1.2 below), the high OPEX significantly reduce the bankability of investments in low-carbon technologies. OPEX for low-carbon steelmaking are expected to increase to a high extent the costs of low-carbon steel according to the stakeholders participating in the survey conducted in the Inception phase.

- **Driver FD1.1.1**: **Energy costs**, which already play a central role in the OPEX of conventional steel production, would increase when relying on low-carbon technologies. Three factors play a crucial role in raising the energy costs of low-carbon steelmaking: renewable electricity (RES-E) costs, green hydrogen costs, and energy losses.
    - **RES-E:** As discussed in the chapter on RES-E, decarbonisation measures relying on RES-E are expected to increase OPEX for steelmaking. Steel's annual consumption of grid electricity is expected to significantly increase - from 55TWh in 2019 to around 400TWh in 2050 for both direct use in steel production process and for hydrogen production (EUROFER, 2019a, p. 1). While electricity costs currently represent only around 3% of total production costs in blast oxygen furnace (BOF) steel plants, this percentage would increase as a result of the growing electricity demand from decarbonisation technologies.[10] In the Electric arc furnace (EAF) route, electricity costs already correspond to a considerable part of total production costs, i.e. around 10% (CEPS, 2018, p. 203-204). Prices paid for electricity by industrial consumers may increase, despite decreasing generation costs, due to energy taxation, network costs, indirect emission costs and RES levies. Furthermore, steelmakers are expected to face costs to balance the variable electricity demand (due to the features of the low-carbon steelmaking process, especially in the EAF route) and the variable electricity supply from renewable sources (e.g. solar and wind). Balancing/shaping costs further increase the final electricity price paid by steelmakers. (Roland Berger 2020, p. 12; Wyns et. al. 2018, p. 62; CEPS 2019a, p. 27). Finally, regulatory and market obstacles may reduce opportunities for energy-intensive players to sign RE Power purchase agreements (PPAs) (CEPS 2019a, p. 26).
    - **Green hydrogen**: As discussed in the chapter on green hydrogen, the large demand for green hydrogen in both the SCU and CDA technological pathways are expected to raise the energy costs of the decarbonisation technologies. Whether provided from external sources or produced at steel plants, the hydrogen needs to be carbon-free to ensure a low-carbon steel production, although electrolysers running on nuclear energy or partly decarbonised electricity, or 'blue' hydrogen produced from methane combined with CCS measures could still contribute to low-carbon steelmaking ((Navigant 2019, p. 4)). In the main low-

[10] RES-E is mainly needed to produce hydrogen and replace coking coal for iron ore reduction in the CDA pathway; in addition, more electricity will also be needed for the chemical process under the SCU-CCU pathway, which produce methanol from CO and CO_2 off-gases generated during steel production; finally in the SCU-PI pathway, electricity can replace solid carbon energy e.g. for the gas injection in the BF (GREENSTEEL 2021a, p12, 31, 35).

carbon steelmaking routes, hydrogen is generated through electrolysis process integrated into the production process (GREENSTEEL 2021a, p. 12). In these routes, a linear relation[11] between hydrogen cost and electricity cost has been identified ((Vogl et al. 2018, p. 741). The steel sector would need around 5.5 M tonnes of green hydrogen per year towards 2050 ((EUROFER, 2020a), corresponding to two-third of EU's today production of 'grey' hydrogen (i.e. hydrogen produced using unabated natural gas) (Hydrogen Europe 2020b, p. 12) and more than 50% of the total green hydrogen that is expected to be produced in the EU in 2030 (European Commission 2020a, p. 6). It is estimated that the electricity needed for hydrogen production will be equal to 316 TWh in 2050, representing three-fourth of the EU steel's total electricity demand (VHEh 2019, p. 62). At the same time, the electricity market design and future electricity price, which are affected by renewables and carbon pricing policies , pose uncertainty around energy costs for the production of green hydrogen. Besides the costs for RES-E, additional costs to transport the hydrogen will also occur and increase the price for hydrogen generated outside the steel plant. More specifically, these costs are associated either with the construction of new infrastructures, or with the adjustment of existing gas pipelines to transport hydrogen due to the different density of hydrogen and natural gas (GRTgaz 2019, p. 27-33).

- **Additional energy needs to compensate for the loss of blast furnace (BF) and basic oxygen furnace (BOF) gases.** The conventional BF-BOF route for steelmaking generates BF gases and BOF gases, which are carbon-intensive. In fact, decarbonising this production route is largely equivalent to curtail the generation of such gases or capture and utilise them through the Carbon capture utilisation and storage (CCUS) process. At same time, BF and BOF gases are currently one of the main energy sources in the BF-BOF route (Sun et al. 2020, p. 3). More specifically, these gases can be used for power generation, allowing the BF-BOF plants to be mostly self-sufficient when it comes to electricity needs. Besides, these gases can also contribute to the heating of different furnaces. Therefore, other energy sources (such as electricity and natural gas) will be needed to generate the electricity and heating that are now generated by recycling BF and BOF gases. This has an impact on energy optimisation in the conventional BF-BOF route and may eventually increase the overall energy costs for steelmaking (GREENSTEEL 2021a, p. 35).

- **Driver FD1.1.2:** Decarbonisation technologies would face **higher costs for raw materials than conventional routes**. As an example, a shift from the BF-BOF route to the EAF route entails a higher demand of steel scrap, which will most likely record an increase in price affecting the costs for the EAF-based steel production (McKinsey 2020a). In addition, to produce flat steel and steel for automotive or aerospace applications via the EAF route, high-purity scrap will be needed; and this grade of scrap is

[11] Vogl et al. (2018) has found that hydrogen cost increases with electricity cost in case of electrolysis. More specifically, hydrogen cost varies from EUR 1.43 to 5.17/kg at an electricity cost of 20 EUR/MWh and 100 EUR/ MWh respectively.

limitedly available and often requires further processing of end-of-life scrap, thus putting additional pressure on price (OECD 2019b, p.11). As already mentioned, a switch from the conventional BF-BOF route to hydrogen-based steelmaking would increase the demand not only for green hydrogen (see Driver 1.1.1 above) but also for iron ore pellets, which for the time being are mostly purchased from external suppliers and whose price is expected to increase (Mc Kinsey 2020 and GREENSTEEL 2021c).

- **Driver FD1.1.3**: Deployment of **CCS measures** would lead to higher OPEX for steel producers. It is estimated that around 21 M tonnes of CO_2 would be captured, transported, and stored by the steel industry in 2050 (EUROFER, 2019b, p. 14). CCS process for such amount of CO_2 would require not only the additional amount of energy to capture[12] and transport the CO_2, but also additional labour costs to implement and monitor these processes (GREENSTEEL 2021a, p. 48; Wang et al., 2011, p. 2-3; Irlam, 2017, p. 6). The estimated cost of CCS in steelmaking can be up to \$80-90/tonne CO_2, making the current carbon pricing of €25 – 30/tonne CO_2 not sufficient to justify the increased OPEX (Irlam 2017, p. 6; Bui et al. 2018, p. 1075).

All the drivers listed above are considered to increase, at least to some extent, the OPEX for low-carbon steelmaking according to the stakeholders consulted in the Inception phase. High costs for green hydrogen and for deploying CCS solutions are considered to be the most important drivers for OPEX, followed by high costs for sourcing RES-E.

3.1.3.2. Operational problem FD1.2

Decarbonisation technologies would require **significantly higher CAPEX**. The stakeholders in the Inception phase argue that this operational problem is expected to increase the costs of low-carbon steelmaking to a large extent. The CAPEX needed for SCU and CDA pathways towards 2050 are projected to be around €52 B, which is €18 B higher than the investments in the business-as-usual pathway (€34 B)[13] (Navigant 2019, p. iii). By way of example, in the technology route that optimises the condition of steel production in BF-BOF plants, significant changes need to be made to the existing plants (e.g. gas distribution, biomass preparation, new safety measurement and control measures), resulting in the additional CAPEX of up to €110/tonne crude steel annual capacity without CCUS measures and up to €150/tonne crude steel with CCUS (GREENSTEEL 2021c, p. 37). In the technology route using hydrogen-based direct reduction, the CAPEX would be increased between €574 to 874/tonne crude steel, which is 1.3 to 2 times higher than the CAPEX of the conventional integrated route (estimated to be around €444/tonne crude steel[14]) (GREENSTEEL 2021c, p. 39; Vogl et al. 2018, p. 741; Fischedick et al. 2014, p. 33; Navigant 2019, p. 2).

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[12] For instance, one of the potential carbon capture technologies (i.e. separation of carbon from the gas stream) in steel production is chemical absorption. In this technology, thermal energy is used to support the reaction of CO_2 with a chemical solvent which creates a CO_2 stream. Around 2.5 to 2.9 GJ of thermal energy is needed to capture 1 tonne of carbon via this chemical absorption process.

[13] The projection considers a growth of the EU's steel production from 166 Mt in 2015 to 200 Mt in 2050. CAPEX of the decarbonisation pathways include investments for both new plants and for retrofitting existing infrastructure. CAPEX of the business-as-usual pathway covers the retrofitting of current steel production routes.

[14] The CAPEX of the conventional integrated route is calculated based on the investment needed for BF-BOF greenfield plants.

- **Driver FD1.2.1**: The **large size of demonstration plants** is one of the key features that determine low-carbon steel's remarkably higher CAPEX compared to other sectors. The large scale of the demonstration plants is explained by the need to ensure an adequate level of efficiency in the steelmaking process (Neuhoff et al. 2014, pp. 30-31). More specifically, the capacity of a demonstration plant can range between 10 and 100 t per day, which is comparable to that of industrial-scale plants in other process industries (GREENSTEEL 2021b – p. 32). Certain EU steel producers have already developed demonstration plants that require a budget of above €150 M, equivalent to the investment needed for an average industrial-scale cement plant (ArcelorMittal 2020; Imbabi 2013, p. 196). The relatively larger scale of demonstration plants in the steel sector (*vis-à-vis* other energy-intensive industries) leads to higher investment costs to bring steelmaking technologies from lab to industrial reality.
- **Driver FD1.2.2**: The unachieved **economies of scale** and **economies of learning** drive the CAPEX up during first industrial deployment of decarbonisation technologies (TRL9). CAPEX strongly depends on the scale of the steel plant. For example, for the iron bath reactor smelting reduction technology, CAPEX would be at €435/tonne crude steel for a steel plant with capacity of 1.15 Mt/a (million tonnes per annum), but only €400/t crude steel for a 1.5Mt/a plant (GREENSTEEL 2021c – p41). CAPEX would also be expected to be higher during the early stage of industrial deployment compared to the full-scale industrial commercialisation phase. Similar to the economies of scale, the missing economies of learning during the first industrial deployment would entail higher CAPEX. This is because, at the early stage of the plant operation, low-carbon steel plants still would not have optimised their operating conditions due to a lack of experience of the staff. This will result in inefficient productivity at the initial phase of commercialisation.
- **Driver FD1.2.3**: Once brought to industrial level, commercial applications of decarbonisation technologies require not only additional capital for the technologies themselves, but also large **investments to integrate these technologies into existing steel plants**. The first challenge is associated with the addition of new equipment (e.g. carbon capture equipment and hydrogen pipelines) into the limited space of today's brownfield installations (Budinis et al., 2018, p. 65). Secondly, the installation of new technologies and related infrastructures would also lead to long downtimes, potentially interrupting the steelmaking processes and generating production losses.

While the economies of scale and economies of learning are deemed to contribute to some extent to the high CAPEX for low-carbon steelmaking, the stakeholders consulted in the Inception phase emphasised the major role played by costs when it comes to integrating new technologies into existing steel plants. Another issue is represented by the large size of demonstration plants in the steel industry.

3.1.4. Specific problem FD2

Investments in low-carbon technologies in the steel sector are very risky. Similar to other EU's Key Enabling Technologies,[15] the high-risk profile of low-carbon steelmaking projects is associated with both the innovation risks and unknown market potential for green steel (European Parliament 2019a, p. 82). Investors should expect relatively higher ROI to balance out such risks. As analysed under Specific Problem FD1, however, low-carbon steel faces significantly higher production costs compared to conventional steel, while there is no difference in market price between low-carbon steel and steel produced by relying on fossil fuels. Consequently, ROI for low-carbon steelmaking installations is expected to be lower than ROI for conventional steel plants, thus making investments in innovative technologies less attractive. The risk profile of low-carbon steelmaking projects is considered to limit, to some extent, the funding opportunities for decarbonisation technologies by the stakeholders consulted in the Inception phase.

3.1.4.1. Operational problem FD2.1

Low-carbon steelmaking technologies face **innovation risks** associated with either failure to achieve the technical objectives (during the pilot phase), or failure to achieve these objectives on an economically sustainable basis (during the deployment phase) (Vogl 2019, p.3). These risks include, *inter alia*, losses of efficiency, process instabilities, additional maintenance needs and, more generally, higher production costs than conventional technologies. The respondents to the survey conducted in the Inception phase mentioned that innovation risks contribute to some extent to the overall risks of investments in low-carbon steelmaking.

- **Driver FD2.1.1**: There are **technical risks** in developing decarbonisation technologies. **The size of steel production plants**, while having financial impacts as discussed in Driver FD1.2.1, also plays a crucial role in increasing the technical risks of developing decarbonisation technologies. The large scale of demonstration projects creates challenges for testing the technologies, by increasing the project complexity and hindering the stability/efficiency of said technologies (CSL Forum 2019, p. 112; WSP 2015, p. 21).
- **Driver FD2.1.2**: In addition to technical risks, decarbonisation technologies also face **commercial viability risks**. Low-carbon technologies may still fail to produce steel at a cost per tonne that can compete with conventional steel in the market. In addition to the expected increase in CAPEX and costs of raw materials (see Operational Problems FS1.1 and FD1.2), first-of-a-kind (FOAK) industrial plants often cannot rely on optimised operating conditions at the early stage of the plant operation (Vogl et al. 2020, p. 5). Consequently, these inefficient conditions result in increased consumption of material and energy, longer downtime and a higher maintenance effort, which are finally translated into higher production costs. The limited efficiency of FOAK projects, therefore, hinder the competitiveness of innovative decarbonisation technologies against well-established

[15] Key Enabling Technologies (KETs) are the six R&D&I areas that support European global competitiveness across the industrial value chain and its achievement of public health, safety and climate objectives. The manufacturing industry (including steel) is included in one of these six areas. For further details, please see https://ec.europa.eu/info/research-and-innovation/research-area/industrial-research-and-innovation/key-enabling-technologies_en

ones, requiring the technologies to go through optimisation processes before being fully deployed at commercial scale (GREENSTEEL 2021a, p. 31).

The stakeholders consulted in the Inception phase commented that commercial viability risks play a greater role than technical risks in increasing the innovation risks of investments in low-carbon steelmaking.

3.1.4.2. Operational problem FD2.2

There is currently **uncertainty around the market for low-carbon steel** (Ahman et al. 2018, p. 12). The uncertain evolution of this market increases the risks stemming from long-term investments in decarbonisation technologies (Vogl & Ahman 2019, p. 3). The respondents to the survey conducted in the Inception phase agree to a high extent that this uncertainty increases the risks of investing in low-carbon steelmaking.

- **Driver FD2.2.1**: **Future demand** for low-carbon steel in the EU market is still uncertain (Ahman et al. p. 12; IDDRI 2019 p5, 6; Vogl et al. 2020, p. 1). While low-carbon steel would face higher production costs than conventional steel, some customers could still be willing to pay a 'premium price' for cleaner steel (Ahman et al. 2018 pp. 22-23). At this stage, however, the evolution of demand remains unclear. The lack of a secured demand volume for low-carbon steel affects the expected ROI and further deters investment in low-carbon technologies (Vogl et al. 2020, p. 6).
- **Driver FD2.2.2**: **Green public procurement (GPP)** still presents several limitations that do not fully support the green transition of the EU steel sector. First, the public procurement initiatives remain fragmented across the EU, as they are usually voluntarily implemented at national or sub-national level (Núñez Ferrer 2020, p. 8).[16] Such fragmentation might make relevant purchases too small to support large-scale investments in decarbonisation technologies (IDDRI 2019, p. 8). This is a particular concern for the steel industry, given the large size of the steel plants. Second, current GPP initiatives have fewer chances to support decarbonisation measures in the BF-BOF route (Vogl et al. 2020, p. 9). The biggest steel downstream sector is construction, which represents 35% of the total final EU steel consumption in 2019 (EUROFER, 2020c, p. 14). Construction is also one of the main sectors in public procurement in the EU today. This sector mainly uses long steel products, which are mostly produced in the EAF route (Commodity Inside 2019). Other steel products in the primary route have, therefore, lower possibilities to be supported by public procurement initiatives. Third, there are still limited established environmental criteria in the technical specifications of public tenders, e.g. criteria on the limits of climate impacts of the materials included in the final good purchased. Introducing environmental criteria in GPP requires the involvement of both legal expertise and technical knowledge in drafting and evaluating tenders (Núñez Ferrer 2020, p. 6; European Commission 2020b; Cheng et al. 2017).
- **Driver FD2.2.3**: **Carbon leakage risk** connected to carbon pricing may reduce demand for EU steel in favour of cheaper steel coming from third countries where carbon emission

[16] In this respect, the EU launched a GPP initiative, which is however still fully voluntary, with very limited impact in terms of creating a level-playing field across the EU. For further details, please see: https://ec.europa.eu/environment/gpp/index_en.htm

legislation is less strict. Today, the low price of carbon emissions and the system of free allocation of European Union Allowances (EUAs) to the steel sector both play a critical role in avoiding carbon leakage. However, future substantial increases in carbon price and/or changes in mitigation measures could raise steel production costs in the EU. As in most segments of the steel industry competition is based on costs, customers could switch to steel produced in third countries with less stringent climate rules than the EU ones. The magnitude of the carbon leakage challenge is increased by the global overcapacity and strong competitive pressure from the steel global markets (Worldsteel 2020c; OECD 2020b).

Stakeholders consulted in the Inception phase confirmed the relevance of the three drivers presented above. The risk of carbon leakage and limitations in GPP have been identified by industry stakeholders to be relatively strong drivers of uncertainty around market demand for low-carbon steel.

3.1.5. Specific problem FD3

Existing **public funding programmes** do not adequately support the low-carbon transition of the steel industry. While the large investment needs and high-risk profile of low-carbon technology projects require public support, public intervention so far has not ensured adequate funding to catalyse further private investments. During 2021-30, the total resources needed for R&D&I of decarbonisation technologies is estimated at around €3 B. Collaboration among steel producers would create synergies of R&D&I activities and bring down the total investment needs to €2.55 B. Public funding will play a critical role to cover the above-mentioned investment needs, considering that private funding alone would not be sufficient (ESTEP 2020a, p. 60). While most of the EU funding schemes, including Horizon Europe (HEU) and the IF (IF), do not earmark budget specifically for the steel sector, the funding programme dedicated specifically to steel (Research Fund for Coal and Steel, RFCS) has been decreasing its budget due to low interest rates from the European Central Bank (ECB), going from €60 M in 2003 to €22 M in 2019. The limited public funding might not ensure that all relevant decarbonisation technologies for the steel sector can be financed: the current level of funding is adequate only for incremental progress towards low-carbon steelmaking, but far from enough for real breakthrough technologies (GREENSTEEL 2021d, p. 18). The lack of funding consequently delays the decarbonisation progress of the industry and the timely achievement of the EU climate targets. The respondents to the survey conducted in the Inception phase agree to a high extent that the limitations affecting existing public funding programmes can slow down the decarbonisation of the EU steel industry.

3.1.5.1. Operational problem FD3.1

Budget constraints at both EU and national level hinder public investments in low-carbon steelmaking technologies. Budget constraints are considered to limit the effectiveness of public funding for low-carbon steel to a high extent according to stakeholders consulted in the Inception phase.

- **Driver FD3.1.1**: The **limited duration of the current funding programmes** poses a challenge for the development of low-carbon technologies. Most of the EU financing schemes today are planned for a 7-10 year period (e.g. the IF, HEU and the Connecting Europe Facility). Such time span is much shorter than the investment cycle in the steel sector, which often lasts 20-30 years, entailing an unclear perspective for technology development (ESTEP 2020a, p. 20). Certain programmes, such as the IF, explicitly cover the operating costs of projects during the first 10 years of operation (European Commission 2019a, Article 5; IDDRI 2019, p. 7).

- **Driver FD3.1.2**: **OPEX is not covered in most public funding programmes** (GREENSTEEL 2021d, p. 219).[17] The increased OPEX, however, plays a crucial role in raising the total costs of low-carbon steel production, as discussed in the operational problem FD1.1. The IF – currently the only funding programme which covers OPEX – limits the funding rate to 60% of the cost difference between the OPEX of low-carbon and conventional products. Besides, the IF only provides grants for the first ten years of the project operation, while the higher OPEX would persist along the whole project cycle (of around 20-25 years) (IDDRI 2019, p. 7).
- **Driver FD3.1.3**: **EU member states have limited financial capacity** to invest in decarbonisation technologies (Rubio 2017, p. 100). The Covid-19 pandemic has further aggravated the situation: national funds have been immediately reallocated towards healthcare, social security and business continuity to address the urgent sanitary crisis (WEF 2020, p. 7). In addition, this crisis is likely to deteriorate the sustainability of member states' debts. Between the third quarter of 2019 (2019Q3) and the third quarter of 2020 (2020Q3), the government debt to GDP ratio went from 86 to 97% in the Euro area and from 79% to 90% in the EU. All member states have observed a higher ratio of government debt to GDP in 2020Q3 compared to 2019Q3. Some examples include: from 137% to 154% for Italy, from 120% to 131% for Portugal, from 100% to 117% for France, from 98% to 114% for Spain and from 61% to 70% for Germany (Eurostat 2021, p4).[18] The EU Recovery and Resilience Facility (RFF) will, however, make available additional resources (€672.5 B in grants and loans) that could be invested, *inter alia*, to support decarbonisation technologies, if one considers the large emphasis placed by the Facility on sustainability and the green transition (no less than 37% of the available resources should be targeted to green investments and reforms).

Stakeholders consulted in the Inception phase confirmed that the limited financial capacity of EU member states and the limited duration of current funding programmes *vis-à-vis* the investment cycle of the steel industry may affect the decarbonisation of the steel industry.

3.1.5.2. Operational problem FD3.2

There is a **funding gap** (the so-called 'valley of death') between the research, demonstration and deployment phases for decarbonisation technologies. Even technologies that are very promising at low TRLs often fail to reach commercialisation (Neuhoff et al. 2014, p. 11). The valley of death is most prominent in demonstration projects, which sit in the middle stage of the innovation

[17] It is worth remarking that OPEX is not eligible for compensation also in the Guidelines on State aid for environmental protection and energy (2014-2020). The Guidelines establish that eligible costs for environmental aid are "extra investment costs in tangible and/or in intangible assets which are directly linked to the achievement of the common objective" (item 72 under Section 3.2.5.1). For further details, please see:
https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52014XC0628%2801%29

[18] Two factors contributed to the increase in the government debt to GDP ratio: the government debt increasing considerably, and GDP decreasing.

process (Nemet et al. 2018, p. 154-167). A funding gap in this phase can undermine previous research efforts, which received a large amount of public funding. Projects lacking funding during the demonstration phase can face challenges to complete construction, become fully operational, and thereby failing to prove the efficient operational performance of the innovations to the market. Public intervention is needed to guarantee the funding to bring the technologies to demonstration phase, send market signals and provide the enabling infrastructure to scale them up in the later stage (Muscio & Vu forthcoming, p. 7). In the EU steel industry, one issue affecting the innovation process is the currently limited public funding support for the demonstration of low-carbon technologies (Neuhoff et al. 2014, p. 57-58). Under the proposed Clean Steel Partnership (CSP)[19], it is estimated that the joint public-private funding needed to bring decarbonisation technologies from research to demonstration level (from TRL6 to 8) in the steel industry is €2.55 B for the period 2021-2030 (ESTEP 2020a, pp. 30, 60). Stakeholders consulted in the Inception phase confirmed that the funding gap for demonstration and deployment affects the decarbonisation of the EU steel industry.

- **Driver FD3.2.1**: There are currently **limited options for blending and sequencing of funding schemes**. For instance, one issue that challenges synergies between programmes is the different rules on territorial location or cross-border cooperation[20] (European Commission 2017b, p. 26). Some programmes leave room for synergies from a legal standpoint, but do not really promote such potential when implemented (European Parliament 2019a, p. 111). Blending of EU and national/regional funding instruments is not generally allowed, except for very few cases; sequencing has not generally been defined in such instruments, either at the EU or national/regional level (GREENSTEEL 2021d, p176). Three underlying reasons for the lack of synergies between funding schemes can be identified: (i) the lack of a strategic framework; (ii) the absence of concrete guidance and recommendation of good practices, and (iii) limited monitoring and evaluation systems currently in place (i.e. systems that collect data on funding synergies to track their progress and show potential benefits to other projects that can use similar blending/sequencing mechanisms) (European Commission 2017b, pp. 17, 25, 30). The fact that issues with blending and sequencing of funding schemes can exacerbate the funding gap for demonstration and deployment was, to some extent, confirmed by the respondents to the survey conducted in the Inception phase.

3.2. EU right and need to act

EU-level actions are needed to ensure adequate funding to decarbonise the steel industry. Union level intervention complies with the principle of subsidiary established in Article 5 of the **Treaty on European Union** (TEU) and the objective of promoting coordination among undertakings to improve the competitiveness of the Union's industry set in Article 173 of the **Treaty on the Functioning of the European Union** (TFEU). One of the main factors explaining

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[19] For further details on the proposed Clean Steel Partnership, please see: https://www.estep.eu/assets/Uploads/200715-CSP-Roadmap.pdf

[20] This issue arises, for instance, when combining funding from Horizon 2020 and ESIF. While ESIF provides funding mostly for territorial projects (either local, regional or national), Horizon 2020 requires the project to have an international set-up (Kah and Gruber 2019, p4).

the lower effectiveness of separate member states' actions compared to EU-level action is the current context of the EU steel industry. This sector spreads through 500 production sites across 23 member states, with steelmaking technologies varying from plant to plant (Navigant 2019, p. iv; ESTEP 2020a, p. 14). Consequently, there is no 'one-size-fits-all' approach to tackling the climate targets of the EU steel industry, requiring technologies (and the combination thereof) to be developed in parallel and deployed in different production sites (ESTEP 2020a, p. 73).

Actions taken co-ordinately at EU level to remove the funding barriers for low-carbon steel technologies can generate **diverse additional impacts**. First, this approach helps avoid the duplications of efforts taken solely at member state level and allow synergies among them. Second, the Union intervention can create a critical investment mass, addressing the significantly higher costs to develop and commercialise decarbonisation technologies in the steel sector. The availability of large public funding can provide a clearer vision of low-carbon steel markets for the private sector, allowing further private financing to be mobilised and accelerating the deployment and commercialisation of technologies. Finally, EU-level support for better access to funding stimulates healthy competition among different technological solutions, raising the level of scientific excellence in the EU, and it improves the diffusion of best practices across member states.

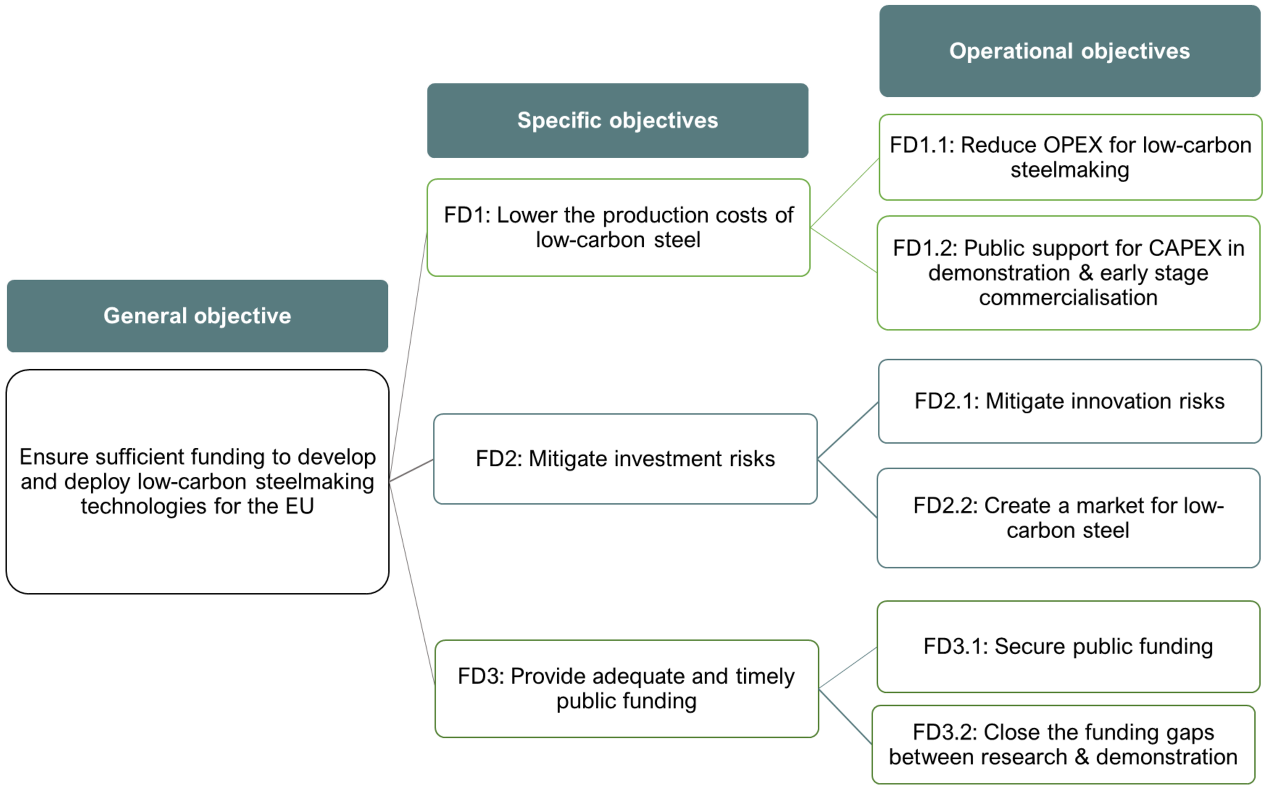
3.3. Policy objectives and options

3.3.1. General objective

The **general objective** of the EU intervention is to ensure sufficient funding to develop and deploy low-carbon steelmaking solutions, thus reducing the risks associated with investments in these innovative technologies and catalysing funding from the private sector. It is estimated that the investment needs to bring decarbonisation technologies from research to industrial-scale deployment will be in the area of €11 B during the period 2021-34, and the steel sector is not going to be able to meet these funding needs without public support (EUROFER 2018, p. 2). The investments to decarbonise the steel industry need to be made in a timely fashion to allow sufficient time for innovations in the sector to materialise and meet the target of reducing emissions stemming from EU steel production by 80-95% by 2050 compared to 1990 levels, ultimately leading to climate neutrality.[21]

[21] For further details on the emission reduction objectives for the EU steel sector, please see: ESTEP (2020), https://www.estep.eu/assets/Uploads/200715-CSP-Roadmap.pdf, p. 21

Figure 8: Policy objective of funding for decarbonisation technologies in the EU steel industry



Source: author's composition.

3.3.2. Specific objective FD1

Specific objective FD1: Reducing the production costs of low-carbon steel to improve its cost competitiveness *vis-à-vis* 'conventional' steel, particularly at the earlier stages of deployment of decarbonisation technologies. Low-carbon steel is expected to cost more than carbon-intensive steel, and technologies with higher CO_2 abatement potential are more expensive and need a longer time to be deployed. The EU policies should aim to lower both the OPEX and CAPEX of low-carbon steelmaking.

3.3.2.1. Operational objective FD1.1 and policy options

Operational objective FD1.1: reducing OPEX for low-carbon steelmaking and keep them at a competitive level *vis-à-vis* OPEX from conventional steelmaking technologies. Low-carbon steel is expected to face higher OPEX (including, *inter alia,* energy costs, costs for raw materials and costs linked to CCUS solutions) than conventional steel. The EU policies need to ensure the availability of affordable RES-E, green hydrogen, and high-quality scrap for low-carbon steelmaking, as well as introduce financial support for OPEX in relevant funding programmes.

Baseline: OPEX to produce low-carbon steel will be higher than the current one for conventional steel production, thus reducing the appetite for private investments. Energy costs for steelmaking may increase due to the growing demand for RES-E and green hydrogen, as well as additional energy needs stemming from the transition to low-carbon steelmaking technologies. Similarly, the costs for raw materials may go up due to growing demand for iron ore pellets and high-quality steel scrap. Also, the introduction of CCUS solutions may further increase OPEX for steelmaking.

Option FD1: promoting the use of EU funding programmes (including the IF) to finance OPEX of low-carbon steel.

The EU IF aims to support the demonstration of innovative decarbonisation technologies. More specifically, it could help cover part of the incremental cost of pilots for key breakthrough technologies and maybe even part of the upfront capital cost of commercial plants later on. However, by itself, this instrument is unlikely to be sufficient to promote large-scale commercialisation. The operation of the IF is regulated by the EU Emissions trading system (ETS) Directive and the Delegated Regulation supplementing the Directive. Article 10a (8) of the EU ETS directive, section 3 and Article 5 (chapter II) of the Delegated Act could be revised to achieve more ambitious targets. The funding rate and period covered by the IF could be extended beyond the threshold of 60% of the cost difference between the OPEX of low-carbon and conventional products and beyond the first 10 years of project operation. The IF is currently the only funding programme covering OPEX. The increased OPEX, however, plays a crucial role in raising the total costs of low-carbon steel production. Other funding programmes should also include OPEX (or at least the cost difference between the OPEX of low-carbon and conventional steel) in their eligible funded costs.

3.3.2.2. Operational objective FD1.2 and policy options

Operational objective FD1.2: ensuring public support for CAPEX in demonstration and early-stage commercialisation of decarbonisation technologies, including the investment needed to integrate these technologies into existing steel plants. Decarbonisation technologies in the steel industry would require significantly higher CAPEX. The policies should aim to provide funding to demonstrate the technologies and facilitate the conversion of brownfield installations into low-carbon steel plants.

Baseline: CAPEX to produce low-carbon steel will be higher than those faced by conventional steelmaking, thus reducing the appetite for private investments. Initially, CAPEX is likely to go up due to the large size of demonstration plants in the steel industry as well as the limited economies of scale and economies of learning achievable during the first industrial deployment. Also, CAPEX for full-scale industrial commercialisation is expected to be high and may further grow when accounting for the investments needed to integrate new technologies into existing plants.

Option FD2: mobilising private funding to support CAPEX of decarbonisation technologies.

Fast adoption and progressive amendment of the EU sustainable finance framework should be promoted. The EU sustainable finance framework should help mobilise private sector in sustainable investments and re-orient capital flows towards sustainable activities and investments. This urgently needed framework is rather new and new insights gained upon its implementation may require new amendments, e.g. to (further) mitigate green-washing. The use of measures under this framework (e.g. the EU Taxonomy for sustainable activities and the Green Bond Standard) should be promoted to encourage market participants to invest in low-carbon steelmaking technologies. In this respect, investments in the decarbonisation of the steel industry should be considered as sustainability investments in the EU taxonomy. Secondly, the current EU sustainable finance framework is de facto a ‘green finance’ framework, but it is not ready yet to support the ‘social’ aspect of the sustainability investments. More emphasis should be put on the social part of sustainability. This would support the greening of the steel industry and protect the labour force in the EU steel industry.

Option FD3: ensuring public support for CAPEX beyond direct public funding (accelerated depreciation, tax abatements, etc).

This option implies devising other EU and national solutions to support major brownfield conversions into low-carbon steelmaking installations, e.g. allowing accelerated depreciation of new assets (to lower the taxation basis) or other tax abatements and financial support for the preparation of site conversion. The EU and national financing instruments will need to take into account the additional constraints that come into play during the conversion of existing process installations which have been written off. Any national solutions allowing for the above measures should comply with State aid rules. In this respect, the EU can play an important role. The EU State Aid Guidelines for Environmental protection and Energy post 2020 (EEAG) are currently under preparation. Ideally, in their upcoming revision, the guidelines should allow member states to introduce such national solutions (e.g. accelerated depreciation, tax abatements, etc.) to support the decarbonisation of the steel sector.

3.3.3. Specific objective FD2

Specific objective FD2: mitigating the risks faced by investors in low-carbon steelmaking technologies, including innovation risks and the existing uncertainty around the market potential for low-carbon steel. Investments in low-carbon technologies in the steel sector are very risky, due to both the high innovation risks and the unknown market potential for low-carbon steel. An EU policy intervention can lower such risks and increase the bankability of investments in decarbonisation technologies.

3.3.3.1. Operational objective FD2.1 and policy options

Operational objective FD2.1: mitigating the innovation risks associated with either failure to achieve technical objectives of low-carbon steel technologies (technical risks during pilot phase), or failure to achieve these objectives on an economically sustainable basis (commercial viability risks during deployment phase). There are high technical risks in developing decarbonisation technologies, particularly due to the scale of demonstration projects. Besides, decarbonisation technologies also face commercial viability risks associated with the limited efficiency of FOAK projects. EU policies should aim to mitigate both these risks by introducing risk mitigation instruments or public guarantees for innovative decarbonisation technologies.

Baseline: EU steelmakers will face high technical and commercial viability risks, as low-carbon steel is expected to cost more than conventional steel. High risks may increase the cost of capital in the steel industry and reduce appetite for private investments, thus slowing down the green transition.

Option FD4: introducing risk mitigation and loan guarantee instruments for investments in decarbonisation technologies.

An EU risk insurance and guarantee fund could be established to hedge risks associated with innovative pilot and pre-commercial projects. Risk mitigation measures could complement the IF and InvestEU, which are currently the two de-risking instruments spreading across different sectors and priorities. This instrument can be funded by new revenues from the EU ETS. The implementation of such an instrument could also promote the design of some private insurance and guarantee products specifically designed for low-carbon steelmaking technologies and provide relevant signalling effects to investors. In addition, loan guarantees through the European Investment Bank (EIB) and member states' public investment banks could contribute to de-risk innovation and deployment of decarbonisation technologies. This option will lower the cost of capital for the steel sector. Ultimately, the de-risking instruments could be combined with private sector investment to enlarge the funding scale.

3.3.3.2. Operational objective 2.2 and policy options

Operational objective FD 2.2: creating a market for low-carbon steel, contributing to decreasing the risks stemming from long-term investments in decarbonisation technologies. There is currently high uncertainty around the market for low-carbon steel due to the limited knowledge about customer demand, the limitations in implementing the GPP initiative and the potential carbon leakage risk. The EU policies to address these barriers would effectively increase certainty around such market.

Baseline: future demand for low-carbon steel will remain uncertain and supported only to a very limited extent by GPP initiatives. In addition, it may be curtailed by imports of cheaper, high-carbon steel from third countries (carbon leakage). This uncertainty will discourage private investments in low-carbon steelmaking.

Option FD5: compulsory standard - Integration of low-carbon standards in the Best Available Techniques Reference.

The EU can establish EU standards to define 'low-carbon steel' or 'green steel', taking into account a life-cycle approach. The EU's Industrial Emission Directive could set a date when the CO_2 performance requirements (the new standards) for major new investments and license extensions will become effective, e.g. after 2030. EU-level standards on low-carbon steel can facilitate GPP; clarify the project eligibility criteria for Carbon contracts for difference (CCfDs) and support the export of EU low-carbon technologies and products.

Option FD6: promotion of low-carbon steel products in public procurement.

New rules on public procurement can be a way to create early demand for low-carbon steel, contributing to lead market creation. The EU should introduce minimum GPP criteria and targets to promote the uptake of GPP at national level. The Public Procurement Directive should be reformed to (i) set declining CO_2 threshold in materials, including steel, that are eligible to be purchased in public projects; (ii) introduce life-cycle CO_2 performance criteria in project assessment, e.g. by monetising environmental criteria in tenders (proposals with higher CO_2 performance should have reduced bid prices), and (iii) support the labelling of low-carbon steel in intermediate and final products.

Beyond the scope of public procurement, the conditionality criteria (both in terms of eligibility and selection) could also be extended to include specifications on the use of EU funds (e.g. the Cohesion Fund (CF), the European Regional Development Fund - ERDF, the European Fund for Strategic Investments - EFSI) and possibly extended to lending requirements of the EIB.

The promotion of GPP would also increase the business case for RES-E, green hydrogen and CCUS solutions and high-quality scrap.

Option FD7: developing a green label for low-carbon steel.

A key challenge for low-carbon steel in the marketplace is that it has to compete with conventional, higher-carbon steel. Policies that enable clearer market differentiation between low- and high-carbon steel could help support demand for green steel, by informing customers interested in lowering their carbon footprint about the embedded carbon in the steel they procure. A green label for low-carbon steel would allow for such differentiation.

The EU could set up a robust EU-wide certification mechanism that allows consumers to identify steel that has been produced using low or zero-carbon technologies. This can constitute a lead market creation instrument for decarbonised steel with its own price formation mechanisms based on supply and demand, as well as embedded carbon contents.

A green label requires agreeing on a definition of what constitutes ‘green steel’. It could contain different classifications, depending on the production process, or multiple tiers related to the carbon content. The label could be applied both to final products using steel, but also to intermediate steel products, so as to enable better market information for contractors procuring steel as part of, for example, construction or transport infrastructure value chains.

The definitions could be aligned with the EU’s sustainable finance taxonomy while such green labels could also be used in public procurement initiatives for decarbonised products. In this respect, the Public Procurement Directive can be reformed to support the labelling of low-carbon steel in intermediate and final products.

This policy option is also expected to support higher availability of RES-E and high-quality scrap, and increase the business case for green hydrogen and CCUS.

3.3.4. Specific objective FD3

Specific objective FD3: ensuring that existing and future public financing support the low-carbon transition of the steel industry, in an adequate and timely manner. The public intervention has so far not guaranteed adequate funding to catalyse further private investments in low-carbon steel. The EU policies need to secure more public funding for low-carbon steel and make the best use of the currently available funding programmes through better synergies between them.

3.3.4.1. Operational objective FD3.1 and policy options

Operational objective FD3.1: securing EU and national financial support for the decarbonisation of the steel sector at sufficient scale and for the entire transition period 2021-50. EU policies should ensure sufficient funding for carbon neutrality in the EU steel industry by 2050.

Baseline: public support to low-carbon steelmaking technologies may be negatively affected by the limited financial capacity of several EU member states. In addition, investment decisions may also be affected by the limited duration of the existing funding programmes (*vis-à-vis* the investment cycle in the steel industry) and the fact that OPEX is often not eligible for funding.

Option FD8: ensuring that EU resources, including those of the Next Generation EU, will support the green transition in the steel industry.

This option should emphasise the need to overcome the financial constraints experienced by some member states, avoiding funding for low-carbon steel to be concentrated only in the few member states where budget is available. A share of the RFF, which is the largest component of Next Generation EU, should be earmarked for the decarbonisation of the steel industry. To achieve that, first of all, the RFF should apply a clear exclusion criterion for fossil fuels and fossil gas. In this respect, the EU Taxonomy can serve as a potential guideline for budget allocation.

Secondly, EU and national funds should be allowed to add up to the RFF. Lastly, the timeline of the Recovery Plan (2021-24) needs to align with the Multiannual Financial Framework (2021-27) to avoid funding gaps after 2024.

Option FD9: identifying pathways (2030 and 2050) for decarbonisation technology routes and ensuring that both EU and national policy makers account for them.

The pathways should identify relevant criteria for the industrial transformation processes, including milestones, timing and the relevant value chains involved. To clarify how different framework conditions can impact the transition of the EU steel sector, these pathways are modelled in different scenarios. Desk research and stakeholder consultations are needed to develop said scenarios. The pathways can include both short-term mitigation technologies towards 2030 and long-term breakthrough technologies towards 2050. Both short- and long-term technologies can be assessed based on different steel plants' site classes. Proper dissemination of such pathways among policy makers and funding authorities can ensure that legislative framework conditions and EU and national funds are efficiently adapted to support the transformation of a decarbonised industrial steel production.

3.3.4.2. Operational objective FD3.2 and policy options

Operational objective FD3.2: closing the funding gap between the research, demonstration, and deployment phases for decarbonisation technologies. The EU policies should help these technologies cross the 'valley of death' and reach the deployment stage.

Baseline: promising technologies with high CO_2 abatement potential may fail to reach commercialisation due to the limited public funding support for the demonstration phase. Limited opportunities for blending and sequencing of public funding programmes may reduce the effectiveness of such programmes and their ability to bring low-carbon, innovative technologies to the market.

Option FD10: creating synergies in EU-level funding via the CSP.

The CSP blends funding from two European research programmes: the HEU and the RFCS. The above-mentioned public sources will be complemented by private funding through the matching contribution principle. Two alternative solutions can be applied to ensure the synergies between HEU and RFCS. The first and best alternative is to establish a single funding mechanism (one stop shop) to manage the research activities under HEU and RFCS. While this alternative could generate greater impact and efficiency, in practice, it can be difficult to implement due to the differences in the operational functioning of the two programmes, such as timelines, eligible TRLs, eligible countries and funding rates. Therefore, a second alternative solution can be implemented, in which the CSP establishes a governance structure to manage differentiated and complementary calls under HEU and RFCS. This structure could simplify the procedures, comply with the legal basis for the implementation of the respective programmes, and fulfil the information obligation to the European Commission (EC) and the respective Committees (the Strategic Programme Committee Horizon Europe for Cluster 4 calls and the Coal and Steel Committee and Steel Advisory Group).

Option FD11: creating additional synergies in EU-level funding via blending and sequencing of different opportunities.

Blending should allow the same project to rely on different funding sources (of course without charging the same costs twice) and to ensure complementarities whenever possible (the combination of HEU/RFCS is a case in point). Sequencing should allow the same project to rely on different funding sources in sequence to move from research to development, from development to deployment and from deployment to commercialisation. The synergies of the funding schemes can follow the approach of the EU Energy-Intensive Industries Masterplan. Some examples include blending of RFCS and HEU, sequencing of HEU/RFCS with IF/LIFE Programme, HEU with ESIF.

Option FD12: establishing an Important Project of Common European Interest (IPCEI) for low-carbon steel.

The IPCEI framework was rarely used until the Commission adopted a dedicate Communication laying out the conditions for its application in 2014. The Strategic forum for IPCEI, created in 2018 aims to facilitate new joint investments in key value chains. The Strategic forum selected six Strategic value chains for the EU, including the 'Low-CO_2 emission industry' value chain. The IPCEI is a legal framework that allows the pooling of different types of funding (EU, national, regional and private ones) for a project with a strong EU added value. The funding gap could be closed by establishing an IPCEI that could provide a legal framework allowing the combination of EU, national, regional and private funding in compliance with the State aid rules. The promotion of a steel-specific IPCEI framework makes sense because this industry spreads through 500 production sites across 23 member states, with steelmaking technologies varying from plant to plant. Consequently, there is no 'one-size-fits-all' approach to tackling the climate targets of the EU steel industry, requiring technologies (and the combination thereof) to be developed in parallel and deployed in different production sites.

The IPCEI for low-carbon steel could allow technologies that entail significant risks and require coordination and transnational investments to receive direct funding from several member states. It can follow the approach of the IPCEIs for batteries and microelectronics, as well as the new IPCEI for hydrogen. First, the EU should engage and closely coordinate with member states and relevant stakeholders (including steel companies) at an early stage. Second, templates and standardised project portfolios can be used in the notification and evaluation process. Last, the IPCEI should facilitate the combination of different national and EU funding sources.

3.4. Impacts

3.4.1. Option FD1: promoting the use EU funding programmes (including the IF) to finance OPEX of low-carbon steel

Economic and competitiveness impact

Many EU and member states funding instruments are limited in their ability to cover OPEX, therefore an EU-wide instrument aimed to cover the increased OPEX specifically could be beneficial in speeding up the decarbonisation of the steel industry. Currently, the IF supports up to 60% of the additional CAPEX and OPEX of large-scale projects and up to 60% of the CAPEX of small-scale projects. This policy option is expected to generate positive economic impacts and enhance the competitiveness of the steel sector through the following mechanisms:

- using the IF and other EU funding programmes to finance OPEX would lower the production cost of green steel, particularly because it will reduce the cost of inputs required to produce green steel. Production inputs (including RES-E, green hydrogen and

CCUS) make up for an important share of OPEX, this policy would therefore help reduce the production costs of low-carbon steel and improve its cost-competitiveness *vis-à-vis* 'conventional' steel:

- in addition, this policy can also **lower cost of capital** for green steel projects. More specifically, the IF would support the risk-sharing for project promoters during the demonstration of first-of-a-kind (FOAK) highly innovative projects. With a lower risk profile, green steel technologies can access financing at cheaper cost;
- the use of the EU funding programmes to finance OPEX could also enhance technological development, **promoting the R&D&I of decarbonisation technologies.** This policy option could ultimately allow for more innovative investments and the spread of low-carbon technologies in the steel sector.

Environmental impact

The IF is specifically aimed at greenhouse gas (GHG) reductions by supporting the deployment of innovative low-carbon technologies. This will, in turn, support the steel sector decarbonisation and the green transition in the EU.

Social impact

The use of EU funding programmes would promote innovation, leveraging private investment in equipment and creating employment in the industry. It will also indirectly entail the upskilling and reskilling of the labour force in the steel industry to adapt to the new steelmaking technologies.

Cross-cutting issues

The IF also supports cross-cutting projects for innovative low-carbon solutions that lead to emission reductions in multiple sectors, for example through industrial symbiosis.

This measure, besides having a great impact on investments in the steel industry, will also support the development of a new value chain for energy/raw materials (i.e., RES-E, green-hydrogen, biomass, CCUS). Most of the low-carbon steelmaking routes are based on electrification, use of clean H_2, higher scrap use and CCUS. Except for scrap, which is a factor impacting only steel, the others cover, by far, a huge range of other sectors (e.g., industry, mobility, etc.). Funding will indirectly enhance the search for solutions dedicated to RES-E, green hydrogen, CCUS and scrap to optimize them and to integrate them into existing processes. In particular, this will have an immediate and relevant impact on areas more linked to steel production, such as scrap and, to a lesser extent, CCUS. The development of hydrogen technologies will increase demand for hydrogen, thereby boosting investments in clean hydrogen supply.

3.4.2. Option FD2: mobilising private funding to support CAPEX of decarbonisation technologies

Economic and competitiveness impact

The promotion of the EU Sustainable Finance Framework in the steel sector would help **reduce the cost of doing business** for green steel. Reduction in CAPEX leads to reduction in total production cost of green steel. CAPEX reduction is particularly relevant to support first-of-a-kind projects, but not only, to get costs down through economies of scale and economies of learning.

Because of the above impact, this policy option could also **promote R&D&I of decarbonisation steelmaking technologies**, thus enhancing the competitiveness of low-carbon production. CAPEX support is a powerful enabler for the introduction of FOAK technologies in carbon-neutral production, and in demonstrating the decarbonisation potential of the steel sector.

Finally, this option is expected to facilitate **access from the steel sector to private funding, particularly risk capital**. The Sustainable Finance Framework could encourage market participants to invest in low-carbon steelmaking technologies. For instance, under the EU Taxonomy, the decarbonisation technologies for steel production should be considered 'green' investments. Technical screening criteria could therefore be designed to support investment in decarbonisation technologies.

This policy option, together with option FD1, presents a valid opportunity to facilitate investments in decarbonisation technologies in the steel sector. It reflects the fact that OPEX and CAPEX should always be considered together from the business viewpoint in the steel industry.

Environmental impact

This measure will support the decarbonisation of the steel industry and the green transition in the EU by directing investments towards steelmaking methods with a lower carbon footprint, compatible with the EU's emissions reductions targets. It will also increase public health and safety in local communities, reducing pollutant emissions in so far as the investments shift the industry away from conventional BF-BOF steelmaking towards more (indirect) electrified or secondary steelmaking.

Social impact

Sustainable finance must rely on the consideration of the social impact of investment (e.g. inequality, labour relations, investment in human capital and communities). This measure will promote investments in greening the steel industry, leveraging private investment in equipment and increasing employment.

Cross-cutting issues

As in the case of policy option FD1, this measure, besides having an impact on investments in the steel industry, will also create demand for RES-E and green hydrogen and to some extent CCUS and high-quality scrap, supporting the development of a new value chain for energy/raw materials. There would be more short- to mid-term demand for RES-E, green hydrogen and CCUS. It is expected that, once deployed, demand for clean energy resources will increase. Therefore, this policy option should be supported by the availability of RES-E, and green hydrogen and smart scrap management by the EU.

3.4.3. Option FD3: ensuring public support for CAPEX beyond direct public funding (accelerated depreciation, tax abatements, etc.).

Economic and competitiveness impact

Tax support measures such as accelerated depreciation or tax abatements could also generate similar impacts on the competitiveness of the EU steel industry as option FD2. Facilitating the major restructuring of steel installations (as discussed above) would entail the substitutions of steelmaking technologies. This plays a crucial role in supporting **R&D&I of steel production technologies** towards decarbonisation. CAPEX support through fiscal measures would also

leverage further private investments, achieving a credible critical mass for decarbonising the EU steel industry.

Similar to option FD2, this option would also entail reduced CAPEX, leading to lower **costs of doing business** for green steel. The mechanism of this impact is however different from that of FD2. More specifically, measures under FD3 will remarkably support the **brownfield conversion** into low-carbon steelmaking installations. Given the upcoming investment cycle of the EU steel industry[22], the support for brownfield conversions in this industry is considered a significant factor, which could perhaps be even more important than greenfield support, especially in the short to medium term.

Environmental impact

It is expected that this solution will promote new investments in steel plants, contributing to **the decarbonisation of the steel industry**. This measure will also support the green transition in the EU by promoting investments in steelmaking methods with a lower carbon footprint, compatible with the EU's emissions reductions targets.

Social impact

The impact of this measure will be similar to those of option FD2. It will promote investments in greening the steel industry, leveraging private investment in equipment, hence increasing employment. By supporting the transformation of the steel industry, jobs in the industry are retained, although there may also be changes in the skill profiles required. When traditional steelmaking methods based on coal are replaced, environmental conditions such as air quality improve.

Cross-cutting issues

Appropriate financial incentives may also increase the supply of green energy and decrease its costs. As for policy options FD1 and FD2, supporting CAPEX of decarbonisation technologies by private funds will create demand for RES-E and green hydrogen and to some extent CCUS and high-quality scrap. Overall, it will have a direct impact on scrap and CCUS (e.g., on new technologies), and an indirect one on the other areas, calling for other actions e.g. on the electrical grid, availability of green hydrogen and H_2 infrastructures.

3.4.4. Option FD4: introducing risk mitigation and loan guarantee instruments for investments in decarbonisation technologies

Economic and competitiveness impact

The creation of an EU risk insurance and guarantee fund would lower the cost of doing business for green steel, especially through i) lowering **the cost of capital** and ii) enabling the production of carbon-neutral steel to achieve the economies of scale. More specifically, this measure would partly address the current market failure conditions for green steel, in which the risks associated with innovative pilot and pre-commercial green steelmaking projects are still considered high, resulting in high interest rates applied to such projects, provided they get any funding in the first place. The EU risk insurance and guarantee fund could be established to hedge such risks and lower the interest rate borne by decarbonisation steelmaking projects. Besides, this policy option

[22] Around 48% of blast furnaces in the steel sector will require reinvestments to remain operational and avoid carbon leakage by 2030. For further details, please see Agora Energiewende (2020b).

– thanks to the support for the demonstration and early commercialisation of decarbonisation technologies – could allow these technologies to reach the minimum scales needed to bring down the prices of such technologies to market-competitive levels.

Coupled with the IF and InvestEU (two EU's major de-risking instruments), the EU risk insurance and guarantee instrument could also provide relevant signalling effects to investors and promote the design of private insurance and guarantee products specifically designed for low-carbon steelmaking technologies. Therefore, this option can **improve steel companies' ability to access risk capital**. Consequently, this policy option could increase the business case for green steel production and contribute to creating the market conditions for the investments in and diffusion of decarbonisation technologies.

The introduction of risk mitigation policies would also affect the **investment cycle of the steel industry**, fostering stakeholders' initiatives and economic commitment aimed at low-carbon production. This applies especially to the costs of investments in steel industry aiming to reduce emissions and is particularly relevant in the context of the upcoming investment cycle in the EU steel industry before 2030.

By mitigating risks and supporting investments, this policy solution could also **promote R&D&I in the decarbonisation of the steel industry**. This impact would materialise as the EU risk insurance and guarantee fund (through the EIB and MS public investment banks) addressed the innovation risk of financing innovative projects, de-risking innovation and deployment of decarbonisation technologies in the industry.

Environmental impact

A risk mitigation measure is a powerful leverage to make investments in the decarbonisation of the steel sector more attractive. It will foster private investment and economic commitment aimed at climate neutral production, thereby contributing to a more sustainable production, and ultimately to the EU's climate targets and the green transition in the EU in general.

Social impact

This measure will promote investments in human capital, increasing employment. It will also indirectly increase public health in local communities by reducing pollutant emissions as traditional steelmaking production is replaced with cleaner technologies.

Cross-cutting issues

Supporting CAPEX of decarbonisation technologies will create demand for RES-E and green hydrogen and, to some extent, for CCUS and high-quality scrap.

3.4.5. Option FD5: integration of compulsory low-carbon standards

Low-carbon standards can be an enabler of sustainable production and ultimately create a level-playing field in the EU, thereby mitigating carbon leakage risk. Before standards can be introduced, the relevant technologies should be competitive, which may require the implementation of other policies. Standards should evolve in line with the investment cycle of the industry and compliance and transaction costs should be limited.

This option is examined more in detail in Chapter 9 on cross-cutting policy options.

3.4.6. Option FD6: promotion of low-carbon steel products in GPP

GPP is a demand-pull measure that can support the creation of markets for green steel. When procurement of green steel increases, this can spur innovation, increase economies of scale and lower the costs of green steel.

This option is examined more in detail in Chapter 9 on cross-cutting policy options.

3.4.7. Option FD7: developing a green label for low-carbon steel

Green labels for green steel would be a demand-pull measure that creates positive interactions with other measures such as GPP or low-carbon standards. Green labels can reduce information asymmetry for customers of green steel, and thereby support sustainable consumption leading to a larger market for green steel.

This option is examined more in detail in Chapter 9 on cross-cutting policy options.

3.4.8. Option FD8: ensuring that EU resources, including those of the Next Generation EU, will support the green transition in the steel industry

Economic and competitiveness impact

This policy option has the potential to **increase the effectiveness of other funding policy options** by ensuring consistency and coherence in the EU industrial decarbonisation public funding framework. Any financing provided through the EU recovery fund should follow similar conditions as those described in options FD1-3 to ensure that there are synergies between funding policies, and to ensure that safeguarding industrial competitiveness during an economic downturn does not undermine the transformation of the steel industry in line with the Green Deal objectives. Using EU recovery funds can compensate for MS funding and State aid, which could be reduced as a result of the economic consequences of the pandemic. Using recovery funds for the green transition of the steel industry could therefore **support investments**, **affect the investment cycles** in the steel industry in an anti-cyclical way, and ultimately **reduce the costs of doing business**. Investments supported with recovery funds can also **promote R&I** throughout the EU MS.

Environmental impact

This measure will have an impact on the reduction of GHG emissions from the steel sector. From an environmental point of view, as the steel industry accounts, for the time being, for a significant share of CO_2 emissions, it is reasonable that funding support should be well accounted for in all the EU funding opportunities. Social and administrative support from both governments and local authorities will be paramount. Continuity of funding will encourage manufacturers to adopt long-term green transition strategies leading to more sustainable production and will allow individual technologies to be developed and improved through R&I. Ultimately, Recovery and resiliency facility (RRF)-induced investments should lead to lower GHG emissions.

Social impact

This option will promote green investments in the steel sector, entailing positive indirect impacts on employment in the steel industry and in sectors in the steel value chain. Supporting steel sector decarbonisation through NextGeneration EU would also anti-cyclically support general economic recovery.

Cross-cutting issues

As in previous options, this option will impact directly steel-manufacturing related areas (scrap, CCUS) and indirectly the others. Supporting CAPEX of decarbonisation technologies will create demand for the development of clean hydrogen production using RES-S sources, CO_2 capture and high-quality scrap.

3.4.9. Option FD9: identifying pathways (2030 and 2050) for decarbonisation technology routes and ensuring that both EU and national policy makers account for them

Economic and competitiveness impact

Development and application of decarbonisation pathways by policy makers would **enhance the investment certainty for decarbonisation projects**. The pathways (ideally endorsed by the EC), could give funding authorities, financial institutions and private investors a clear reference and a better understanding of different technology routes to decarbonise the sector. These stakeholders would therefore have higher confidence in lending money to such projects. Consequently, this would **promote the business case for green steel**.

The identified pathways would have a tangible impact on the **investment cycle of the steel industry**, bringing major restructuring processes depending on local conditions, driving to the proper choice of pathway. The level of the impact on different areas will be driven by the scenario chosen at local level.

Finally, similar to options FD1-3, this measure would also give a great impulse to R&I of decarbonisation technologies in the steel industry.

Environmental impact

Agreement on technological pathways will increase the ability of the EU to cut GHG emissions from the steel sector by supporting greater coherence between policy areas and enabling coherence with long-term EU climate goals. Over time, this will support a more sustainable production and consumption.

Social impact

This measure will promote investments and employment. With greater consensus on technology and decarbonisation pathways, any adjustments necessary in labour markets with regards to skills and reskilling would be easier to achieve. Social acceptability might increase as clear measures are presented to reach the politically defined climate targets. This option will also promote sustainable production related to the decarbonisation of the steel industry.

Cross-cutting issues

A clear identification of decarbonisation pathways will lead to better insight into the future demand for RES-E, hydrogen, CCUS and scrap.

3.4.10. Option FD10: creating synergies in EU level funding via the CSP

Economic and competitiveness impact

Improved synergies between the funding schemes under the CSP could increase the **impact** and **efficiency of such funding instruments**. Being currently the only large-scale instrument supporting collaboration among steel producers, better synergies of HEU and RFCS under the

CSP would increase the level of **collaboration between steel companies.** Synergies will lead to higher success in decarbonisation efforts and lower the required funding budget, compared to the separate use of the current available funding opportunities.

Another important impact of this policy option is the **promotion of R&D&I for decarbonisation technologies in steel production**. As HEU and RFCS target different TRLs, the synergies of these two funding programmes would allow to combine research efforts with demonstration and early deployment of the technologies. Synergies of funding under the Partnership will help remove R&D&I and systemic bottlenecks such as i) the transition from the pilot phase to industrial-scale deployment; ii) high technology risks; iii) large capital requirements and iv) higher production costs (ESTEP 2020b). Regarding the timeline of such impacts, as the CSP supports R&D&I, the impact of these activities are expected to materialise in 2030 at the earliest.

Environmental impact

The CSP will enable the decarbonisation of the steel sector in the EU, including by making the business case for green hydrogen. As the CSP targets the wider steel value chain, the green transition for energy and energy-intensive industries (who can also benefit from cross-cutting technology developments in hydrogen, CCUS and renewables) in general would be supported.

Social impact

The CSP can lead to the enhanced growth of an innovative, clean and more competitive European industry. It could promote job creation and inclusiveness as well as an increased leverage effect with other industries such as the hydrogen economy, the chemical industry, fossil free energy industries and technology providers in the transition to climate neutrality. Furthermore, it can lead to better EU public health (less pollutant emissions resulting in cleaner air and water, European Commission, 2020c).

Cross-cutting issues

The CSP can support demand for RES-E, green hydrogen, CCUS and high-quality scrap, although it may not be observed before 2030 at the earliest. If the demand for CO_2-lean manufacturing processes increases, the demand for the associated auxiliary processes will also increase and this would have a positive effect on their development.

3.4.11. Option FD11: creating additional synergies in EU funding via blending and sequencing of different opportunities

Economic and competitiveness impact

Similar to option FD10, better synergies of public funding could **generate a greater impact and efficiency of the funding instruments** through stronger collaboration among steelmakers. Blending and sequencing funding would also secure R&D funding from low to high TRLs, **promoting R&D&I activities** of decarbonisation technologies.

Environmental impact

This measure will promote the decarbonisation of the steel industry as well as the green transition in the EU.

Social impact

The impact of this measure will be similar to those of options FD1 and FD2. It will promote investments in greening of the steel industry, **increasing employment and upgrading skills** (i.e. promoting research in the steel sector), and increase **public health and safety** in local communities, reducing emissions.

Cross-cutting issues

This measure will have a more direct impact on steel-production-related areas (CCUS, scrap), while the impact on other areas will be indirect. The influence of the proposed mechanism on demand for RES-E, green hydrogen, CCUS and high-quality scrap will be observed in 2030 at the earliest. If the demand for CO_2-lean manufacturing processes increases, the demand for the associated auxiliary processes will also increase and this would have a positive effect on their development. It will also have a positive impact on generating the proper pathways as sequencing of different efforts and further integration in common process approach.

3.4.12. Option FD12: establishing an IPCEI for low-carbon steel

Economic and competitiveness impact

The establishment of an IPCEI framework for green steel would **increase the impacts and efficiency of the funding instruments**. This framework would allow for the pooling of different types of public funding (EU, national, regional), while also sending investment signals to private investors. Creating appropriate financing and management mechanisms as well as prioritising the process of green transformation of the steel sector under such IPCEI framework would entail the development and implementation of carbon-free steel production technologies.

An IPCEI for green steel would also **support R&D&I and industrial-scale deployment** of low-carbon steelmaking technologies. The IPCEI is expected to lead to the implementation of larger scale projects, thus further accelerating the TRL progress and implementation potentials of decarbonisation technologies.

Environmental impact

The IPCEI represents a synergic initiative, which is expected to have a considerable impact on the steel industry and, as a consequence, on environment-related issues. The IPCEI can promote the achievement of the long-term EU climate goals as outlined in the Green Deal.

Social impact

This measure will promote investments towards the greening of the steel industry, increasing employment and upgrading skills (i.e. promoting research in the steel sector).

Cross-cutting issues

The impact on other sectors depends on the pathways most involved in the IPCEI. In principle, these pathways are those needed to achieve the full efficiency of the new technologies to be deployed, i.e. those mostly related to a strong CO_2 abatement potential (such as CCUS), but also actions on green energy and infrastructure. The influence of the proposed mechanism on RES-E, green hydrogen, CCUS and high-quality scrap demand will be observed after the IPCEI's completion. An IPCEI ideally covers the entire value chain – hence both RES-E and green hydrogen projects could find their place in the IPCEI on hydrogen that is already being developed. Scrap and CCUS projects would probably require a separate approach.

If the demand for low-CO_2 manufacturing processes increases, then the demand for the associated auxiliary processes will also increase, and this would have a positive effect on their development.

CSP is good if it takes a long-term climate ambition as a starting point. It is directly linked to the carbon storage, CO_2 infrastructure, or hydrogen infrastructure, so it would be upstream as a common interest. It would make sense to have an IPCEI for cross cutting technology (e.g. hydrogen), not sectors.

General environmental and social impacts

All the proposed options support the steel sector's decarbonisation and contribute to the green transition in the EU. Specifically, the goals of the European Green Deal and the climate targets as defined in the EU climate law and Fit-for-55 package are easier to reach with the proposed options. The technology-push funding options (FD1-4) would have a greater impact on **sustainable production** through changes in capital investments, favourable fiscal measures and improved insurance and guarantee services for carbon-neutral steel production, which could ultimately bring down the costs of green steel. Meanwhile, the demand-pull options (FD5-7) can support **sustainable consumption** through setting standards for green steel and increasing consumers' awareness of environmentally friendly steel products. All options are expected to generate additional environmental impacts on **air quality and local pollution** as they support the steelmaking's fuel mix transition from coal-based sources to carbon-neutral, renewable ones. This leads to positive impacts on **public health**. Finally, in so far as scrap-based secondary steelmaking processes benefit from the funding options, the EU's **circular economy** goals are supported.

In terms of social impacts, all options generally support the **job creation** in the steel industry but also in the wider value chain, as green steel production require the expansion of low-carbon energy sources and infrastructure. Besides job creation, new green steel production methods require **upskilling and reskilling**. Some options that lead to increases in steel prices (which, to an extent, are inherent to green steelmaking until costs drop significantly) may affect lower-income consumers in particular, as the price of downstream goods would increase. Just transition policies can mitigate this, just as they do with higher energy prices.

3.5. Comparative assessment

While all the proposed policy solutions are expected to promote and accelerate the decarbonisation of the steel sector, their impacts might vary when it comes to the effectiveness, efficiency, feasibility and coherence with existing EU and national rules.

3.5.1. Effectiveness

Option FD1: promoting the use of EU funding programmes (including the IF) to finance OPEX of low-carbon steel.

Option FD1 is considered highly effective in supporting OPEX – a great share of green steel's production costs. Economic and sector-specific conditions make it challenging to carry higher OPEX. Therefore, the sector needs public support to leverage private resources, and plan new long-lasting investment decisions. Even full subsidies for CAPEX would not provide the necessary incentive to accelerate innovation and commercialization of decarbonization technologies. For instance, for hydrogen-based steelmaking technologies, green hydrogen costs are a crucial part in production cost, and around 70-80% of such cost it is made up by the price for RES-E. In this regard, OPEX support during a transition phase where high investments are required will be a key instrument enabling the transition towards green steel. Investments in innovative low-carbon technologies should make green steel commercially competitive in 5-10 years. Funding will enable the execution of projects with higher budgets, speeding-up the TRL deployment towards industrial-scale technologies. Meanwhile, the use of the IF should be complemented by other measures to ensure OPEX support is sufficient to boost innovation and deployment of decarbonization technologies. In this respect, CCfDs can be another good financing tool for OPEX of green steel (see the Chapter 4 on carbon pricing).

Option FD2: mobilising private funding to support CAPEX of decarbonisation technologies.

This option received the highest support from the steel sector stakeholders to achieve the Operational Objective FD1.2 (ensuring public support for CAPEX). This option is expected to help mobilise sustainable investments from the private sector and re-orient capital flows towards sustainable activities and investments. To achieve this, fast adoption and progressive amendment of the EU Sustainable Finance framework should be promoted.

While this measure will lead to the industrial deployment of decarbonisation technologies, their economical operation might still be limited due to OPEX issues. In fact, the enabling technologies use more expensive raw materials, which also contributes to higher OPEX.

Option FD3: ensuring public support for CAPEX beyond direct public funding (accelerated depreciation, tax abatements, etc).

This option shares the same level of support as option FD2 (both options support CAPEX) and is expected to have a similar level of effectiveness. CAPEX support through fiscal measures – which go beyond public funding - will further leverage private investments, with an effective impact on the restructuring of the sector and the renewal of production lines. However, there are concerns that old steel mills may misuse this measure to upgrade existing technology with incremental measures, that will or may strand investments on the long run towards climate neutrality. Therefore, this measure should apply only to steel plants which want to switch to innovative decarbonisation technologies.

Option FD4: introducing risk mitigation and loan guarantee instruments for investments in decarbonisation technologies.

According to stakeholders, this option is highly effective in promoting private investments aimed at greening the steel sector. The introduction of risk mitigation policies is an effective, fundamental step in revitalizing the investment cycle in the steel industry.

Option FD5: compulsory standard - integration of low-carbon standards in the BREF.

The integration of compulsory low-carbon standards received warm support from the stakeholders. This option will facilitate the achievement of the Operational Objective FD2.1 (creating a market for low-carbon steel).

According to some stakeholders, compulsory standards generally can work even better than public support (either to OPEX or CAPEX, see options FD1-3). The advantage of the introduction of standards is that they do not require any public resources. On the other hand, the disadvantage is that they will end up making the final product more expensive, which could decrease low-carbon steel's competitiveness against extra-EU competition or substitute products produced in the EU, with chain effects on other industries downstream (e.g. increase in steel prices will make shipbuilding in Europe more vulnerable against competition from Far Eastern countries). Enforcing low-carbon standards might create a market where low carbon solutions must no longer compete against fossil options, but against other low carbon solutions instead. As a result, a previously economically unviable solution could become viable if it represents the only way of complying with a standard or fulfilling a quota.

Option FD6: promotion of low-carbon steel products in public procurement.

This option will be highly effective in generating investments and innovation without necessarily generating new public spending. GPP represents an important opportunity for promoting the production of green steel and meeting social consensus. It can be an effective tool in improving sustainability and, at the same time, encourage the adoption of a lifecycle approach.

Option FD7: developing a green label for low-carbon steel.

This option, together with options FD5 and FD6, are among the favourite ones for many stakeholders. Introducing incentives for steel users (e.g. in the automotive industry) to use low-carbon steel could be an effective demand-pull policy option. Demand-led options create a market for low-carbon-steel while being more flexible and – if needed– more adjustable than the other options.

Option FD8: ensuring that EU resources, including those of the Next Generation EU, will support the green transition in the steel industry.

Considering the magnitude of the RRF, which is the largest component of Next Generation EU, the fast-tracked implementation of initiatives it promotes and their compliance with the green objectives of the EU, this option will be highly effective in accelerating the transition towards green steel manufacturing.

To increase the effectiveness of this option, two elements should be considered. First, it is important that funding under the RRF for green steel aligns with the measures proposed in options FD1 (public funding should support OPEX), FD2 (public funding should ultimately lead to private funding) and FD3 (ensure that fiscal measures are also deployed to support CAPEX of green steel). Second, to ensure the continuation and increase the magnitude of RRF funding, EU and national funds should be allowed to add up to the RRF.

Option FD9: identifying pathways (2030 and 2050) for decarbonisation technology routes and ensuring that both EU and national policy makers account for them.

Defining pathways for decarbonisation technology routes is paramount to define and select the technological regimes that the steel sector will adopt to implement the industrial transformation processes needed to gradually shift towards green steel. Identifying relevant decarbonisation pathways can lead to a more focused and coherent approach in the decarbonisation process, including policy and investments. This tool is particularly helpful for policymaker to avoid path dependency and direct their regulatory and financial support towards different decarbonisation routes. It will be an effective measure in setting the relevant technologies, their milestones and the value chains involved.

As noted, a proper dissemination of such pathways among policy makers and funding authorities can ensure that legislative framework conditions and EU and national funds are efficiently and effectively adapted to support the transformation of a decarbonised industrial steel production.

Finally, several stakeholders argued that the pathways should define policy conditions rather than technology routes. Roadmaps or pathways should by no means result in mandatory technology choices. That would counteract innovation and interfere on company business cases. Finally, both EU and national policy makers should account for them.

Option FD10: creating synergies in EU level funding via the CSP.

Synergies of funding are necessary to decarbonise the steel industry and the CSP is one way to create synergies. While technologies for direct electrification or use of green hydrogen are available, there is room for improvements and many other decarbonisation technologies are still at early stages of development. More coordination between funding schemes is paramount to enhance the effectiveness of individual measures and the CSP will have a tangible positive effect on technology development and the decarbonisation of the steel industry.

Option FD11: creating additional synergies in EU level funding via blending and sequencing of different opportunities.

Coordination and integration of funding schemes is key to increase their effectiveness. As for option FD10, the sequencing and blending of different public funding opportunities suggested in option FD11 could play an essential role in ensuring sufficient funding to develop and deploy low-carbon steelmaking technologies for the EU.

Option FD12: establishing an IPCEI for low-carbon steel.

Establishing an IPCEI was one of the preferred solutions to achieve Operational Objective FD3.2 (closing the funding gap between the research, demonstration, and deployment phases) by the consulted stakeholders. An IPCEI for the steel sector could be effective in closing the gap between different schemes, providing a legal framework that allows the combination of EU, national, regional, and private funding in compliance with the state aid rules.

While IPCEI funding might have similar limits as other CAPEX funding options have, some of its advantages include: i) up to 100% of the funding gap can be covered; ii) it can cover the entire value chain (e.g. the generation of RES-E needed to produce green steel) so OPEX support might not be necessary, and iii) it allows for very large-scale projects which are needed to reduce the costs of green hydrogen or other decarbonisation pathways. The effectiveness of this policy option will also depend on the approach taken by competition authorities. If the assessment of State aid compatibility is very strict, e.g. regarding final investment decisions for industrial deployment projects, the potential of this option might remain limited.

3.5.2. Efficiency

Unlike the Effectiveness section which assesses the policy options separately, the Efficiency and Feasibility sections (below) group the policy option into three main categories: technology-push (options FD1-4), demand-pull (options FD5-7) and level playing field (FD8-12). This grouping allows to evaluate those policy options that tend to have similar impact mechanisms and levels of efficiency and feasibility and to avoid duplication.

TECHNOLOGY-PUSH (OPTIONS FD1-4)

Option FD1: promoting the use of EU funding programmes (including the IF) to finance OPEX of low-carbon steel

The cost-efficiency is estimated based on CAPEX and OPEX calculations in relation to foreseeable emissions avoidance. Therefore, the systemic approach of the IF, which does not target just the steel sector, and its potential impact on both CAPEX and OPEX, makes it an extremely efficient solution in greening the steel industry. The EU ETS IF aims to support the demonstration of innovative decarbonisation technologies, particularly large-scale demonstration projects of CO_2-reducing and/or low-carbon technologies. Eligible projects, besides showing effectiveness in GHG emissions avoidance and innovation potential, are assessed in terms of scalability and market potential (in 2050) and their cost efficiency.

Option FD2: mobilising private funding to support CAPEX of decarbonisation technologies

The EU Sustainable finance framework will enhance the efficiency of market dynamics by promoting the use of private funding and directing capital flows towards sustainable development activities. The adoption of the framework will help mobilise sustainable investments from the private sector, promoting sustainability. Effective and efficient R&D will be a prerequisite for innovation activities, as well as for a more efficient use of raw materials.

Option FD3: ensuring public support for CAPEX beyond direct public funding (accelerated depreciation, tax abatements, etc.)

This measure requires that ideally the EEAG guidelines, in their upcoming revision in 2022, should allow member states to introduce national solutions (e.g. accelerated depreciation, tax abatements, etc.) to support major brownfield conversions into low-carbon installations in the steel sector. The forthcoming revision of the EEAG is vital given that the Green Deal has significantly stepped up the EU's environmental ambition. A clear understanding of the process, its scope and possible consequences is key to determine whether and how stakeholders should participate in this important review (Baker Botts 2020).

Option FD4: introducing risk mitigation and loan guarantee instruments for investments in decarbonisation technologies

Introducing risk mitigation instruments might require a complex process to avoid overlaps and increase synergies with possible existing measures. In order for this measure to be efficient, it would be mandatory to involve in its design all relevant stakeholders coordinated by the EC. As in the case of option FD1, the conditions for investing in new technologies will improve, even if there are some concerns among stakeholders about the technologies the size of projects that investors should prioritise.

DEMAND-PULL (OPTIONS FD5-7)

Options FD5-7 are also discussed in Chapter 9 on cross-cutting policy options. In general, demand-pull options can carry higher costs in the short-term, while the benefits accrue in the longer term. As the market size of green steel expands, economies of scale will lead to cost reductions and increased competitiveness. In combination with pricing policies, demand-pull options can increase the efficiency of decarbonisation policies. However, administrative costs and other transaction costs can undermine their efficiency, especially for policies such as GPP or green labelling.

PLAYING FIELD/SYNERGIES (OPTIONS FD8-12)

Option FD8: ensuring that EU resources, including those of the Next Generation EU, will support the green transition in the steel industry

This policy option requires the EC to develop a diversified financing strategy to raise the resources necessary to fund the Next Generation EU. This funding strategy will allow the funding of sustainable initiatives in the steel industry and in other carbon-intensive sectors, in an efficient and systemic manner. Moreover, the strategy specifically aims at promoting a more efficient use of resources. The cost associated with the development of such funding strategy would be however small compared to the funding opportunities that it can raise for decarbonisation projects in the steel sector.

Option FD9: identifying pathways (2030 and 2050) for decarbonisation technology routes and ensuring that both EU and national policy makers account for them.

To develop the decarbonisation pathways, EU steel companies and companies along the value chain must collaborate in order to identify the most promising decarbonisation pathways. Collaboration among competitors is quite challenging, hence technology development and implementation in the industry is affected in many cases by a duplication of efforts – both in the case of successful developments and implementations as well as failures. Still, each company must adapt existing measures to their specific conditions, in terms of product mix, process configuration and national and local conditions.

Option FD10: creating synergies in EU level funding via the CSP

This option requires enhanced communication between policymakers, steel companies, project developers and banks/investors (e.g. EIB). Creating synergies between funding sources would allow for the accumulation of a critical mass of resources and a better coordination among industry stakeholders. This option will also require a clear definition of technological pathways to foster its efficiency.

Option FD11: creating additional synergies in EU-level funding via blending and sequencing of different opportunities

This option is considered highly efficient. The sequencing of funding schemes following the approach of the energy-intensive industry masterplan is an efficient approach in fostering the dissemination of carbon-neutral steelmaking technologies. Thanks to such synergies, decarbonisation technologies would move from research to development, from development to deployment, or from deployment to commercialisation in a faster and smoother way.

Option FD12: establishing an IPCEI for low-carbon steel

To increase the impact of this policy option, the EU should engage and closely coordinate with member states and relevant stakeholders (including steel companies) at early stages in the implementation of a dedicated IPCEI. In addition, templates and standardised project portfolios might need to be used in the notification and evaluation process. Finally, the IPCEI should facilitate the combination of different national and EU funding sources. This process comes at a price, e.g. the communication costs or the human resources needed to develop the standardization of the notification and evaluation process. However, these costs are considered small compared to the funding that steel sector can receive via the IPECI framework to finance its decarbonisation efforts.

3.5.3. Feasibility

TECHNOLOGY-PUSH (OPTIONS FD1-4)

Option FD1: promoting the use EU funding programmes (including the IF) to finance OPEX of low-carbon steel

Besides having a tangible impact on investments and innovation activity in the steel sector, this option is also one of the most feasible ones. It does not depend on new schemes, but on the use of existing measures to leverage investments in the steel industry, with direct positive effects on decarbonisation.

Option FD2: mobilising private funding to support CAPEX of decarbonisation technologies

The feasibility of this policy options is high since its implementation is underway, and it just needs to be promoted. Within the framework of the European Green Deal, the EC announced a renewed sustainable finance strategy. The EU Taxonomy Climate Delegated Act, which aims to support sustainable investment by clearly defining which economic activities most contribute to meeting the EU's environmental objectives, and the Sustainable Finance Disclosure Regulation (SFDR), have just been approved. The latter is specifically targeted at the financial sector.

Option FD3: ensuring public support for CAPEX beyond direct public funding (accelerated depreciation, tax abatements, etc.).

The EU State Aid Guidelines for Environmental protection and Energy post 2020 (EEAG) are under preparation. These guidelines have a distinct added value, providing uniform rules that will guide the EC's assessment of national compensation schemes under EU State aid rules. The Guidelines will provide guidance to member states when designing compensation schemes, levelling the playing field. The feasibility of this option is considered higher, given that it pertains regulatory choices and is consistent with other EU policies, in light of the Green Deal.

Option FD4: introducing risk mitigation and loan guarantee instruments for investments in decarbonisation technologies

The feasibility of this measure is moderate as it involves the assessment of local conditions. In practice, some member states have already started promoting national guarantee funds23. While challenging in terms of feasibility, this measure is urgent for levelling the playing field across Europe. The introduction of a risk mitigation policy instrument is of outmost importance to foster stakeholders' initiatives and economic commitment aimed at carbon neutral production.

DEMAND-PULL (OPTIONS FD5-7)

Options FD5-7 are discussed in detail in Chapter 9 on cross-cutting policy options. Overall, the feasibility of the three options is moderate. It is affected by: i) pressure to adopt not too stringent standards and concerns about compatibility with international trade rules (option FD5); ii) the

[23] For further details, please see the following EC state aid ruling: https://ec.europa.eu/commission/presscorner/detail/en/ip_20_2407

limited acceptability of GPP (option FD6), and iii) a need for clear criteria of green products (options FD6 and FD7).**PLAYING FIELD/SYNERGY (OPTIONS FD9-12)**

Option FD8: ensuring that EU resources, including those of the Next Generation EU, will support the green transition in the steel industry

The feasibility of this option can be considered as being high, if the appropriate roadmaps are agreed and pursued (see option FD9). Climate change mitigation has been included as a main pillar of the Next Generation EU. Steel is capable of being one of the first hard-to-abate sectors to produce green products. However, this is a race against time. The steel industry has extremely long investment cycles, with long-lasting capital assets, and 2050 is just one investment cycle away for a sector like steel. While the use of resources from the RRF could be key in the transformation of the European steel sector, the 2020s will be crucial for determining whether European companies will be able to develop clean breakthrough technologies and processes to make steel or not.

Option FD9: identifying pathways (2030 and 2050) for decarbonisation technology routes and ensuring that both EU and national policy makers account for them

The feasibility of option FD9 is moderate as it is challenging for policymakers to endorse specific technological pathways ex-ante. Most low-carbon steel production pathways are not yet at technological maturity and it is not yet clear which process will dominate the steel production in the future. Nevertheless, they show a high potential for future, innovative technologies, benefitting not only climate but also air quality trough a reduction of non-GHG emissions. Therefore, further research, close-to- market innovation and demonstration of multiple pathways will be necessary.

Option FD10: creating synergies in EU level funding via the CSP

The feasibility of this option varies across the two alternatives. The first alternative (establishing a single funding mechanism, i.e. a one-stop-shop to manage R&D&I activities under HEU and RFCS) has low feasibility due to the difference in the operational functioning of the two programmes, in particular the eligible TRLs, eligible countries, timeline of the calls, funding rates etc. The second alternative (creating a governance structure to collectively manage complementary calls under the two programmes) is highly feasible. This governance body can help identify activities for collaboration among steelmakers and avoid potential overlaps in the funding. Altogether, this option can be considered to have moderate feasibility.

Option FD11: creating additional synergies in EU-level funding via blending and sequencing of different opportunities

Sequencing and blending of different public funding opportunities can be moderately feasible. A rapid transition towards low-carbon steel calls for an ecosystem encompassing both EU and national funding schemes. Some steps in this direction have already been made with the promotion of the CSP. However, examples of synergies between different EU funding programmes show that such synergies were limited to ‘ad-hoc’ level, e.g. using ERDF funding to support the dissemination and exploitation of R&D&I results developed under H2020. The synergies are often constrained by factors such as different regulations, lack of information or different geographical coverage (European Parliament 2019a, p49). This explains the moderate feasibility of this policy option.

Option FD12: establishing an IPCEI for low-carbon steel

The feasibility of this policy option can be assessed from different angles. First, some stakeholders point out that it would make sense to have an IPCEI for cross cutting technologies (e.g., Hydrogen and low-CO_2 emission industries) rather than for individual sectors. Therefore, the feasibility of this option can be considered moderate. Second, however, specific technological circumstances in the steel industry, combined with the large contribution of the industry to GHG emissions, may still justify a dedicated IPCEI. The EC has identified 6 key strategic value chains (SVC) of systemic importance and with a clear contribution to EU's growth, jobs, and competitiveness. These SVC form the basis for the development of IPCEI projects dedicated to the decarbonisation of the steel industry.

3.5.4. Coherence

Stakeholders agree that the proposed solutions are coherent with the overall EU framework in the steel sector and with EU policies in other domains. Overall, none of the solutions go against the current EU policy framework and they are coherent with the spirit of the EU legislation in the field of energy, climate and innovation.

All policy options are in principle coherent with the spirit of the European Green Deal. The policy mix is generally well balanced, as it includes “technology-push” and “demand-pull” options, as well as creating market conditions that are favourable to the gradual introduction, dissemination and adoption of low-carbon steel products, promoting sustainability in the manufacturing process and acceptability by final consumers.

Table 7: Overview of policy solutions[24] – Funding

	Effectiveness	**Efficiency**	**Feasibility**	**Coherence**
Option FD1: promoting the use EU funding programmes to finance OPEX of low-carbon steel				
Option FD2: mobilising private funding to support CAPEX of decarbonisation technologies				
Option FD3: ensuring public support for CAPEX beyond direct public funding				
Option FD4: introducing risk mitigation and loan guarantee instruments for investments in decarbonisation technologies				
Option FD8: ensuring that EU resources will support the green transition in the steel industry				
Option FD9: identifying pathways (2030 & 2050) for decarbonisation technology routes and ensuring that EU & national policy makers account for them				
Option FD10: creating synergies in EU level funding via the Clean Steel Partnership				
Option FD11: creating additional synergies in EU level funding via blending & sequencing of different opportunities				
Option FD12: establishing an IPCEI for low-carbon steel				

Note: This table presents the policy options in the funding area that would support the decarbonisation of the EU steel industry. The options are assessed based on the four criteria under the Better Regulation guidelines: their effectiveness, efficiency, feasibility and coherence. Colour legend: orange - low, yellow – moderate, green – high. For instance, a policy option that has a green cell in the Effectiveness column is considered to be "highly" effective. Source: authors' own composition

[24] Policy options FD3-5 have not been included in this overview as these options are assessed in the cross-cutting policy chapter

4. Carbon pricing

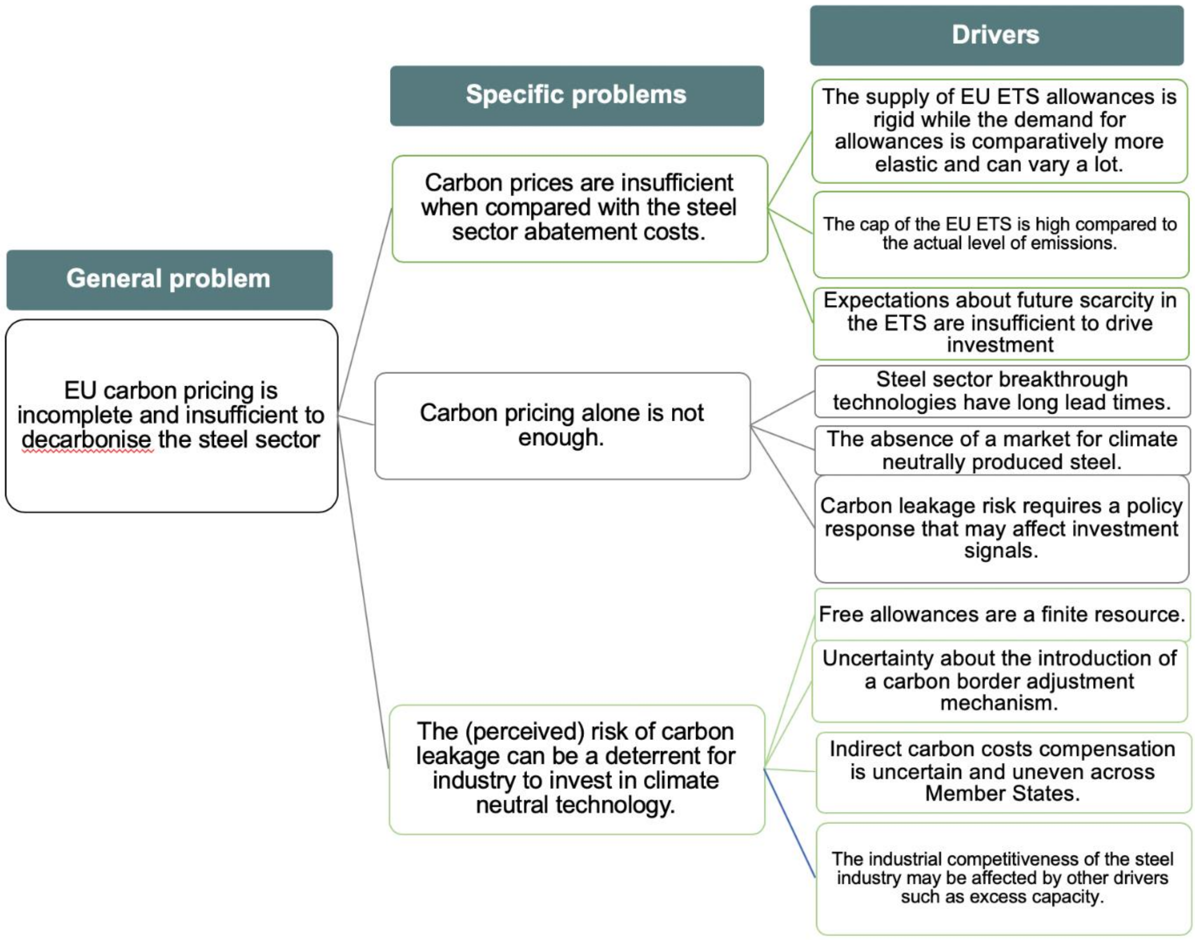
4.1. Problem identification

4.1.1. Background

The European carbon market – embodied by the **EU ETS** – is incomplete: it only covers emissions from installations based in the European economic area (EEA) and only **covers about 40% of GHG emissions** within its geographical boundary. Incomplete markets have implications in terms of efficiency and in terms of policy design to mitigate this. Concerns about the risk of **carbon leakage** emanating from the higher carbon costs faced by European producers vis-à-vis producers outside the EEA have led to the maintenance of **high levels of free allocation**[25], as well as the discussion on the CBAM as an alternative carbon-leakage risk mitigation measure.[26] Concerns about carbon leakage may translate into concerns about **industrial competitiveness**, which in turn can act as a deterrent to investment into climate-neutral production methods. This is connected to the **absence of (significant) demand for green steel,** without which the **investment case** is made more difficult. While carbon prices have increased significantly in recent years compared to the 2013-2017 period, they are still well below the abatement costs of other options in line with a climate-neutral transformation in the steel industry. Even with higher carbon prices, **the EU ETS alone may be an insufficient policy approach to decarbonise the steel industry**.

[25] The steel sector will have received > 95% of its ETS allowances for free for ETS Phase 3 (2013-2020). Source: EU Transaction Log
[26] As discussed in the European Green Deal Communication as well as in the updated 2030 framework impact assessment.

Figure 9: Problems associated with carbon pricing and the steel sector's decarbonisation



Source: author's composition.

4.1.2. General problem

Carbon pricing in the EU – through the EU ETS – is in itself **insufficient to decarbonise the steel industry**. This general issue was, to some extent, confirmed by the stakeholders consulted in the Inception phase. The EU's carbon market covers many sectors, including the steel industry, that are trade-intensive and, therefore, exposed to carbon leakage risk. The risk of carbon leakage leads to certain design choices that have impacts on investment signals and decarbonisation incentives. Specific design elements of the EU ETS that can affect these incentives are the rigidity of supply, a cap above the level of recent emissions and changing rules on free allocation, indirect carbon costs and a potential CBAM. However, even a perfect ETS would still be insufficient to decarbonise steelmaking due to long lead times of breakthrough technology and the absence of a market for green steel.

4.1.3. Specific problem CP1

Carbon prices are not high enough: Carbon prices in the EU ETS (currently around € 30 per tonne) are below the abatement costs reported for low-carbon technologies that are close to the industrial development in the steel sector (such as hydrogen or CCS-based steelmaking)[27], let alone other breakthrough technologies that have high CO_2 mitigation potential but are currently less mature. This specific problem was confirmed, to some extent, by respondents to the survey conducted during the Inception phase. There are a number of drivers behind the current carbon price, mostly linked to supply and demand in the ETS, but also to expectations of future scarcity, which can affect demand.[28]

- **Driver CP1.1**: The **supply of EU ETS allowances is rigid**, while the **demand** for them is comparatively **more elastic**. Both auctions and free allocation volumes are set based on specific rules derived from the legislation. Demand, however, can fluctuate in line with economic growth trends. Additionally, international 'Kyoto' credits[29] have added to the available supply throughout ETS Phase 2 and parts of Phase 3.
- **Driver CP1.2**: The **cap of the EU ETS is high compared to the actual level of emissions** and is not reduced annually in line with long-term EU climate goals. The current trajectory of the cap reflects a political consensus reached in 2014 at the European Council.[30] Since then, however, several high-impact international climate policy developments have occurred – the most prominent of which are the **Paris Agreement**[31] and the **1.5C Special Report** by the **International panel on climate change (IPCC)** (IPCC, 2018). While the Von der Leyen Commission will introduce legislative proposals to update the EU's climate and energy policies, including the ETS, for now the cap reflects a less ambitious long-term climate policy.
- **Driver CP1.3**: The **expectations about future scarcity** in the ETS are insufficient to drive investment (Lewis, 2020). Even if supply in the ETS has exceeded demand for all of the current third trading phase, carbon prices have not dropped to zero, as they did during the first trading phase. The role of speculators – who can expect increased scarcity in the future pending certain policy decision – can still lead to demand for EUAs. Conversely, if market participants expect that the ETS price will not reach price levels similar to industrial sector abatement costs, the ETS price may rather be dampened. The **credibility of the ETS** as a climate policy instrument for different industries can therefore affect supply and demand in the system.

Consulted stakeholder agree that, at least to some extent, these drivers are contributing to keeping the carbon price below abetment costs, and the most relevant drivers are the high cap of the EU ETS and insufficient expectations about future scarcity.

[27] Depending on estimates these range from €50 to well above €100 per tonne
[28] For further details on the role of the ETS price signal, please see: https://www.ceps.eu/ceps-publications/eu-ets-price-may-continue-be-low-foreseeable-future-should-we-care/
[29] The Kyoto Protocol sets up two mechanisms which allow industrialised countries to: (i) invest in projects that reduce emissions in developing countries as an alternative to more expensive emissions reductions in their own countries, or (ii) meet part of their required cuts in GHG emissions by paying for projects that reduce emissions in other industrialised countries. For further details, please see: https://ec.europa.eu/clima/policies/ets/credits_en
[30] The revised ETS Directive is discussed in Elkerbout (2017)
[31] In particular the long-term ambition expressed in Articles 2 and 4.

4.1.4. Specific problem CP2

Carbon pricing alone is not enough to make investments in decarbonisation technologies viable**.** This problem is considered highly relevant by the stakeholders consulted in the Inception phase. Even if carbon prices in the EU ETS would be higher, carbon pricing alone may be insufficient to drive sufficient levels of investment and deployment of transformational climate-neutral technology (Elkerbout, 2019). For companies, investment and deployment of climate-neutral technology amount to investing in new, not existing production, for which there needs to be a business case as well, covering revenues streams for both CAPEX and OPEX. The power sector, i.e. the sector that has realised the most emission reduction to date, is also covered by multiple policies and targets. Some of these specifically target technology development (such as renewables policies). **Likewise, deep decarbonisation in the steel sector may face a number of economic and non-economic barriers as well as market failures**, some of which require policies beyond carbon pricing. One such example are innovation externalities, where risky investments may not be undertaken because of uncertain returns.

- **Driver CP2.1**: The technological pathways available to the steel sector that are compatible with net-zero emissions require **capital investments and infrastructure** that take time to deploy (Juntueng et al., 2020). The production of low-carbon steel would entail **higher OPEX** (due to higher energy costs, more expensive raw materials and additional costs related with CCS measures), and significantly **higher CAPEX** (due to the large size of demonstration plants, the unachieved **economies of scale and economies of learning** during first industrial deployment and investments needed to integrate decarbonisation technologies into existing steel plants). The total investment needs from research to industrial-scale deployment of decarbonisation technologies is estimated in the area of €11 B during the period 2021-34 (EUROFER, 2018, p. 2). Even if, due to scarcity, carbon prices would eventually be at a level where more transformational changes in the steel industry become attractive, it would take too long to deploy the required infrastructure and capital at scale.
- **Driver CP2.2**: In the absence of a specific market for climate-neutral steel, EU steel producers may not be able to **compete globally with conventional steelmakers**. As such, a **market-making role for policy** may be identified (Elkerbout et al., 2018). This is also linked to the problem of the risk of carbon leakage. While **carbon-leakage risk** itself is a problem that **can deter investment**, even if mitigated to some extent (see Specific problem CP3), these mitigation measures can also have an impact on the policy design of carbon pricing instruments, for example with free allocation. This, in turn, can **distort investment signals** and **hinder carbon cost pass-through** that ultimately limits the role carbon pricing can play in a climate neutrality policy mix.

During the Inception phase survey, stakeholders considered that both drivers will increase the specific problem CP2 to a high extent.

4.1.5. Specific problem CP3

Risk of carbon leakage: The (perceived) risk of carbon leakage can be a deterrent for the industry to invest in climate-neutral technology. Also, this specific problem is considered to limit the functioning of the current EU carbon pricing system to a high extent by the stakeholders consulted in the Inception phase. The EU has passed several measures to **mitigate the carbon leakage risk**. However, uncertainty about their future or specific design elements can nevertheless be drivers of continued underinvestment.

- **Driver CP3.1: Free allowances are a finite resource** (Zetterberg et al., 2020). Free allocation based on efficiency benchmarks and historical production levels are currently the main method of mitigating carbon leakage risk (EU ETS Directive, art.10a). However, allowances are a scarce resource, and the supply of free allowances is limited by legislation. In the long run, with the cap of the ETS declining, the potential supply of free allowances would be more limited.[32]
- **Driver CP3.2:** There is uncertainty about the introduction of a CBAM, which could be an alternative carbon leakage risk safeguard - albeit one that comes with its own set of challenges (Droege et al., 2019). Depending on the design and political choices, it could (partially) replace or complement free allocation. A CBAM, in its design, ideally **differentiates between carbon-intensive and lower-carbon products** and between the carbon intensities and carbon costs of different trade partners, ensures World Trade Organisation (WTO) compatibility and allows for exemptions (e.g. for the least developed countries). However, such a design may involve significant administrative complexity and high transaction costs. Therefore, uncertainty about the introduction of a CBAM and especially its interaction with free allocation can create uncertainty about the impact on the bottom line of certain investments, hindering the development of decarbonisation technologies in the EU steel sector.
- **Driver 3.3: The indirect carbon costs compensation[33] is uncertain and uneven across member states**. Carbon leakage risk is also driven by concerns about indirect carbon costs, arising from potentially higher electricity prices once carbon costs are accounted for. While member states can compensate for these costs through State aid – harmonised by EU rules (European Commission, 2020a) – it is nevertheless up to individual member states to decide whether to provide this compensation, which can drive uncertainty for companies wanting to invest in electrification. Furthermore, compared to the multi-decade investment cycle in the steel industry, the short-term validity of State aid rules adds to this uncertainty.
- **Driver 3.4:** The close linkage between the carbon-leakage risk and the **industrial competitiveness** of the steel industry also affects the decarbonisation of the sector (Elkerbout, 2019). While climate policy design and carbon-leakage risk can affect industrial competitiveness, there are also challenges to industrial competitiveness unrelated to climate policy that can nevertheless have an impact on the capability or willingness of an industry to invest in climate-neutral production processes. An example in the steel industry is the **overcapacity** in global steel markets that can put

[32] The cap will reach zero by 2058 under the current EU ETS Directive. This date will be brought forward considerably with a climate neutrality target and revised ETS Directive, as foreseen under the European Green Deal.

[33] Indirect carbon costs, in the context of the EU ETS and related state aid legislation, refer specifically to emissions costs that are passed on in electricity prices. Article 10a(6) of the ETS Directive allows for MS to provide financial compensation to indirect emission costs, in the form of State aid. (European Commission, 2015)

margins under pressure and lead to unfair trade practices. A related issue that may arise in the future is high levels of material efficiency putting primary steel demand under pressure. While the circular economy is an essential element in making the long-term objective of industrial decarbonisation more manageable, it can nevertheless also create additional market challenges (Rizos et al, 2019). With lower demand for basic materials, some production capacity may become surplus to requirements.

Most of the stakeholders consulted in the Inception phase believe that these drivers contribute to carbon leakage risk being a barrier to decarbonisation. Free allowances as a finite resource represent the least concerning driver.

4.2. EU right and need to act

The legal basis for an EU carbon pricing policy can be found in **Article 191 of the** TFEU that requires the EU to maintain policies that protect the environment. More specifically, there have to be international-level measures aimed “to deal with regional or worldwide environmental problems, and in particular combating climate change.” **Article 191(2)** specifies that EU environmental policies should follow the **precautionary principle, rectify damage at the source, and ensure that polluters pay**. Carbon pricing mechanisms promote the reductions of GHG emissions in a cost-effective and economically efficient manner and thereby support the EU’s climate change mitigation policy. Carbon pricing through the EU ETS specifically addresses emissions at the source while ensuring that the polluter pays.

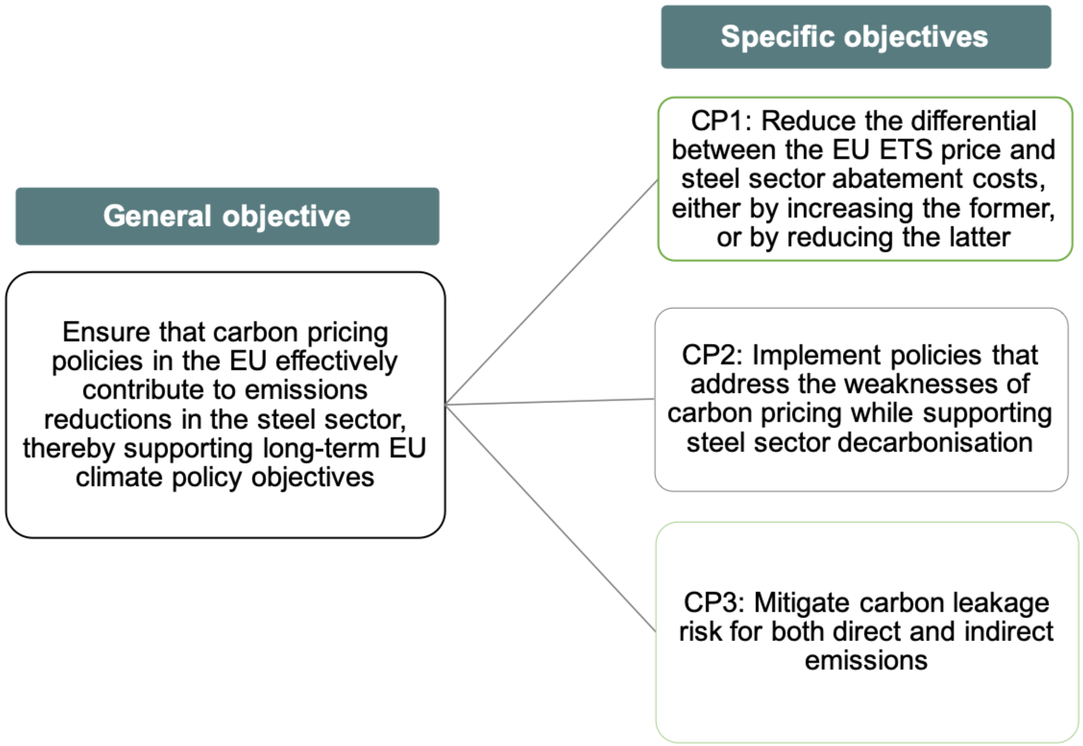
Article 4(2) of the TFEU also makes clear that environmental and energy policies are based on **shared competence** between the EU and its member states. **Article 6 TFEU** states that in the area of **industrial policy, EU policy should support, coordinate or supplement** member states’ policies. As a global problem, climate change cannot be addressed by a single country. EU cooperation is therefore advantageous. Divergent European policies supporting emission reduction could also undermine the efficiency of individual member states policies due to the risk of carbon leakage. A domestic approach to emission trading would be inefficient, as there would be an incentive to set too high caps or to over-allocate allowances. As environment is a shared competence, EU action on climate change and carbon pricing is not intended to fully replace national policies, but to complement and to act only where it is efficient to do so.

4.3. Policy objectives and options

4.3.1. General objectives

The policy options considered in this section should ensure that carbon pricing effectively contributes to steel sector emissions reduction, to help achieve the EU long-term climate goals in line with the Paris Agreement and Art 191 TFEU, but also ensure that carbon pricing instruments are complemented by other policy interventions where necessary.

Figure 10: Policy objectives on carbon pricing to decarbonise the EU steel sector



Source: authors' composition.

4.3.2. Specific objective CP1

Specific objective CP1: Carbon prices are not high enough, relative to steel sector abatement costs. Therefore, the policy objective should be to reduce the differential between the EU ETS price and steel sector abatement costs, either by increasing the former, or by reducing the latter.

Baseline: The Market Stability Reserve (MSR) will continue to address the balance between supply and demand, especially with the invalidation (i.e. cancellation of allowances) after 2023. However, while carbon prices may somewhat increase, it is unlikely that they will reach levels in line with deep decarbonisation abatement options for the steel industry, at least in the short term.

Option CP1: Hybrid design approach to the MSR

A hybrid design approach to the MSR is one approach to achieve the objective of reducing the differential between the EU ETS price and the abatement costs in the steel sector. Specifically, it could result in a higher carbon price to be realised in the EU ETS. All else unchanged, increased scarcity in the EU ETS could be expected to lead to higher carbon prices.

Some of the more straightforward ways to increase ETS are already foreseen by the European Green Deal and will likely be part of the "Fit-for-55%" policy package. This includes revising the cap of the ETS to align with the -55% target, either by increasing the linear reduction factor, or by setting a new baseline for the cap. Changing the cap will constrain the supply of ETS allowances more in the long run.

The supply of ETS allowances is also affected by the MSR, which makes automatic adjustments to the auction schedule based on pre-defined supply parameters. Allowances held in the MSR can also be automatically invalidated from 2023 onwards, thereby permanently reducing supply. A hybrid MSR design could retain the two core operating principles of the MSR, but change the triggers for intervention. Currently allowances are withheld from auction if the total number of allowances in circulation exceeds a certain threshold, but this could be changed into a pre-defined carbon price. As a purely illustrative example, the auction supply of a given year could be reduced by 25% if the average carbon price in the preceding year was below €50. This retains the supply-based operations of the MSR, but also introduces elements from a carbon price floor design, albeit with less certainty for the carbon price. Following the adjustment to the auctions, the primary and secondary market would continue to operate as normal leading to a market-based carbon price signal. The role of expectations by market participants, including on the ‘desired’ carbon price level embedded in the MSR legislation, would also affect price formation.

Option CP2: Reducing steel sector abatement costs

An alternative approach to reduce the differential between the ETS price and steel sector abatement costs is to focus on reducing abatement costs. Lead market creation could be one approach. The premise of such an intervention is that increased demand and scale will lead to learning effects, which in turn leads to cost reductions. These “demand-side innovation policy instruments” could complement supply-side policies such as the EU ETS. There are various ways in which policies can support the lead market creation. The essence of such interventions would be that green steel is forced onto the market using public policies and funding. Public procurement, standards, regulations or certain forms of subsidies can all play a role.

As an example, public procurement regulations can make use of the purchasing power of governments to mandate greater use of green steel in public construction projects. However, before the use of green steel can be mandated, it does need to be available in certain volumes – even if the costs are (significantly) higher than those of conventional steel. A similar approach could be applied more widely through standards regulating the carbon intensity of steel. However, in the absence of sufficient volumes of green steel, it may be necessary to provide targeting subsidies or de-risking measures so that producers have a business case for investing in initial green steel production. Some of lead-market measures are also analysed more in-depth as part of Specific objective CP2 and in Chapter 3 of this study (on funding opportunities to decarbonise the steel industry). EU funding for demonstration (and to a lesser extent further deployment) of industrial decarbonisation projects is currently available through instruments such at the EU ETS IF or the Horizon Europe programme.

While the funding of demonstration and deployment projects could be quite expensive, if measured in terms of the implicit carbon price associated with the measures, it should also lead to learning effects and thereby enable lower costs of green steel, considering that scale increases with deployment. Once abatement costs have been reduced, the role of the EU ETS in reducing the GHG emissions from the steel sector increases. Specifically, the carbon price level at which green steel would be competitive in the marketplace would be lower, thereby increasing the degree to which carbon-intensive steel production is discouraged by the ETS price signal.

4.3.3. Specific objective CP2

Specific objective CP2: irrespective of how high the ETS price is, relying just on carbon pricing may not be sufficient to decarbonise steelmaking. The policy objective should therefore be to implement policies that address the weaknesses of carbon pricing while supporting steel decarbonisation, such as high-cost differentials, investment across different stages of innovation and addressing long lead times.

Baseline: The EU ETS remains the main instrument to promote emissions reductions. Some support for various innovation projects may be forthcoming through the ETS IF. Some infrastructure deployment may be supported through cross-sectoral IPCEIs (hydrogen or CCS). The Clean Steel initiative proposed as part of the European Green Deal does not lead to major legislative changes.

Option CP3: enabling market differentiation between low- and high-carbon steel

The policy options on lead-market creation, and in particular on a label for green steel, could support market differentiation. They are assessed more in detail in Chapter 9 on cross-cutting policies.

Option CP4: green public procurement

The interaction of GPP with the EU ETS is not a direct one. Products or materials procured publicly may be covered by the EU ETS. Over time, the impact of demand measures and lead markets should lead to economies of scale and cost reductions. Once green steel is more competitive versus conventional steel, the impact of the ETS price signal increases as green steel producers would need to acquire and surrender fewer, if any, allowances.

The main impact of green public procurement is assessed under the cross-cutting policies chapter.

Option CP5: introducing CCfDs

CCfDs could complement the carbon price signal from the EU ETS by creating targeted subsidies linked to the production of green steel. A CCfD can be designed to cover the difference between a CO_2 strike price and the actual CO_2 price under the EU ETS. This stabilises the revenue stream by removing the uncertainty associated with fluctuating carbon prices under the EU ETS.[34] Depending on the ETS price, a CCfD may result in a premium paid, but also a payment by the producer, in case the ETS price exceeds the strike price (depending on the design – it is also an option to simply not ask for a payment in case the strike price is lower than the ETS price). This limits the expenditure for the issuer of CCfDs (i.e. the EU or a member state).

CCfDs would be expected to be limited in duration, as their goal is to increase early deployment of green steel production. With sufficient scale and learning effects, the costs of green steel should drop and the EU ETS price would have a greater impact in discouraging more carbon-intensive steel production, to the benefit of green steel producers.

[34] *For instance, national or regional authorities can intervene through a compensation mechanism based on a guaranteed price for EUAs – the 'strike price'. At the end of each year, the public authority pays the investors the positive difference, if any, between the strike price and the market price of the EUAs. For example, if the strike price is set at €50/t CO_2 and the EUA price is at €30/t CO_2 that year, the public authority would pay steelmakers a compensation of €20/t CO2. For further details on the CCfD mechanism, please see* GREENSTEEL (2021b).

4.3.4. Specific objective CP3

Specific objective CP3: Carbon leakage risk is a deterrent to investing in transformational decarbonisation technology in the steel sector. The policy objective should be to mitigate carbon leakage risk for both direct and indirect emissions.

Baseline: No changes to carbon-leakage risk mitigation measures. Free allocation continues with updated benchmarks and activity levels. A limited CBAM may be introduced for selected sectors, which could include basic steel production. Indirect carbon cost compensation continues according to recently updated environmental State aid guidelines.

Option CP6: introducing a CBAM

The instrument for mitigating the carbon leakage risk for EU ETS sectors, including steel, is currently free allocation of allowances. A key challenge to free allocation is that the overall volume of free allowances is limited and set to decline further as the EU revises the ETS in line with the -55% target for 2030. An alternative approach to carbon leakage risk mitigation is a CBAM, for which a proposal will be forthcoming as part of the European Green Deal.

Carbon border adjustments work by levying a charge on imports from countries that do not have equivalent climate policies as the EU. This allows for a "levelling of the playing field" between domestic steel producers that need to surrender ETS allowances, and importers. Several designs are possible. The CBAM could be designed as a tax, although doing so would require unanimity in the Council of Ministers. It can also be linked to the ETS, with importers having to acquire (shadow) allowances.

A CBAM should be WTO compatible, but this constrains its design. One implication of ensuring WTO compatibility may be the fact that free allocation to the steel industry is removed. Another implication could be that it is not possible to design a CBAM for exports. The equivalent 'adjustment' for exports would be a rebate of the ETS-imposed carbon costs. This could, however, be interpreted as an (illegal) export subsidy. A CBAM could apply either to basic steel products, but also to products using steel (e.g. vehicles). The latter would be more comprehensive and potentially more effective, but also requires more data and administration.

Option CP7: introducing a separate industrial competitiveness policy for the steel industry

A separate industrial competitiveness policy for the steel industry could be developed, regardless of carbon leakage measures. Such a policy does not have to focus on green steel per se, but it should not be a barrier to its deployment – or to the attainment of EU climate objectives – either. Having a dedicated industrial policy would be an acknowledgement that supporting industrial competitiveness and mitigating carbon leakage risk are not always the same. An EU industrial policy is inherently limited by the EU Treaties, which assign a supporting and coordinating role to the EU but primarily leaves industrial policy to member states.

State aid control and competition policy (including merger control and horizontal agreements) could be reformed with industrial competitiveness in mind. Taxation provides another potential avenue to support industrial competitiveness in general, although it may be challenging to target sectors individually. The lead market creation initiatives of a revised EU industrial strategy can also support green steel-making (see also the Operational objective FD2.2 of Chapter 3 on funding).

4.4. Impacts

4.4.1. Option CP1: adopting a hybrid MSR design

Economic and competitiveness impact

A hybrid MSR design could lead to both higher and lower **costs of doing business for the steel industry and other industries in Europe**. The exact impact would depend on the politically determined price level at which the supply of allowances would be adjusted, as well as how this level compares with the current ETS carbon price.

If the new MSR design would lead to higher carbon prices, costs of doing business would increase, due to increased carbon costs. At the same time, such a design could also be more predictable, thereby **affecting investments**. Changes in effective carbon costs can affect trade flows for trade-intensive sectors such as the steel industry.

Mechanisms such as the MSR may make it more difficult to integrate the European carbon market with those of third countries, unless the design is coordinated with potential "linking partners". It therefore affects **regulatory convergence with third countries.**

If a revised MSR leads to more stable and higher carbon prices**, investments in green steel technologies become more attractive** and profitable. However, **the steel sector's capacity to innovate** also depends on adequate mitigation of carbon leakage risk, which may be adversely affected by higher carbon prices.

As the MSR applies to the EU ETS as a whole, there should only be minor impacts on the **functioning of the internal market and on competition**. Member states whose steel industry is comparatively less carbon-efficient would face higher impacts. Increased carbon costs and scarcity in the EU ETS in general could lead to increased indirect carbon costs, which put greater pressure on member states to provide compensation through State aid.

Changes in carbon costs can **affect the market shares and competitive position of the EU steel industry vis-à-vis non-EU competitors**, although this impact will primarily depend on effective carbon leakage risk mitigation. If increased carbon costs lead to increased investment in climate-neutral steelmaking, the competitiveness of EU industry in green steel markets increases.

Environmental impact

Increased scarcity in the EU ETS and higher carbon prices would, all else unchanged, lead to a GHG emission reduction in the atmosphere. However, since the MSR applies to the EU ETS as a whole, such reduction does not necessarily have to be realised in the steel sector.

A stronger ETS price signal should lead to an increase in **sustainable production**. **Sustainable consumption** impacts depend on the ability of industries to pass through carbon costs, which may be limited in case of carbon leakage risk. **Prices of consumer goods** using steel could increase, but the impact is likely to be marginal due to the limited share of material costs in consumer goods.

A revised MSR affects the whole EU ETS and therefore also the **green transition in the EU**. A stronger carbon price signal can further discourage carbon-intensive production methods, including in the electricity sector, which will also have an impact on the economics of renewables and (green) hydrogen.

Other impacts

If a revised MSR leads to higher carbon prices, revenues from ETS allowance auctions should increase, benefiting **member states' budgets**. It can also lead to lower expenditures for policies based on the ETS price, such as potential future CCfDs. Conversely, the costs for the compensation of indirect carbon cost could increase.

4.4.2. Option CP2: reducing steel sector abatement costs

Economic and competitiveness impact

Reducing the steel sector's abatement costs would lead to the EU ETS price signal having a greater impact, all other things unchanged. This could reduce the costs of doing business for the steel industry, as they would have more options to address carbon costs arising from the ETS. Depending on the instrument to reduce abatement costs, the **costs of doing business for other industries** may also be affected, if they can use similar abatement technologies as the steel sector.

Trade and investment flows would be affected in so far as the market conditions for (investing in) green steel change both inside and outside the EU.

The **capacity of the EU steel industry to innovate** could be positively impacted by measures that lead to cheaper abatement options in the steel industry, especially as learning effects of early projects have positive externalities for the sector as a whole.

Reducing the steel sector's abatement costs can adversely impact the **functioning of the internal market and competition**. Some measures to support cost reductions, such as subsidies, can distort competition. Different fiscal capacities between member states can lead to divergent State aid volumes. State aid control is important to alleviate this. With EU measures, cohesion in the internal market may be affected due to the geographic circumstances of some member states affecting decarbonisation options.

The market share and competitive position of the EU steel industry vis-à-vis non-EU producers could increase, but only in so far as a market for green steel exists. This depends on climate and industrial policies in third countries. A challenge is that non-EU steel producers could also benefit in the longer term from innovation and lower abatement costs made possible by EU policies. However, EU producers could have a first-mover advantage as they would already have experience in deploying low-carbon production methods.

Environmental impact

Reducing the steel sector's abatement costs does not directly lead to lower GHG emissions in the steel sector. Indirectly, however, the impact could be significant. With lower abatement costs, and more climate neutral production technologies available, the impact of the ETS at a given price level will be greater. In other words, the ETS will have a significant impact in discouraging high-carbon steelmaking at lower prices, all to the benefit of green steelmaking.

Reducing the steel sector's abatement costs should directly lead to more **sustainable production** and indirectly to more **sustainable consumption**. Lower abatement costs help making green steel more competitive compared to conventional steel, and, as it happens, demand for green steel should increase, while the relative price of environmentally-friendly goods should drop.

The impact on the green transition in the EU will be limited, unless instruments implemented to bring down the steel sector's abatement costs were also applied to other industrial sectors.

Other impacts

Industrial policies that bring down the steel sector's abatement costs could carry a high price tag and therefore impact the budgets of member states. Some instruments could also be funded through existing EU policies, or as part of the EU budget, but this may have an impact on other areas where spending is reduced.

4.4.3. Option CP3: enabling market differentiation between low- and high-carbon steel

The impact of this option is assessed in detail in Chapter 9 on Cross-cutting policy options.

4.4.4. Option CP4: GPP

The impact of this option is assessed in detail in Chapter 9 on Cross-cutting policy options.

4.4.5. Option CP5: introducing CCfDs

Economic and competitiveness impact

Introducing CCfDs could **reduce the costs of doing business for the steel industry and for other industries which are eligible.** CCfDs can de-risk investments and lead to revenue streams which improve the business case for investment. It should be noted that CCfDs would always be linked to investments leading to emissions reductions. Therefore, it is not a general reduction in costs.

Trade and investment flows could both be affected by CCfDs, although investments flows would likely see greater and earlier impacts. CCfDs would have a strong impact on the business case for green steel investments in Europe, which could attract inward investment. In so far as a market for green steel emerges, the expansion of green steel production capacity spurred by CCfDs would affect trade flows.

The **capacity of the EU steel industry to innovate** could be significantly improved by CCfDs, as they would be made available specifically for investments in innovative green steel production.

Reducing the steel sector's abatement costs can adversely impact the **functioning of the internal market and competition**. If CCfDs are implemented at member state level, the level playing field within the internal market can be affected. Some member states may not have the fiscal capacities to fund CCfDs. If CCfDs were funded at EU-level this problem would be alleviated, although there might still be distortions in regions where green steel investments are not attractive.

The market share and competitive position of the EU steel industry vis-à-vis non-EU producers could increase, but only in so far as a market for green steel exists. This depends on climate and industrial policies in third countries.

Environmental impact

CCfDs do not directly lead to lower **GHG emissions** in the steel sector. Indirectly, however, the impact could be significant. The use of CCfDs in the steel industry should lead to an expansion of green steel production capacity, which will lower the emission footprint of the steel industry.

CCfDs deployed in the steel sector should directly lead to more **sustainable production** and, indirectly, to more **sustainable consumption**. Depending on their design, CCfDs can support both reductions in CAPEX and OPEX, thereby making green steel more competitive versus conventional steel.

The impact on the **green transition in the EU** will be limited, unless instruments implemented to bring down the steel sector's abatement costs were applied to other industrial sectors too.

Other impacts

CCfDs would have a significant impact on member states' budgets. CCfDs are a form of subsidies (or State aid) and the difference between the politically-determined strike price and the ETS price would determine the amount of public finances needed. Here are two examples in which member state's budgets could be affected even if CCfDs are implemented at EU level: if the size of the EU budget is changed; or if the CCfDs are funded by monetising EUAs, which would then no longer be auctioned.

4.4.6. Option CP6: implementing a CBAM

Economic and competitiveness impact

A CBAM could affect the **costs of doing business for the steel industry and for other industries to which the CBAM would apply.** However, the magnitude and direction of this impact depends on different factors. A CBAM can mitigate carbon leakage risk, thereby improving the competitiveness of EU industry vis-à-vis trade partners whose production is more carbon-intensive than that of EU producers.

Trade and investment flows could be significantly affected by a CBAM. With a CBAM, importers into the EU would face equivalent carbon costs as EU producers (unless exemptions apply). This may make it less attractive for carbon-intensive producers to sell to the EU market. Investment flows could be affected both inside and outside the EU, as the effective carbon costs faced by producers change. Furthermore, there may be more investments in abatement by non-EU producers in order to mitigate the impact of a CBAM.

The **capacity of the EU steel industry to innovate** could be positively impacted by a CBAM, as the risk of carbon leakage can hinder investments in low-carbon technologies.

The impact of a CBAM on the **functioning of the internal market and competition** should be limited. A CBAM would have to be implemented EU-wide with no differences between member states. However, in so far as a CBAM leads to a reduction in trade, EU producers could become less competitive in the long-run due to reduced exposure to international competition. **The market share and competitive position of the EU steel industry vis-à-vis non-EU producers** could be affected by a CBAM. The market share of EU producers within the internal market could increase, provided that the carbon intensity of EU production is lower than that of non-EU producers (hence ensuring that the CBAM has an impact on imports).

Environmental impact

A CBAM could indirectly lead to **lower GHG emissions**, by providing an effective safeguard against the risk of carbon leakage. A CBAM could also foster innovation and investment in low-carbon technology, allowing for more emission reduction in the long term. Conversely, there is a risk of "reshuffling", where trade partners export their lowest-carbon products to the EU in order to minimise the impact of the CBAM, while consuming higher-carbon products domestically. In such a case, the CBAM's impact on emissions is more neutral.

A CBAM can indirectly lead to more **sustainable production** by mitigating the risk of carbon leakage. **Sustainable consumption** could also increase in so far as a CBAM induces investment in abatement technology.

The impact on the **green transition in the EU** could come through potential revenues from the CBAM which are reinvested in line with the European Green Deal.

Other impacts

A CBAM could have a significant impact on **compliance with legal commitments**. A CBAM would need to be designed in line with WTO rules. Even then, a CBAM (and potentially related climate measures) could be challenged at WTO level. A CBAM could also have an impact on **regulatory convergence with third countries**. One potential impact could be that third countries raise their climate targets in response to a CBAM, leading to more climate policy convergence. Retaliation is also a possibility. In this case, there might be adverse impacts on the trade system leading to regulatory divergence. Finally, a CBAM could be pursued in a cooperative manner. This could lead to the development of new **international standards** on, e.g., the carbon content of traded goods.

A CBAM could have a significant impact on **member states' budgets**. The revenues from a CBAM could be distributed to member states, as is also done already for ETS revenues. If the CBAM contributes to the EU's own resources, this could have an impact on the balance of payments and on receivables from the EU budget. Finally, a CBAM could replace free allocation. If those allowances were auctioned instead, this would increase revenues for member states.

4.4.7. Option CP7: introducing a separate industrial competitiveness policy for the steel industry

Economic and competitiveness impact

A separate competitiveness policy could have a positive impact on the **EU steel industry's ability to innovate**, as there would be a greater investment capacity. Conversely, if the competitiveness policy implicitly leads to the shielding of EU producers, the ability to innovate could suffer in the long-term.

The impact of a separate competitiveness policy on the **functioning of the internal market and competition** could be considerable. The use of taxation and State aid can lead to distortions in the internal market, especially given the fiscal competency of member states and the discretionary character of State aid. Nevertheless, the EC does have tools to safeguard the internal market.

The market share and competitive position of the EU steel industry vis-à-vis non-EU producers could be strengthened in so far as EU producers become more competitive on global markets.

Environmental impact

A separate competitiveness policy for the steel industry would not have a direct impact on **GHG emissions** in the sector. Indirectly, the impact can be both positive and negative. A more competitive EU steel industry could be **better positioned to invest** in climate neutral technologies, thereby having a positive impact on emission reduction in the long term.

Conversely, a poorly designed policy could lead to undue protectionism, which could harm the transition to greener steel-making.

Other impacts

Policies to support the competitiveness of individual industries would need to comply both with multilateral agreements, such as subsidy control at the WTO, as well as with bilateral trade agreements. These agreements may contain provisions on subsidies, investment, intellectual property etc., which could constrain the design of a competitiveness policy. It therefore affects **compliance with legal commitments**.

A separate competitiveness policy could have a significant impact on **member states' budgets**. The impact, however, depends on the extent to which fiscal changes are made. Changes to both corporate and energy taxation could have a considerable impact on industrial competitiveness, but could come at the expense of lower tax receipts.

4.5. Comparative assessment

4.5.1. Effectiveness

Option CP1: hybrid MSR design

A hybrid MSR design would have uncertain effectiveness. It could be moderately positive in strengthening the ETS price signal; however, this depends on the political choices made as to the appropriate price level at which the supply of allowances is adjusted. It is unlikely that this type of intervention would be set at a price level that would significantly affect abatement costs in the steel industry. Therefore, while a hybrid MSR design could lead to a somewhat stronger ETS price signal, it is unlikely to impact the role of the carbon price in the decarbonisation of the steel sector. On the other hand, the impact on emission reduction in the EU ETS in general could be more significant.

The responses from stakeholders reflect the uncertain effectiveness of this policy option. While some stakeholders are moderately positive, a slightly larger group have a less-than-positive outlook on this option.

Option CP2: reducing steel sector abatement costs

Introducing measures that could reduce the abatement costs of the steel sector would be effective in strengthening the role of the ETS in decarbonising the industry. The impact would be both direct and indirect. Some measures that lead to a reduction in abatement costs will be the result of increased deployment of low-carbon technology, which delivers learning effects. Their deployment directly reduces steel sector emissions. Once the abatement costs have declined, the impact of a given carbon price in the ETS will be greater, as it will be easier to further reduce emissions due to the more competitive low-carbon technology.

The high effectiveness of this policy option is equally supported by steel-sector and non-steel-sector stakeholders.

Option CP 5: introducing CCfDs

The impact of this option is assessed in detail in Chapter 9 on Cross-cutting policy options*.*

Option CP6: implementing a CBAM

The introduction of a CBAM is considered to be a reasonably effective option to ensure that carbon pricing policies in the EU contribute to the decarbonisation of the steel sector. However, stakeholders from outside the steel industry are more positive about a CBAM than steel-sector stakeholders. While measures to mitigate the risk of carbon leakage can play an important role in enabling industry to invest in low-carbon technology, a CBAM would not protect industrial competitiveness in the same way as free allocation does today. Exports of EU steel producers would unlikely be covered. Nevertheless, by making carbon-intensive steel imports more expensive, the competitive position of those EU steel producers that are more carbon-efficient would be strengthened. Another difficulty of a CBAM in effectively mitigating the risk of carbon leakage is the complexity of the design and the potential data requirements. Simpler designs, for example targeting only basic steel production, are possible but have lower effectiveness, while a CBAM targeting steel in final products could be more effective, albeit at an increased administrative cost.

Option CP7: introducing a separate industrial competitiveness policy for the steel industry

Stakeholders consider the introduction of a separate industrial competitiveness policy for the steel industry to be a reasonably effective option. A strengthened competitive position for EU steel producers would increase the financial capacity of producers to invest in emission reductions. However, this option would strongly depend on other climate (not industrial) policies to ensure that investments would be promoted and would benefit decarbonisation in line with the 2050 objectives. Fiscal measures are, in principle, able to support both industrial competitiveness and climate goals. Their implementation, though, would most likely be up to member states, due to the requirement for unanimity at EU level for fiscal measures.

4.5.2. Efficiency

Option CP1: hybrid MSR design

A hybrid MSR design could be implemented through a change in the ETS legislation. It nevertheless requires political agreement on what a desirable price level in the ETS is. If there is support to constrain the allowance supply at levels exceeding the current ETS price, this option would result in more auction revenues for member states that can support other climate policies. In addition, a higher ETS price would increase the value of the IF. Conversely, a higher ETS price could also increase the costs for the steel industry without directly leading to increased emission reductions, so long as abatement costs remain far higher than the ETS price. For sectors other than the steel one, abatement costs can be lower (e.g. for the power sector). Therefore, the efficiency of this measure would be higher from an economy-wide perspective than from the perspective of the steel sector, where it is limited.

Option CP2: reducing steel sector abatement costs

Measures that can achieve a reduction of steel sector abatement costs are likely to be costly, as they will require financial support to currently uncompetitive production methods. Nevertheless, due to learning effects and economies of scale, such measures could have a limited duration and therefore be highly efficient to increase and strengthen the impact of carbon pricing policies in the long-term.

Option CP5: introducing CCfDs

CCfDs have the potential to be highly effective, but they also carry a high price tag. The economic efficiency of CCfDs is supported by their positive interaction with the EU ETS price. This ensures that the subsidies offered to producers decline if the ETS price increases. Nevertheless, if CCfDs were offered at a significant volume or for a long duration, then there would be the need to also find public revenue streams.

Option CP6: implementing a CBAM

The efficiency of a CBAM is supported by the revenue-raising aspects of levying a charge on imports. A CBAM also has the potential of (partially) replacing free allocation under the EU ETS, although stakeholders do not agree on how desirable this is. With a reduced free allocation, revenues from auctions will increase. Auctioning is also considered to be an economically-efficient allocation method for ETS. Conversely, the complexity of a CBAM may lead to administrative and transaction costs. Retaliation by trade partners could affect the competitiveness of EU steel producers.

Option CP7: introducing a separate industrial competitiveness policy for the steel industry

The impact of a separate industrial competitiveness policy for the steel industry would be primarily distributional. An effective industrial competitiveness policy could increase the capacity of the steel industry to invest in climate-neutral production; this could potentially lower the need for public policies to support emission reduction efforts. On the other hand, the public resources used to support the steel sector's competitiveness could not be used for other public policies, including climate and energy ones.

4.5.3. Feasibility

Option CP1: hybrid MSR design

A hybrid MSR design could be enacted by changing the operating parameters of the MSR in the EU ETS Directive. This could be done through qualified majority voting. As such, it is a more feasible option than the somewhat similar carbon price floor, which could require unanimity. However, any form of price management in the ETS, even if indirect, remains controversial, and requires political capital to agree on appropriate levels of intervention. Therefore, this option is not among the ones which are most likely to receive support. This is reflected by the stakeholders' responses to the survey, which rank this option the lowest in terms of feasibility.

Option CP2: reducing the steel sector's abatement costs

Stakeholders consider this option to be highly likely to receive support by policymakers. There is overlap with other options, such as CCfDs, GPP and the public funding options described in other chapters – all of which can support abatement cost reductions. At least some of these options – in particular CCfDs – are considered highly feasible, too. As such, some form of policy support to reduce the steel sector's abatement costs is highly feasible.

Option CP5: introducing CCfDs

CCfDs are considered to be the policy option the most likely to receive support by policymakers. The updated industrial strategy of the EU also refers to them. While there may be political disagreement on how much budget should be allocated to make CCfDs possible, or the extent to which they should be introduced at EU level (in addition to the national level, where they have already been introduced[35]), it seems highly likely that CCfDs will play a role in the EU's industrial decarbonisation policy.

Option CP6: implementing a CBAM

The feasibility of a CBAM is contested between steel sector stakeholders and non-industry ones. The latter consider that a CBAM is highly likely to receive support by EU policymakers, whereas the steel sector respondents expected only a moderate support. A CBAM is, in principle, intended to be applied to all sectors at risk of carbon leakage. However, due to the complexity of the mechanism – both technically and politically – the initial application may be limited to certain sectors. While the steel sector, being the largest industrial emitter, is among the top candidates for inclusion, it is not as homogenous a sector as, for example, the cement or electricity sector. The heavy trade of steel products, both as an intermediate product and in final goods, as well as covering imports and exports alike, may deter policymakers form including the (entire) steel sector in a CBAM at first.

Option CP7: introducing a separate industrial competitiveness policy for the steel industry

This policy option is considered moderately likely to receive support by policymakers in the EU. Industrial competitiveness in general is high on the EU agenda and the recently updated industrial strategy is accompanied by a Staff Working Document (SWD) on "clean European steel". This shows the importance of the steel sector for the EC. The SWD describes a wide range of regulatory and funding instruments that could support competitiveness and the transformation of the steel industry towards climate neutrality. However, additional support for the steel industry requires revising these legislative and regulatory instruments, for which political support is uncertain.

4.5.4. Coherence

All policy options are, in principle, coherent with the spirit of the European Green Deal. The policy options augment the EU ETS directly (such as CCfDs), provide alternatives to current measures such as the free allocation (CBAM), or represent an incremental change to current measures (hybrid MSR). A possible conflict may arise with a separate competitiveness policy for the steel industry. In the absence of policies clearly distinguishing between high- and low-carbon steel, such a competitiveness policy may unduly support business-as-usual steelmaking, which can hinder the transformation of the industry towards climate neutrality. This shows the importance of a balanced policy mix.

[35] A recent example is the SDE++ policy in the Netherlands, which supports investment in a CCUS cluster.

Table 8: Overview of policy solutions[36] – Carbon pricing

	Effectiveness	Efficiency	Feasibility	Coherence
Option CP1: adopting a hybrid MSR design				
Option CP2: reducing steel sector abatement costs				
Option CP5: introducing CCfDs				
Option CP6: implementing a CBAM				
Option CP7: introducing a separate industrial competitiveness policy for the steel industry				

Note: This table presents the policy options in the carbon pricing area that would support the decarbonisation of the EU steel industry. The options are assessed based on the four criteria under the Better Regulation guidelines: their effectiveness, efficiency, feasibility and coherence. Colour legend: orange - low, yellow – moderate, green – high. For instance, a policy option that has a green cell in the Effectiveness column is considered to be "highly" effective. Source: authors' own composition.

[36] Policy options CP3 and CP4 have not been included in this overview as these options are assessed in the cross-cutting policy chapter

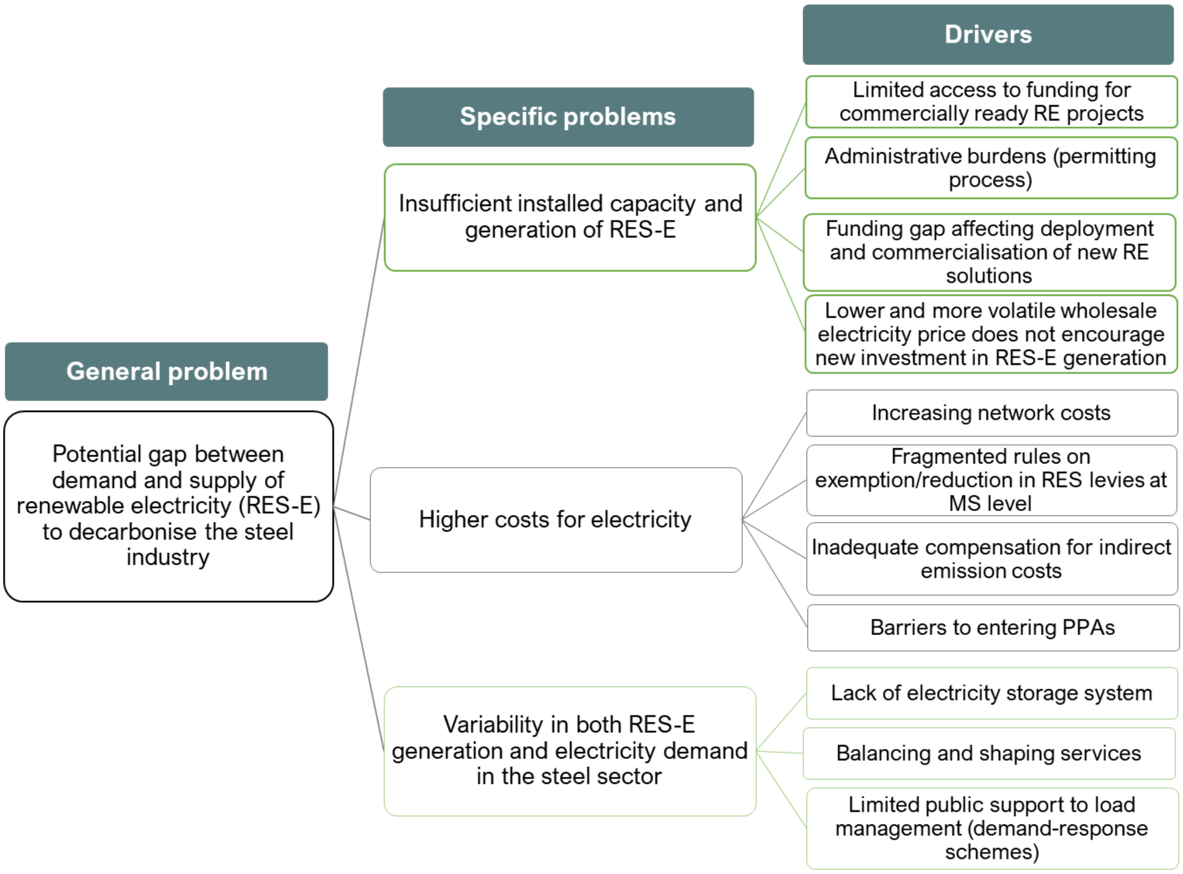
5. Availability of renewable electricity

5.1. Problem identification

5.1.1. Background

Most decarbonisation technologies in the steel sector entail the **substitution of fossil fuels with electricity**. Electricity will be needed in both the SCU and CDA technological pathways, as well as in the circular economy approach to steelmaking (GREENSTEEL 2021a, p. 19; Navigant, 2019, p. 23; Roland Berger, 2020, pp. 8-13; Vogl, 2020, p. 5). By way of example, the Carbon capture and utilisation (CCU) process, which is central in the SCU pathway, relies on electricity in the chemical process to produce methanol from CO and CO_2 off-gases generated during the steel production (European Commission, 2018a, pp. 15-16). In the EAF route, which is at the core of the circular economy approach, electricity is used in various processes, such as melting, refining and tapping. Finally, in both the BF-BOF and EAF routes, electricity may be used to replace carbon with hydrogen produced via electrolysis (Kovacic et al., 2019, pp. 4-9). To meet the target of reducing CO_2 emissions stemming from EU steel production by 80-95% compared to 1990 levels by 2050 and ultimately achieving climate neutrality, **the electricity needed for steelmaking must be generated using low-carbon sources**, particularly renewable sources (ESTEP, 2020a, p. 23). Therefore, the steel sector's transition towards low-carbon solutions will require enhanced coupling with the green energy transition. More specifically, the problems presented in Figure 11 and discussed in the following sections need to be timely addressed.

Figure 11: Problems hindering the availability of renewable electricity



Source: author's composition.

5.1.2. General problem

There is **a potential gap between the increasing demand for renewable electricity** (RES-E) to decarbonise the steel industry **and the available supply of RES-E in the EU**. In the EU, the annual consumption of grid electricity by the steel sector is expected to significantly increase, going from 55 TWh in 2019 up to 400TWh in 2050 for both direct use in steel production process and hydrogen production (EUROFER, 2019a, p. 1).[37] Meanwhile, EU28's electricity generation was 2,867 TWh in 2019, and is projected to be 3,646 TWh in 2050 (Eurostat n.d., European Commission, 2020d, p. 33). The share of RES-E in the total production of electricity in the EU is expected to increase from 35% in 2019 to more than 85% in 2050 (European Commission, 2020d, p. 54). Based on these projections, the steel's sector share of EU's total electricity consumption would rise from 2% in 2019 to about 11% in 2050. The steel's sector electricity consumption is also expected to amount to 13% of the total RES-E generated in the EU in 2050. The projected growth in EU's total RES-E supply would therefore not necessarily catch up with **the remarkable increase in demand for electricity from the steel sector** and other energy-

[37] Demand of electricity will also increase to compensate for the loss of BF and BOF gases, which currently are the main sources of self-generated electricity in the BF-BOF route (Sun et al., 2020, p. 3).

intensive industries. This gap could potentially prevent the steel sector from meeting its decarbonisation targets for both **direct and indirect emissions**..

5.1.3. Specific problem RE1

The **installation of new RES-E plants in the EU and the electricity they will generate** may not provide the amount of electricity needed for low-carbon steelmaking technologies. This concern is shared by most of the stakeholders consulted during the Inception phase.

- **Driver RE1.1**: The 2019 reform of the EU electricity market[38] introduced new rules that are expected to accommodate for larger shares or renewables in the energy mix and ensure investment in back-up capacity and energy storage to compensate for variable electricity generation. The reform, however, did not review the way wholesale electricity is priced in the EU (Intereconomics, 2019, p. 338). On the one hand, it is likely that the increasing penetration of RES-E (with low or zero marginal costs) will put **downward pressure on the wholesale electricity price and increase volatility**, thus inflating investment risks and making it more difficult to remunerate new RES-E generation capacity. On the other hand, fostering private investments will require higher (wholesale) prices or a radical market reform
- **Driver RE1.2**: RES-E projects still face **limited access to funding**, while investments in some RE technologies (e.g. wind energy) are capital intensive. First, public financial support, which played a crucial role in several renewable technologies, has been reduced in recent years. Following the EU State aid guidelines (European Commission, 2014), member states are transitioning from administratively-determined feed-in tariffs to feed-in premiums determined by competitive bidding procedures. On LCOE basis, some RE technologies are already competitive, thus public support does not need to be as intense as in the previous period. This change has entailed thinner margins for RE projects, exposing them to some extent to the volatility of electricity prices. Meanwhile, higher electricity prices might strengthen investment signals but come out as a cost to electricity consumers, including steel producers.. Second, investors' confidence in financing RES-E projects has been undermined. While RE has become increasingly competitive in the market, the risk in new RE projects nevertheless may affect investment decisions. Finally, the uncertainty about future energy prices and demand (not only from steel but also other industries and sectors) has resulted in a slowdown in funding for new projects (IEA, 2020a). At EU level, investment in renewables in 2019 was down 4% from 2018 and 64% since its peak in 2011 (REN21, 2020, pp. 167,169).[39]
- **Driver RE1.3**: **The administrative burden** to develop renewable projects is very high in certain member states, particularly during the **permitting process**. The permit-granting procedures for new and repowered projects can be long, complex and uncertain. This can become a particularly challenging issue in the renewable sector, where the slow authorisation process may not follow the speed of technological change: the proposed

[38] For further details, please see: https://ec.europa.eu/energy/topics/markets-and-consumers/market-legislation/electricity-market-design_en

[39] In 2020, the decline in investment was even larger, i.e. one-third less compared to 2019 (an unprecedented decline for the EU) due to the Covid-19 crisis (IEA, 2020b).

technology may already be obsolete by the time the application is approved (CEPS, 2019a, p. 31).

- **Driver RE1.4**: Innovative renewable technologies face **difficulties in bringing new solutions to the market**. As an example, upscaling geothermal technologies is quite challenging due to high capital requirements, geological risks, and limited insurance policies to cover such risks (ETIP-DG, 2019, p. 13; European Commission, 2016a, pp. 145-146). Similar challenges are faced by ocean energy, with tidal technologies considered as being at the pre-commercial stage and most wave energy technologies are still at the R&D. Another noteworthy argument is the **lack of (affordable) risk insurance and guarantee services** for renewable projects relying on new technologies (JRC 2019, p. 39; Ocean Energy Forum, 2016, p. 47).

Stakeholders consulted for the Inception phase claimed that all drivers are to some extent contributing to increasing the specific problem RE1, with driver RE1.1 (low and volatile wholesale electricity price) driver RE1.3 (administrative burden for permitting) being the most prominent ones. Some of the respondents also agreed that **member state-specific aspects** (e.g., limited public funding for new investments in RE generation and power grid, social acceptance of RE installations, and limited availability of RE sources in certain member states) may further limit the RES-E capacity in the EU.

5.1.4. Specific problem RE2

Decarbonisation measures relying on electricity are expected to **increase the operating costs for steelmaking** in the EU. This reduces the business case for steelmakers to rely on RES-E, and potentially slows down the decarbonisation of the industry. This specific problem was to some extent confirmed by the respondents of the survey performed during the Inception phase. While electricity costs currently represent only around 3% of total production costs in BF-BOF steel plants, this percentage is expected to increase as a result of the growing electricity demand from decarbonisation technologies. In the EAF route (42% of the EU crude steel production in 2018), electricity costs already amount to a considerable portion of total production costs, i.e. around 10% (Worldsteel, 2020a, p. 3; CEPS, 2018, pp. 203-204) and can further increase when using green hydrogen in the direct iron reduction route. The energy costs increase the overall costs for energy procurement in the steel industry and reduce the global cost competitiveness of low carbon steel. For instance, while the electricity price paid by EU EAF plants was on average €€53/MWh in 2017, it needs to be lower than €€25-27/MWh to make the EAF route using green hydrogen in direct iron reduction competitive (CEPS, 2018, p. 213; Wyns et. al., 2018, p. 61; McKinsey, 2020a, p. 8).

- **Driver RE2.1**: **Network costs** paid on top of the energy component of the electricity price create an additional barrier to the implementation of low-carbon steel production pathways. Charges for network costs have increased by 13% between 2008 and 2017 for EAF plants (CEPS, 2018, p. 213), and are expected to grow further in the coming years due to the large investments in the electricity grid that are needed to allow for distributed energy generation systems. The impact of network costs on electricity costs also depends on national decisions to invest in the grid and allocate such costs on different types of electricity consumers. For instance, in most member states, the transmission and distribution charges depend, *inter alia*, on the size of the steel plants: plants consuming more electricity enjoy relatively lower network costs than their smaller counterparts (CEPS, 2018, p. 214). In member states where industries pay for network costs, electricity costs are likely to go up as network costs are increasing.

- **Driver RE2.2: RES levies** charged on electricity consumers to fund the generation of RES-E play a considerable role in raising the electricity price in most member states. RES levies increased on average from €0.8€/MWh in 2008 to €3.1€/MWh (for EAF) and €3.7€/MWh (for BOF) in 2017 (CEPS, 2018, pp. 214, 353). While steel producers are subsidised through exemption from RES levies in some member states, the type and magnitude of exemptions vary greatly across EU countries (CEPS, 2018, p. 361-362). Again, national decisions will play a pivotal role when it comes to electricity costs borne by steelmakers.
- **Driver RE2.3**: As a sector exposed to carbon leakage risk, the steel sector is eligible for **compensation for indirect emission costs**[40] through State aid schemes (European Commission, 2012, section 1.1 (7) and Annex II; European Commission, 2014, Articles 179, 180). However, the compensation system and relevant State aid schemes are not always adequate to foster higher electrification of the steel industry. Currently, the system provides only partial, digressive, and voluntary compensation (Wyns et. al., 2018, pp. 62-63) (Roland Berger, 2020, p. 14). In addition, the validity of the current version of the relevant State aid guidelines (for 2014-2020) has been prolonged only until 31 December 2021, and new rules may apply after that date (European Commission, 2020e). As electricity use in the steel industry is projected to increase, indirect carbon cost compensation will play a more central role in determining the production costs of low-carbon steel.
- **Driver RE2.4**: **Renewable PPAs** can be considered as a tool to address price volatility and ensure enough RES-E for steel producers. However, there are still unaddressed barriers for steel companies to enter into PPAs such as: (i) PPAs inherently link the electricity price risk to the uncertainty of future electricity prices and the long duration of these contracts, (ii) the high interest rate of the bank guarantees requested by electricity generators, (iii) the regulatory barriers to contracting between generators and buyers and the prohibition to sign contracts with more than one generator/supplier, and (iv) the variability of RES-E sources generating high balance/shaping costs (CEPS, 2019a, p. 24, 26; CEPS, 2013, p. 717-719; SPE, 2016, p. 24).

Most of the stakeholders consulted in the Inception phase believed that the generation costs for RE are not problematic. In fact, the most recent RE technologies are cost-competitive against conventional electricity sources: the generation costs of certain technologies such as solar photovoltaic (PV) and onshore wind have declined thanks to technology improvement (lower capital costs, higher performance) and the availability of high-quality materials (EIA, 2020, pp. 11-

[40] Indirect emission costs, in the context of the EU ETS and related state aid legislation, refer specifically to emissions costs that are passed on in electricity prices. Article 10a(6) of the ETS Directive allows for MS to provide financial compensation to indirect emission costs, in the form of state aid. The compensation level is decided at the discretion of each MS. Only sectors that meet the (quantitative or qualitative) criteria indicated in the guidelines on state aid in the context of the EU ETS are eligible for this compensation. For further details, please see: European Commission, 2015, pp. 60,65.

12). By contrast, they confirmed that all the drivers listed above were at least to some extent contributing to an increase in electricity costs, with driver RE2.1 (increasing network costs in several member states) being the most prominent one. One respondent from the steel industry emphasised that the imperfect functioning of the EU electricity markets and the existing **differences among member states** when it comes to, e.g., energy taxation, allocation of network costs, support schemes for renewable energy and compensation for indirect EU ETS costs may lead to significant differences in production costs for steel across the EU.

5.1.5. Specific problem RE3

The **variability of both RES-E generation and electricity demand** by the steel sector increases the operating costs of decarbonisation technologies. While this specific problem was confirmed, at least to some extent, by the stakeholders consulted in the Inception phase, it ranks relatively lower than specific problems RE1 and RE2. Unlike some other metal industries that have flat electricity consumption profiles,[41] such as aluminium, the steel sector's electricity demand is relatively more variable (CEPS, 2019b, p. 8; Kovacic et al., 2019, p. 7). This is especially the case for the EAF route. Using RES-E in steel decarbonisation technologies, therefore, faces a double challenge: a variable electricity demand due to the features of low-carbon steelmaking process and a variable electricity supply due to the nature of renewable sources (especially solar and wind). To match the RES-E demand and supply, steel producers need to either use electricity storage systems or to reach out to balancing and shaping arrangements (Otto et al., 2017, p. 2; Roland Berger, 2020, p. 12; Wyns et al., 2018, p. 62; European Commission, 2018, p. 21; CEPS, 2019a, p. 27).

- **Driver RE3.1:** There is a lack of large-scale **electricity storage** systems in the EU to compensate for the temporal imbalances between production and demand (Roland Berger, 2020, p. 12; LCF, 2020, pp. 9-10). The costs of power storage may vary depending on the storage technologies and the conditions of the storage site (McKinsey, 2018, p. 29). Some storage technologies particularly suitable for the steel sector such as power-to-gas[42] currently find themselves in the 'valley of death' due to limited scaling-up investments (LCF, 2020, pp. 9-10; European Commission, 2018, p. 21; Store&Go, 2019, p. 8). The deployment of energy storage has been included as one of the measures to support the transition to climate neutrality in the Green Deal. However, to date, such policy tools (e.g., revision of the Trans-European energy networks - TEN-E - Regulation) have not been put into practice to ensure a holistic approach to energy storage for the EU (European Parliament, 2020a, p. 6).
- **Driver RE3.2:** Another solution to balance the electricity demand and supply is to use **balancing and shaping services**. However, despite the efforts made by the EU, the European network of transmission system operators for electricity (ENTSO-E) and the member states (Commission Regulation (EU) 2017/2195; ENTSO-E 2020), these services are currently provided by intermediaries at relatively high costs, resulting in an increase in the power costs for steel manufacturers (CEPS, 2019a, p. 27).

[41] A flat consumption profile means that production requires the same amount of electricity at any moment of the day, throughout all seasons of the year.
[42] Electricity converted to and stored as, e.g., hydrogen/methane.

- **Driver RE3.3**: Finally, solutions such as **load management in steel-making processes** (operational flexibility) have not received clear public support so far and this will affect both production costs and performance (European Commission, 2018, p. 21; LCF, 2020, pp. 9-10). More specifically, despite the recent reform of the rules on the functioning of the electricity market, the EU demand-response market is still **fragmented**. The status of demand flexibility varies largely across member states (IEA, 2020c, pp. 15-16).

Respondents to the survey conducted in the Inception phase claimed that all drivers were worsening the specific problem RE3, with driver RE3.1 (lack of large-scale electricity storage systems) being the most significant one.

5.2. EU right and need to act

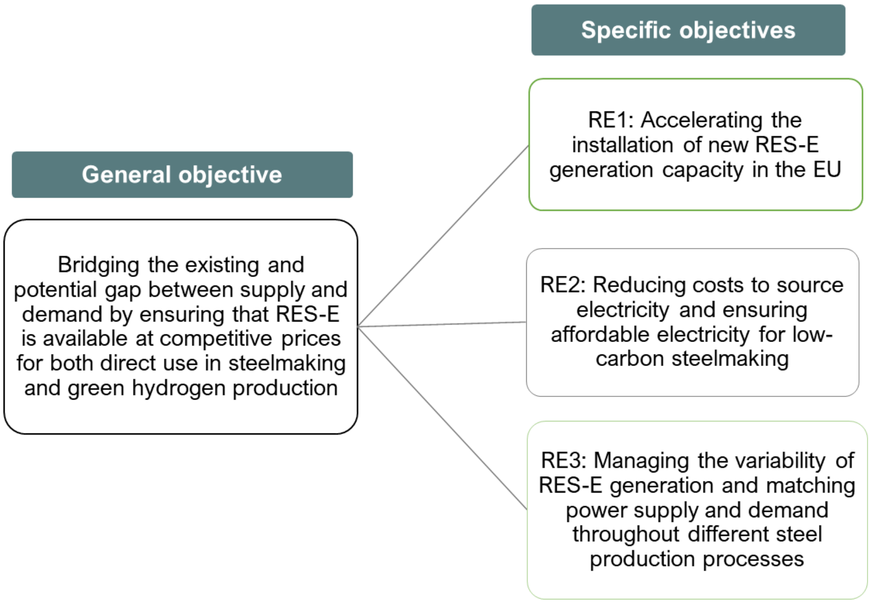
The main legal basis behind the EU interventions aimed at ensuring the availability of RES-E to decarbonise the steel sector is to be found in **Article 194 of the Treaty on the functioning of the European Union (TFEU)**: "*In the context of the establishment and functioning of the internal market and with regard for the need to preserve and improve the environment, Union policy on energy shall aim, in a spirit of solidarity between member states, to: (…) (b)* ***ensure security of energy supply in the Union****; (c) promote energy efficiency and energy saving and the* ***development of new and renewable forms of energy*** *(…)*." The EU should act when **uncoordinated actions at member state level can supposedly lead to a more limited and more expensive RES-E development** (European Commission, 2016b, p. 60; European Commission, 2020f, p. 2). Besides, the lack of an EU-level approach to address the above-mentioned problems may entail a concrete risk of falling short on the 2050 carbon neutrality target. This goal is part of the long-term strategy of the Union and is, by its very own nature, a trans-boundary objective that cannot be achieved through actions at national or local levels alone (European Commission, 2020f, p. 2). Decarbonising the steel industry by acting in the field of RES-E is also in line with **Article 173 TFEU**: "*The Union and the member states shall ensure that the* ***conditions necessary for the competitiveness of the Union's industry exist****. For that purpose, in accordance with a system of open and competitive markets, their action shall be aimed at: speeding up the* ***adjustment of industry to structural changes****; (…) fostering better exploitation of the* ***industrial potential of policies of innovation, research and technological development***".

5.3. Policy objectives and options

5.3.1. General objective

The general objective of the policy response is to **bridge the existing and potential gap between the supply and demand of RES-E.** It is also to support the decarbonisation of the EU steel industry towards 2050 by ensuring that RES-E is available at competitive prices for both direct use in steelmaking and green hydrogen production. With no EU policy intervention, the projected growth of the EU's RES-E supply is not going to catch up with the significant increase in demand for electricity from the steel sector. Considering both direct and indirect emissions of steelmaking, any gap between supply and demand of RES-E is going to create an obstacle to achieving the decarbonisation targets of the steel industry. Any policy solution has to consider the future electricity demand from not only the EU steel sector, but also other energy-intensive industries that need a high amount of RES-E to achieve their decarbonisation targets.

Figure 12: Policy objectives on the availability of RES-E to decarbonise the EU steel sector



Source: author's composition.

5.3.2. Specific objective 1 and policy options

Specific objective RE1: accelerating the installation of new RES-E generation capacity in the EU and ensuring that a sufficient amount of RES-E is available for low-carbon steelmaking. At the current pace, the additional capacity of new RES-E plants in the EU may not provide sufficient electricity for low-carbon steelmaking technologies. EU policies should aim to speed up the addition of new RES-E capacity via a better access to funding for RES-E projects, i.e. removing the administrative burden to develop them (particularly during the permitting process). They should also aim to bridge the gap between R&D and market commercialisation of new RE technologies.

Baseline: Installation of new RE generation capacity will mostly rely on private investment which, however, may be discouraged by decreasing wholesale electricity prices. The administrative burden stemming from the permitting process may slow down new investments in RES-E. Less mature RE technologies may face financial obstacles in reaching the commercialisation phase.

Policy option RE1: improving the use and coordination of EU funding programmes for RE projects.

- **For commercially-ready RE technologies**, the EU and member states should work together to coordinate EU funding programmes, such as the Connecting Europe Facility (CEF), the CF, the Modernisation Fund, InvestEU and the ERDF. Within the 2021-27 multiannual financial framework of EU budget and the NextGenerationEU recovery fund, the EU should coordinate more dialogue between the different granting authorities, or create a helpdesk to support investors with identifying opportunities and preparing applications for the relevant funding programmes. Besides, the EIB and member states public investment banks should be engaged in project financing (including both direct investment and guarantee) to de-risk private investments in the RE sector;

- **for innovative RE technologies** that face the funding gaps between research and commercialisation, the EU - in cooperation with member states, should act to improve the synergies between EU funding programmes. One possible approach is to **better sequence and blend EU funding sources**, adopting a strategy similar to the one included in the EU Energy-intensive Industries Masterplan[43]: HEU for R&D activities, IF for demonstration, and CEF/Modernisation Fund/CF for the deployment of the technologies. For instance, the evaluation of HEU projects should consider the potential for further funding (TRL 7-9) under the IF to create an EU-sustainable technology development pipeline.

Policy option RE2: drafting EU guidelines to streamline permitting process, ensuring the simplification of national permitting procedures of both new and repowered RE projects. The guidelines should support the proper transposition and implementation of Art. 15 and 16 of the recast Renewable Energy Directive (REDII) (European Union, 2018a) on administrative procedures and organisation of permitting process for new and repowered RE projects as well as Art. 17 REDII and Art. 8 of the Electricity Market Directive (European Union, 2019a) on authorisation of new capacity generation and grid connections. The guidance should target central governments and any relevant national/local authority involved in administrative procedures for RE installations. It needs to provide clear instructions on, *inter alia*: (i) predictable timeframes to complete the permitting process considering different RE technologies and project sizes;, (ii) the one-stop-shop(s) to facilitate the entire process (including grid connection); (iii) the notification procedures; (iv) the simplified procedure for repowering of existing plants and small production units/self-consumers; (v) the flexibility in technology specifications between permit application and start of the project (via, e.g., the so-called ‘box permits’) (Vindenergi 2018, p. 14), and (vi) the dispute resolution mechanisms. The guidance should also present examples of good practices adopted at member-state level.[44]

5.3.3. Specific objective 2 and policy options

Specific objective RE2: reducing costs to source electricity and ensuring affordable electricity for low-carbon steelmaking. While the generation costs of RES-E are competitive with conventional energy sources, other components of the electricity price (particularly network costs) contribute to increase electricity costs for industrial players (steel sector included). The EU policy

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[43] For further details, please see: https://op.europa.eu/en/publication-detail/-/publication/be308ba7-14da-11ea-8c1f-01aa75ed71a1

[44] See, for example, the Danish solution to increase certainty of the costs for connecting a RE project to the grid. The project developer is obliged to pay for the connection costs only up to the closest connection point, thus allowing an accurate estimate of the project costs from the very outset. Art. 67 of the Danish Electricity Supply Act (2016) spells out that RE projects “only bear the cost that would be associated with being connected to the 10-20 kV grid, regardless of whether the network company chooses a different connection point based on objective criteria”. For further details, please see: https://danskelove.dk/elforsyningsloven. The Danish Energy Agency is also a good example of one-stop-shop for offshore wind energy. For further details, please see: https://ens.dk/en

intervention should support technologies to reduce generation costs, while also stabilising the regulatory components of the electricity price and facilitating the use of PPAs in corporate sourcing of RES-E.

Baseline: prices paid for electricity by industrial consumers may increase, despite decreasing generation costs, due to trends in energy taxation, network costs, indirect emission costs and RES levies. Regulatory and market obstacles may reduce opportunities for energy-intensive players to sign RE PPAs.

Policy option RE3: improving the mechanism for compensation of indirect emission costs to foster the use of RES-E in the steel sector. The overall legal framework could be adapted to enable full compensation of indirect costs in all member states, without reductions or uneven application (Institute for European Studies, 2018, p. 71). In particular, relevant provisions under the ETS Directive (European Union, 2003) including Art. 10a (6), can be revised to (i) make indirect cost compensation through State aid legally binding, and (ii) increase the threshold on the overall compensation to be above 25% and even up to 100%.[45] To ensure sufficient resources for the compensation mechanism, ideally, the long-term EU multiannual guidelines (European Commission, 2020h) enabling the compensation for indirect EU ETS costs should be accompanied by a stable budgetary and regulatory framework at national levels.[46]

Policy option RE4: drafting EU guidelines to promote and harmonise demand-response measures (i.e. interruptibility scheme) across member states This guidance should facilitate the transposition and implementation of relevant articles on demand-response under the Recast Electricity Directive (European Union, 2019), such as Art. 3, 17 and 32 requiring member states' support for demand-response, as well as Art. 31 on distribution system operators' (DSOs) responsibility to ensure effective engagement of demand-response participants. The guidelines should promote technologies on demand flexibility of steels plants, such as: (i) combination of production of ethanol from steel gases with cost-effective load management services in BF-BOF plants, and (ii) adaptation of steel production processes to match variable RE in EAF plants (European Commission, 2018, pp. 15-16; Wyns et al, 2019, p. 39).[47] The guidance also needs to promote smart grid and the use of artificial intelligence in forecasting the energy needs of steel plants, thus enabling higher demand flexibility. While contributing to addressing the variability of RES-E generation and matching power supply and demand in steelmaking, this policy solution would also lower the grid costs thanks to reduced peak load.[48]

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[45] Art. 10a (6) of the ETS directive currently sets out the legal provision for indirect cost compensation through State aid. However, the wording is not legally binding: "Member states should adopt financial measures […]", nor is the requirement to limit the overall compensation for this purpose to 25% of auction revenues: "[…] shall seek to use no more than 25% […]"

[46] However, this solution may be difficult to implement due to the current high level of government debt in many MS.

[47] Success story: the German primary aluminium producer TRIMET has been successfully experimenting with this new type of business model. For further details, please see: http://www.bloomberg.com/news/articles/2014-11-27/molten-aluminum-lakes-offer-power-storage-for-german-wind-farms

[48] The grid costs of DSOs mostly depend on the capacity of the grid rather than the volumes of usage (CEER, 2017, p. 33). For instance, a self-sufficient consumer might need to use the grid for few hours a year, but the same grid capacity will be required, thereby imposing nearly the same costs as regular consumers.

Policy option RE5: reducing energy costs for renewable electricity purchased via PPAs or green energy offers. Different measures contribute to the successful implementation of this policy option:

- First, the EU (possibly through the EIB) and member states can issue **public-supported guarantees** for steel companies that want to enter long-term RE PPAs. Such guarantees can be inspired by the “Energy Purchase Guarantee Scheme” in the Norwegian system (CEPS, 2019b, p. 11). Accordingly, guarantees can take two forms: (i) guarantees issued to *energy sellers* to protects against off-takers’ non-fulfilment of the PPAs, or (ii) guarantees issued to *banks* to ensure the repayment of loans taken out by off-takers in order to pay the electricity delivery in advance. The guarantee should cover both physical and financial PPAs;[49]
- second, the EU and member states can remove the regulatory barriers affecting the transfer of **guarantees of origin** (GO) to off-takers, or the barriers not allowing RE generators and corporate buyers to enter RE PPAs. Some EU guidelines to enforce the implementation of Art. 19 of REDII on Guarantees of origin for energy from renewable sources (European Union, 2018a) can contribute to harmonising the GO systems across member states, reducing the administrative burden of managing, transferring, and cancelling GOs and increasing market transparency;
- last but not least, **cross-border PPAs** need to be promoted to help steel companies benefit from RES-E from areas where it is generated with the most efficiency (CEPS, 2019a). The EU and member states should coordinate to develop cross-border transmission infrastructure and to open up existing networks to the increased transmission capacity allocation. Proper implementation of the provisions in Section 1, Chapter 3 of the Electricity Market Regulation (European Union, 2019b) would contribute to achieving these goals.

5.3.4. Specific objective 3 and policy options

Specific objective RE3: **managing the variability of RES-E generation and matching power supply and demand** in steelmaking, thus contributing to decreasing the operating costs of decarbonisation technologies. The electrification of the EU steel industry faces a double challenge: (i) a variable electricity demand, due to the features of low-carbon steelmaking process, and (ii) a variable electricity supply, due to the nature of renewable sources (particularly solar and wind). EU policies need to ensure that the supply of RES-E matches the electricity demand of the steel sector by facilitating the development of large-scale electricity storage systems, creating a policy framework that supports balancing, and shaping market and demand-response scheme.

Baseline: variability in both RES-E generation and electricity demand in the steel sector may increase costs to rely on RES-E for steelmaking. The development and deployment of large-scale energy storage systems will be mostly left to the private initiative. Costs for balancing and shaping services may remain high in some member states. In the same vein, demand-response schemes could be introduced in an uncoordinated manner across member states.

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[49] For further details, please see the Norwegian Export Credit Guarantee Agency, Power purchase guarantee, (www.giek.no/power-purchase-guarantee/)

Policy option RE6: reducing the costs of balancing and shaping services in national markets. First, the EU should promote further integration of the EU electricity market to increase the size of the balancing control area, reaping the advantage that RES production becomes less variable when aggregated into larger geographic areas (Grossi et al., 2018, p. 801; Verzijlbergh et al., 2017, p. 664). One important measure to integrate the EU electricity market is to accelerate the physical integration of energy infrastructure across member states (European Parliament, 2019b). In this respect, the revision of the TEN-E regulation (European Commission, 2020i, expected to be finished by 2021) should take into account the 15% electricity interconnection target for 2030 (set in the Energy Union[50] and confirmed by the Clean Energy Package[51]) (European Commission, 2020j, pp. 17-18). Second, measures to improve the liquidity of the balancing services market[52] can also contribute to decreasing the balancing costs (CEPS, 2019a, p. 27; Van Der Veen, 2012, p. 36). The Commission's Guideline on electricity balancing (EBGL) (European Commission, 2017a) has set a milestone in harmonising national balancing markets. The coordination between ENTSO-E and national TSOs to accelerate the implementation of this Guideline should be reinforced.

Policy option RE7: revision and implementation of policies on energy storage in the Green Deal. The nature of energy storage system benefits from integrated infrastructure that goes beyond the scope of the steel sector or of a single member state. In this context, the **Trans-European energy infrastructure (TEN-E) Regulation** (European Union, 2013) can provide a holistic approach to energy storage for the EU (European Commission, 2020i, p. 9; European Commission, 2020k). One of the most important elements of TEN-E is the list of energy projects of common interest (PCIs), including electricity storage projects, that are eligible for CEF funding. Some rules in the TEN-E should be updated in its upcoming revision (expected in 2021), in order to promote energy storage:

- First of all, the **eligibility criteria and electricity infrastructure categories** (Art. 4, Chapter II) need to be revised to better facilitate the development of energy storage facilities. Review of such rule would allow more storage projects to be included in the next lists of PCIs. Chemical storage technologies (i.e. power-to-X, one of the most relevant energy storage technologies for steelmaking) should be underlined as a key enabler to integrate RES-E in the industries, and therefore eligible for the next PCIs list, and
- Secondly, while the TEN-E Regulation grants PCIs with 'priority status' an accelerated **permit-granting process** (Art. 7 of Chapter III), in practice, several member states' authorisation of storage projects took considerably longer than the maximum period

[50] For further details on the Energy Union, please see: .https://ec.europa.eu/energy/topics/energy-strategy/energy-union_en
[51] Each MS should have in place electricity cables that allow at least 15% of the electricity produced by its power plants to be transported across its borders to neighbouring countries, as set forth by Art. 21 of the proposed Regulation on the Governance of the Energy Union (European Commission, 2017c)
[52] For instance, measures to achieve TSOs' harmonisation of technical parameters (e.g. operation windows and gate closure times) and pricing schemes can help increase the participation of bidders from both the demand and the supply side.

allowed for PCI projects[53] stipulated by this regulation (European Parliament 2020b). The EU should ensure a timely and synchronised enforcement of this rule across member states.

5.4. Impacts

5.4.1. Option RE1: improving the use and coordination of EU funding programmes for commercially-ready and new RE technologies

Economic and competitiveness impact

Improved funding for new RE technologies with high up-front costs would **increase the availability of renewable electricity for the steel industry**. Better use and coordination of EU funding will facilitate the development and deployment of RE technologies, though the mechanisms of such impact are different across innovative and mature RE technologies. A better access to public funding for innovative RE technologies (e.g. ocean energy, floating offshore wind and floating solar PV) could decrease the CAPEX of RE technologies, largely thanks to the upscaling of RE production. Better use and synergies of EU funding programmes can facilitate the demonstration phase, bringing down the cost of FOAK projects and pushing the technologies closer to commercialisation. For mature RE technologies (e.g. onshore wind and solar PV), EU funding is not considered as a main element that could bring down technology costs, but rather as a tool to leverage private investments. Some stable public financial support (e.g. participation of the EIB or national counterparts such as the German Kreditanstalt für Wiederaufbau (KfW) or the Italian Cassa Depositi e Prestiti (CDP) can send positive signals to RE investors. Higher investors' confidence would then bring down financing costs and pave the way for more RE projects.

Option RE1 is also expected to affect the costs of doing business for green steel, particularly through **changing the energy costs borne by the EU steel industry**. However, the impact of this option is still unclear, as it could result in two opposite outcomes. In the first scenario,, an increase in RE installations could decrease the levelized cost of energy (LCOE) from renewable sources, which can, in turn, contribute to lowering the wholesale power prices for steel manufacturers. However, from an industry point of view, the impact on energy price reduction is limited because many funding programmes are currently designed just to bridge the gap between RES-E production costs and the market price (particularly for new RE technologies). In this respect, policy RE1 would prevent electricity prices from rising, but would not result in a price reduction. In the second scenario, the electricity market design ultimately affects the wholesale electricity price, which might remain relatively high even with larger share of RES-E in the total power supply.

As a consequence of the above-mentioned impact, increased RE installations and changes in wholesale electricity price **could also lead to changes in steel sector's demand for renewable energy**. When ssessing this impact, however, other factors (such as the cost, availability and price elasticity of alternative energy sources, as well as carbon pricing policies) should be taken

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[53] Art. 10 of Chapter III stipulates that the permit granting process shall consist of two procedures: the pre-application procedure, which shall take maximum two years, and the statutory permit granting procedure, which shall not exceed one year and a half.

into account. Progressively, the cost of fossil-fuel based electricity generation is unlikely to become cheaper, but will rather probably increase due to resource scarcity and higher consumption. within addition, the phasing-out of public support for some important fossil fuels, such as crude oil make them less cost-competitive. These factors would orient industries' energy consumption towards renewable sources (Kåberger, 2018, pp. 48-49). Similarly, carbon pricing policies, (such as the increase of carbon prices), would raise the energy generation costs of CO_2-emitting power plants, as these plants must internalise the carbon price as a variable cost. An immediate consequence is that wholesale electricity price would increase, as many carbon-intensive generators face higher costs. In the long run, however, higher carbon prices would entail a fuel switch from high- to low/zero-carbon RE sources. The fuel switch would be particularly led by marginal generators (Ting, 2017).

Another potential impact of policy option RE1 is the **increased budgetary obligations for EU and member states.** This option requires governments to secure funding (grants, subsidies, guarantees, loans, etc.) to support RE projects. The funding must come from additional revenue sources, or through budget restructuring. Regarding the magnitude of this impact, at EU level, many funding programmes have already allocated budget for RE technologies, so the key element is to enhance the use of these funding instruments for RES and to better coordinate them. Meanwhile, financial institutions such as the EIB have been phasing out lending to fossil-fuel energy projects (EIB, 2019, p. 14), therefore savings from these lending sources can be considered to be transferred to RE projects in case there is demand for increased public finance in the sector. Altogether, this policy option would probably have a small to medium impact on the EUs' budget. Across theEU, the budget burden will be potentially higher on lower-income member states (EIB, 2019, p. 15).

Environmental impact

More RE installation capacity can contribute to **decreasing the emissions of GHGs from the steel secto**r, facilitating **the decarbonisation of this industry**. This impact is generated thanks to the fact that the most effective steel production technologies in terms of CO_2 abatement rely on RES-E use. More RES-E available at competitive prices can replace carbon-intensive energy sources in the steel production. The emission reduction potential varies across different steelmaking technologies, e.g. integrating RES-E in BF-BOF route can mitigate less CO_2 than using RES-E for direct iron reduction in EAF route. Besides, higher use of RES-E in steelmaking would also promote **sustainable production**. Through a switch to sustainable energy sources, steel will depend less on non-renewable, carbon-intensive energy sources.

Option RE1 would also **support the green transition in the EU**. Today steel is one of the major emitters of GHGs in the EU, accounting for 4% of all EU emissions in 2017 and 23% of emissions of the manufacturing industry (JRC, 2020a). Decarbonising the steel production will therefore contribute largely to the green transition in the EU. Public funding support for RE projects could increase RE generation, make more RES-E available for industries, and contribute to the achievement of the 2030 climate and energy targets.

It is however important to consider **several negative environmental impacts of RE technologies**. First, not all RE technologies are environmentally sustainable. By way of example, the first generation of bioenergy requires a lot of land[54]. Certain types of biomass combustion can also produce relatively high emissions, which require a careful monitoring and a controlling system (U.S. Department of Energy, 2016). Second, higher RE deployment also entails higher use of some non-renewable resources. For example, several RE technologies and ancillary systems, such as solar panels or batteries, require rare earth materials that are often pollutant and difficult to recycle. In addition, these materials are not available in the EU and need to be imported from third countries (such as China). Finally, some RE technologies face challenges associated with the lack of social acceptance: some onshore wind projects are accused of having a negative impact on the surrounding landscape, while some solar PV plants built on agricultural land are considered to have controversial impacts on the biodiversity in the areas where they are installed. Despite these downsides, RE will be the main driver of the energy transformation to tackle the climate crisis. Globally, the share of RE in the total output need to increase from 29% in 2020 to 60% in 2030 and up to nearly 90% in 2050 to reach net-zero emissions by mid-century (IEA, 2021, p. 99).

Social impact

Better funding for RES would also **indirectly contribute to improving public health**. GHGs and most air pollutants are energy-related since they are mainly generated from burning fossil fuels (Schmid et al., 2019, p. 1). Replacing fossil fuels with RE not relying on combustion will drive changes in reducing air pollution levels, followed by cleaner air, a low-carbon society and improved public health.

Finally, higher deployment of RE technologies would **create employment for RES and foster the skill of the labour force of this sector.**[55] Besides a positive impact on job creation, better funding for RE can improve the labour skillset for the EU. This impact materialises as new RE technologies operating in harsh environmental conditions (e.g. offshore) need to be reliable and precise. Developing and mastering these technologies require high-skilled labour. This opens doors for member states not having substantial RE resources to participate in the EU RE value chain. By way of example, Italy has been the emerging champion in recent years in producing wave devices, while Spain is also tapping in offshore expertise (Muscio and Vu, forthcoming).

5.4.2. Option RE2: drafting EU guidelines to streamline the permitting process and to ensure the simplification of national permitting procedures

Economic and competitiveness impact

EU guidance on the permitting process could contribute to i**ncrease the availability of renewable electricity for steel and other industries**. First, better permitting rules can accelerate the launch of RE projects, thanks to higher success rate and less economic and legal uncertainty for RE applicants. The EU can therefore better exploit its untapped RE potential. This impact is more significant for new RE technologies (e.g. geothermal, wave and tidal energy, and

[54] For instance, energy-generation per square metre from solar and wind is much larger than energy-generation per square meter from bio-energy.
[55] In the scenario of net-zero emissions by 2050, the IEA estimated that clean energy employment would increase by 14 million jobs by 2030, while the oil, gas and coal fuel sectors would lose about 5 million jobs. Therefore, the global net increase of the energy transition would be nearly 9 million jobs in 2030. For further details, please see IEA (2021) pp. 157-158

offshore wind), which face a much higher rejection rate than mature technologies due to the limited familiarity of the permit-granting authorities with these technologies and/or a lack of public acceptance (Simonelli and Vu, forthcoming). Second, an improved permitting process may allow RE developers to rely on the most modern, efficient technologies available. RE project developers can benefit from faster project authorisation times and more flexibility, so that they could slightly change the technologies without having to apply for new permits.[56] While having a similar impact pattern as RE1, this option's impact on the availability of RES-E is, however, considered smaller.

EU guidance on the permitting process would also **reduce the costs of doing business for RES in the EU**. An improved permit-granting process can lower the administrative costs for RE projects, thanks to a shorter process and a lower rejection ratio. This cost reduction includes the sunk costs, which are paid even when the permit is not granted. Such costs might include, e.g., the time spent on preparing the application and interacting with the public authorities; the irrecoverable expenses for external experts, or the irrecoverable permit fees. Moreover, a better permitting process can help RE developers avoid foregone revenues, i.e. loss of public financial support for RE projects. Reportedly, several RE installations were no longer eligible for public support because they were finally granted a smaller capacity than what had been requested in the original application, or the large projects were divided into smaller lots. The magnitude of the cost reduction for RE projects is however relatively small, because the permitting costs accounts for a small portion of the total RE project costs (around 0.5-1% for wind and solar, depending on project size).

Environmental impact

This policy option is expected to increase the availability of RES-E for steel and other industries, so very similar to option RE1, it can contribute to **decreasing the emission of GHGs from the steel sector**, facilitating the **decarbonisation of the steel industry**, and supporting the **green transition** in the EU. However, the magnitude of its impact is relatively lower than option RE1.

Social impact

Acceleration of RE installations will also generate positive impacts on **improving public health**, as discussed in option RE1. The transition from fossil fuels towards RE will reduce air pollution levels, followed by better public health.

5.4.3. Option RE3: improving the compensation mechanism for indirect emission costs to foster the use of RES-E in the steel sector

Economic and competitiveness impact

An improved legal framework for indirect cost compensation would **reduce the energy costs borne by the EU steel sector,** as well as those other sectors that are subject to carbon leakage risks. As RES-E is one of the most important cost factors in both direct electrification and green hydrogen steelmaking technologies, compensation of indirect emission costs in the electricity price would act as an OPEX support for green steel. While the compensation currently accounts

[56] E.g. the case of box permit for wind turbine in Sweden.

for a small portion of electricity prices applied to steel plants,[57] indirect compensation would become more relevant as the price for electricity is projected to increase. This impact will eventually lower the production costs of green steel, making it more cost-competitive. Not only will the steel sector benefit from this impact, but the competitive and stable price of electricity will also positively affect electricity costs in other energy-intensive industries.

A better mechanism for compensation of indirect emission costs could also **ensure the market shares and competitive position of the EU steel industry vis-à-vis non-EU competitors**. Indirect compensation can contribute to protecting steel against carbon leakage risks. Higher compensation amounts can marginally improve the turnover, the value of total assets and the number of employees – which are important indicators of carbon leakage risks.[58] The Joint Research Center estimated that a 1% increase in subsidies can expand firms' turnover and their assets value by 0.1%, and their workforce by 0.07%.[59]

This policy option would also **increase the budgetary obligations for the EU and member states**. To ensure a higher compensation rate (going from 25% to 100% of indirect emission costs), member states will need to secure a stable budget and establish a regulatory framework to support the new compensation scheme. To reduce the budget pressure on member states, the compensation might need to move away from a State-aid approach to an EU-level approach. Therefore, the EU would also need to allocate financial resources to support this mechanism.

Environmental impact

Through lower electricity costs for steel plants, this policy option would indirectly contribute, to a certain extent, to **lower the GHG emission from the steel sector**. More specially, lower energy prices will encourage the electrification and use of green hydrogen in the steel sector, thus supporting the steel sector's transition to production methods with lower emissions. Electricity-based steelmaking technologies have remarkably lower emissions than the traditional coal-based BF-BOF route. However, the emission reduction potential of this policy option can be lower than the other options because not 100% of the electricity currently used in steel production comes from renewable sources. Its advantage is that this option can generate an immediate impact in lowering electricity costs. It is therefore needed during the transition period of the electricity sector towards 100% renewable sources.

Social impact

This option might **decrease the revenue available for the Just Transition in the EU.** Art. 10(3)(k) of the ETS Directive (European Union, 2003) suggests that member states should use part of the revenues generated from the auctioning of allowances to support a just transition in carbon-dependent regions. Such support can be provided through the promotion of training for new skillsets and through the reallocation of labour. If indirect compensation increases, it will take a higher share of the total auction revenues, and potentially reduce the other portion of revenue available for the just transition.

[57] The comprehensive analysis of the composition of electricity prices and costs in the EU steel sector is available at CEPS (2018)

[58] More at EUROFER position paper (2020)

[59] These estimates are based on a panel dataset at firm-level in the period 2013-17, collected by DG COMP. The dataset contains detailed information on the eligible sector(s) of the ETS indirect cost compensation. For further details, please see: JRC (2020a), pp. 20-21

Besides, a revised compensation mechanism might **exacerbate the distributional impacts in the EU.** If member states' budgets are to cover the additional cost compensation for steel and other industries, such costs will be ultimately borne by taxpayers. There is also concern that not all households reap the same (indirect) environmental benefits from such policy. For instance, households living in proximity to manufacturing installations might face greater exposure to local air pollution and other environmental risks compared to others (OECD, n.d., p. 1).

5.4.4. Option RE4: drafting EU guidelines to promote and harmonise demand-response measures across member states

Economic and competitiveness impact

An EU guidance to facilitate the transposition and implementation of EU law on demand-response measures (DSR) would contribute to **increase the availability of RES-E for the steel sector and other industries.** Promotion of DSR can allow an increase in electricity consumption when renewable energy generation is available, and a decrease when the system faces generation constraints. Variations in renewable energy output can therefore be balanced with demand response (IRENA, 2019a, p. 1).This policy option can address the variability of RE to some extent, and entail higher shares of RE in the power mix.

This policy option would also lead to a **reduction in the energy costs borne by the EU steel industry** through three mechanisms. First, DSR enables steel plants to save their energy expense through shifting their electricity consumption to specific time intervals where the tariffs are lower (the time-of-use tariffs, IRENA, 2019a, p. 1)). Second, enhanced demand-response measures can contribute to reducing grid costs for the whole power sector and eventually lower electricity costs for steel plants. The grid cost is reduced thanks to the fact that when electricity demand of steel plants becomes more flexible, the volumes of real usage/peak load will be closer to the grid capacity. Thus lower grid capacity will be required, leading to lower grid costs. Finally, better demand-response measures can also lower the costs to address the variability of RES-E generation. Such costs might be linked to: (i) the use of electricity storage systems, or (ii) the balancing and shaping costs. The above cost savings would entail higher demand for renewable energy from the steel sector.

This option is expected to **increase the capacity to innovate of the EU steel industry**. With a better regulatory framework on DSR, steel manufacturers will be encouraged to invest more in innovation for demand-response solutions in steel plants, enabling them to consume electricity during non-peak hours. DSR measures are particularly relevant in the EAF route, which could integrate power-to-hydrogen as part of demand-side flexibility schemes, or allow some demand flexibility by shifting load of electricity-based processes if required (IRENA, 2019b, p. 18). While positive, the magnitude of this policy's impact on the innovation capacity of the steel sector is considered to be lower compared to other policy options that tackle directly the innovation funding issues for the industry, such as the use of IF or the introduction of risk mitigation products for decarbonisation technologies.

Environmental impact

An indirect impact of this policy option **is the lower emission of GHGs, contributing to the decarbonisation of the steel industry**. The use of DSR can help lower RES-E costs for steel producers, thus encouraging the industry to rely more on RES-E based technologies, which are less carbon-intensive than conventional ones.

Finally, this option contributes to **enhancing the ability of the EU to mitigate climate change, accelerating the green transition.** As analysed in the paragraph on the economic impact, effective DSR systems in steelmaking would allow for a higher share of RES-E in the total power mix of the EU. This would in turn enable lower emissions from the steel sector and other ones.

5.4.5. Option RE5: reducing energy costs for RES-E purchased via PPAs or green energy offers

Economic and competitiveness impact

Strengthening the legal and financial support for PPAs could help **reduce energy costs borne by steel plants.** Steel producers will have more incentives to enter PPAs when barriers such as bank guarantees, transfer of guarantees of origin or challenges related to cross-border PPAs are removed. Using PPAs ensures a stable amount of RES-E for steel producers and protects them against the price volatility of electricity.

Public-supported guarantees for steel companies that want to enter long-term RE PPAs can reduce financial costs, including the guarantee costs that steel plants have to bear, thus increasing the steel companies' ability to borrow for additional investment. Meanwhile, cross-border PPAs can help steel companies benefit from RES-E from areas where it is generated with the most efficiency.

This option acts as an important OPEX support for green steel, as RES-E is one of the biggest cost factors in both direct electrification and green hydrogen use in steelmaking. Through a similar mechanism, this option would also reduce energy costs for other industrial sectors.

Option RE5 would contribute to increasing the supply and demand of RE. On RE suppliers' side, PPAs secure a revenue stream for utilities and project developers, thus improving RE projects' access to finance and accelerating the deployment of these projects. This will lead to an **increase in the availability of renewable electricity for steel and other industries**. On the off-takers' side, steel producers will be more interested in using RES-E in their production as PPAs guarantee large amounts of RES-E at stable prices. This would entail an **increase in the demand for RES-Efrom the steel sector**.

The sub-option of providing public-supported guarantees for steel companies or other industrial off-takers would lead to additional **budgetary obligations for the EU and member states.** EU financing institutions (such as the EIB) and national credit agencies need to secure financial resources for such guarantee products. These budget obligations could be compensated by a premium that credit agencies could charge upon issuing PPA guarantees.[60]

Finally, the sub-option of promoting cross-border PPAs could **contribute to the functioning of the internal energy market**. As cross-border PPAs require the development of interconnection across member states, the implementation of this instrument strengthens the unification of the EU energy market. Steel companies can purchase RES-E from regions where it is generated more efficiently.

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[60] See, for instance, the Norwegian public-back purchase power guarantee: https://www.giek.no/power-purchase-guarantee

Environmental impact

This policy option indirectly leads to a **decrease in the emission of GHGs from the steel sector, facilitating the decarbonisation of the steel industry**. An enabling regulatory framework for PPAs can lead to an increased availability of RES-E at predictable prices for steel plants, replacing carbon-intensive energy with RE sources in steel production. Besides, higher use of RES-E in steelmaking would also **promote sustainable production**. Steel producers will be less dependent on non-renewable, carbon-intensive energy resources. Nevertheless, there are concerns about whether this impact can be the same between physical and financial PPAs. Under financial PPAs, the electricity is produced in a separate energy grid from where it is consumed, or in the same system but on the other branch of the grid congestions. Hence, the real impacts on decarbonisation of financial PPAs can be questionable.

Facilitating PPAs is also expected to **support the green transition in the EU**. Increased use of RES-E in the steel sector and in other energy-intensive industries creates a momentum for the introduction of higher shares of RE sources in the fuel mix for energy production. This will result in a reduction of CO_2 emissions in the EU and contributes to the achievement of the 2030 climate and energy targets

Social impact

A higher use of PPAs to purchase electricity for steel and other industries could lead to **improved public health**. The transition from fossil-based towards RE will reduce air pollution levels, with a consequent improvement in public health.

5.4.6. Option RE6: reducing the costs of balancing and shaping services in national markets

Economic and competitiveness impact

The EU intervention to reduce balancing and shaping costs could **reduce the energy costs borne by the EU steel sector,** contributing to **lower production costs for this industry.** In fact, if RE takes a higher share in the total energy production, balancing costs can increase to address the variability of RES-E. If such costs are reduced, the electricity costs would be lower (ENTSO-E 2011, p7). In this respect, better interconnection and more liquidity of the balancing markets across member states will lead to a wider range of TSOs, operating at lower prices, as more bidders participate from both demand and supply side. A second-order impact of electricity costs reduction is the increased **demand for RES-E from the steel sector.** Steel producers will be encouraged to use more RES-E in their production.

This policy option is also expected to help increase **the availability of RES-E for the steel sector and other industries**. Reinforcing the balancing market can help integrate RE into the wholesale electricity market (IRENA, 2017b, p. 13). All other things being equal, an enhanced balancing system contributes to growing volumes of RE generation (ENTSO-E, 2011, p. 13).

Finally, proper implementation of this policy option could contribute to the **functioning of the internal energy market**. To increase the size of the balancing areas, the EU electricity market will be further integrated, particularly through (i) accelerating the physical integration of energy infrastructure across member states, and (ii) harmonising and increasing the liquidity of national balancing markets. Both measures are expected to further promote the integration of the EU electricity market.

Environmental impact

An improved balancing market could indirectly **decrease the emission of GHGs** from the steel sector, facilitating the **decarbonisation of this industry**. As discussed above, the measures under this option are expected to raise the availability and reduce the costs of RES-E for steel plants. These benefits give steel producers more incentives to electrify their production and increase the use of green hydrogen. A higher use of RES-E in steel production will reduce the emissions from the sector. Steel production would also become more sustainable thanks to its decreasing dependence on non-renewable, carbon-intensive energy resources.

Measures to accelerate the physical integration of energy infrastructures across member states and to improve the liquidity of the balancing services market would also **support the green transition in the EU**. A higher share of renewable sources in the fuel mix for energy production will contribute to a reduction in CO_2 emissions in the EU and to the achievement of the 2030 climate and energy targets.

5.4.7. Option RE7: revising and implementing policies on energy storage in the Green Deal

Economic and competitiveness impact

This policy option would **reduce costs of doing business for steel and other industries in the EU**. The direct beneficiaries of this policy are storage projects, who will profit from better access to funding (e.g. PCI projects funded under CEF), and an improved permit-granting process. These factors pave way for storage projects at a large scale, eventually bringing down the costs of energy storage (which are currently very high[61]) thanks to the economies of scale and economies of learning. As a second-order impact, RES-E costs for steel and other industrial sectors will decrease.

Lower electricity storage costs can **increase the availability of RES-E for the steel and other ones**. Lower storage costs bring down the cost to address the variability of RES-E, contributing to better integration of renewables into the power systems. This will **increase the demand for RES-E**, fostering the use of RES-E in steel and other industries.

Finally, improved energy storage capacity would i**ncrease the innovating capacity of the EU steel industry**. Better access to funding and improved permitting process can foster innovation of energy storage technologies. Storage technologies such as power-to-X (e.g. hydrogen storage technologies) can be developed and brought to commercial deployment**.** These technologies are not only relevant for steel sector, but can also deliver energy storage solutions for, and contribute to the decarbonisation of, other industrial processes, especially the hydrogen industry.

Environmental impact

The short-run impacts of storage on GHG emissions are uncertain. For instance, data shows that storage can increase emissions when used for ‘wind balancing’, if such storage is based on a comparatively high-carbon electricity mix. Meanwhile, storage can reduce emissions if used for

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[61] For further details on electricity storage costs, please see: IRENA (2017a)

'wind power curtailment'.[62] In the longer run, with the electricity system decarbonising, wider deployment of electricity storage would entail a **decrease in the emission of GHGs** (McKenna et al., 2017, p. 600), contributing to the **decarbonisation of the steel sector**. This impact stems from the higher use of RES-E in the steelmaking process. This will, in turn, lead to lower emissions from the steel sector. Besides, higher EU's electricity storage capacity would **promote sustainable production** in the industry. Steel plants would progressively switch from non-renewable, carbon-intensive energy sources to sustainable energy sources.

In addition, this policy option will **support the green transition in the EU**. An increase in the share of RE in the energy production fuel mix is going to contribute to a reduction of CO_2 emissions in the EU and to the achievement of the 2030 climate and energy targets.

Nevertheless, **potential negative environmental impacts of some energy storage technologies** need special attention. For instance, hydrogen energy storage, which is one of the most relevant storage technologies for the steel production, uses a large amount of water as feedstock. This is an important factor for consideration in dry areas (Institute for Sustainable Futures, 2017).

Social impact

Deployment of large-scale energy storage might create **potential safety issues**. For instance, in the case of hydrogen storage, hydrogen is flammable and potentially explosive at a wide range of concentrations. Well-established management and mitigation measures are required to ensure safety in hydrogen storage areas. The magnitude of this potential impact is however small, compared to the health benefit that energy storage brings to the society. Promotion of energy storage technologies would foster the use of RE, reducing air pollution levels and **improving public health**.

5.5. Comparative assessment

5.5.1. Effectiveness

Option RE1: improving EU funding programmes for commercially-ready and new RE technologies

This option would contribute to bridging the gap between the supply and demand of RES-E for the EU steel sector. Its effectiveness would however vary across RE technologies and EU regions. Technology-wise, EU funding support is needed to bring new technologies to the market, while national-level financial support is better suited to support more mature RE technologies. The effectiveness of this policy option might not be immediate, as innovation support would generate its benefits in a rather long term. Region-wise, better access to funding programmes can particularly increase RES-E installations in certain regions, such as Central and Eastern Europe and South-east Europe, where not much RE is being deployed. Member states in these regions would receive greater benefits from EU funding. Meanwhile, the benefits for regions where RES-E already takes a higher share in the energy mix, such as Northern Europe, will be

[62] In 'wind balancing' measures, energy is stored when wind output is high, and discharged when wind output is low. In 'wind curtailment' measures, energy is stored using excess wind generation, and discharged when net demand is high (Pimm et al., 2021)

less remarkable. According to the stakeholders involved in the consultation activities, option RE1 is the second most effective one among the seven proposed options.

Option RE2: drafting EU guidelines to streamline the permitting process for RE projects

EU guidance to streamline the work of permitting authorities can improve the authorisation process in all member states. The implementation of this option can be relatively quick[63], but its effectiveness is rather limited. This is because member states' compliance with this guidance document would be voluntary. As permitting remains a local decision, permitting authorities might interpret the guidance in different ways.

Option RE3: improving the compensation mechanism for indirect emission costs in the electricity price

This policy option might have an increasing effectiveness. While indirect compensation currently amounts to a partial share of the electricity prices born by steel plants, this cost component will become more relevant if the electricity price increases. Nevertheless, the effectiveness of this option is challenged by the competition factor. More specifically, a higher compensation rate, if not assessed carefully, can become overcompensation and eventually entail market distortion, i.e. subsidising firms' activities which could otherwise be unprofitable. While market distortion has not been detected in the past period (with a compensation rate capped at 80% during 2016-18 and at 75% in 2019-20 - JRC, 2020b, p. 16; European Commission, 2021), some stakeholders estimated that such risk could be significantly higher if the compensation rate were raised to 100%. Besides competition risks, this policy is considered insufficiently effective because it does not address the other important cost components of wholesale electricity price, e.g. network costs or levies. The above limitations might explain the relatively low ratings that this option received in terms of effectiveness among stakeholders involved in the Inception phase. Finally, the impact of this option would materialise in short- and medium-term.

Option RE4: drafting EU guidelines to promote and harmonise demand-response measures across member states

EU's promotion and harmonisation of national DRS measures can generate positive impacts on the price and availability of electricity for the steel sector, but the effectiveness of this option is considerably small. Stakeholders operating both in steel and non-steel industries shared the view that there currently is little need for changes in the DSR regulation, and that the non-binding nature of the proposed guidance can reduce its effectiveness in closing the gap between demand and supply of RES-E to the steel plants. On average, this option scores the lowest in terms of effectiveness among the seven policy options examined.

Option RE5: reducing energy costs for RES-E purchased via PPAs or green energy offers

All the three proposed sub-options are considered to improve the legal framework to support PPAs, effectively reducing costs and increasing availability of RES-E for steel plants.

- Market-based PPAs backed by public guarantees can generate higher effectiveness than fully public-backed PPAs. Some stakeholders argued that fully public-backed PPAs could

[63] For instance, the guidance document may take about two years to be drafted, including establishment of an expert group, collection of information and feedback from stakeholders via consultation activities.

be replaced by CfD (Contract for Differences) measures or CCfD (Carbon Contract for Differences);

- the measures to remove barriers in the GOs system are extremely important and a proper functioning of GOs is paramount to sign PPAs, and
- finally, support for cross-border PPAs can facilitate RE purchasing across different member states, in particular in a long-term timeframe (e.g. 20 year).

The consulted stakeholders expressed their highest support for this option, in fact they ranked it at the first place in terms of effectiveness. The impacts of this option are expected to materialise in the short term.

Option RE6: reducing the costs of balancing and shaping services in national markets

The proposed measures to reduce the balancing and shaping costs might contribute to closing the demand-supply gap of affordable RES-E for green steel producers through reducing electricity costs and further integrating RE. However, stakeholders from both steel and non-steel sectors considered that the effectiveness of this option would be limited if this option is not combined with other measures such as energy storage. The option was ranked the second least effective amongst the proposed ones.

Option RE7: revising and implementing policies on energy storage in the Green Deal

Better regulation to promote energy storage technologies is considered to be one of the most effective approaches to foster the integration of RES-E in industrial production. This policy option is expected to secure more funding and address the administrative burden of energy storage projects. Stakeholders representing steel and non-steel industries and research institutes showed high confidence in the effectiveness of this policy option – it ranked third on average among seven options. The impacts of the policy option are expected to be generated in the medium-long term, given the current low TRL of energy storage technologies and the timeline planned to bring storage costs down (IRENA, 2017a).

5.5.2. Efficiency

Option RE1: improving EU funding programmes for commercially-ready and new RE technologies

The implementation of this policy option may result in additional costs, such as those needed to (i) foster the dialogue and coordination between granting authorities (e.g. a working group or task force), or (ii) create a helpdesk or information platform on funding opportunities for RE project developers. However, the costs generated are expected to be low compared to the potential benefits.

Option RE2: drafting EU guidelines to streamline the permitting process for RE projects

Establishing an EU guidance document on permitting process requires the coordination of the EC services and contribution from relevant stakeholders. The exercise should be led by an expert group featuring both national and local authorities, subject specialists, industry stakeholders and other interest groups. The costs associated with these activities are considered to be small compared to the benefits that this option generates.

Option RE3: improving the compensation mechanism for indirect emission costs in the electricity price

The revision of relevant provisions under the ETS Directive requires a complex legislative process, including achieving a political agreement, carrying out an impact assessment, doing review and adoption, monitoring, and evaluation. At national level, member states will have to secure a stable budget and change national legislation to comply with the new rules imposed by the EU. An increase in the threshold of the compensation (up to 100%) might require the compensation mechanism to move away from a State aid approach to a EU-level one. Consequently, the EU also needs to allocate financial resources to support this mechanism. Budget-wise, stakeholders representing research institutions argued that a CBAM could be a good alternative to the currently proposed option.

Option RE4: drafting EU guidelines to promote and harmonise demand-response measures across member states

Drafting and disseminating EU guidelines on DSR require a collective effort from DG ENER and other related Commission services. The drafting process should also involve stakeholder consultation activities. More importantly, proper application of the guidelines will require high commitment and coordination of national authorities.

Option RE5: reducing energy costs for RES-E purchased via PPAs or green energy offers

Public-supported guarantees for steel companies that want to enter long-term RE PPAs require EU and national credit institutes to allocate budget for guarantee services. The drafting of EU guidelines on GOs requires a joint effort from the Commission, member states, industries and relevant market players. Finally, the development of cross-border PPAs will particularly rely on improving the interconnection infrastructure and transmission capacity of member states.

Option RE6: reducing the costs of balancing and shaping services in national markets

The sub-option of accelerating the physical integration of energy infrastructure across M S requires investment in transmission infrastructure (such as electricity cables needed to allow for interconnection across member states) and in intelligent management systems. The sub-option to accelerate the implementation of the EBGL entails costs needed to support the coordination between ENTSO-E and national TSOs.

Option RE7: revising and implementing policies on energy storage in the Green Deal

Revising the articles on energy storage in the TEN-E Regulation is a long and complex legislative process. The EU also needs to secure important funding support (e.g. through CEF funding) to facilitate the deployment of large-scale storage projects. Besides, some costs, such as coordination and monitoring ones, will also occur if the EU wishes to ensure proper implementation of the permit-granting process for priority energy storage at member-state level.

5.5.3. Feasibility

Option RE1: improving EU funding programmes for commercially-ready and new RE technologies

Better use and coordination of funding programmes at the EU level is moderately feasible, while member states may be less interested in getting too stringent indications on how to spend EU funds they manage or their own national resources.

Option RE2: drafting EU guidelines to streamline the permitting process for RE projects

Being a soft law intervention, EU guidance might be politically more feasible than intervening with a hard-law approach. However, member states would not be in favour of a too-prescriptive approach on permitting process at the EU level. There is a chance that they prefer to keep a more flexible approach adapted to national specificities. Some items in the guidelines, e.g. establishing one-stop-shops for all permitting process, face challenges in terms of their full practical implementation.

Option RE3: improving the compensation mechanism for indirect emission costs in the electricity price

A stable budgetary and regulatory framework at national level, securing compensation for energy-intensive players, may be difficult to implement due to the current high level of government debt in many member states. More importantly, if the compensation mechanism is moved to the EU level, the limits of the EU budget might be a major challenge. The Covid-19 crisis has worsened this challenge, as governments must reallocate their resources to healthcare services and economic recovery packages. In addition, increasing the compensation rate to 100%, even if it is technically not State aid anymore, would be controversial. This option scores the lowest in terms of feasibility among the seven proposed ones.

Option RE4: drafting EU guidelines to promote and harmonise demand-response measures across Member States

Similar to RE2, EU guidance (soft law) might score better in terms of political feasibility than intervening with a hard-law approach. Putting the guidance into practice is however challenging, particularly because the existing system needs to be adapted (e.g. smart grids to be installed, artificial intelligence to be applied to forecast the electricity needs, etc.).

Option RE5: reducing energy costs for RES-E purchased via PPAs or green energy offers

The implementation of the three sub-options is feasible. The Norwegian power purchase guarantee system (Norwegian Export Credit Guarantee Agency nod) proves that public-supported guarantees for PPAs can be put into practice. The EU and member states can learn lessons from this model to build their PPA support mechanisms. The EU guidance on the transferring of GOs might be politically feasible, but difficult to be properly adopted by member states, who would prefer to keep their own approach that can adapt to national specificities. Finally, cross-border PPAs require more interconnection infrastructure, which is still not fully developed in the EU. Besides, PPAs require that the wholesale electricity price in the market(s) where the generation asset is located correlate with the wholesale price in the market(s) where the load is located. If this is not the case, the producers and corporate buyers or off-takers have to negotiate on risk allocation and mitigation options (WBCSD, 2020).

Option RE6: reducing the costs of balancing and shaping services in national markets

The feasibility of this option is relatively lower than the others. Accelerating the physical integration of energy infrastructure across member states is quite difficult. Currently, member states' progress to reach the 10% interconnection targets vary greatly, with some member states unable to reach this target for 2020. Given such progress, achieving the 15% target by 2030 will be challenging (European Commission, 2020l). Harmonising the national balancing markets is an ongoing task led by the ENTSO-E and national TSOs. Though difficult, the harmonisation has already shown some positive results, thanks to the close coordination between ENTSO-E and national TSOs.

Option RE7: revising and implementing policies on energy storage in the Green Deal

This policy option is considered to be politically feasible. The European Parliament, in its resolution of 10 July 2020 on a comprehensive European approach to energy storage, expressed its support for revising and ensuring a proper implementation of the TEN-E regulation to better support energy storage (European Parliament, 2020).

5.5.4. Coherence

In general, all the proposed policy solutions are coherent with the spirit of the EU legislation in the field of energy, climate change and sustainable development, and can contribute to achieving the EU energy and climate targets. Some policy options might, however, be potentially incoherent with EU initiatives. For instance, Option RE3 may not fit well into the concept of the just transition. As the indirect cost compensation scheme targets operational costs, it would be challenging to justify such compensation and distributional choices.

Table 9: ***Overview of policy solutions – Renewable electricity***

	Effectiveness	**Efficiency**	**Feasibility**	**Coherence**
Option RE1: EU funding for RE technologies				
Option RE2: EU guidelines on permitting process for RE projects				
Option RE3: compensation of indirect emission costs				
Option RE4: EU guidelines on demand-response measures				
Option RE5: PPAs or green energy offers				
Option RE6: balancing and shaping costs in national markets				
Option RE7: policies on energy storage				

Note: This table presents the policy options in the energy area that would support the decarbonisation of the EU steel industry. The options are assessed based on the four criteria under the Better Regulation guidelines: their effectiveness, efficiency, feasibility and coherence. Colour legend: orange - low, yellow – moderate, green – high. For instance, a policy option that has a green cell in the Effectiveness column is considered to be “highly” effective. Source: authors’ own composition

6. Green hydrogen

6.1. Problem identification

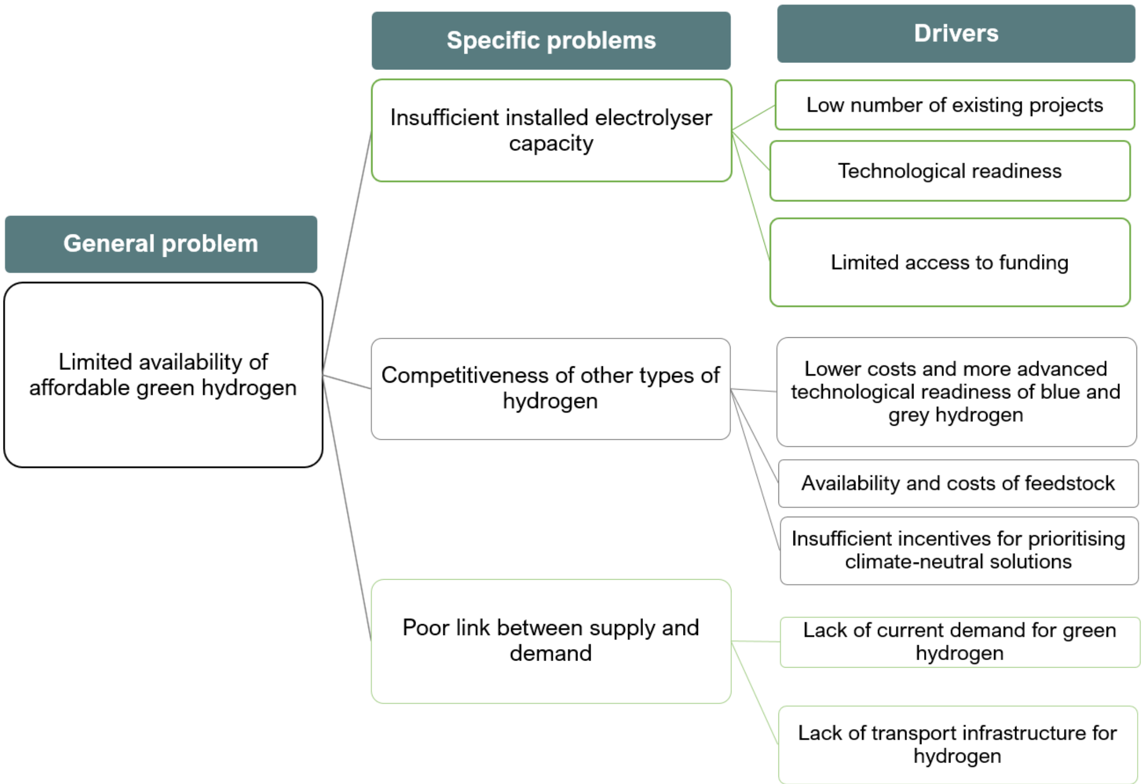
6.1.1. Background

The use of **hydrogen** represents a key technology for the decarbonisation of the steel-making process, being one of the measures in the CDA technological route, as well as in the Process integration (PI) pathways presented by the European Steel Association, EUROFER (2019b). This can be achieved through a process **of hydrogen direct reduction**: several regions with cheap natural gas (e.g. Russia, Iran, Saudi Arabia) have already extensive experience in the direct reduction of iron ore using natural gas (Neuhoff et al,. 2020, p. 2). Nonetheless, while such an option is technologically feasible, the **availability of affordable clean hydrogen is an important bottleneck**. Moreover, hydrogen used for industrial processes should ultimately be produced in a climate-neutral manner to ensure compatibility with long-term EU climate policy objectives (European Commission, 2020a). Therefore, the decarbonisation of the steel sector through this pathway relies on an **affordable and consistent supply of green hydrogen**, which currently does not exist in the EU. Green hydrogen is produced from electrolysis using RES-E, representing a form of clean hydrogen. Electricity-based hydrogen that does not use RES-E exclusively represents a form of low-carbon hydrogen[64] and is therefore not referred to as 'green'. Hydrogen used in industry today is mainly produced through an emission-intensive process using unabated natural gas,[65] commonly referred to as grey hydrogen (produced without CCS).

[64] Hydrogen produced from fossil sources with the use of carbon capture or from electrolysis regardless of electricity source

[65] Steam methane reforming (SMR). For further details, see Muradov (2015).

Figure 13: Problems hindering the availability of green hydrogen



Source: author's composition.

6.1.2. General problem

There is **insufficient availability of affordable green hydrogen** at the moment in the EU. The stakeholders consulted during the Inception phase confirmed the high relevance of this problem. While hydrogen is already produced and used at scale in European industry,[66] it is not commonly used so far in the steel sector. According to an inventory by the Oxford Institute for Energy Studies and the Sustainable Gas Institute, the production of zero and low-emission hydrogen is still in its infancy, both from a technological and a deployment-level perspective. When it comes to the use of green hydrogen in the steel sector, the Hybrit project in Luleå (Sweden) will start producing green hydrogen-based steel in late 2020 (Hybrit, 2020), but this will only represent a very small part of the EU steel market. For now, both the supply of green hydrogen and the steel production facilities that could use it are lacking. The **limited availability of green hydrogen, therefore, has issues both on the supply and the demand side**. Price also represents a problem for the uptake of green hydrogen, as it currently is uncompetitive compared to grey or blue hydrogen. However, this may change in the future.

[66] E.g. in ammonia production and industries such as chemicals and refining.

6.1.3. Specific problem GH1

So far, there is limited availability of renewable-power-run electrolysers or, more in general, of any other low-carbon sources of hydrogen. Currently, there are 43 low-carbon hydrogen projects[67] in Europe: most of them are in Germany, followed by the UK, France, the Netherlands and Austria (Lambert et al., 2019, p. 12). Five projects are designed to produce hydrogen from fossil fuels with the use of CCS, four of them will use steam-methane reforming (SMR), while the other one will use electricity for hydrogen production. Only 20 projects are currently operational or under construction, meaning that a large-scale deployment in the near future is unlikely. The EU plans to install **6 GW of renewable electrolysers by 2024**, according to the Commission's hydrogen strategy. However, until today, the global, newly-installed capacity has peaked at 33 MW (in 2017) and has often been below 20 MW in recent years (IEA, 2019). EUROFER already estimates that by 2050 the steel sector's demand for hydrogen produced from carbon-free electricity will be 5.5 M tonnes (EUROFER, 2020a, p. 1), compared to only 0.37 M tonnes of global low-carbon hydrogen production in 2017 (IEA, 2020d). The current number of upcoming projects may also be **insufficient** to allow for a large-scale switch from fossil fuels to hydrogen in the steel sector, while future uptake has to overcome challenges related to technological readiness and inadequate business case. This specific issue has been confirmed (at least to some extent) by most of the stakeholders consulted during the Inception phase.

- **Driver GH1.1**: Despite a recent spike in interest in using green hydrogen as an option for reducing emissions in difficult-to-decarbonise sectors, **the number of concrete upcoming projects is too low** to meet the Commission's target of 6GW of installed capacity by 2024. The Clean Hydrogen Alliance set the goal of installing 2x40GW of electrolysers (40GW domestically and 40GW from imports) by 2030, but this is yet to materialise. In total, in Europe there are only 4.5GW of projects under development, though it cannot be assumed that all of them will progress from feasibility to positive investment decision (Lambert, 2020, p. 4). Besides the number of projects, **the small size of the electrolysers** also constrains the large-scale deployment of hydrogen-based steelmaking technologies. More specifically, the largest electrolyser under construction in Europe has a capacity of 10MW, while Europe's electrolyser construction capacity is under 1GW per year (Lambert, 2020, p. 3). The EU still needs to scale up its ability to manufacture large electrolysers of up to 100MW to kick-start green hydrogen production at large scale (European Commission, 2020a, p. 5).
- **Driver GH1.2**: Another driver for the problem of insufficient electrolyser capacity is the **level of technological readiness**. While electrolysis is a tested technology, it has not yet reached a level of commercial scale-up, being used mostly in demonstration and smaller-scale projects. This means that the technology is still considered expensive and is yet to develop economies of scale, which will bring about significant cost reductions. Some of the most significant cost-reduction potential come, however, from technologies that are still in their infancy. Currently, alkaline electrolysis is the most common technology for

[67] Most of these projects are not even strictly 'clean', according to the European Commission's definition. Hydrogen obtained from SMR with CCS does not completely eliminate CO_2 emissions and most electricity-based projects in the list do not use 100% RES-E.

green hydrogen, with capital costs between €1,000 and 2,000 €/kWel. However, some estimations of hydrogen uptake potential (Navigant, 2019) rely on significant evolution of the Proton exchange membrane (PEM) technology, which has the potential to reduce its capital costs from about €1,000€/KWel to €400€/kWel by 2050 (European Parliament, 2018, p. 29). This technology is currently only used in niche applications and does not benefit from the same TRL as alkaline electrolysis. Given the early-stage deployment of electrolyser capacity, the technology still needs to overcome the **'valley of death'** between R&D and commercialisation. Only then, any emerging technology can move from a stage where the underlying technology is proven, but manufacturing costs are too high, to the stage where it becomes competitive with other alternatives on the market.

- **Driver GH1.3**: The uptake in green hydrogen investments **relies to some degree on governmental support** (BNEF, 2020). The Commission, in its hydrogen strategy, estimates an investment requirement of €€180 - 470 B (not considering investments in additional RE capacities). While the Commission prioritises investments in green hydrogen over other hydrogen production technologies, the mechanisms through which public support will be provided are only being discussed at the moment. Therefore, the lack of dedicated public support instruments may also represent a driver for the low deployment of electrolysers. Support may be needed both for reaching technological readiness for already-proven electrolysis technologies, and for R&D in processes that have not yet reached that level.

Stakeholders consulted for the Inception phase confirmed that all drivers are to some extent contributing to increase the specific problem GH1, with driver GH1.1 (low number of new projects) and driver GH1.2 (electrolysis still far from commercial scale-up) being the most prominent ones. One respondent also stressed that the current production of green hydrogen is highly inefficient when it comes to energy conversion. It should be noted that efficiency losses associated with the use of hydrogen are already accounted for in the high costs of green hydrogen.

6.1.4. Specific problem GH2

While green hydrogen is the most desirable one from a climate neutrality policy perspective, it has nevertheless to **compete** with other types of hydrogen, especially in the short and medium-term. For now, blue hydrogen (using SMR with CCS) and, especially, grey hydrogen (using SMR without CCS) are expected to be **lower-cost alternatives**. The cost of production for blue hydrogen is forecast to be about €36-63€/MWh in 2050 (Navigant, 2019, p. 30). Depending on the source of RE (wind or solar) and on the geographical location, the cost of green hydrogen is projected to be around €44-61€/MWh in 2050 (Navigant, 2019, p. 23). It should be noted that these cost estimations rely on the availability and access to cheap RES-E, which would be required from both dedicated capacity and surplus.[68] This problem was confirmed by the stakeholders responding to the online survey conducted during the Inception phase.

[68] An Agora Energiewende (2018) study done by Frontier Economics shows that inexpensive RES-E will be needed in order for power-to-x and power-to-liquid solutions to be economically efficient. However, such renewable power will not be enough to cover all production needs, therefore dedicated renewable power plants will likely need to be built.

- **Driver GH2.1**: Currently, the **costs and technological readiness of blue and grey hydrogen are more competitive than those of green hydrogen**. The EC estimates in its hydrogen strategy (European Commission 2020a) the price of the current grey hydrogen production at around 38 €/MWh, that of blue hydrogen at 50 €/MWh and green hydrogen at 65-135 €/MWh. Moreover, according to Guidehouse (2020), blue hydrogen could scale-up rapidly irrespective of the availability of plentiful low-cost RES-E, which is a limitation to a similar scale-up of electrolysis using RES-E, in addition to the lower level of technological development of electrolysers. The price of electrolysis would have to more than halve[69] to reach a similar cost level as blue hydrogen. The EC's proposal of a more immediate ramp-up of electrolyser installations of at least 6 GW of renewable hydrogen in the EU by 2024 and 40 GW by 2030 may bring the cost of renewable hydrogen at the same level as hydrogen from fossil fuels with CCS as early as 2030, also depending on the evolution of the carbon price.
- **Driver GH2.2**: The **availability of and access to feedstock** make fossil-based hydrogen production more competitive than green hydrogen. Blue hydrogen benefits from large amounts of plentifully available natural gas. Meanwhile, the current hydrogen production through electrolysis using power from the electricity grid (i.e. not fully renewable) has more than **twice the level of CO_2 emissions** of hydrogen obtained through SMR without CCS (Belmans et al., 2020, p. 3), and is therefore undesirable from a climate perspective. To produce green hydrogen at scale, electrolysers, therefore, need access to a significant amount of cheap RES-E and, from the perspective of the electrolyser's operator, a dedicated, reliable, constant electricity supply is needed. The business case for investments in electrolysers, therefore, partly depends on a sufficient, constant, and affordable RES-E supply. Limiting the operation of electrolysers to periods when (surplus) RES-E is in high supply may be incompatible with the required returns for investors, thus becoming a barrier to investment. Belmans and Vingerhoets (2020)) explain why the reliance on cheap surplus RES-E may be unrealistic. Demand-side management, batteries and other electricity storage technologies may disincentivise such uses of electrolysers, which require high capacity factors (or roughly 5,000 hours per year) to be cost-effective. Expecting the availability of large quantities of surplus electricity also relies on unprofitable and potentially unsustainable business models for renewable power generation. Meanwhile, producing significant volumes of green hydrogen using dedicated RES installations could risk drawing resources away from the decarbonisation of the electricity sector.
- **Driver GH2.3:** There are currently **insufficient incentives** for motivating the direct uptake of green hydrogen. Different types of hydrogen may be treated as a **homogenous** product that does not differentiate between varying carbon contents. This challenge is similar to the ones of decarbonising other basic materials and commodities: carbon-intensive products are functionally equivalent and often cheaper than climate neutral

[69] Based also on the potential development of PEM electrolysis and availability of RES-E. See cost estimations by Navigant (2019).

equivalents. Hence, a business case for investment in climate neutrality only exists once the market demands the lowest carbon products specifically.[70]

Respondents to the survey conducted in the Inception phase confirmed that all drivers are at least to some extent affecting the cost competitiveness of green hydrogen. Some respondents also mentioned that the price of blue and especially of grey hydrogen does not adequately account for the ensuing costs of carbon emissions, and this is further impinging on the competitiveness of green hydrogen.

6.1.5. Specific problem GH3

Due to its higher costs, at the moment there is **no immediate demand for green hydrogen**. This applies not only to the steel sector, but also to other energy-intensive industries. In this context, any increase in the use of green hydrogen would need to be based on policy support, as there is currently no market for green hydrogen in Europe. Moreover, there is a **lack of physical infrastructure** for ultimately linking hydrogen demand and supply. This is, to some extent, confirmed by the stakeholders consulted during the Inception phase.

- **Driver GH3.1:** While green hydrogen represents a feasible solution for reducing emissions of hard-to-decarbonise sectors, such as energy-intensive industries, there is **currently a lack of demand** for such alternatives given the significantly higher costs that such a transition would entail, especially in the context of the current carbon prices. The 2020 Hydrogen Economy Outlook, produced by BNEF ((2020)), shows that a carbon price of \$50/tCO_2 would be required for a switch from coal to green hydrogen in steelmaking by 2050.[71] The current carbon price under the ETS is roughly \$31/tCO_2. In the absence of market drivers for a switch to green hydrogen, the EC, in its hydrogen strategy (2020), acknowledges ()the need for demand-side support and the need to lead market creation policies.
- **Driver GH3.2:** There are also **limited options for transporting hydrogen** from its point of production to where the demand is. This may require dedicated infrastructures, such as pipelines, compressed gas containers, or liquid tankers (Hydrogen Europe, 2020a; ERIA, 2019).[72] As a medium-term strategy, networks can inject hydrogen into the current gas

[70] For blue hydrogen, most emissions stem from the natural gas supply chain, while the use of CCS adds efficiency losses and a higher fuel consumption. For green hydrogen and electrolysis, it is the carbon intensity of electricity production and the emissions related to the manufacture of the electricity generation technologies, such as solar panels and wind turbines that determine embedded emissions. There are trade-offs between the cost of mitigation and the proportion of decarbonisation achieved through different means of hydrogen production: the most cost-effective methods use fossil feedstock, but provide lower emission cuts, even with the use of CCS; meanwhile, hydrogen from electrolysis has 80-95% fewer emissions compared to SMR with CCS, but has twice the cost (Parkinson et al., 2018). This is due to the different cost structure between the two alternatives. While SMR costs depend on the capital costs of the production plant, the cost of natural gas, and the carbon capture installation and CO_2 storage; the cost of electrolysis is skewed by the high price of electrolysers, their limited capacity and the cost of feedstock electricity (Lambert et al., 2019).

[71] Based on a hydrogen production cost of \$1/kg. According to the European Commission ((2020)), the current price for green hydrogen production is \$2.9-6.5/kg.

[72] The viability of converting the pipeline used for transporting natural gas into transporting hydrogen has been tested through projects such as the Gasunie hydrogen pipeline from Dow to Yara (Gasunie, 2018) and the H21 Leeds City Gate pilot project in the UK. For further details, please see H21

grid to boost cash flows at low marginal costs towards breakeven for hydrogen-producing facilities in the early technological phases, when the risks of insufficient demand are very high (IRENA, 2019, p. 38). However, differences in the density of natural gas versus hydrogen limit the use of existing networks for hydrogen transportation. The creation of a **dedicated infrastructure** for hydrogen has high costs, due to either capital investment or costs related to the conversion of existing pipelines. If pipelines are used, additional energy will be required for the compression and pumping of hydrogen (IEA, 2014). The EU's hydrogen strategy foresees costs of €€65 B for transport, distribution and storage of hydrogen up to 2030, as well as the development of 'Hydrogen valleys' where hydrogen is both produced and consumed without the need for long-distance transport (European Commission, 2020f, p. 7). This may be more challenging in the case of green hydrogen, if the electrolysers are installed in the vicinity of RE installations. Blue hydrogen may have an advantage in the short term from a transport perspective, as existing production facilities can be retrofitted with CCS and hydrogen can be used on-site where it is produced, for example in refineries. Electrolysers may, however, be installed closer to the point of consumption, which may alleviate some of these challenges.

Most of the respondents to the survey conducted during the Inception phase emphasised that both drivers are to a high extent impinging on the links between demand and supply for green hydrogen.

6.2. EU right and need to act

The legal basis for an EU policy supporting the deployment of green hydrogen produced through electrolyser installations can be found in **Article 11 of the** TFEU, according to which environmental protection requirements must be integrated into the Union's policies and activities, in particular to promote sustainable development. Moreover, **Article 191 of the TFEU** requires the EU to maintain policies that protect the environment and specific measures that promote "at international level to deal with regional or worldwide environmental problems, and in particular combating climate change." **Article 191(2)** specifies that the EU's environmental policies should follow the **precautionary principle, rectify damage at the source, and ensure that polluters pay**. Green hydrogen can reduce GHG emissions and thereby support the EU's climate change mitigation objectives, as it may replace the use of natural gas and that of hydrogen produced with higher GHG emissions.

Article 173 TFEU on industry states that the EU's actions shall ensure that the conditions necessary for the competitiveness of the Union's industry exist. The EU's industrial policy should be aimed at "speeding up the adjustment of industry to structural changes", which applies to industrial transformation in the context of the energy transition, climate policy and the European Green Deal. The EU's action should also foster "better exploitation of the industrial potential of policies of innovation, research and technological development". Electrolysers represent an emerging technology that can benefit from increased innovation and technological development.

((2016)). The project shows that the heat demand for the city of Leeds can be met with hydrogen produced through SMR, stored in caverns, and distributed through the upgraded existing pipeline.

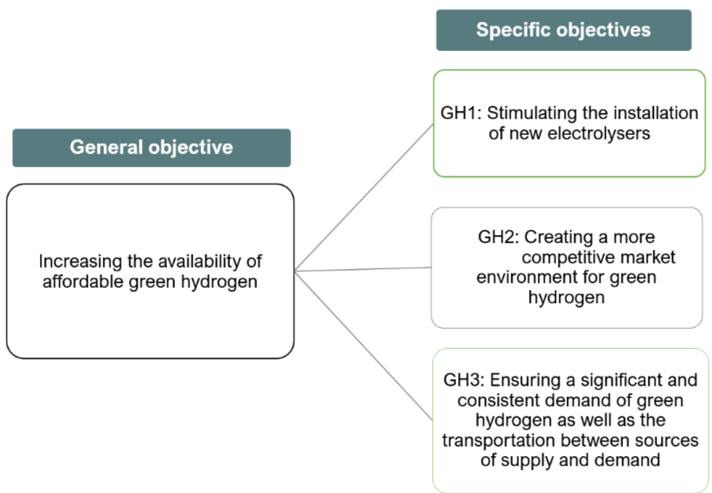
Article 4(2) of the TFEU also makes clear that environmental and energy policies are based on **shared competence** between the EU and its member states. **Article 6 TFEU** states that, in the area of **industrial policy, the EU's interventions should support, coordinate or supplement** member states' policies. Climate change is a trans-boundary problem that cannot be addressed by a single country. The EU's cooperation is therefore advantageous. Coordination at the European level enhances climate action and the EU's action is thus justified on the grounds of subsidiarity, in line with **Article 191 of the TFEU**. It also provides added value. Divergent European policies supporting emissions reduction could also undermine the efficiency of individual member states' policies due to the risk of carbon leakage. From a technological development point of view, there are innovation spillovers that create added-value for an EU intervention. Said intervention can reach a higher scale, and therefore greater efficiency, than individual member states actions. However, as environment and industry are shared and supporting competences respectively, any EU action on climate change and green hydrogen is not intended to replace national policies fully, but to complement and to act only where it is efficient to do so.

6.3. Policy objectives and options

6.3.1. General objective

Any EU policy intervention in the field should aim **to increase the availability of affordable green hydrogen**, thus enabling direct and indirect emissions reduction in the steel industry and contributing to the EU 2030 and 2050 energy and climate goals. To ensure that green hydrogen can become a decarbonisation solution for the steel sector, it must be cost-competitive, available in sufficient quantities and easily transported to the source of demand.

Figure 14: Policy objectives on availability of green hydrogen



Source: authors' composition.

6.3.2. Specific objective GH1 and policy options

Specific objective GH1: Stimulating the **installation of new electrolysers**. The current projects to be developed in the EU are insufficient to meet the EU's plans of 6 GW of renewable electrolysers by 2024. Currently, the largest electrolyser capacity under construction in Europe is of approximately 10 MW. Therefore, targeted support is needed for stimulating the implementation of electrolyser projects in the EU, in order to bridge the funding gap and to motivate more actors to pursue such projects.

Baseline: Allow industry to independently create and develop a pipeline of projects.

Option GH1: supporting member states' initiatives towards early deployment

While EU strategies and legislation are necessary for providing strategic guidance, most projects will be developed within the bounds of individual member states. EU policy could also play a more supportive and coordinating role to streamline member states' initiatives. Member states could be encouraged to develop national hydrogen strategies, including through their National energy and climate plans.

The clarification of what State aid requirements are for green hydrogen projects thanks to *ad hoc* guidelines could also enable MS to pursue an increased deployment. A more structured approach could entail the funding of electrolysers' deployment as part of the recently launched IPCEI for hydrogen, which can be used to finance green hydrogen projects. IPCEIs involve co-financing by project beneficiaries and are also subject to State aid rules.

Coordination between the EU and MS could take place via high-level working groups, while the macro-regional strategies of the EU can provide platforms for MS to discuss their plans and ambitions. Such platforms can enable the exchange of best practices to support green hydrogen deployment.

Option GH2: supporting financing and deployment of (public or private) electrolysers at EU level

Financial support for new electrolyser capacities can be provided more directly through EU mechanisms, such as HEU, the EU ETS IF or other instruments linked to the EU budget or the Recovery and resilience facility. As part of the HEU programme, a European Partnership for clean hydrogen has been launched. Direct EU funding is not subject to EU State aid rules. The amount of funding earmarked for the hydrogen economy in the RFF could be expanded, although some State aid conditions can apply here. However, due to the limited size of the EU's budget and own resources, the amount of available funding could be constrained.

Support should also be given for consortiums that encourage cooperation between market actors across MS in order to ensure early deployment across the EU.

6.3.3. Specific objective GH2 and policy options

Specific objective GH2: creating a more **competitive market environment for green hydrogen.** While green hydrogen is the most desirable one from a climate neutrality perspective, it is currently uncompetitive compared to the production of grey hydrogen. Moreover, when SMR installations will be retrofitted with CCS, it is expected that their production cost of hydrogen will be lower than that of green hydrogen, at least for a few years. Therefore, a more even playing field could **internalise the negative externalities** of CO_2 emissions associated with the production of hydrogen from natural gas, while simultaneously offering a premium for the production of green hydrogen and ensuring the availability of sufficient quantities of RES-E.

Baseline: ensure equal market access for all technologies while waiting for green hydrogen to become competitive, as EUA prices increase and technological costs drop.

Option GH3: improving the EU-wide framework for RES-E GOs (covering both electrons and molecules).

GOs today already exist as an instrument to track and prove the origin of RES-E generation. The REDII directive has extended this system to cover also renewables gases, which can include hydrogen. Such a mechanism should be valid across the EU, certifying the climate-neutral production of hydrogen.

Once issued, GOs hold a market value and can be traded. This allows a large variety of economic operators to add to the demand for green hydrogen without directly being involved in its production or consumption. If the market value of GOs is sufficiently high, the system could contribute to further investments in green hydrogen capacity, and become part of the revenue stream. The market price of GOs will be affected by the supply of certificates which is first and foremost linked to additional renewable hydrogen being produced. However, it is in principle possible to limit the issuance of GOs to specific cases to ensure additionality, in particular if the expansion of renewable hydrogen production benefited from public funding. The REDII directive provides for the introduction of a green label linked to RE coming from new installations specifically.

The demand for green hydrogen also depends on the availability and costs of other types of hydrogen, including ‘blue’ and ‘turquoise’ hydrogen. A GO system for hydrogen, therefore, needs to agree on common terminology, recognised by a wide array of parties.

Option GH4: offering a premium to producers of green hydrogen (e.g., through CCfDs)

Producers could receive a premium for the production of green hydrogen, which can be linked to specific production volumes or electrolyser capacities, or to a reduction in emissions vis-à-vis a benchmark. The premium should cover part of the increased CAPEX and OPEX and thereby make it more attractive to invest in green hydrogen production. With increased installed capacity, costs should decline through economies of scale and learning by doing, thereby making green hydrogen more competitive.

CCfDs could be one possible design. A CCfD can be designed to cover the difference between a CO_2 strike price and the actual CO_2 price under the EU ETS. The strike price can be set at the level necessary to make investment in green hydrogen competitive. This stabilises the revenue stream by removing the uncertainty associated with fluctuating carbon prices under the EU ETS. Depending on the ETS price and the design of the mechanism, a CCfD can result in a premium paid, but also a payment by the producer, in case the ETS price exceeds the strike price. This limits the expenditure for the issuer of CCfDs.

Other competitive support schemes can also be developed similar to those offered for RES-E. Examples include public tendering and reverse auctions. Public tenders allow companies to make bids to install a given amount of green hydrogen production capacity, with governments picking the winners based on predetermined criteria such as cost and location. With reverse auctions, multiple sellers compete for a single buyer, which facilitates price discovery and economic efficiency while supporting the deployment of green hydrogen.

Specific objectives GH1 and GH2 are closely related, as learning economies and economies of scale associated with an increasing number of installed electrolyser projects in Europe would ultimately make green hydrogen more competitive. Therefore, GH1 policy options could also provide solutions for specific objective GH2.

6.3.4. Specific objective GH3 and policy options

Specific objective GH3: ensuring a significant and **consistent demand for green hydrogen**. Currently, even if green hydrogen production ramped up, there is still the need to create **lead markets** aimed to increase the demand for the product. Besides, it also needs to be ensured that green hydrogen can be **transported from the source of supply to that of demand**.

Baseline: allow hydrogen supply and demand to connect through market forces and an incrementally increasing price of carbon.

Option GH5: providing financial support for the development of hydrogen transport infrastructure

The deployment of a hydrogen economy will rely upon the development of transport infrastructure, which can consist of both newly-built, dedicated hydrogen infrastructure and retrofitted natural gas infrastructure, where this is possible. The EU Hydrogen Strategy provides a good starting point for how this can be developed. It envisions that initially hydrogen infrastructure will develop within local hydrogen clusters, also called the ‘Hydrogen Valleys’, while the long-term objective is to establish a liquid and liberalised pan-European market.

The planning and development of hydrogen transport infrastructure may require more intense public support. The Connecting Europe Facility for Energy could provide avenues for additional funding of hydrogen infrastructure. The EU ETS IF, while focusing on demonstration plants, can increase hydrogen demand in certain industrial clusters and thus support the business case for more hydrogen infrastructure. The Just Transition Fund could target hydrogen infrastructure in regions that are carbon-intensive today and where hydrogen clusters could emerge. More EU funding from the EU budget, including from the CF and the Recovery and Resilience Facility, could be considered, including by leveraging private investments. Member states’ investment in hydrogen infrastructure can be streamlined via the hydrogen IPCEI.

6.4. Impacts

6.4.1. Option GH1: supporting member states initiatives towards an early deployment of electrolysers

Economic and competitiveness impact

The elaboration of national hydrogen strategies coordinated at EU-level could have a positive impact on the **operating costs and conduct of business**, by creating certainty and clarity regarding the deployment plans for green hydrogen. In turn, this could, in the long run, decrease compliance costs with upcoming regulatory changes by allowing business to anticipate the direction of change. This policy option could also positively impact access to finance, particularly for projects that are chosen as part of an IPCEI, but also more generally by clarifying State aid requirements and enabling the development of public procurement programmes. This option could also have an impact on the investment cycle of businesses, which would have to be aligned with national and EU hydrogen strategies.

This policy option could have a positive impact on the **competitiveness of business**, especially in the long run, by creating an enabling environment that can stimulate businesses’ capacity to innovate. This could stem both from the development of national plans targeted at stimulating and financing innovation, or from the creation of a stable regulatory environment that encourages businesses to innovate when it comes to clean hydrogen production.

The elaboration of coordinated national hydrogen strategies could also have a positive impact on i**nnovation and research** and **innovative competitiveness.** This policy option could, more broadly, stimulate the hydrogen sector's capacity to bring to the market new products and to improve the features of the current ones, through the application of new electrolysis technologies, such as PEM. It could also impact the innovative competitiveness of the steel sector to develop and adopt the technologies that are the most innovative and have the highest emission mitigation potential but that have not yet reached maturity levels.

This policy option would also impact **public authorities**, mainly through budgetary consequences. It is believed that this can have a particularly important impact at local level, especially in countries which have not yet sufficiently developed their hydrogen sector. Another aspect worth considering is the potential disparities that may arise between more developed member states, that have superior financial capabilities, and less developed ones. More developed member states could transfer knowledge to the other member states. Regions with a less developed industrial infrastructure would also need to receive a more dedicated support. In the short run, support should focus on the elaboration of strategies, while in the long run support should focus on implementation. Budgetary consequences may also arise from the implementation of IPCEI projects and public procurement programmes. It should be noted that large State aid campaigns can incur a significant financial cost to State and local budgets.

Environmental impact

This policy option could, in the long run, have indirect effects on **the emission of GHGs into the atmosphere**, by facilitating the decarbonisation of various sectors, such as the steel industry. It is also believed that the deployment of green hydrogen as opposed to other types of hydrogen can provide some of the highest GHG emission mitigation potential for a hydrogen decarbonisation pathway in the steel sector.

By outlining strategic directions regarding the future fuel mix used in energy production, and by promoting the production and consumption of hydrogen from RE sources, this option could also have an impact on the **transport and use of energy**. The increased supply of green hydrogen would also lead to an increased demand for RES-E in order to produce it.

This option also **promotes sustainable production**, by fostering a more sustainable production and consumption of green hydrogen in industry and other sectors of the economy. This can in turn decrease the use of alternative carbon-intensive energy and feedstock sources.

Social impact

In the long run, this option could have a positive impact on **employment**, by both enhancing the potential to create jobs and by preventing job loss in currently carbon-intensive sectors. For the steel industry it can contribute, in particular, to avoid job losses, as it will support production using new technologies. Additional jobs may also be created through the development of a green hydrogen value chain within the EU. It is believed that hydrogen strategies should also be accompanied by education for facilitating the acceptance of new steel production technologies, especially those that achieve significant GHG emission reductions.

6.4.2. Option GH2: supporting financing and deployment of (public or private) electrolysers at EU level

Economic and competitiveness impact

An impact could be expected on **operating costs and conduct of business**, especially for entities that receive direct funding for developing electrolyser capacities. By covering part of the CAPEX of green hydrogen producers, investors would be encouraged to develop electrolyser projects. This policy option could also have a positive impact on access to funding for projects that are partly funded through EU instruments, which can act as a de-risking instrument for investors. This could, in the long run, lead to cost reductions through economies of scale, thus making green hydrogen more competitive. By increasing the demand for RES-E, an uptake in green hydrogen production could also lead to increases in the price of RES-E, especially in the case of a slow deployment of new renewable generation assets.

By reducing uncertainty, this option could have an impact on **cost/price competitiveness**, as it will reduce the cost of capital and increase the availability of funding opportunities for projects involving green hydrogen production.

Through risk-reduction and stabilisation of revenue streams for producers, this policy option could have a positive impact on the **competitiveness of businesses**, as it will create an enabling environment that can foster the businesses' capacity to innovate. This can also promote R&D of technologies for the production of hydrogen from RE sources, thus also having an impact on **innovation and research**, as well as on **innovative competitiveness.** This policy option could, more generally, foster the hydrogen sector's capacity to bring new products to the market and to improve the features of the current ones, through the application of new electrolysis technologies, such as PEM. It could also have an impact on the innovative competitiveness of the steel sector to develop and adopt the most innovative technologies with the highest emission mitigation potential, but that have not reached maturity levels yet.

The impact on **public authorities** stems from the budgetary consequences at EU-level associated with a direct funding of electrolyser projects. In order to mitigate the impact on public budgets, this type of policy solution could focus on transnational projects and international consortiums for projects that would otherwise face difficulty in raising the necessary funds. This can also contribute to foster cooperation between market actors across member states in order to ensure early deployment across the EU. Another aspect worth considering is the potential disparities that may arise between more developed member states, that have superior financial capabilities, and less developed ones. More developed member states could transfer knowledge to the other member states. Regions with a less developed industrial infrastructure would also need to receive a more dedicated support.EU firms benefiting from such support could enjoy a more competitive position compared to non-EU firms that do not benefit from similar levels of public funding, thus having an impact on **international competitiveness**.

Environmental impact

This policy option could have indirect effects on **the emission of GHGs into the atmosphere**, by facilitating the production of green hydrogen over more emission-intensive forms of hydrogen that can be used in various industrial sectors, including the steel industry.

This option also **promotes sustainable production**, by fostering a more sustainable production of hydrogen, which can be used in industry and other sectors of the economy. This can in turn reduce the use of alternative carbon-intensive sources of energy and feedstock.

This option could also have an impact on the **transport and use of energy,** by increasing the demand for green hydrogen and subsequently for RES-E in order to produce it.

6.4.3. Option GH3: improving the EU-wide framework for RES-E GOs (covering both electrons and molecules)

Economic and competitiveness impact

An impact could be expected on the **operating costs for businesses**, as some products will be treated differently from others in a comparable situation, namely green hydrogen compared to hydrogen produced from non-carbon-neutral sources. By fostering the consumption of green hydrogen, investments in electrolyser capacities could be encouraged. In the long run, this could lead to cost reductions through economies of scale, thus making green hydrogen more competitive. Businesses would also incur some adjustment and compliance costs for aligning to the standards set by a GO scheme. Additional transaction costs could also arise from the exchange of GOs between producers and consumers. The price paid by industrial users for hydrogen could also be higher for those consumers that want to use green hydrogen, and this could also be reflected in the final price paid by the consumer. If adequate public support is given for the deployment of new electrolyser capacities, the impact on costs for the steel industry could be mitigated. By increasing the demand for RES-E, an uptake in green hydrogen production could also lead to increases in the price of RES-E, especially in case of a slow deployment of new renewable generation assets.

Trade and investment flows could be impacted, especially as domestically-produced green hydrogen with GOs could be favoured by consumers over imports that do not comply with the same certification standards. The potential development of different product standards could also affect the regulatory convergence with third countries that do not apply the same framework for GOs. At the same time, there are some concerns that a GO system could lead to a disconnection between green hydrogen production and consumption, especially if the production country is different from the consumption one(s), and the GOs are traded across borders.

A more competitive market environment for green hydrogen could foster R&D in the field of RE sources for hydrogen production technologies, thus having an impact on **innovation and research**.

This policy option would also impact **public authorities**, having budgetary consequences related to the development and harmonised implementation of national GO frameworks.

The price for **consumers** for goods such as green hydrogen could also be affected, as producers could charge a premium on hydrogen produced from carbon-intensive sources. This policy option could also have a positive impact on consumer information, knowledge, trust and protection, by providing a framework for tracking and proving the origin of green hydrogen.

In terms of **international competitiveness,** this policy option could offer a better competitive position for EU firms compared to non-EU firms, thanks to the application of a widely recognised and verifiable certification system. At the same time, it could also offer a competitive advantage to green hydrogen producers over those sourcing hydrogen from fossil fuels, with or without the use of CCS.

Environmental impact

This policy option could have indirect effects on **the emission of GHGs into the atmosphere**, by facilitating the use of green hydrogen over more emission-intensive forms of hydrogen in various industrial sectors, including the steel one. While the hydrogen end-users' emissions would not change, regardless of the type of hydrogen used, the positive impact on emissions would be most significant for producers of hydrogen.

This option also **promotes sustainable production**, by spurring more sustainable consumption of hydrogen in industry and other sectors of the economy. This can in turn decrease the use of alternative carbon-intensive sources of energy and feedstock, as well as of other types of hydrogen whose production leads to higher amounts of GHG emissions.

6.4.4. Option GH4: offering a premium to producers of green hydrogen (e.g. through CCfDs)

Economic and competitiveness impact

An impact could be expected on the **operating costs for businesses**, as some products will be treated differently from others in a comparable situation, namely green hydrogen compared to hydrogen produced from sources that are not considered carbon neutral. By covering part of the CAPEX and OPEX of green hydrogen producers, investors would be encouraged to develop electrolyser projects. This could, in the long run, lead to cost reductions through economies of scale, thus making green hydrogen more competitive. By increasing the demand for RES-E, an uptake in green hydrogen production could also lead to increases in the price of RES-E, especially in the case of a slow deployment of new renewable generation assets.

Through risk-reduction and stabilisation of revenue streams for producers, this policy option could have a positive impact on the **competitiveness of businesses**, as it will create an enabling environment that can foster the businesses' capacity to innovate. This could also foster R&D in the field of RE sources for hydrogen production technologies, thus having an impact on **innovation and research too**.

The impact on **public authorities** stems from the budgetary consequences associated with financing a subsidy scheme for green hydrogen producers, for example for covering the premium to be paid through a CCfD when ETS prices are below the strike price. In order to mitigate the impact on public budgets, some believe that a time limit should apply to any such form of State aid.

EU firms benefiting from such support could enjoy a more competitive position compared to non-EU firms that do not benefit from similar levels of public funding, thus having an impact on **international competitiveness**.

By reducing uncertainty, this option could have an impact on **cost/price competitiveness**, as the cost of capital would be reduced and the availability of funding for projects involving green hydrogen production would be increased.

The premium offered to green hydrogen producers could have an impact on i**nnovation and research** and **innovative competitiveness.** This policy option could, more generally, foster the hydrogen sector's capacity to bring new products to the market and to improve the features of the current ones, through the application of new electrolysis technologies, such as PEM.

Environmental impact

This policy option could have indirect effects on **the emission of GHGs into the atmosphere**, by facilitating the production of green hydrogen over more emission-intensive forms of hydrogen that can be used in various industrial sectors, including the steel industry.

This option also **promotes sustainable production**, by fostering a more sustainable production of hydrogen, which can be used in industry and other sectors of the economy. This can, in turn, reduce the use of alternative carbon-intensive sources of energy and feedstock.

This option could also have an impact on the **transport and use of energy,** by increasing the demand for green hydrogen and, subsequently, for the RES-E needed to produce it.

6.4.5. Option GH5: providing financial support for the development of hydrogen transport infrastructure

Economic and competitiveness impact

This option could have a positive impact on **trade and investment flows**, especially in the long run. The development of a large-scale hydrogen transport infrastructure could enable imports and exports of green hydrogen outside and inside the EU, provided that there is some level of regulatory convergence regarding product standards, that would need to be applicable and verifiable in third countries too. Nonetheless, this could come at the expense of other decarbonisation options, including, for example, the increased electrification of hard-to-abate sectors and the development of biomass-based solutions.

This policy option would also have a positive impact on the **competitiveness of businesses**, lowering the cost of doing business by reducing costs associated with the transport of hydrogen. This can also have an impact on **cost/competitiveness**, as ic could potentially lead to a reduction of the energy price for green hydrogen consumers. If proven cost-effective, the retrofitting of existing natural gas pipelines could also result in a cost reduction. The retrofitting of pipelines would involve some level of restructuring in the natural gas sector. At the same time, the development of a green hydrogen pathway at the expense of hydrogen produced from natural gas could have a negative impact on the size of the natural gas grid. Some stakeholders believe that this option could have a positive impact on cost, as pipelines could represent the most cost-effective means to transport hydrogen.

An impact on **public authorities** could also be expected in terms of budgetary consequences. The planning and development of hydrogen transport infrastructure may require more intense public support, stemming from both national and EU-level funding sources.

Based on the location of the specific transport infrastructure(s) that will receive financial support, the economic impact could be greater in **specific regions** . The choices made by public authorities could influence the location of green hydrogen production and consumption hubs, which can have a significant positive impact on local job creation and retention.

Environmental impact

The policy option could, in the long run, **lower the emission of GHGs into the atmosphere** by replacing natural gas infrastructure. This can have a positive impact on both carbon dioxide and methane emissions. By facilitating the transportation of green hydrogen to industrial consumers, such as the steel sector, their respective emissions could also be impacted indirectly.

This option promotes more **sustainable consumption and production patterns**, by facilitating the use of green hydrogen and by replacing the use of natural gas.

Transport and energy use could also be affected, by decreasing the amount of natural gas in the fuel mix.

Social impact

The construction and retrofitting of large-scale infrastructure could have a positive impact on **employment** for companies in the natural gas transport field, as it will help create jobs in the short run and prevent job losses in the long run.

6.5. Comparative assessment

6.5.1. Effectiveness

Option GH1: supporting member states' initiatives towards an early deployment of electrolysers

Supporting member states towards the early deployment of electrolyser capacity is highly effective for stimulating green hydrogen production, which can in turn enable the decarbonisation of the steel industry. Given that member states actions alone could be insufficient, EU-level guidance and coordination coming in the form of strategies and legislation could provide effective solutions for stimulating the green hydrogen production in the EU. In particular, more clarity on State aid rules could allow member states to implement their green hydrogen plans more effectively. Instruments such IPCEIs can provide complementary mechanisms to measures implemented at national level. Further coordination through high-level groups could also allow member states to share best practices and refine their domestic initiatives. Overall, stakeholders that participated in the public survey considered this option the most effective one, especially in regard to bridging the potential gap between supply and demand for RES-E. Respondents to the in-depth interviews highlighted that the EU support should focus on increasing the production of low-cost green hydrogen.

Option GH2: supporting financing and deployment of (public or private) electrolysers at EU level

Providing financial support at EU level for the deployment of electrolysers is a highly effective option to foster green hydrogen production, which can in turn enable the decarbonisation of the steel industry. This represents one of the more direct approaches that could be adopted at EU level for targeting specific investments. It also represents an effective option for developing cross-border projects between EU member states. Overall, the stakeholders that participated in the public survey considered this option to be highly effective.

Option GH3: improving the EU-wide framework for RES-E GOs (covering both electrons and molecules)

This option, which is more administrative in nature, can provide valuable information for final consumers of green hydrogen, which is necessary for showing the reduction in GHG emissions. It can also ultimately allow green hydrogen producers to charge a premium for their product. This can in turn spur further investments and expand electrolyser capacity in the EU. Nonetheless, this option does not provide any mechanism for direct intervention and, therefore, its effectiveness depends on the behaviour of market actors. Some stakeholders consider it as a necessary condition for the development of green hydrogen, which will then provide a framework for proving and ensuring the reduction in GHG emissions. However, the respondents of the public survey overall considered it as the least effective option among the ones provided.

Option GH4: offering a premium to producers of green hydrogen (e.g. through CCfDs)

By covering part of the OPEX and CAPEX of green hydrogen producers, and especially by stabilising revenue streams and reducing risk, this option could provide a highly effective solution to foster the deployment of new electrolyser capacity in the EU. By adjusting the amount of funding available, this option can also enable member states to control the pace at which new electrolysers are developed and the total capacity that will be installed. Both the respondents of the public survey and the participants of the in-depth interviews considered this option as highly effective.

Policy Option GH5: providing financial support for the development of hydrogen transport infrastructure

Providing financial support for the development of hydrogen transport infrastructure is an effective option to foster the development of a hydrogen economy at both national and EU level. It can allow suppliers to be easily linked to the sources of demand, such as the steel industry. Nonetheless, this option does not provide a targeted solution for the deployment of green hydrogen in particular, providing the same benefits for all types of hydrogen. Respondents to the public survey considered this option to be very effective, but less so than other solutions that were presented. Still, in some in-depth interviews, the development and expansion of the hydrogen pipeline networks were seen as one of the most significant public intervention measures for promoting green hydrogen production. It was also deemed to have one of the highest CO2 mitigation potentials.

6.5.2. Efficiency

Option GH1: supporting member states' initiatives towards an early deployment of electrolysers

Given the importance of coordinating the efforts for the deployment of electrolyser capacity in the EU, and its relatively low cost compared to other policy options, this alternative represents a highly efficient solution to foster the production of green hydrogen. By providing strategic planning at EU level and drafting legislation that could even out obstacles and clarify requirements, this option could further decrease national-level costs for the deployment of electrolyser capacity. By fostering cooperation between member states, the EU could also ensure that best practices are shared and joint projects that increase efficiency can be developed.

Option GH2: supporting financing and deployment of (public or private) electrolysers at EU level

Supporting the financing and deployment of electrolysers at EU level provides targeted support that can have a direct impact on the development of electrolyser capacity. Nonetheless, this option has one of the most significant impacts on the EU budget. The high costs involved can limit the amount of funding that could be available for this option. Therefore, this type of measure should be targeted at supporting consortiums that encourage the cooperation between market actors across member states, which would otherwise face significant barriers to deployment.

Option GH3: improving the EU-wide framework for RES-E GOs (covering both electrons and molecules)

Improving the EU-wide framework for RES-E GOs is an important option to foster the production of green hydrogen, but it does not provide any direct means to control the size and pace at which electrolysers are developed. Nonetheless, being a mostly administrative measure, it does represent one of the less costly options that can be implemented.

Option GH4: offering a premium to producers of green hydrogen (e.g. through CCfDs)

Offering a premium to producers of green hydrogen provides one of the most direct methods to ensure that member states are capable of developing new electrolyser capacity, with a significant amount of control over pace and size. However, it does represent one of the most expensive options. The price tag of schemes such as the CCfD can surge if carbon prices are lower than expected for extended periods of time. Therefore, a significant financial buffer could be needed to ensure that CCfD prices can be honoured by the awarding authority. Nonetheless, if such support schemes are developed in a competitive auctioning setting, this could lead to increases in efficiency, as competition between suppliers will spur them to develop technologies that can produce the highest amount of green hydrogen possible at the lowest possible costs.

Option GH5: providing financial support for the development of hydrogen transport infrastructure

While necessary for a broader deployment of hydrogen economy, this option is very costly and does not provide any targeted solution to ensure the deployment of green hydrogen specifically. Nonetheless, providing financial support for the development of hydrogen infrastructure could guarantee investors in electrolyser capacity that they will be able to deliver to the product where demand is located, such as the steel industry.

6.5.3. Feasibility

Option GH1: supporting member states' initiatives towards an early deployment of electrolysers

Most member states have already developed national hydrogen strategies that aim to stimulate domestic production and consumption, in line with EU-level objectives. EU-level coordination efforts through the elaboration, revision, and implementation of the National Energy and Climate Plans and the Long-term Strategies, in accordance with the Regulation on the Governance of the Energy Union, as well as the National Recovery and Resilience Plans, provide a means for supporting member states in their initiatives. On average, stakeholders (especially those from the non-steel sector) believed that it is very likely that this policy option received enough support from EU and national policymakers to be properly implemented.

Option GH2: supporting financing and deployment of (public or private) electrolysers at EU level

Already existing EU instruments can support financing new electrolyser capacities. Such sources include HEU, the EU ETS IF, and the RFF. However, due to the limited size of the EU's budget, the amount of available funding could be limited if member states do not provide adequate funding at domestic level. Stakeholders believed that this policy option is the least likely to receive enough support from EU and national policymakers to be properly implemented.

Option GH3: improving the EU-wide framework for RES-E GOs (covering both electrons and molecules)

GOs are already used as an instrument to track and prove the origin of RES-E generation. The legal basis for this policy option is also already in place, as the REDII Directive has extended this system to renewables gases too, which can include hydrogen. To ensure harmonisation between the GO systems of the various member states, however, more efforts are needed. On average, stakeholders believed that this policy option is somewhat likely to receive enough support from EU and national policymakers to be properly implemented.

Option GH4: offering a premium to producers of green hydrogen (e.g. through CCfDs)

This policy option can be feasible, provided that the premium is awarded to green hydrogen producers via a competitive and open auctioning scheme. Mechanisms such as CCfDs can have the additional advantage of fostering competition between different technologies, in order to ensure that the lowest premium possible is offered to producers. On average, stakeholders believed that it is somewhat likely for this policy option to receive enough support from EU and national policymakers to be properly implemented. Steel industry respondents believed this to be true significantly more than non-steel industry respondents.

Option GH5: providing financial support for the development of hydrogen transport infrastructure

The measures adopted as part of the revisions of the TEN-E Regulation can increase the feasibility of this option. Initiatives such as the European Hydrogen Backbone already offer a vision for a dedicated hydrogen infrastructure across Europe. Stakeholders believed that this policy option is the most likely to receive enough support from EU and national policymakers to be properly implemented, especially by non-steel industry respondents, mainly because it represents a necessary condition for the development of a hydrogen economy in Europe.

6.5.4. Coherence

Stakeholders generally considered that all policy options are conducive to the decarbonisation of the steel sector through the use of hydrogen technologies, therefore they are compatible with EU targets and objectives for energy and climate policy. Respondents sait that the above mentioned policy options were to a high extent coherent with other relevant EU initiatives in the field. The options are aligned with the EC's hydrogen strategy for a climate-neutral Europe. Option GH2 of supporting financing and deployment of (public or private) electrolysers at EU level was believed to be the most coherent with other relevant EU initiatives, while Option GH4 of offering a premium to producers of green hydrogen (e.g. through CCfDs) was believed to be the least coherent option with EU initiatives among the ones presented.

*Table 10: **Overview of policy solutions – Green hydrogen***

	Effectiveness	Efficiency	Feasibility	Coherence
Option GH1: supporting MS initiatives				
Option GH2: providing financing for electrolysers at EU level				
Option GH3: improving the GOs framework				
Option GH4: offering a premium such as CCfDs				
Option GH5: financial support for hydrogen transport infrastructure				

Note: This table presents the policy options in the green hydrogen area that would support the decarbonisation of the EU steel industry. The options are assessed based on the four criteria under the Better Regulation guidelines: their effectiveness, efficiency, feasibility and coherence. Colour legend: orange - low, yellow – moderate, green – high. For instance, a policy option that has a green cell in the Effectiveness column is considered to be "highly" effective. Source: authors' own composition

Source: CEPS (2021)

7. Carbon capture, usage, and storage

7.1. Problem identification

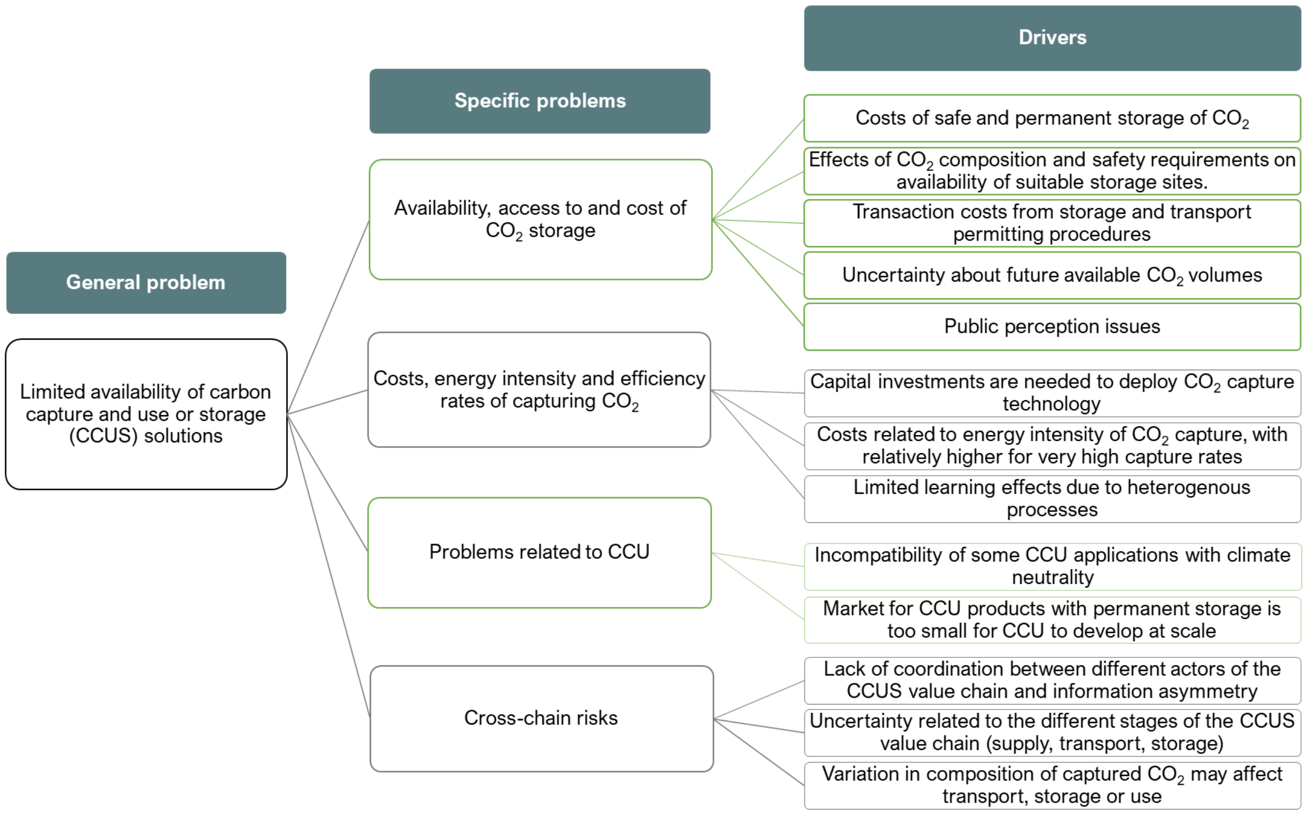
Carbon capture and use or storage (or sequestration) (CCUS) is a technology that has long been discussed as an abatement option (Elkerbout et al., 2019). Initially, this was aimed at the power sector, the idea being that power plants could continue to run on fossil fuels, and the CO_2 produced was to be captured and permanently stored to avoid increasing the CO_2 concentration in the atmosphere. Even if the intent to support CCS deployment was reflected in EU policies, such as the EU ETS NER300 funding mechanism, **CCUS deployment did not materialise at scale**.

An alternative to storing the CO_2, is using it (CCU). However, the potential contribution of CCU to the EU climate neutrality target depends greatly on **how long the CO_2 remains bound** in products. While markets for the use of CO_2 already exist, their scale is small, particularly for such uses that avoid a later release of the CO_2 in the atmosphere for such a timeframe that would be **compatible with climate neutrality**.

CCUS can be especially useful for the processes for which **alternative decarbonisation options are either absent, too few or too costly** (De Bruyn et al., 2020, p. 31). One of the technological pathways considered by the steel industry, SCU, recognises the potential for CCUS to decarbonise the steel industry (for further details, see also GREENSTEEL Deliverable D1.2). One of the advantages of a CCS pathway is that the core process of producing steel does not need major transformations, as the CCS installation is used to capture existing BF gases (Toktarova, 2020, p. 15). Indeed, the International energy agency (IEA, 2020f, p. 23) appreciates that **steel production routes based on CCUS currently represent the most advanced and less costly decarbonisation option for virgin steel**, which currently amounts to around 70% of the global steel production.

In the context of climate neutrality, emissions need to be reduced as far as possible. **Technologies and infrastructures that can address hard-to-abate emissions** across various industries are therefore desirable. While CO_2 capture, as well as its transportation and storage, come with their own set of challenges, CCS has nonetheless a prominent position in many decarbonisation scenarios. For example, in the EC's long-term strategy (2018b), **the contribution of CCS to decarbonisation is between 52 and 606 MtCO2 per year in 2050**, depending on the scenario. When it comes to technological readiness, the Global CCS Institute (2020) estimates that there are currently 51 large-scale CCS facilities worldwide, 19 of which are operating and the rest are at various stages of development. CCU is already applied commercially today, although it is mainly used in enhanced oil recovery – an activity which is not compatible with climate neutrality in the long term.

Figure 15: Problems hindering the use of CCUS



Source: author's composition.

7.1.1. General problem

While CCUS has received support both through EU policies and funding instruments, large-scale commercial deployment of CCUS has not materialised in energy-intensive industries. Specific challenges related to **CO_2-capture, transportation, and storage or use, as well as cross-chain risks** between these different parts of a CCS-value chain, have contributed, to various extent, to undermine the case for CCUS. This general problem is confirmed by the stakeholders consulted in the Inception phase.

7.1.2. Specific problem CCUS1

Availability, access to and costs of CO_2 storage: CO_2 can be stored on land or in geological formations offshore. Examples include depleted natural gas and oil fields or aquifers. In theory, storage in such conditions is technically mature, but currently it is only profitable if used for enhanced oil and gas recovery (EOR) (De Bruyn et al., 2020, p. 31). In principle, it is possible to store CO_2 safely and permanently, but this comes at a cost. CO_2 storage also needs to be coordinated with suppliers of CO_2 (i.e. those capturing CO_2), for reasons relating to both the certainty of available supply and its composition. Additional transaction costs may arise due to permitting issue for the transport and storage of CO_2. The IEA (2020f, p. 16) estimates that 70% of current CO_2 emissions are within 100 km of potential storage, a relatively practical and cost-effective range for transporting captured CO_2. Nonetheless, costs can vary based on the location of both the CCS installation and the storage facility: pipelines in sparsely populated areas can cost 50-80% compared to pipelines in densely populated areas, while offshore pipelines can increase transport infrastructure costs by 40-70% (IEA 2020e, p.105).

Cost estimates for CO_2 storage in Europe range from €1-20€/tonne and vary depending on the formation type. Storage in depleted oil and gas fields can, for example, significantly reduce costs compared to storage in saline aquifers offshore (IOGP, 2019). The role of CO_2 transport is also important, as it links the two primary components of the CCS value chain Transport costs range from €5€/tonne for pipeline transport to €16€/tonne for long-distance shipping (ZEP, 2020).

- **Driver CCUS1.1**: **storing CO_2 permanently and safely is costly**. While CO_2 storage in a safe and permanent way is possible, the associated costs may limit the availability and profitability of appropriate storage sites and discourage their operation.
- **Driver CCUS1.2**: **CO_2 composition and safety requirements can limit the availability** of suitable storage sites, as the composition of the CO_2 stream and its purity can affect storage requirements, something that adds up to cross-chain risks (see Specific problem CCUS4).
- **Driver CCUS1.3**: **permitting procedures for storage and transport** may create additional transaction costs. These procedures may simply be administrative ones, but they may hinder the deployment of CCUS. Transportation can add costs, particularly if the capture site is far from the storage site; in addition, other means of transportation than pipelines remain to be fully recognized.
- **Driver CCUS1.4: uncertainty about future available CO_2 volumes affects the business case for storage operators.** Difficulties in coordination with companies capturing CO_2 leads to uncertainty about available volumes, which has wide effects across the CCUS value chain, including on the business case for storage operators (see Specific problem CCUS4).
- **Driver CCUS1.5: public perception** issues linked to CCUS may create a barrier to identify storage sites, as it is not universally accepted as a desirable climate change mitigation technology. Even if accepted at (supra)national level, local governments may object to CO_2 storage for fear of public backlash.

Respondents to the survey carried out in the Inception phase confirmed, at least to some extent, the above-mentioned drivers. Public perception issues, followed by complex permitting procedures and the need to comply with specific requirements for safe and permanent storage of CO_2, are the most significant drivers limiting the availability and increasing costs of CO2 storage.

7.1.3. Specific problem CCUS2

Costs of capturing CO_2: for climate neutrality, the highest feasible capture rates are desirable to limit the amount of residual emissions. While carbon capture technology already exists, the technology may need to be adapted to specific installations such as primary steelmaking. In addition to such upfront capital investments, costs also arise from its energy intensity, particularly at higher capture rates. Depending on the exact production process and capture process, the composition of captured CO_2 may vary, thereby necessitating further purification processes. Heterogeneity in capture processes may limit learning effects across different industries, which may lead to sustained high technology costs. For example, CO_2 capture can take place in either the pre-combustion or post-combustion stage, or through oxy-fuel capture (Jackson et al., 2019).

Limited learning economies can therefore also be a driver of (sustained) costs of capturing CO_2. Process emissions unrelated to fuel combustion can add further complexity. This may add to competitiveness issues of steel produced using carbon capture versus conventional steel, especially on global markets.

This specific problem was confirmed, at least to some extent, by stakeholders consulted in the Inception phase.

- **Driver CCUS2.1**: **capital investments** are needed to deploy CO_2 capture technology, as it is a specific technological process that requires capital investments for existing or future production facilities to adapt specific installations. Cost estimations show a price increase of steel by 20-25% (De Bruyne et al., 2020, p. 77) or even up to 30-41% (Global CCS Institute, 2017, p. 6). The Global CCS Institute (2017) estimated the cost of CO_2 avoided for the iron and steel industries at roughly €73-87/tonne CO_2. While these estimates include all stages of the CCS process, the capture costs represent the greatest cost component. Indeed, CAPEX estimates for CO_2 capture can range up to €90/tonne CO_2, with investment needs for a full industrial plant estimated to be around €200 M (GREENSTEEL 2021c, p. 33). The CAPEX costs for CO_2 capture in steel are estimated at €500/tonne of steel (De Bruyne et al., 2020).
- **Driver CCUS2.2: CO_2 capture is energy-intensive, and energy costs are higher at very high capture rates.** Most CCS installations are designed to capture around 85-90% of CO_2 from the point sources (Budinis et al., 2018). Increasing the capture rate is not a matter of technical barriers (as capture rates of 98% or higher are technically feasible), but of the costs that an increased capture rate would require. To support climate neutrality, it is inherent that the additional energy required (over time) needs to be produced without emissions as well.
- **Driver CCUS2.3**: due to the **heterogeneity** of industrial processes to which carbon capture may be applied, **learning economies may be limited**. Even within the steel sector itself, costs can vary depending on how much of the steelmaking process is covered by carbon capture installations. Toktraova et al. (2020, p. 12) estimate that the cost of CO_2 avoidance for BF gases capture varies between €54-72/tCO_2, but the price can go up to €60-100/tCO_2 if CO_2 is captured from other sources as well (i.e. coke ovens, sinter plant lime kiln, etc.), meaning that multiple CO_2 streams need to be equipped with capture technology.

All these drivers are considered at least to some extent important by the respondents to the survey conducted during the Inception phase. High capital investments and energy costs linked to high CO_2 capture rates are considered as the main causes of high capture costs. One stakeholder also stressed that R&D investments in CCUS are quite limited, thus slowing down cost reductions stemming from technological progress; while one steel-sector respondent noted they considered capture technology to be state of the art and without facing any significant bottlenecks.

7.1.4. Specific problem CCUS3

Challenges related to carbon capture and use (CCU): an alternative to storing CO_2 is to use it. Using CO_2 is not necessarily equivalent in climate policy terms to storing it, however. Depending on how the CO_2 is used, some part of the captured CO_2 may still end up in the atmosphere. While this specific problem was to some extent confirmed by the respondents to the survey conducted in the inception phase, its relevance for the respondents appears to be lower than the relevance of the other specific problems affecting CCUS.

- **Driver CCUS3.1: not all use cases for CO_2 are compatible with the EU's climate neutrality objective** (if applied at scale), as the CO_2 may be used in a way where it will still be emitted at a later stage. Examples include synfuel production or EOR, the latter linked to oil production (Biniek et al., 2020). This means that CCU is a qualitatively different type of abatement option compared to CCS, which has implications for its desirability in being deployed at scale in a climate neutrality policy framework.
- **Driver CCUS3.2:** permanent use of CO_2 in products is possible but the **global market for these products is, for now, too small** for CCU to develop at scale. While there are use cases where CO_2 is stored permanently (or at least on climate-policy relevant timeframes), such as certain materials including plastics or concrete (SETIS, 2016), this potential market may be smaller than non-permanent ways of using captured CO_2, such as using it to produce transport fuels, as explained in Driver CCUS3.1. Nevertheless, the existence of a market for using non-permanently stored CO_2 could make carbon capture itself more attractive, thereby helping reduce the costs of CCS overall.

Stakeholders consulted in the Inception phase confirmed that both drivers may limit to some extent the climate neutrality of CCUS. Interestingly, steelmakers gave less importance to the size of global markets for CCU products as a driver compared to others.

7.1.5. Specific problem CCUS4

Cross-chain risk may hinder deployment of CCUS for the steel industry.

CCUS requires a full value chain across the different stages of capturing CO_2, transporting it, and storing or using it. There are potentially different operators for the different stages, but each depends on the other delivering. Without the availability of storage sites there may not be sufficient interest to invest in transportation infrastructure, and vice versa. Without sufficient volumes of captured CO_2, there may not be sufficient incentive to invest in the downstream infrastructure, and vice versa. The driver of these cross-chain problems (Ku et al., 2020) is the difficulty of coordinating between several different actors, often in different countries and industries, which thereby raises transaction costs. This specific problem was, to some extent, confirmed by the stakeholders participating in the online survey on policy problems conducted during the Inception phase.

- **Driver 4.1:** it is **challenging to coordinate** between the different actors of the **CCUS value chain**. Information asymmetry plays a role. The transnational and cross-sectoral nature of the CCUS value chain can further complicate this.
- **Driver 4.2: uncertainty** about any of the stages of the CCUS value chains, such as future supply of CO_2, or of transport and storage infrastructure, can **undercut the investment case** for actors in other stages. As all the stages depend on each other for their success, investment in one stage does not necessarily make sense in the absence of (future) availability of the others.
- **Driver 4.3:** the **composition of the captured CO_2** may affect how it can be transported, stored, or used and increase coordination costs with transport and storage operators.

The three drivers are considered to contribute (to some extent) to cross-chain risks in the CCUS value chain according to the stakeholders consulted in the Inception phase. Uncertainty about the supply of either CO_2 or of transport and storage infrastructure is considered the most important among the drivers in contributing to cross-chain risk and hindering the deployment of CCUS for the steel industry.

7.2. EU right and need to act

The legal basis for an EU policy supporting the deployment of CCUS solutions can be found in **Art. 191 of the TFEU**, which requires the EU to maintain policies that protect the environment and, specifically, measures "at international level to deal with regional or worldwide environmental problems, and in particular combating climate change." **Art. 191(2)** specifies that EU environmental policies should follow the **precautionary principle, rectify damage at the source, and ensure that polluters pay.**

CCUS technologies can reduce GHG emissions and thereby support the EU's climate change mitigation policy. Since CCUS can prevent carbon dioxide from entering the atmosphere, it fulfils the precautionary principle, while the application of CCUS technologies can also address emissions at the source.

Art. 173 TFEU on industry states that EU action **shall ensure that the conditions necessary for the competitiveness of the Union's industry exist**. The EU industrial policy should be aimed at **"speeding up the adjustment of industry to structural changes"**, which applies to industrial transformation in the context of the energy transition, climate policy and the European Green Deal. EU action should also **foster "better exploitation of the industrial potential of policies of innovation, research and technological development".** CCUS as a set of emerging technologies can benefit from increased innovation and technological development.

Art. 4(2) of the TFEU also makes clear that environmental and energy policies are based on **shared competence** between the EU and its member states. **Art. 6 TFEU** states that, in the area of **industrial policy, EU policy should support, coordinate or supplement** member states' policies.

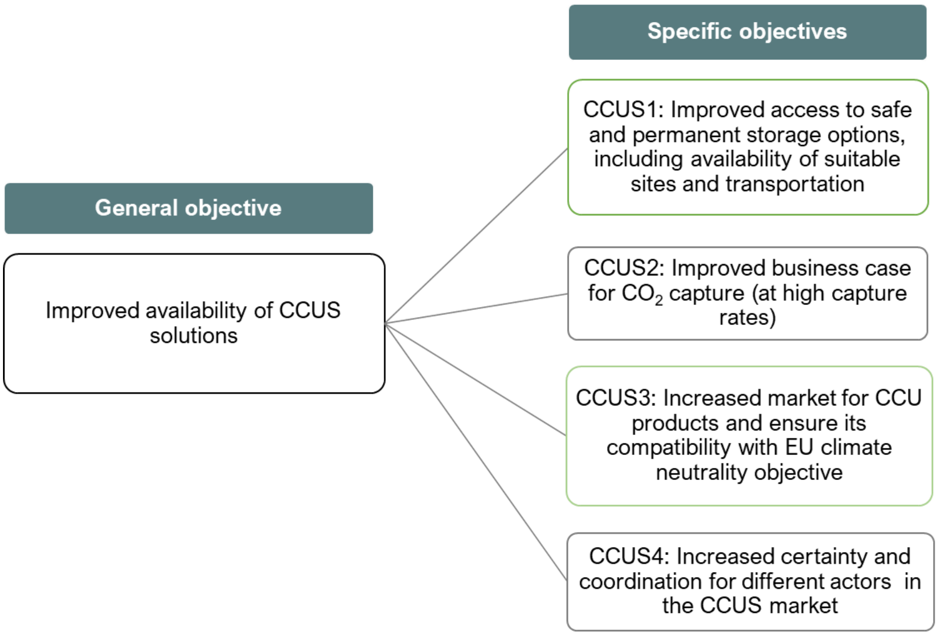
As a global problem, climate change cannot be addressed by a single country. EU cooperation is therefore advantageous. Divergent European policies supporting emissions reductions could also undermine the efficiency of individual member states' policies due to the risk of carbon leakage. From a technological development point of view, there are innovation spillovers that create added value for EU intervention. EU intervention can reach a higher scale, and therefore greater efficiency than individual member states' action. However, as environment and industry are shared and supporting competences respectively, EU action on climate change and CCUS is not intended to replace national policies fully, but to complement and to act only where it is efficient to do so.

7.3. Policy objectives and options

7.3.1. General objective

The general objective of an EU policy intervention in the field would be to **improve the availability of CCUS solutions** so that they could contribute to the emission reductions targets of the EU and the decarbonisation of hard-to-abate industries such as steel.

Figure 16: Policy objectives on availability of CCUS solutions



Source: author's composition.

7.3.2. Specific objective CCUS1 and policy options

Specific objective CCUS1: improved access to safe and permanent storage options, including the availability of suitable sites and transport methods: storing CO_2 permanently and safely can be costly, and storage sites must be identified and made available before any CO_2 can be stored. CO_2 composition, safety requirements, permitting procedures and public perceptions can all limit the availability or increase the cost of such sites. Uncertainty about future available volumes to be stored also negatively affects the business case. Therefore, EU policies should aim to improve the availability of, and transportation to, safe and permanent storage options, including through improving the business case for making available and operating storage sites.

Baseline: leave it to the market and certain member states to invest in storage and transportation options and spearhead the development of CCUS as an option for decarbonising industry. Let storage remain ineligible for funding under CEF, while providing potential funding opportunities through the IF.

Option CCUS1: supporting a market for low carbon/decarbonised products, for example through standards or public procurement.

By creating demand for low carbon or decarbonised products, through product standards or public procurement, the EU can also create demand for the technologies needed to produce such products. In this way, EU support can pass through to support the uptake of, and market for, different technologies. While the effect would not be specific to CCUS technology, increased demand for low carbon or decarbonised products could also create a greater demand for transportation and storage options. This may thus improve certainty and the investment case for operating CO_2 transportation and storage and promoting improved availability and access for the purpose of producing low carbon products including green steel.

Public procurement and standards are examined more in detail in the Funding chapter.

Option CCUS2: supporting other CO_2 transport methods beyond pipelines, as well as recognising and promoting negative emissions technologies in ETS.

The current ETS Directive only refers to the transport of CO_2 by pipeline. This could be amended to explicitly include and support other transport methods (such as by ship or road/rail), so that there is clarity and certainty for market actors that all forms of CO_2 transport are treated equally. As some CO_2 storage sites can accept CO_2 transported by other means than pipelines, this could encourage greater confidence in investments in such sites, and transportation modes other than pipelines, as well as promote expectations of more flexible access to more storage sites for those involved in the capture stage. The EC has indicated its interest in making this change, but it is yet to be completed.

Recognising and promoting negative emissions in the ETS Directive could also create greater demand for CCS infrastructure, and thus improve availability and access also for the steel sector. Bioenergy with CCS and Direct Air Capture with CCS are two ways in which negative emissions could be realised, and they also rely on CCS technology and infrastructure. By fostering an increased supply of CO_2 for storage through the promotion of negative emissions, it could have a positive effect on the investment case for CO_2 transport and storage operators. This would entail including a definition of negative emissions in the ETS Directive. Negative emission governance requires strict carbon accounting and monitoring, reporting and verification (MRV) rules.

Option CCUS3: providing funding (CAPEX and OPEX) for CO_2 storage and transport infrastructure, for new infrastructure or the adaptation of existing ones.

Storage and transport infrastructure is key to enable the use of CCUS technology for the decarbonisation of the industry, including the steel sector, but suffers from high investment costs and uncertainties. In this regard, efforts at member-state level could be important, but funding could also come from EU level. Using existing infrastructure, such as gas pipelines and storage from depleted oil fields, could avoid the installation of new infrastructure and, potentially, reduce costs. However, while significant gas pipeline networks exist in the EU, other technologies such as hydrogen or biogas may compete for the same infrastructure. Previous oil and gas sites may also potentially be repurposed for CO_2 storage and transport at a relatively lower cost than building new sites. While there are few competing uses for this infrastructure, it could be important to facilitate a timely transfer of ownership before it is decommissioned. New infrastructure could also be supported by EU funds through the CEF or through an IPCEI, which would enable more direct support from member states in terms of State aid. The role of member states would also be important with regards to operation of the infrastructure, as the EU may not have authority to do so. Such operations should guarantee equal access for third parties, while also ensuring any supply of CO_2 meets the required criteria to be compatible with the infrastructure needs. Member states could be encouraged to develop national CCUS strategies, including through their National Energy and Climate Plans.

7.3.3. Specific objective CCUS2 and policy options

Specific objective CCUS2: improved business case for CO_2 capture, especially at high-capture rates: while the technology for CO_2 capture already exists, it is energy-intensive and costs can increase significantly at high-capture rates; moreover, heterogeneity of industrial processes makes learning difficult. For CCUS to be able to contribute to the decarbonisation of the steel industry, the economic rationale would need to be improved for capture to take place at high rates. EU policies should thus help improve the business case for CO_2 capture, particularly at high-capture rates, through helping reduce costs, facilitate learning, or improve the economic rationale.

Baseline: leave it to the market and certain member states to provide investment and support for CO_2 capture, while providing some funding through CEF and the IF.

Option CCUS4: increasing carbon price to foster emission reductions, potentially as a result of higher (short-term) climate targets.

The chapter on carbon pricing (Chapter 4) includes options that may lead to further scarcity in the EU ETS, and therefore to higher ETS prices. A second-order effect may be that CCUS may become more competitive with higher carbon prices. Higher carbon prices may also foster higher capture rates, as the carbon costs of any residual emissions would increase with higher carbon prices.

The impacts of this option are accessed in detail in Chapter 4.

Option CCUS5: providing increased public support and funding for R&D&I to optimise capture at high rates.

While technology for capturing CO_2 at high rates exists, this is often tied to high energy intensity and, as a result, costs. Optimizing capture at high rates would be important for CCUS to be able to contribute to the EU's climate neutrality target, as without capture at high rates, some emissions would still be released and would need to be compensated for otherwise.

Support could take the form of increased focus on CCUS in HEU funding and the EU ETS IF, with emphasis on improving the process for high capture rates. Support can also go beyond funding and focus on creating enabling conditions for R&D&I, for example in the form of designating an additional European Research Infrastructure Consortium specifically focused on improving capture at high rates.

If funding is provided for CCU projects, this should be limited to climate-neutral compatible CCU applications, in line with the closed list suggested in policy option CCUS6 below.

7.3.4. Specific objective CCUS3 and policy options

Specific objective CCUS3: increased market for CCU products and ensure its compatibility with EU climate neutrality objective: the market for CCU products is currently small, particularly for products that permanently use CO_2. The use of CO_2 could also potentially be at odds with the

EU climate neutrality objective, if emitted at a later stage and applied at scale. As such, this policy objective should aim to help increase the market for CCU products, taking into account the implications on the EU's climate neutrality target.

Baseline: leave it to the market and individual countries to promote the development of a market for CCU with more or less permanence of CO_2.

Option CCUS6: promoting the use of climate-neutral CO_2 (based on a list of CCU applications considered compatible with EU climate targets).

The ETS Directive could be revised so that the CO_2 captured for later use (CCU) would not result in an obligation to surrender allowances. The market for using CO_2 could be larger than the market for storing CO_2. By allowing CCU, capturing CO_2 in general may become more attractive and cost-competitive.

However, not all CCU applications are equal, and only those that are compatible with climate neutrality should be considered in such an ETS revision in order to support the 2050 EU climate targets. In this regard, the creation of a list that includes only CCU applications considered compatible with EU climate targets should be used as a basis. This list would need to be created in a transparent manner, should be based upon rigorous accounting and monitoring, and should be periodically reviewed.

7.3.5. Specific objective CCUS4 and policy options

Specific objective CCUS4: increased certainty and improved coordination for different actors in the CCUS market: with asymmetry of information, uncertainty about the supply of CO_2 volumes, transport infrastructure and storage, as well as implications on potential transport, use and storage based on composition, there are significant challenges related to cross-chain risks and lack of coordination. EU policies could therefore facilitate information sharing, improve coordination, and increase the certainty of supply of CO_2, transport, and storage options.

Baseline: allow market actors and individual countries to make ad hoc agreements between themselves to increase coordination and certainty.

Option CCUS7: providing a platform where different actors in the value chain meet and coordinate (e.g., by establishing an EU CCUS alliance), with the purpose of facilitating increased certainty and mitigating cross-chain risks in the CCUS value chain.

Such a platform would need to be inclusive and facilitate cooperation between a broad range of stakeholders, to ensure wide acceptance and buy-in as well as promote collaboration and ideas between various actors in the whole CCUS value chain. An EU industrial alliance, a CCUS Alliance, could be well placed to deliver such a platform, and it could be modelled on existing successful alliances. This could have the potential to help improve coordination and planning, and to promote coherent development of whole CCUS value chains. Importantly, it could facilitate joint projects and cooperation among industry actors, thus reducing cross-chain issues of uncertainty of supply, transportation and storage availability for CO_2, which can negatively affect the investment case for different stages of the value chain. Moreover, by promoting broad participation of non-industry actors too, such an alliance could help mitigate potential public perception issues.

Option CCUS8: supporting clusters/industrial symbiosis (e.g., through the creation of an IPCEI).

Clusters and industrial symbiosis can importantly allow for scaling up CCUS, sharing of transport infrastructure among different actors, and provide greater certainty for market actors through continuous or formalised cooperation. As such, they can help mitigate much of the cross-chain risk in the CCUS value chain. Such support from the EU could take the form of a designated IPCEI, which would enable member states to utilise State aid and mobilise market actors to support the creation of a European CCUS value chain. Such an IPCEI could be focused on either CCS or CCU, and should be compatible with the EU climate neutrality goal.

7.4. Impacts

7.4.1. Option CCUS1: supporting a market for low carbon/decarbonised products, for example through standards or public procurement

See Chapter 3 on Funding.

7.4.2. Option CCUS2: supporting other CO2 transport methods beyond pipelines, as well as recognising and promoting negative emissions technologies in ETS.

Such an ETS revision would have two distinct aspects: supporting other modes of transport beyond pipelines, and promoting negative emissions technologies, which would have separate impacts.

Economic and competitiveness impact

Economic incentives set up by market based mechanisms created by Union law: while supporting other means of CO_2 transport beyond pipelines in a revision of the ETS Directive may mainly be a formality from a legislative perspective, it could create greater certainty for those making investment decisions into CCUS (Zero Emission Platform, 2020). Thus, it may affect relevant actors' perception of costs and economic benefits, particularly regarding the cost of carbon emissions, as it would create certainty that CO_2 captured and transported through other means of transport would be eligible to be discounted under the ETS. Fostering negative emissions, by allowing them to be credited under the ETS, would entail a more notable change in policy. While there are several negative emissions technologies, CCS is a key aspect of many, such as bioenergy with CCS (BECCS) and direct air capture with CCS (DACCS). As such, it could reduce the cost of carbon emissions for those using negative emissions technologies, as they would not need to surrender or buy allowances for the associated emissions. For the ETS market, promoting negative emissions could make more allowances available, and potentially reduce the carbon price (depending on scale). As such, it could affect the price signals under ETS, unless correcting mechanisms are implemented.

The cost of capital, e.g. price and availability of financing: similarly, supporting other modes of transport could improve the availability of financing, especially for alternative transport methods. It could also make funding for capture technology installation more easily available, if investors had greater certainty that the emissions captured and transported would be eligible under ETS. Investment in capture technologies could become more attractive also as a result of promoting negative emissions. If it triggers investments in CCUS at a sufficient scale, it could, over time, potentially contribute to a reduction in the cost of capital (especially installation costs), as a result of economies of learning and scale. Such a revision of the ETS Directive may also make investment in transport and storage more attractive, due to incentives for capturing emissions and greater demand for storage and transport infrastructure likely to follow.

Specific impact on certain regions: greater certainty as a result of supporting other modes of transport could also positively affect investment decisions into CCUS in regions where transport by pipeline would be difficult or too costly.

Budgetary consequences for public authorities at different levels of government: strict carbon accounting and MRV rules may be necessary for an inclusion of negative emissions in the ETS Directive, and that could entail some administrative burden with an impact on member states' budgets.

The introduction and dissemination of new production methods, technologies and products: by supporting other modes of transport and fostering capture, which could create an increased demand for transport, this option could also encourage the development of transport solutions optimized for CO_2.

Competitive position of EU firms with respect to non-EU competitors: overall, this option could have an indirect, but positive, impact on the competitiveness of the EU steel sector. The stronger investment case and greater certainty created by an ETS revision could improve the availability of CCUS solutions for industry, including the steel sector. This may, in turn, affect the competitiveness of the industry in the long run, as it will have to adapt to a net-zero reality in the EU by 2050. Availability and economic feasibility of decarbonisation technologies such as CCUS matters.

Environmental impact

Emission of GHGs (e.g. carbon dioxide, methane, nitrous oxide, etc.) into the atmosphere: through its potential effects on the cost and availability of CCUS solutions, this policy option could help reduce emissions of GHGs from industries, steel sector included. However, some additional emissions could be associated in the short run, because of the erection and operation of capture installations. Additionally, fostering negative emissions in the ETS could make the use of BECCS more attractive for the production of steel. This could have a positive impact on the overall emissions from the sector, especially if it replaces fossil sources of energy, and may lead to negative emissions. As such, it could help facilitate the decarbonisation of the steel sector.

Change in land use: while indirect, should the use of biomass by industries be promoted to a large degree, this option could affect land use. Larger demand for biomass could mean competitive pressures between different land uses, should this option result in stronger incentives for land owners to use their land for biomass.

Social and other impacts

Factors that would prevent or enhance the potential to create jobs or prevent job losses: social impacts may materialise through the potentially improved availability of CCUS solutions for industry, including the steel sector. Capturing emissions from steel (and other industrial) plants would only require retrofitting capture installations on existing plants, therefore already existing plants could keep working and they would likely not require any significant changes to their production technology. Especially if other modes of transport are supported, this option could avoid pressures to move production, and the associated jobs, to new locations. Moreover, retrofitting capture installations may ensure that industrial production largely remains the same, with the addition of capture technology. This, in turn, may avoid issues related to the need for new or different skill sets among employees, and the potential associated re-training or changes in employee composition at production plants (the only exception being capture operating skills). As a result, it may have a positive social impact by enabling jobs to remain where they are without pressures to change location or skills needed. Additionally, it could create jobs associated with the operation or creation of transport infrastructure more directly. These could be related to the creation of new infrastructure or the adaptation of the existing one. Overall, this option could have a positive impact with regards to the Just Transition, as employment and the economy in certain regions that have focused on fossil energy may be less negatively affected by the green transition.

7.4.3. Option CCUS3: providing funding (CAPEX and OPEX) for CO2 storage and transport infrastructure, for new infrastructure or the adaptation of existing ones.

Economic and competitiveness impact

The cost of capital (e.g. price and availability of financing): CAPEX and OPEX funding will notably improve the availability of financing for storage and transport infrastructure, and may also help mobilise private funding. In the longer term it could also translate to lower capital costs, provided that these investments are able to trigger process standardization and production at scale.

Budgetary consequences for public authorities at different levels of government: if funding is provided directly by member states, it could entail the allocation of significant financial resources, so it will have an impact on member states' budgets. Funding provided from the EU budget would likely be from a reallocation of already existing funds, and would not have an impact on member states' budgets, unless a larger share of the next MFF would be earmarked for this purpose.

Competitive position of EU firms compared to non-EU competitors: if funding for storage and transport of CO_2 results in readily available and affordable options for business, than it could have a somewhat positive impact on the competitiveness of the EU industries such as steel, especially in the long run. Availability of technologies that can help industries decarbonise production processes could be key in order to ensure the competitiveness of EU industry, as it will have to decarbonise towards the net-zero target in 2050. Other countries outside the EU may also move to decarbonise their industries or potentially regulate the carbon content of imported products, therefore, the ability of the EU industry to compete could in the future depend on its ability to decarbonise production.

Introduction and dissemination of new production methods, technologies and products: if the existing infrastructure is adapted and used for CO_2 transport, then it would no longer be available for other purposes – having therefore a specific impact on CAPEX and OPEX. This may be more or less relevant depending on the type of infrastructure concerned. Pipelines connected to decommissioned oil and gas fields would have few competing purposes. For existing gas pipelines, however, there could be the competition of other technologies, such as hydrogen.. Thus, a decision to fund the adaptation of existing infrastructure for transport could have an impact on the availability of other green technologies.

Competitive position of EU firms with respect to non-EU competitors: by itself, funding could help improve the competitiveness of EU companies in the CCUS value chain, as it would provide investment or operational support. If the support is successful in improving the availability of CCUS solutions for industry, it could also improve their competitiveness, as they will need affordable and available decarbonisation options to remain competitive in the longer term.

Environmental impact

Emission of GHGs (e.g. carbon dioxide, methane, nitrous oxide, etc.) into the atmosphere: funding for CCUS infrastructure, through its potential effects on improving its availability, may have indirect environmental impacts. These are likely to be a reduction of GHG emission from the steel sector if, similarly to other options, the available CCUS solutions are used by the steel sector to capture and store its emissions. Notably, however, the construction of new infrastructure (whose CAPEX would be covered by this option), as well as the production and transport of the material needed, could result in additional GHG emissions. OPEX or CAPEX funding for the adaptation of existing infrastructure, however, may be less likely associated with additional GHG emissions.

Social and other impacts

See Option CCUS2.

7.4.4. Option CCUS4: increasing carbon price to foster emission reductions, potentially as a result of higher (short-term) climate targets

See Chapter 9 on cross-cutting policy options: policy option on higher carbon price due to increased scarcity in the EU ETS.

7.4.5. Option CCUS5: providing increased public support and funding for R&D&I to optimise capture at high rates

Economic and competitiveness impacts

The cost of capital (e.g. price and availability of financing): similar to Option CCUS3, the funding aspect of this option would have the direct effect of improving the availability of financing for CCUS solutions, notably for R&D&I on the capture stage. Increased public support, including through funding, could also help to mobilise additional private funding and may, in the long run, help drive down costs of capital investments needed for capture - provided that the support leads to more cost-effective innovations. Costs tend to run high for high capture rates, therefore any R&D&I solution that enables high capture rates at lower prices could make CCUS become a more attractive decarbonisation solution for the steel industry and other sectors. As this option is focused on capturing emissions at source, it may have a more direct impact on the steel industry (but not only) compared to other options focused on infrastructure. In this scenario, capture installations would be paid directly by steel producers and other industrial emitters, whereas the investment costs for other types of infrastructure could be borne by other actors too, and possibly passed down to industries in the price they would have to pay for their utilise.

Budgetary consequences for public authorities at different levels of government: depending on where funding would come from, this option could have a considerable impact on member states' budgets. However, if resources were allocated from the EU budget, it would then be possible to use existing funds that are targeted towards R&D&I, which would not lead to any impact on member states' budgets, unless a large share of the next MFF were allocated to this purpose.

Competitive position of EU firms compared to non-EU competitors: if public support is successful in developing more cost-effective ways to capture emissions at higher rates, then it could improve the availability of CCUS solutions for the steel industry, which will need affordable and available decarbonisation options to remain competitive in the longer term. Moreover, such innovation could also ensure the EU would become a leader in CCUS technology, therefore this could help improve competitiveness in this field too.

Environmental impact

Emission of GHGs (e.g. carbon dioxide, methane, nitrous oxide, etc.) into the atmosphere: the particular emphasis on optimising capture at high rates would likely have a positive impact on reducing GHG emissions, especially if R&D&I support leads to more effective CCUS technologies in terms of capture rates and cost. High capture rates are a prerequisite for compatibility with climate neutrality. As such, R&D&I aiming to optimise capture rates could be particularly important. Especially in the longer term, given the goal of a green transition in the EU and net zero emissions, it would be paramount for technologies to deliver achievable high capture rates.

Increase/decrease in energy and fuel needs/consumption: notably, innovations in this field may also reduce the additional energy needed for capture at high rates.

Social and other impacts

Factors that would prevent or enhance the potential to create jobs or prevent job losses: similarly to other options that may improve the availability of CCUS solutions for industry, including the steel sector, this option too could potentially prevent job losses and create new ones. The main possible outcomes could be to prevent job losses in industries deploying CCUS technology, and to create new jobs in the CCUS value chain. Notably, this option could also more directly create jobs in the R&D&I field for CCUS technology.

7.4.6. Option CCUS6: promoting the use of climate-neutral CO2 (based on a list of CCU applications considered compatible with EU climate targets)

Economic and competitiveness impacts

The cost of capital, e.g. price and availability of financing: an ETS revision that would promote the use of CO_2, may have some impacts similar to fostering negative emissions under ETS (CCUS2). Notably, if allowances do not have to be surrendered from the use of CO_2 and the CO_2 could instead be sold for use, or used by the industries themselves for profit, it could make capture more economically attractive. As a result, it could encourage investments into, and improve the availability of, CCUS solutions, particularly capture installations and transport infrastructure.

Economic incentives set up by market based mechanisms created by Union law: this option could have a direct effect on the cost of carbon emissions for emitting plants due to allowances not having to be surrendered, or bought, for the emissions that are captured for use. In this case, captured emissions would not face a trade-off between the cost of the associated allowances, and the price companies could get for the CO_2, should the emissions be used instead of stored. However, by allowing for CCU under ETS, it could make more allowances available on the ETS market and this may, depending on scale, affect the price signals under ETS by reducing the carbon price.

The introduction and dissemination of new production methods, technologies and products: by encouraging a market for CO_2, it could also facilitate the introduction of new products made with captured CO_2, by increasing the supply. This could improve the business case for CCU.

Additional governmental administrative burden: a key aspect from a policy perspective would be that the use of CO_2 is compatible with the climate neutrality target. In order to ensure this, a list would have to be created of CCU cases that are considered compatible at the EU level due to its connection to the ETS Directive, as well as the need to ensure a coherent approach within the Union. This could entail some administrative burden for the EU, as resources would have to be dedicated to developing a first list, monitoring and periodic reviews.

Budgetary consequences for public authorities at different levels of government: the potential administrative burden on the EU could have a small budget implication, with necessary funds having to be (re)allocated for both the first development of a list, as well as periodic reviews.

Competitive position of EU firms with respect to non-EU competitors: by facilitating a market for CCUS products within the EU, this option could help ensure there are innovation and a market for such products in the EU. Moreover, similarly to other options, this solution too has the potential to improve the availability of CCUS solutions. Therefore it could foster the competitiveness of the EU industry, which will need affordable and available decarbonisation options to remain competitive in the long term.

Environmental impact

Emission of GHGs (e.g. carbon dioxide, methane, nitrous oxide, etc.) into the atmosphere: As long as the use of CO_2 is compatible with climate neutrality, i.e. it is stored in products for a significant period of time without the risk of being released before, it could have a positive environmental impact, as it could contribute to the reduction of GHG emissions. If industrial emitters were able to make a profit from selling CO_2, or from using it themselves without bearing the associated cost of surrendering allowances, then emissions would more likely be captured instead of emitted. However, should a market for CO_2 emerge at scale where carbon has a value, it would be important to make sure that the price for CO_2 would not encourage industries to avoid decarbonising production through other means and technologies in order to sell captured carbon to the market. If that happened, it could potentially have a negative impact on the uptake of other decarbonisation options by the industry.

Social and other impacts

Factors that would prevent or enhance the potential to create jobs or prevent job losses: similarly to other options that may improve the availability of CCUS solutions for industry, including the steel sector, this option could potentially prevent job losses and create new ones. The main possible outcomes could be to prevent job losses in industries deploying CCUS technology, and to create new jobs in the CCUS value chain in general. The focus on fostering CCU, in particular, could contribute to job creation in the field of CCU technologies, should a market develop for this.

7.4.7. Option CCUS7: providing a platform where different actors in the value chain meet and coordinate (e.g., by establishing an EU CCUS alliance), with the purpose of fostering increased certainty and mitigating cross-chain risks in the CCUS value chain

Economic and competitiveness impacts

The cost of capital, e.g. price and availability of financing: a platform for cooperation, such as a CCUS alliance, could have positive effects on the CCUS value chain, including industrial emitters, by mitigating cross-chain risks and uncertainty among the actors of different stages of the value chain. Due to the interconnectedness and dependence of the different stages of the value chain, increased cooperation and dialogue could help mitigate uncertainty around the other stages. This could have indirect effects on the availability of financing, by facilitating private investments into CCUS infrastructure and capture installations.

Budgetary consequences for public authorities at different levels of government: the organisation and setting up of such a platform (or alliance) would require some resources from the EU, as such it may have a small administrative and budgetary burden. However, the resources needed to set up and manage such a platform would likely be small.

Competitive position of EU firms with respect to non-EU competitors: this option would likely not have a significant direct impact on the competitiveness of the EU industry. However, it would make CCUS solutions for the steel and other industries more readily available in the long run and it would encourage cooperation, therefore it may have an indirect positive effect on competitiveness. Notably, it could facilitate synergies between companies, which could be beneficial for their competitiveness.

Environmental impact

Emission of GHGs (e.g. carbon dioxide, methane, nitrous oxide, etc.) into the atmosphere: The environmental impact of setting up a platform for cooperation would mainly stem from the potential it has to improve the availability of CCUS solutions for the industry. As such, and similarly to other options that may reasonably be expected to contribute to this, it could help reduce GHG emissions in the longer term. The emission reduction would depend on the CO_2 being captured and used or stored.

Social and other impacts

See Option CCUS5.

7.4.8. Option CCUS8: supporting clusters/industrial symbiosis (e.g., through the creation of an IPCEI)

Economic and competitiveness impacts

The cost of capital, e.g. price and availability of financing: supporting clusters or industrial symbiosis could have a similar impact to option CCUS7 on supporting a platform for collaboration. The impact could, however, possibly be higher, due to the more active support for collaboration. The very idea of industrial symbiosis would be that the by-products of one actor could be used by another. If the carbon produced as part of the steelmaking process could be used by other industries, this could create an economic incentive to capture emissions. By encouraging the formation of clusters, sharing transport infrastructure could become easier. This could thus reduce the cost of investing in the infrastructure for each individual actor, if the investment is done by the companies themselves, or make such an investment more attractive for other market actors due to the fact that there would be larger supplies. All in all, this could help improve availability of financing and encourage investments into CCUS capture and transport in particular.

Budgetary consequences for public authorities at different levels of government: taking part in an IPCEI would be on a voluntary basis; if member states decided to do so, however, their budgets will be impacted because considerable State aid resources would have to be mobilised in order to support the development of an EU value chain. This could entail significant financial commitments.

Competitive position of EU firms compared to non-EU competitors: this option could directly improve the availability of CCUS solutions for industries, especially in the form of an IPCEI, thus having a positive impact on their competitiveness. The availability of decarbonisation options for industries could be key in enabling their continued presence and production within the EU in the longer term with net zero as the target. Clusters and industrial symbiosis would also be economically beneficial for companies partaking by default, as they could for example benefit from each other's processes and by-products, jointly invest and use infrastructure, and in this way improve their competitiveness. In particular, an IPCEI could positively affect competitiveness also of other actors involved in the CCUS value chain, through the associated mechanisms of allowing State aid from member states and mobilisation of resources.

Environmental impact

Emission of GHGs (e.g. carbon dioxide, methane, nitrous oxide, etc.) into the atmosphere: through potentially improving the availability of CCUS solutions for the steel industry, this option could help reduce GHG emissions from the sector, as emissions will be captured and used or stored instead of emitted. One caveat, however, could be the relocation and construction of new plants and infrastructure, which may be needed. This could result in additional emissions from the construction itself, and associated transport and production of raw materials. As such, the impact on emissions could depend on the time scale considered. In the short term they may increase, while in the longer term the emission reduction through capture may offset the initial emissions. For the green transition in the EU, however, it could be important to have key technological value chains developed and available. The availability of such technologies could be necessary for the success of the green transition in the EU. With regards to the net zero target, CCUS could allow for the decarbonisation of primary steelmaking without fully abandoning BFs, as well as allow capturing process emissions from other hard-to-abate industries. As such, support for an IPCEI on CCUS, or support for the development of strong CCUS value chain(s), could help ensure the availability of the technology for the green transition in the EU.

Social and other impacts

Factors that could prevent or enhance the potential to create jobs or prevent job losses: similarly to other options that may improve the availability of CCUS solutions for industries, including the steel sector, this option could potentially prevent job losses and create new ones. The main outcomes could be to prevent job losses in industries deploying CCUS technology and to create new jobs in the CCUS value chain.

Regional impacts: while a focus on either existing or future industrial clusters could be justified from an efficiency point of view, it may come at a cost for regions that do not have favourable (geographic) conditions for low-carbon industry. This has implications for the Just Transition.

7.5. Comparative assessment

7.5.1. Effectiveness

CCUS1: supporting a market for low carbon/decarbonised products, for example through standards or public procurement: See also Chapter 9 on cross-cutting policy options. This option was considered to be able to help improve the availability of CCUS solutions to a high extent, though steel-sector respondents considered it less likely to do so compared to others.

CCUS2: supporting other CO2 transport methods beyond pipelines, as well as recognising and promoting negative emissions technologies in ETS: through fostering investment in CCUS technology and the capture of emissions, this option could be effective in improving the availability of CCUS solutions for industries such as the steel sector, which in turn could contribute to the emission reductions targets of the EU and the decarbonisation of hard-to-abate industries such as steel. While this option was considered somewhat effective at improving the availability of CCUS solutions by stakeholders, it was seen as the least effective among the options considered.

CCUS3: providing funding (CAPEX and OPEX) for CO2 storage and transport infrastructure, for new infrastructure or the adaptation of existing ones.: this option could be important to help improve the availability of CCUS solutions by improving the availability of necessary infrastructure. By contributing to the availability of all stages of the CCS value chain, it could enable the technology to contribute to the emission reductions targets of the EU and the decarbonisation of hard-to-abate industries such as steel. Considered highly effective at improving the availability of CCUS by stakeholders, this option was the second most effective amongst the options evaluated according to the stakeholders consulted.

CCUS4: increasing carbon price to foster emission reductions, potentially as a result of higher (short-term) climate targets: See also Chapter 9 on cross-cutting options. This option was considered to be somewhat likely to help improve the availability of CCUS solutions.

CCUS5: providing increased public support and funding for research, development, and innovation to optimise capture at high rates: similarly to other options, this one too would likely help improve the availability of CCUS solutions and enable the technology to contribute to the emission reductions targets of the EU and the decarbonisation of hard-to-abate industries such as steel. The particular focus on optimising capture rates could, moreover, considerably improve the ability of CCUS to contribute to the decarbonisation of the industry, especially in the long term towards net zero. This option was considered highly effective at improving the availability of CCUS solutions also by stakeholders.

CCUS6: promoting the use of climate-neutral CO2 (based on a list of CCU applications considered compatible with EU climate targets): this option could contribute to the availability of CCUS solutions by improving the business case for capture and use. It could also contribute to creating a market for captured carbon which, as long as the uses are compatible with net zero, could help contribute to the emission reductions targets of the EU. This option was considered highly likely to help improve the availability of CCUS solutions among stakeholders, though steel sector respondents were in general less convinced than others.

CCUS7: providing a platform where different actors in the value chain meet and coordinate (e.g., by establishing an EU CCUS alliance), with the purpose of facilitating increased certainty and mitigating cross-chain risks in the CCUS value chain: due to the uncertainty and cross-chain risk associated with the CCUS value chain, a platform for cooperation and coordination could help improve the availability of CCUS in the longer term by bringing relevant stakeholders together. However, any improvements in the availability of the technology would depend on the investment decisions of relevant actors, who may also look at costs, price and legislative requirements, and as a result any effect would be uncertain. Moreover, as this is an option focused on creating dialogue, the impact would likely be smaller than options more actively promoting or funding concrete actions. This option was considered likely to help improve the availability of CCUS solutions, though not to have a significant impact. Similarly to other options, stakeholders from the steel sector were less convinced than others.

CCUS8: supporting clusters/industrial symbiosis (e.g., through the creation of an IPCEI): actively supporting the creation of a CCUS value chain, especially if done through establishing an IPCEI, would likely highly improve the availability of CCUS solutions. By its nature, this would involve bringing relevant actors together and allow the provision of State aid: for other technologies, this has led to the successful launched of consortiums in different fields. Among the options, this was considered by stakeholders as the most effective one to help improve the availability of CCUS solutions by stakeholders.

7.5.2. Efficiency

CCUS1: supporting a market for low carbon/decarbonised products, for example through standards or public procurement: See Chapter 9 on cross-cutting policy options.

CCUS2: supporting other CO2 transport methods beyond pipelines, as well as recognising and promoting negative emissions technologies in ETS: in the case of support to other transport options, the costs associated with this option would largely be borne by those choosing to invest in transportation. With regards to promoting negative emissions, some costs could be associated with administrative work and monitoring. More indirectly, there could also be cost reduction implications for other industries as well, should there be an impact on the price signals under ETS.

CCUS3: providing funding (CAPEX and OPEX) for CO2 storage and transport infrastructure, for new infrastructure or the adaptation of existing ones.: as this option is focused on provision of funding, it would naturally come with costs, which would have to come from the EU budget or member states' budgets.

CCUS4: increasing carbon price to foster emission reductions, potentially as a result of higher (short-term) climate targets: See Chapter 9 on cross-cutting options.

CCUS5: providing increased public support and funding for R&D&I to optimise capture at high rates: this option would have cost implications due to the nature of increased funding being directed towards R&D&I for capture at high rates. This could have smaller budgetary impacts, by requiring additional funding and redirecting funds from other sources. However, in the longer term, if it leads to more cost-effective innovations, it could bring down the cost of carbon capture.

CCUS6: promoting the use of climate-neutral CO2 (based on a list of CCU applications considered compatible with EU climate targets): this option could entail some administrative costs, especially in relation to the creation and update of a list of CCU applications that are compatible with the EU's climate neutrality target. It could also positively affect the costs of emitting industries choosing to capture emissions. Similarly to CCUS2, it could however have an impact on the price signals under ETS and the carbon cost.

CCUS7: providing a platform where different actors in the value chain meet and coordinate (e.g., by establishing an EU CCUS alliance), with the purpose of facilitating increased certainty and mitigating cross-chain risks in the CCUS value chain: the costs associated with this option would likely only be administrative ones, from the creation of the platform, and likely small.

CCUS8: supporting clusters/industrial symbiosis (e.g., through the creation of an IPCEI): the establishment of an IPCEI could entail some administrative costs. It could also create costs for member states joining the IPCEI, that will take the form of mobilisation of resources and provision of State aid. From the business perspective, it could have the opposite effect, due to the potential of receiving State aid.

7.5.3. Feasibility

CCUS1: supporting a market for low carbon/decarbonised products, for example through standards or public procurement: See Chapter 9 on cross-cutting issues.

CCUS2: supporting other CO2 transport methods beyond pipelines, as well as recognising and promoting negative emissions technologies in ETS: a revision of the ETS Directive that supports transport options beyond pipelines is likely highly feasible, as it would mainly serve to formalise and clarify rules regarding transport. Supporting negative emissions, however, would constitute more of a change in policy and could be politically more difficult due to differences in opinion on what role negative emissions should play in the EU's decarbonisation. While this option was considered somewhat likely to receive sufficient support from policymakers overall, stakeholders found this option the least likely to receive political support. Notably, stakeholders from the steel sector found it less feasible than respondents from other sectors.

CCUS3: providing funding (CAPEX and OPEX) for CO2 storage and transport infrastructure, for new infrastructure or the adaptation of existing ones: the feasibility of this option may depend on whether it relates to CAPEX or OPEX. CAPEX support may be more feasible compared to OPEX support, as public investment is generally more common than public support for OPEX and the latter is more difficult to justify under State aid rules. In either case, financial support would likely be the most feasible alternative. Using existing EU instruments, such as the IF, could allow for both funding of CAPEX and OPEX. Notably, if this option were combined with the creation of an IPCEI (see CCUS8), it could remove obstacles in relation to State aid both for CAPEX and OPEX (if related to R&D&I or first industrial deployment). By itself, this option was considered only somewhat feasible by stakeholders, and less likely to receive support by policymakers compared to all but one option (CCUS2).

CCUS4: increasing carbon price to foster emission reductions, potentially as a result of higher (short-term) climate targets: See Chapter 9 on cross-cutting issues.

CCUS5: Providing increased public support and funding for R&D&I to optimise capture at high rates: similarly to CCUS3, increased financial support for R&D&I targeted towards optimising capture at high rates seems likely to be a feasible option, especially in light of the many relevant EU funding mechanisms that already exist. This may only require increasing focus of such funds towards this purpose, which, while it may move funds away from other purposes, could avoid a political discussion associated with allocation additional resources. Accordingly, this option was considered likely to receive support by policymakers, especially by steel and other industries.

CCUS6: promoting the use of climate-neutral CO2 (based on a list of CCU applications considered compatible with EU climate targets): fostering of CCU may arise discussions on whether this is desirable from a political perspective. However, by making CCU deployment contingent on an agreed list of applications that are compatible with net neutrality, it could mitigate some concerns about fostering CCU from a sustainability perspective. Agreeing on a list of applications could, however, be politically difficult, and discussions may emerge on what options should qualify, while others may disagree with the principle of excluding options. Whether only unavoidable process emissions should be eligible may also prove to be a sticking point in political discussions. While stakeholders generally found this option to be between somewhat and highly feasible, such political discussions could affect its ability to receive sufficient support from policymakers.

CCUS7: providing a platform where different actors in the value chain meet and coordinate (e.g., by establishing an EU CCUS alliance), with the purpose of facilitating increased certainty and mitigating cross-chain risks in the CCUS value chain: the creation of a CCUS platform would likely be feasible from a political point of view, as limited public resources would be needed and it would likely not involve significant trade-offs. This assessment was confirmed by stakeholders who considered this option the second most feasible among the ones presented. A broad participation beyond industry stakeholders in the platform was also considered to be potentially able to mitigate public perception issues.

CCUS8: supporting clusters/industrial symbiosis (e.g., through the creation of an IPCEI): while the creation of an IPCEI could entail some costs, the larger costs associated with active member states support would be voluntary and thus would likely not affect the feasibility of this option. However, as few IPCEI's have been launched so far, there may be a perceived trade-off associated with selecting a technology. As such, policymakers may wish to prioritise other technologies over CCUS, which could affect the feasibility of this option. This option was considered to be the most likely to receive enough support from policymakers out of the ones among stakeholders, with stakeholders from non-steel industry finding it to be a particularly feasible option.

7.5.4. Coherence

CCUS1: supporting a market for low carbon/decarbonised products, for example through standards or public procurement: See Chapter 9 on cross-cutting issues.

CCUS2: supporting other CO2 transport methods beyond pipelines, as well as recognising and promoting negative emissions technologies in ETS: this option would likely be coherent with the spirit of other relevant EU initiatives in the field of climate change, energy and sustainable development. Stakeholders considered it overall coherent; however, steel-sector respondents were less convinced than others.

CCUS3: providing funding (CAPEX and OPEX) for CO2 storage and transport infrastructure, for new infrastructure or the adaptation of existing ones: depending on how the support would materialise, this option would likely be coherent with other relevant EU initiatives in the field of climate change, energy and sustainable development. However, attention should be given to ensure that repurposing of existing infrastructure does not limit their availability for other technologies to the extent desired, and that any new infrastructure is built as sustainably as possible. This option was considered coherent with other EU policies and initiatives in the field by stakeholders, though non-industry respondents were slightly less convinced.

CCUS4: increasing carbon price to foster emission reductions, potentially as a result of higher (short-term) climate targets: See Chapter 9 on cross-cutting issues.

CCUS5: Providing increased public support and funding for research, development, and innovation to optimise capture at high rates: this option would likely be coherent with the spirit of other relevant EU initiatives in the field of climate change, energy and sustainable development. Together with CCUS8, it was considered the option most in line with other EU policies and initiatives.

CCUS6: promoting the use of climate-neutral CO2 (based on a list of CCU applications considered compatible with EU climate targets): as long as any use is compatible with the climate neutrality target, it would likely be coherent with the spirit of other relevant EU initiatives in the field of climate change, energy and sustainable development. Among stakeholders there were however contrasting views on the coherence of this option, ranging between finding it somewhat to highly coherent, with non-industry and steel-sector respondents more hesitant than others.

CCUS7: providing a platform where different actors in the value chain meet and coordinate (e.g., by establishing an EU CCUS alliance), with the purpose of facilitating increased certainty and mitigating cross-chain risks in the CCUS value chain: this option would likely be coherent with the spirit of other relevant EU initiatives in the field of climate change, energy and sustainable development. It was considered highly feasible among stakeholders, though steel sector respondents considered it on average less coherent than others.

CCUS8: supporting clusters/industrial symbiosis (e.g., through the creation of an IPCEI): this option would likely be coherent with the spirit of other relevant EU initiatives in the field of climate change, energy and sustainable development. This was confirmed by stakeholders, who, together with option CCUS5, found it to be the most coherent among the options presented.

Table 11: Overview of policy solutions[73] – CCUS

	Effectiveness	Efficiency	Feasibility	Coherence
Option CCUS2: supporting other CO_2transport methods beyond pipelines, as well as recognising and promoting negative emissions technologies in ETS				
Option CCUS3: providing funding (CAPEX and OPEX) for CO_2 storage and transport infrastructure				
Option CCUS5: providing increased public support and funding for R&D&I to optimise capture at high rates				
Option CCUS6: promoting the use of climate-neutral CO_2				
Option CCUS7: providing a platform where different actors in the value chain meet and coordinate				
Option CCUS8: supporting clusters/industrial symbiosis				

Note: This table presents the policy options in the CCUS area that would support the decarbonisation of the EU steel industry. The options are assessed based on the four criteria under the Better Regulation guidelines: their effectiveness, efficiency, feasibility and coherence. Colour legend: orange - low, yellow – moderate, green – high. For instance, a policy option that has a green cell in the Effectiveness column is considered to be "highly" effective. Source: authors' own composition.

[73] Options CCUS1 and CCUS4 have not been included in this overview as these options are assessed in the cross-cutting policy chapter

8. Iron and steel scrap

8.1. Problem identification

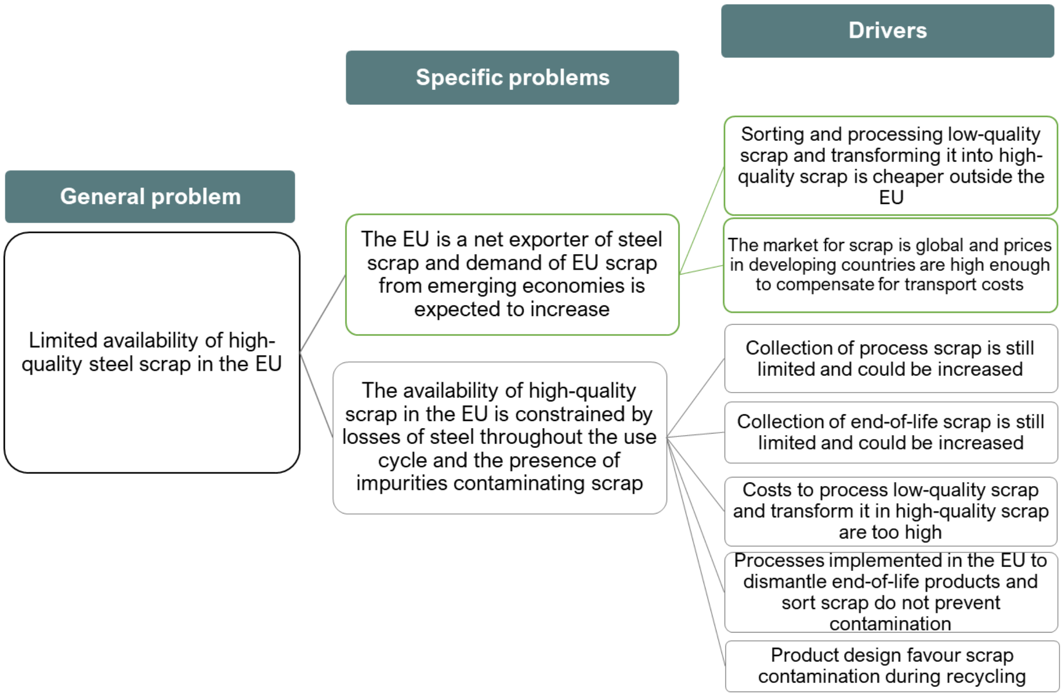
8.1.1. Background

In 2019, the EU-28 was the second-biggest crude steel producer (159.4 Mt) and steel scrap consumer (87.5 Mt). **In the EU, about 40% of crude steel production comes from the EAF route**, which relies on steel scrap as the main raw material; overall, **the ratio between steel scrap use and crude steel production in the EU was in the area of 55%** between 2015 and 2019 (BIR, 2020). CO_2 emissions generated by the EAF route depend on the emission intensity of the electricity used by the furnace: CO_2 emissions could be as low as 60 kg CO_2/t of crude steel for plants relying on carbon-free electricity and biofuels for downstream processing. This is a fraction of the current emissions from the BF-BOF route, that are estimated in the area of 1,800 kg CO_2/t of crude steel (VHEh, 2019). Hence, by fostering the reuse of steel scrap and ensuring that a larger quantity of high-quality scrap is available to EU steelmakers, the EU can contribute to the **circular economy and substantially reduce CO_2 emissions from steelmaking**.

8.1.2. General problem

The limited availability of high-quality steel scrap is hindering the decarbonisation of the EU steel sector. This general problem was confirmed, to some extent, by the stakeholders consulted in the Inception phase.

Figure 17: Problems hindering the availability of steel scrap in the EU



Source: author's composition.

A large share of the **steel scrap generated in the EU is exported to third countries**: therefore, it does not contribute to the EU circular economy and it affects the ability of the EU steel industry to further expand production via the EAF route (EUROFER, 2015). Besides, the availability of steel scrap is also limited by **insufficient collection of scrap** and **impurities** affecting the quality of scrap generated in the EU.

8.1.3. Specific problem SC1

Around 20% of the steel scrap generated in the EU – a strategic 'secondary' resource – is exported to third countries (EUROFER, 2015). **The EU is a net exporter of steel scrap;** in 2019, it was the world's largest exporter of scrap: it exported 21.8 Mt of steel scrap and imported 2.9 Mt (BIR, 2020; Worldsteel, 2020b). The three biggest buyers of EU exports were Turkey (12.0 Mt), Egypt (2.0 Mt)[74] and India (1.9 Mt) (BIR, 2020). Interestingly, since 2017, exports to China have been limited by import quotas established by the Chinese government to reduce the import of solid waste and encourage collection and processing of domestic scrap. China is, however, progressively lifting import quotas on scraps to meet growing industrial needs, and Chinese demand for EU steel scrap may increase in the next future (Reuters, 2018; Reuters, 2019; S&P Global Platts, 2020).

[74] Egypt is a relatively small producer of steel (7.3Mt), which relies almost entirely on the EAF route (97.5%).

Table 12 lists the six biggest steel scrap users worldwide. On a global scale, **the EAF route is more common in developed economies**, while developing economies rely more on the BF-BOF route. In fact, excluding environmental reasons, the decision to switch from BF-BOF to EAF is based on cost considerations (in developing economies BF-BOF are rather new and efficient installations, built no more than 20 years ago) and scrap availability (steel has a lifecycle of around 40 years on average). In this respect, scrap consumed today depends on steel produced yesterday: while in the Western economies there are significant quantities of scrap, the situation is still different in China and other emerging economies, where the first "steel industrialisation wave" is relatively more recent (Luchetta et al., 2013). McKinsey (2017) forecasts, however, that China will dramatically increase EAF production in the near future, thus boosting Chinese demand for steel scrap, which is already much higher than the EU demand in absolute terms.

More generally, **the demand for steel scrap from developing countries is expected to increase** as EAF production will be fostered for environmental reasons, progressive obsolescence of existing BF-BOF plants and increased availability of local scrap. Respondents to the survey performed during the Inception phase agreed, to some extent, that an increase in the demand of steel scrap from developing countries will constrain the availability of scrap in the EU and impinge on the ability of the EU steel industry to further expand EAF route production.

Table 12: Steel scrap use and percentage of EAF production over total crude steel production in 2019

Country	Steel scrap use	% EAF production	Tot steel production
China	215.9 Mt	10.4%	996.3 Mt
EU-28	87.54 Mt	40.9%	158.8 Mt
USA	60.7 Mt	69.7%	87.8 Mt
Japan	33.7 Mt	24.5%	99.3 Mt
India	32 Mt	56.2%	111.2 Mt
Russia	30.3 Mt	33.6%	71.9 Mt

Source: BIR 2020; Worldsteel, 2020b; India CSR Network 2019.

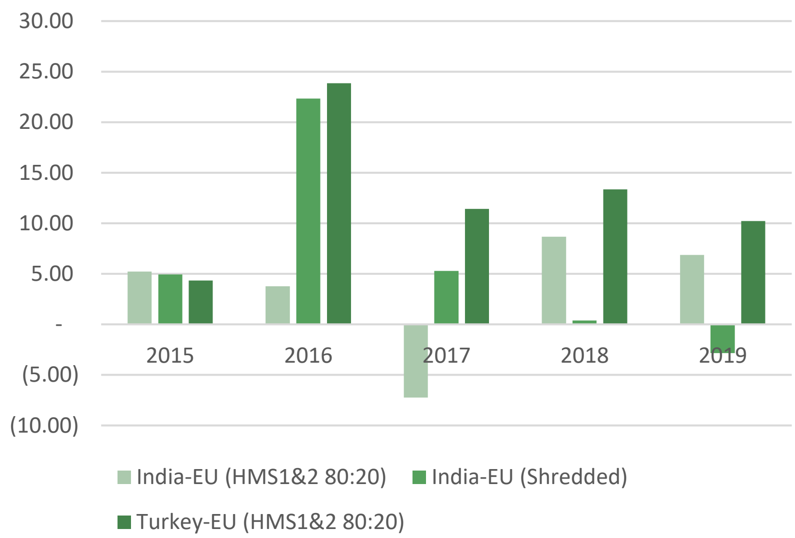
- **Driver SC1.1**: **steel scrap leaves the EU because the cost for scrap processing in third countries is relatively lower due to both lower labour costs and lower environmental standards** (Luchetta et al., 2013, p. 716). Even if steel is the most recycled material (Worldsteel, 2020b), scrap must comply with specific quality requirements regarding its composition if it is to be used in the EAF production route.[75] Low-quality scrap generated in the EU, which would not find any application inside the EU without further processing, is often exported in countries where sorting and processing are cheaper, and where lower-quality steel is produced. In this context, India is expected

[75] Steel essentially does not suffer any downgrading when scrap is recycled, therefore it can almost be recycled indefinitely. There are, however, residuals elements/impurities in steel scrap. The level of residues that can be tolerated depends on product requirements (EUROFER, 2015).

to become a new large export destination for European steel scrap. Similarly to China, the Indian government unveiled its new steel scrap recycling policy in November 2019, which entails*, inter alia*, the establishment of 70 scrap processing centres in the country to ensure the availability of high-quality scrap for the local steel industry (OECD, 2020a, p. 32). Several market players believe that this will increase India's ability to process scrap at a competitive cost and will lead to a surge in imports of mixed metal and unprocessed scrap into India (S&P Global Platts, 2019). On a more general note, products made of steel are becoming more and more complex and steel is often combined with other materials (e.g. plastics or other metals). This poses new challenges for the steel recycling industry and increases the relevance of collection, sorting and processing activities, which will need to be optimised to further develop the circular economy in Europe (BDSV, 2019).

- **Driver SC1.2**: the scrap market is global and **steel scrap leaves the EU because prices are higher in third countries**, high enough to compensate for transport costs.[76] There are differences in scrap prices across regions, both in terms of price levels and price dynamics (OECD, 2019a, p. 28). Figure 18 shows spreads in average annual prices for low-quality scrap between the EU and Turkey, and the EU and India, including delivery costs to the port of destination. With few exceptions, such spreads are small but positive, thus allowing EU dealers to export scrap and pursue a profitable, high-volume/low-margin strategy.

Figure 18: Average annual spread in scrap price



Note: Unit = $/tonne, cost and freight. HMS stands for heavy melting scrap recovered from items demolished or dismantled at the end of their life. Shredded scrap is more processed than HMS as the metal is torn into small pieces; it usually travels longer distances, as it can be better transported in containers. Cost and freight prices account for transport costs up to the port of destination either in Turkey or India.
Source: EUROFER (2020)

[76] This also depends on the load factors of container ships leaving Europe towards the Far-East, which are usually quite low in the outbound leg (Luchetta et al., 2013).

Stakeholders consulted for the Inception phase believe that both drivers identified – relatively lower costs for scrap processing and higher prices of scrap in third countries – contribute to some extent to limiting the availability of steel scrap in the EU.

8.1.4. Specific problem SC2

In a mature steel market such as the European one, it is estimated that the amount of available steel scrap in 2050 will reach about 80% of the total demand of steel in the same year (Material Economics, 2018, p. 65). From an environmental and economic standpoint, it is then important to seize the opportunity of recycling the available scrap. Indeed, the CO_2 emissions from the steel industry can be reduced to close to zero if secondary steelmaking processes with steel scrap and RES-E are used (ICF, 2017, p. 15). The **losses of steel throughout the use cycle**, however, impinge on the recycling of steel scrap: almost 150 Mt are lost each year globally (Material Economics, 2018, p. 66). Different factors contribute to the losses of steel, such as the presence of end-of-life steel structures that are not accessible (e.g. underground structures), low collection rates of end-of-life products and process scrap, or losses happening during the re-melting process. In addition, another factor that constrains the availability of high-quality scrap is the presence of **impurities contaminating end-of-life scrap**, including copper and other residual elements, which affect the quality of steel produced by the EAF route. These issues are considered to constrain (to some extent) the availability of scrap in the EU to increase steel production via the EAF route .

- **Driver SC2.1**: the **collection of process scrap** is still limited and could be increased. During the production process of some product categories, such as automobiles, not all the steel used in the production is turned into the final product, but there is a part that becomes process scrap. It is estimated that only a share (70-90%) of the scrap generated in the forming and fabrication stage is then collected (Material Economics, 2018, p. 67)
- **Driver SC2.2**: the **collection of end-of-life scrap** is still limited and could be increased. The share of end-of-life scrap that is not collected because of inaccessibility or corrosion can reach 10% in some categories, such as underground structures. Despite being end-of-life, steel has a high recycling rate; the share of end-of-life products that are not collected for recycling, however, ranges from 15% to 50% in some categories (Material Economics, 2018, p. 67).
- **Driver SC2.3**: **costs to process low-quality scrap and transform it into high-quality scrap are too high**. Since the supply of scrap is not tightly controlled, steel scrap with very different content is often mixed, causing a down cycling of steel. Low-quality scrap is often contaminated by copper and the removal of copper impurities is not a commercially available option once scrap is melted (Material Economics, 2018, p. 75). The costs related to the use of improved scrap processing technologies are mainly related to capital investments and regulatory compliance (e.g. permits, approval, operational costs) (ECSIP, 2013, p. 27). Furthermore, a high administrative burden is reported when trying to upgrade waste into new raw material (Trinomics, 2016, p. 270).
- **Driver SC2.4**: processes implemented in the EU to **dismantle end-of-life products and sort scrap** do not prevent **contamination**. Indeed, when products are dismantled, it can occur that copper is mixed with steel. Copper often enters steel scrap at the point of

recycling, permanently downgrading the quality of the scrap (Material Economics, 2018, p. 68; Bowyer et al., 2015, p. 7).[77]

- **Driver SC2.5**: **product design favours scrap contamination during recycling.** Broadbent (2016) highlights the importance of improving the design of products so that they can easily enter into the recycling stream, reducing the need for primary raw material. For instance, end-of-life vehicles are a major source of contamination, as cars often have a copper content of 0.5% or more (Material Economics, 2018, p. 69).

Stakeholders consulted during the Inception phase confirmed that, at least to some extent, all the drivers listed above reduce the quality and availability of scrap in the EU. The most important driver appears to be product design, which currently makes recycling very complex, followed by the high costs to transform low-quality scrap into a high-quality one.

8.2. EU right and need to act

The actions taken by the EU to ensure the availability of high-quality steel scrap to be used in the EAF route contribute to the EU's objective of decarbonising the steel industry, in line with the EU's long-term strategy of achieving carbon neutrality by 2050. An intervention at EU level can be justified given the **trans-boundary nature** of the problem: the decarbonisation objective cannot be sufficiently achieved by the member states and the actions carried out at EU level provide an added value; therefore, an EU intervention would comply with the principle of subsidiarity laid down in Art. 5 (3) TEU.

Ensuring the availability of high-quality steel scrap in the EU is linked to the EU environmental objectives and the competitiveness of the EU steel industry. In the area of **environmental policies**, the EU and the member states have shared competences (Art. 4 TFEU). According to Art. 11 TFEU, environmental protection requirements must be integrated into EU's policies and activities. Art. 191 to 193 TFEU are the legal basis for the EU's secondary legislation in this field: on this ground, the EU has already been active in the areas of waste management and shipment of waste. The availability of steel scrap for secondary steel production is also a condition necessary for the future **competitiveness of the EU steel industry**, which can be supported by EU interventions according to Art. 173 TFEU.

8.3. Policy objectives and options

8.3.1. General objective

The limited availability of high-quality steel scrap in the EU is hindering the decarbonisation of the EU steel industry. Therefore, the general objective of the EU policy response is to **ensure the availability of a sufficient amount of high-quality scrap in Europe,** thus supporting the decarbonisation of the EU steel industry towards 2050 by increasing production of steel via the EAF route**.**

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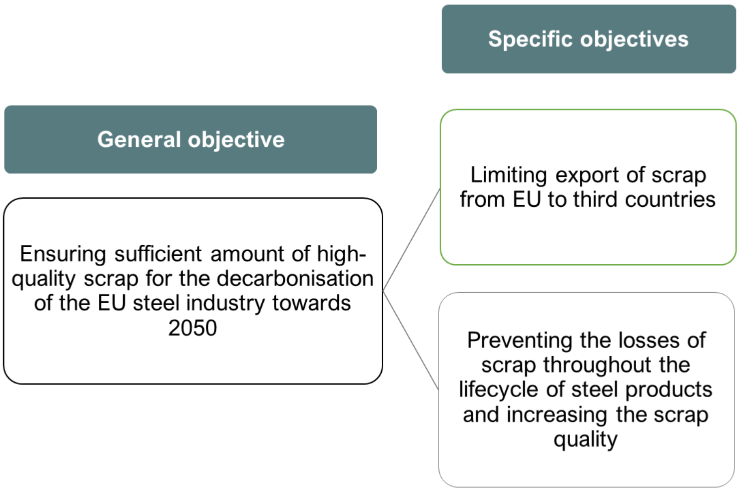
[77] Even low levels of copper drastically affect the quality of steel: at a share of around 0.15%, steel becomes inadequate for some applications (Material Economics, 2018, p. 69). The presence of copper in steel reduces the quality and the potential uses of secondary steel and, as such, it is identified as the main barrier to the production of high-quality steel from recycled scrap (Daehen et al., 2017).

Figure 19: Policy objectives on the availability of steel scrap in the EU



Source: author's composition.

8.3.2. Specific objective 1 and policy options

Specific objective SC1: the EU is a net exporter of steel scrap and, in the near future, the demand of EU steel scrap from emerging economies is expected to increase, as the EAF production will grow in those countries, together with their ability to sort and process scrap. Reducing the export of scrap generated in the EU to third countries would help expand EAF steel production in Europe.

Baseline: the EU will export an increasing percentage of steel scrap to third countries, since the demand for steel scrap from emerging economies is expected to grow. The EU steel industry will face additional constraints in the availability of high-quality scrap to be used in the EAF route.

Option SC1: revision of the EU regulatory framework on scrap exports

Steel scrap demand from developing countries is expected to increase in the near future. In this context, the EU regulatory framework should be revised to avoid illegal steel scrap exports that generate environmental and social side effects to third countries. This could promote recycling in the EU to support the transition to the circular economy.

Firstly, the Waste Framework Directive should be revised to avoid illegal exports of scrap through a more stringent application of Art. 11a (8) on export of waste from the EU to third countries (European Union, 2018b). More specifically, there is a need to better enforce the requirement that scrap can be exported only if the treatment of waste outside the EU takes place in conditions that are equivalent to the requirements of EU environmental law.

Secondly, the End-of-life Vehicles (ELV) Directive can be revised to combat illegal exports of ELVs through an improved registration and deregistration mechanism. Export of ELVs to non-OECD countries is prohibited by the Waste Shipment Regulation. In particular, Guideline No 9 defines criteria for the differentiation between second-hand vehicles and ELVs; this provision, however, is not legally binding.[78] Making this provision legally binding and establishing a reverse bonus clause (making the exporter responsible to demonstrate that the used vehicle is not an ELV) could limit export of ELVs.

Thirdly, the Waste Shipments Regulation (WSR) can be revised by introducing a better inspection system, measures against illicit shipments and measures to avoid potential environment-and-health-related adverse effects on the environment and public health caused by shipments of waste to third countries. In addition, a revision of the WSR could limit scrap exports by authorising exports only when the broad equivalence with mandatory EU standards (environmental, human, health, climate, circularity) can all be effectively verified and demonstrated (EUROFER, 2020d).

8.3.3. Specific objective 2 and policy options

Specific objective SC2: recycling steel scrap available in the EU is important to reach the EU's decarbonisation targets. Losses of steel throughout the use cycle and the presence of impurities in end-of-life scrap limit the reuse of steel scrap in the EAF route. Therefore, EU policies should aim to prevent the losses of steel throughout the lifecycle of steel products and limiting impurities contaminating end-of-life scrap, thus ensuring more and higher-quality scrap for the EAF route.

Baseline: the EU will lose its opportunity of maximising the reuse of steel scrap as secondary material in the EAF route because of limited collection rate of steel scrap, contamination of steel scrap with residual elements, and the inadequate approach to scrap sorting and processing.

Option SC2: improve the quality of scrap available in the EU

Losses of steel throughout the use cycle and the presence of impurities in end-of-life scrap reduce the quality of steel scrap available in the EU and then the employability in the EAF route. The quality of scrap can be increased at the processor level in several ways. Firstly, by supporting R&D&I in technologies to improve the quality of steel scrap. R&D&I in this field could benefit from the IF (Material Economics, 2018, p. 75). For instance, new technologies could determine the content of alloys and avoid downgrading by mixing steel scrap in a more efficient way to obtain a specific end-product. There are technologies in rapid evolution that allow for the recognition of the contents, such as laser-induced breakdown spectroscopy (Material Economics, 2018, p. 75). Secondly, by fostering the use of the best-available technologies by scrap handlers to provide high-quality steel scrap. For instance, the most modern sorting technologies make use of high-performance sensor systems for classification and analysis of inorganic materials which would favour the selection of steel scrap of a high quality. The best-available technologies can be used to support public funding to buy new equipment, tax rebates or accelerated depreciation for scrap handlers which buy new equipment.

Option SC3: ensuring that final products are recyclable

Since recycling of steel scrap available in the EU is an important element to reach the EU's decarbonisation targets, EU policies should ensure the recyclability of final products. This can happen through specific provisions addressed to producers. The EU could deter final products with low recyclability or poor material efficiency. For instance, the EU could introduce incentives to design vehicles, machines or buildings to ensure longevity, and introduce a labelling system to

[78] https://ec.europa.eu/environment/pdf/waste/shipments/correspondents_guidelines9_en.pdf

differentiate such products (Agora, 2020b, p. 31). In addition, the EU could ensure that final products comply with minimum requirements in terms of disassembling, demolition, and separation of component materials. For instance, in compliance with the EU circular economy package and the eco-design regulation, it can be ensured that products are designed in a way that facilitate the separation of different materials and hence make recycling easier (Agora, 2020b, p. 30-31; European Commission, 2019c, p. 9, 62; Navigant, 2019, p. 30).

8.4. Impacts

8.4.1. Option SC1: revision of the EU regulatory framework on scrap exports

Economic and competitiveness impact

This policy option is expected to **reduce the volume of illegal exports of steel scrap, leading to increased availability of steel scrap for EU steelmakers.** This impact would materialise as the legal framework on waste shipment is reinforced to retain illicit export of steel-containing waste including ELVs within the EU. However the magnitude of this impact is considered limited. For instance, the Waste Shipment Regulation only prohibits the export of ELVs that contain hazardous waste.[79] Therefore, ELVs that are depolluted (non-hazardous waste) do not fall under the scope of export restrictions. This waste is only subject to the inspection and monitoring of the environmental and social conditions associated with its shipment and treatment outside the EU.

Environmental impact

A potential indirect impact of increased availability of steel scrap in the EU is **the reduction of GHG emissions from the steel sector,** contributing to the **decarbonisation of this industry**. Higher availability of steel scrap can promote the use of the secondary steelmaking route in steel production, which is less carbon-intensive than the conventional integrated BF-BOF route.

Furthermore, this policy option would contribute to **promoting sustainable production and accelerating the green transition in the EU**. More specifically, the enhanced use of scrap in steel production is going to make steel less dependent on primary resources (e.g. iron ore), which will translate into a reduction of resource extraction and processing needed for the steel sector. This will contribute to the EU’s transition towards the circular economy, as set in the European Green Deal (European Commission, 2019d) and further developed under the New Circular Economy Action Plan (European Commission, 2020n).

At global level, revision of the legal framework to better control illicit shipments of steel scrap would also **minimise the environmental impact of ELVs and other steel-containing products outside the EU**. Illegal shipments that potentially lead to environment and health-related adverse effects in third countries will be further restricted. For instance, the revision of the EU regulation on waste can better ensure that the treatment of ELVs that contain burned oil, unsafe fluorinated

[79] Export from the EU of ELVs that are depolluted – non-hazardous waste - is prohibited only to those non-OECD countries that have explicitly banned their import in accordance with Regulation (EC) No 1417/2007 (Trade Regulation on procedures of export of green-listed waste to non-OECD countries).

and chlorinated hydrocarbons (FCHC) and lead-acid[80] only takes place in conditions that are equivalent to the requirements of EU environmental law.

Social impact

As an indirect impact, this policy option can contribute to **improving public health for the EU**. Increased availability of scrap will facilitate the steel industry's transition from conventional BF-BOF route to EAF scrap-based steelmaking route, reducing air pollution levels and decreasing people's exposure to such pollution. Outside the EU, better monitoring and control procedures of waste shipments could **mitigate negative health impacts in the countries of destination.** Proper implementation of the Waste Shipment Regulation ensures that the shipments themselves and their recovery or disposal in third countries respect EU and international rules. The exporters or the importing countries must prove that the waste treatment facilities operate in accordance with human health protection standards broadly equivalent to those established by the relevant EU legislation. Furthermore, increased availability of steel scrap within the EU would increase the material inputs for the **EU recycling industry**, leading to the expansion of this sector and creation of jobs for the EU.

8.4.2. Option SC2: improving the quality of scrap available in the EU

Economic and competitiveness impact

This policy option is expected to **foster R&D&I of technologies for scrap sorting and handling**. Currently, some technologies for scrap treatment to get rid of impurity have been developed, but have not yet reached commercial deployment due to high costs. EU funding support such as the IF can help commercialise technologies to reduce the impurities in post-consumer scrap before the melting process.

Consequently, promoting the use of BATs and fostering innovation of scrap-refining solutions would **increase the availability of high-quality steel scrap in the EU.** Scrap with higher purity can promote the use of the EAF route in the EU, which relies on the scrap quality. The increased use of high-quality steel scrap in the EAF route has two main advantages. First, this allows for the production of higher steel grade, which requires a lower content of trace element (Ruth, 2004; McKinsey, 2020a, p. 5). Increased use of quality steel scrap in the EAF route will therefore increase the production of quality steel grades.[81] Second, the EAF route has lower CO_2 emissions than the BF-BOF route. Currently the scrap-based EAF generates a total of 330-470 kg of CO_2 per tonne of crude steel (including 250-350 kg/tCS from indirect emissions), compared to 1.3 to 1.8 t of CO_2 from the integrated BF-BOF processes (ESTEP, 2020b, p. 12). With further integration of RES-E and green hydrogen, the CO_2 mitigation potential of EAF route can reach almost 100%, without any need of CCUS (GREENSTEEL, 2021a).

Environmental impact

Promoting the use of scrap handling and refining technologies can contribute to **reducing GHG emissions from the steel sector and support the decarbonisation of this industry.** This

[80] For further details on the environmental and human health concerns related to illegal exports of ELVs, please see European Commission (2020n), p. 5

[81] Today, 79% of steel long products in EU is produced by EAF, while 91% of flat is product by BF-BOF route. Detailed analysis is available at ESTEP (2020b), p. 80.

impact materialises through two mechanisms. First, scrap-based production helps avoid the preparation of raw materials needed for conventional steel production, which are carbon-intensive. Second, scrap with higher purity guarantees lower CO_2 emissions during the melting process in the EAF route.

The enhanced use of technologies to improve scrap quality would also **promote sustainable production** in the EU. The use of scrap in steel production helps save primary resources, including iron ore, and therefore contributes to the EU's green transitions towards resource efficiency and the circular economy.

Social impact

Lower emissions from the steel sector play a crucial role in **improving public health for the EU**. As discussed in option SC1, the transition from conventional steelmaking to the scrap-based route will reduce air pollution levels, followed by improved public health. In addition, the deployment of technologies for scrap sorting and handling that generate higher scrap quality would contribute to the development of **the EU's recycling industry**, creating additional jobs and upskill the workforces in this area to adapt to the new technologies

8.4.3. Option SC3: ensuring that final products are recyclable

Economic and competitiveness impact

Improving the recyclability of end-of-life products can **increase the scrap availability for steel production in the EU**. A labelling system can raise consumers' awareness and orient them towards more recyclable products. The revision of the Eco-design Directive may give more incentive for economic players such car manufacturers and construction operators to offer products that facilitate the disassembling and separation of component materials - including steel scrap - for reuse. Altogether, these measures can guarantee the higher recovery of scrap needed for steel production.

This policy option is also expected to **increase the information requirements** on producers or importers of steel-containing products. To comply with the regulation on recyclability labelling or eco-design, these economic actors might be required to gather and report to the regulators (and final users) data on, *inter alia*, recycled material content, recyclability of the products or how the product should be recycled or handled at the end of life.

Finally, this policy might entail a **decrease in the availability of products with low recyclability of steel material**. If products of low recyclability are banned or no longer supported, manufacturers or importers (in cases the manufacturer is not established within the EU) shall have the obligation to switch their production/imports to those of higher recyclability.

Environmental impact

This option would **improve resource efficiency and give great pulse to the circular economy.** Disincentives for poorly recyclable products, a recyclability labelling system and tighter rules on eco-design could increase the recycled content in products, preserve the resources needed in steel production and reduce waste.

As an indirect impact of increasing the scrap availability for steel production, this option could also contribute to a **reduction in GHG emissions from the steel sector** and **support towards the decarbonisation of this industry**. Higher availability of steel scrap will promote the use of the secondary steelmaking route, which is remarkably less carbon-intensive than the primary one.

Finally, this option is also expected to **promote sustainable production and consumption in the EU.** Producers will be encouraged to design products with higher recyclability, e.g. through advertising the recycled content of their products as an environmental marketing edge. Consumers will have adequate and reliable information on the sustainability (including recyclability) of the products, and be more inclined to buy products with higher recyclability.

Social impact

Option SC3 would also have a **positive impact on the EU's recycling industry**. Improved retrieval of waste will enable the EU to improve its recycling capacity and add value to waste inside the EU. Enhancing the recyclability of products can also create additional jobs in this area. This opens the door for scrap recycling job opportunities across a wide range, from material handlers, recycle technicians, warehouse specialists to plant operation managers. This option would also create additional jobs and upskill the workforce of the deconstruction sector. Finally, similar to options SC1 and SC2, this policy option would also support the transition from BF-BOF to EAF route, reducing emission from the steel sector and contributing to improving public health for the EU

8.5. Comparative assessment

8.5.1. Effectiveness

Option SC1: revision of the EU regulatory framework on scrap exports

A large part of the consulted stakeholders agreed that enhanced regulation and monitoring of scrap export (especially illegal export) can contribute to increasing the availability of scrap for the steel industry to some extent. However, the effectiveness this policy option faces several concerns.

- First, this option is only partially effective in reducing scrap export, since EU law (e.g. the Waste Shipment Regulation) only prohibits the export of ELVs that contain hazardous elements, therefore depolluted ELVs do not fall under the scope of export restrictions. Export of non-hazardous waste, while not prohibited, is still subject to the inspection and control of Member States. In practice, however it has been reported that waste exporters often failed to monitor and control the environmental impacts of shipment and treatment of waste outside the EU, potentially provoking adverse environmental impact in the importing countries (European Commission, 2020o, p. 40);
- second, this policy option might not effectively tackle the underlying driver explaining why scrap is exported to non-EU countries in a large quantity. The EU currently has relatively low demand for steel scrap for the EAF route, compared to the steel industry in other countries such as the US or Turkey (Turkish Steel, 2020, p. 9)[82], which are more oriented towards the EAF route. This low demand can be explained by the absence of the conditions needed to increase the EAF capacity in the EU, such as availability of electricity at affordable price, a business case for investments in EAF routes, the

[82] Turkey, for instance, has 68 share of EAF route in total steel production. For further details, please see: Turkish Steel (2020), p. 9

technologies and infrastructure for scrap recycling, and the price-competitiveness of recycled steel and high quality scrap (EURIC, 2021, p. 1).

The concerns above explain the stakeholders' low preference for this policy option. On average, this option scored the lowest in terms of effectiveness compared to options SC1 and SC2.

Option SC2: improving the quality of scrap available in the EU

Promoting the use of technologies for better segregation and processing of steel scrap is highly effective in ensuring sufficient amount of high-quality scrap for the EU steel sector. At present, forecasts show that supply of steel scrap structurally meets European demand (EURIC, 2021, p. 1), but the real concern is to convert recycled scrap into high-quality one. It is therefore important to support R&D&I for scrap quality improvement, leading to the degrees of purity needed for the EAF scrap-based route.

Overall, stakeholders considered that the proposed option supports this process. Results from the public consultation and in-depth interviews showed that this policy option was the most preferred one. Nevertheless, this policy option has certain areas for further improvement, as suggested by some stakeholders. First, the R&D&I should not focus only on the scrap quality, but also on the sustainability factors (e.g. the CO_2 emission related to the handling, transporting and processing of such scrap and the waste water streams related to the scrap treatment). Second, besides R&D&I support, a better scrap price mechanism is also needed to ensure the viability of investments in segregation and processing systems of high-quality scrap (EURIC 2021, p. 7).

Option SC3: ensuring that final products are recyclable

Product labelling can help raise the consumers' awareness about the recyclability, potentially increasing the demand for highly recyclable steel-containing products (EURIC, 2021, p. 15). However, even if the labelling is compulsory, whether or not a label drives consumer choice is difficult to predict. For corporate customers, labelling can provide necessary information for organisations which want to switch their purchase towards products with higher recycled content, especially if such organisations aim to reduce their scope 3 emissions (defined under the GHG Protocol[83]). For individual customers, the incentives to improve recyclability would be lower if the consumers do not look at the specific label when buying goods. In case of voluntary labelling, the effectiveness of this policy measure would be even lower.

Revision of the Eco-design Directive can ensure that products are designed in a way that enables the separation of different materials and hence facilitates recycling. Better recycling of scrap will entail less effort required to sort scrap and remove impurity in the later phase. While increasing the availability of steel scrap, product design optimisation might contribute to higher scrap quality only to a limited extent, and additional efforts for scrap pre-treatment to clean the impurities are still needed.

[83] The GHG Protocol breaks corporates' emissions into three categories: scope 1 emissions cover direct emission caused directly by an organisation's activities, scope 2 emissions covers indirect emissions from the organisation's energy consumption, and scope 3 emissions are all other indirect emissions that occur in the organisation's value chain. More about the GHG Protocol at: https://ghgprotocol.org/scope-3-technical-calculation-guidance

8.5.2. Efficiency

Option SC1: revision of the EU regulatory framework on scrap exports

This option requires the EU to carry out an impact assessment and consult different groups of stakeholders. Once the revision is adopted and implemented, the member states would need to reinforce their inspection and control of shipments and treatment of waste outside the EU. This option also requires harmonised and uniform enforcement across member states. In addition, businesses, such as exporters of steel scrap, will bear additional costs to collect information and report on the condition of the waste shipment and treatment (European Parliament, 2021, p. 6).

Revision of the EU regulatory framework on waste would also **increase the information obligations** on member states' authorities and businesses. Member states will be required to strengthen their inspection systems of waste shipments themselves, as well as of all related recovery and disposal operations. One important area for improvement is that member states need to establish an electronic system for mutual data exchange on the notification procedures.[84] On the businesses' side, to support the strengthened governance of scrap export, economic operators such as waste treatment facilities, producers and exporters of steel-containing products (e.g. car manufacturers) will need to collect and provide information on the environmental and social conditions of the shipment and the treatment of the waste.

Option SC2: improve the quality of scrap available in the EU

Achievement of higher degrees of scrap purity requires significant investments. On the public side, funding for scrap quality improvement innovation needs secured budget from funds such as Horizon Europe, the CF and the IF. The use of BATs for scrap processing requires the exchange of information and good practices among experts from EU member states, industries, academics, civil society organisations and the EC.[85]

Option SC3: ensuring that final products are recyclable

The labelling system can generate its optimal benefits if accompanied with adequate measures to raise the awareness and educate the consumers about sustainable consumption. The revision of the Eco-design Directive would require member states to set up their surveillance systems (themselves or through third party certification) to verify the products' compliance with recyclability or material efficiency requirements.

8.5.3. Feasibility

Option SC1: revision of the EU regulatory framework on scrap exports

This option is politically feasible, as it received support from the European Parliament. The European Parliament, in its Implementation Appraisal on the Waste Shipment Regulation, expressed support for the Commission's revision of the Waste Shipment Directive to "halt the

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[84] The notification procedure is a control procedure applied by MS. It applies to the shipment of, among others, hazardous waste. This procedure requires that the competent authorities of all MS concerned by the shipment give their consent to the shipment. For further details, please see European Parliament (2021), Implementation Appraisal: Waste Shipment Regulation, p. 3.

[85] For instance, the BREF requires the exchange of information between EU MS, the industries concerned, non-governmental organisations promoting environmental protection and the EC in order to draw up, review and, if necessary, update BREFs. For further details, please see: https://publications.jrc.ec.europa.eu/repository/handle/JRC69967

export to third countries of waste that causes environmental or human health damage" (European Parliament, 2021, p. 8). Its implementation would, however, be more challenging. The stringent control of waste export from the EU to third countries would require the establishment or reinforcement of a monitoring system on the treatment of waste (scrap in our case) in the importing countries. This process happens outside the EU, and data on illegal shipments of waste are often difficult to obtain (European Parliament, 2021, p. 5). The feasibility of diligently monitoring this inspection system of waste treatment outside the EU might be low.

Finally, there is concern that this policy option might **affect the EU's compliance with legal commitments with trade agreements.** The proposed revision of the Waste Shipments Regulation and the ELV Directive, if not carefully assessed, can create the risk of introducing trade-restrictive measures that go against the trade agreements entered into by the EU. It is therefore important to assess the unintended consequences if the supply chain is affected by a restriction on scrap export or other trade restrictions, potentially entailing market distortions on availability and prices in the long run.

Option SC2: improve the quality of scrap available in the EU

This policy option is likely to receive support from EU and national policymakers to be properly implemented. For instance, the European Parliament has demanded the EC to provide support for recycling capacities and waste treatment infrastructure within the EU (European Parliament, 2021, p. 8). In practice, R&D&I to improve the scrap quality has already received budget from several EU funding programmes such as H2020, HEU, the CF, the European Fund for Strategic Investments and Innovfin (the most recent example is the HEU funding for scrap treatment technologies under the CSP (ESTEP, 2020a, p. 45)). The continuation of EU funding for higher TRLs (e.g. under the IF) also aligns well with the EU's Masterplan for energy-intensive industries (European Commission, 2019e, pp. 30-33). The exchange of BATs in the Iron and Steel Production has been actively maintained by EU member states, the industries, non-governmental organisations and the EC.

Option SC3: ensuring that final products are recyclable

The Eco-design Directive is under revision phase, with the public consultation being completed in June 2021 and the Commission's adoption planned for the fourth quarter of 2021 (European Commission n.d.). Itis important that the revision relevant to steel downstream-products, such as vehicles and buildings, is carefully assessed and take into account the use of green steel in the production of such products.

8.5.4. Coherence

All the proposed policy solutions are coherent with the spirit of the EU Green Deal, particularly the Circular Economy Action Plan, which is one of the main building blocks of the Green Deal. The EU's agenda on the circular economy focuses on steel-downstream sectors with high circularity potential such as construction, vehicles and electronics. In addition, the proposed solutions also align well with EU legislation on waste, including the Waste Shipment Regulation, the Waste Framework Directive and ELV Directive. Finally, they are also coherent with different agreements which the EU is part of, including the Basel Convention on the control of transboundary movements of hazardous waste[86] and the OECD Decision on the control of transboundary movements of waste destined for recovery operations[87].

Table 13 ***Overview of policy solutions – Iron and steel scrap***

	Effectiveness	**Efficiency**	**Feasibility**	**Coherence**
Option SC1: revision of the EU regulatory framework on scrap exports				
Option SC2: improving the quality of scrap available in the EU				
Option SC3: ensuring that final products are recyclable				

Note: This table presents the policy options linked to steel scrap that would support the decarbonisation of the EU steel industry. The options are assessed based on the four criteria under the Better Regulation guidelines: their effectiveness, efficiency, feasibility and coherence. Colour legend: orange - low, yellow – moderate, green – high. For instance, a policy option that has a green cell in the Effectiveness column is considered to be "highly" effective. Source: authors' own composition.

[86] The text of the Basel Convention is available at http://www.basel.int/TheConvention/Overview/TextoftheConvention/tabid/1275/Default.aspx

[87] The text of the OECD Decision is available at https://legalinstruments.oecd.org/en/instruments/OECD-LEGAL-0266

9. Cross-cutting policy options

9.1. Impacts

9.1.1. Policy option: integration of compulsory low-carbon standards

Economic and competitiveness impact

This measure will have a tangible impact on investments and R&D&I because producers will have a strong interest in aligning their products and processes to the standards. This will also be an enabler of sustainable production and consumption and, as a result, of the decarbonisation of the steel sector.

The integration of green standards in the BREFs would have a great impact on the development and deployment of relevant technologies. While integrating low-emission standards with BATs will force producers to introduce new technologies, some argue that it may delay new investments, as equipment will become more expensive. This, in turn, could limit this measure's impact magnitude. The implementation of BATs required by this option will cause, at least in the initial phase, some additional inconvenience to steelmakers. On the other hand, it will positively affect all environmental aspects of steel production. Overall, it will imply additional adjustment, compliance and transaction costs, as well as additional information obligations for steel companies.

In addition, standards can contribute to the allowance of a "premium price" which, in turn, can increase the ROI of 'low-carbon' or 'green' investments and support the investment in EU low-carbon technologies development. Positive effects can be envisioned also on green public procurement and "green" project eligibility criteria.

Environmental impact

As noted in the US (Feldmann and Kennedy, 2021), low-carbon standards for steel can foster the adoption of green technologies and result in emission reductions while, at the same time, preserving the competitiveness of domestic steel manufacturers. This can drive a reduction in emission intensity in the steel industry; provide incentives to adopt existing abatement options and to invest in emerging technologies, and reduce the administrative burden. Therefore, it is expected that this option will **reduce the emission of GHGs from the steel sector into the atmosphere, improving the ability of the EU to adapt to climate change and promoting the decarbonisation of the steel industry.**

Social impact

The introduction of EU standards can help overcome green washing, support the EU production and regulate the export/import of low-carbon steel - if properly connected with action at international level. This measure is also expected to meet social consensus and improve awareness about the climate and energy transition in education.

Impacts on other policy areas:

The proposed solution will have a positive impact on steel production from scrap, as already demonstrated in the past (cf. the French project "the cycle of iron" in the 1990s). RES-E, CCUS and green hydrogen demand is expected to be lower compared to other options. The impact in these areas will be indirect. If steel manufacturers have no choice but to use RES-E, green hydrogen or CCUS to comply with the new standard, this will create demand for those technologies and **boost the development of new RES-E, green hydrogen and CCUS projects**.

9.1.2. Policy option: green public procurement

Economic and competitiveness impact

The primary impact of the promotion of green steel in public procurement would be to increase the demand of such product, and to foster and the business and investment case for green steel production. Over time, this could have an impact on **the costs of doing business in the steel industry**, depending on whether the assets available to a producer can fulfil the 'green' demand. GPP would thus have a direct positive impact on **sustainable consumption** and an indirect positive impact on **sustainable production**.

GPP does not necessarily have to target individual sectors or products. It could be desirable to maintain a degree of technology neutrality and leave it up to project developers to decide how carbon reductions can be achieved. This means that green public procurement can also boost demand for green production in other industrial sectors, some of which may use similar decarbonisation technologies as the steel sector. This would affect the **costs of doing business for other sectors** as well and have an **impact on investment patterns**.

GPP may **increase transaction costs**. The requirements to comply with new green public procurement standards can lead to **administrative costs**. However, the impact may only be indirect for steel producers: the greatest impact will be felt by those making procurement decisions.

Greater demand for green steel can support the investment case for breakthrough technologies. As a result, the **investment cycles of the steel industry** can be affected. As conventional steel will get replaced by green steel, investments in older facilities could also be affected. Policy-mandated demand for green steel would also increase the need for **R&D&I** (especially later-stage innovation).

Environmental impact

GHG emissions would not be directly impacted by GPP. The indirect impact, however, can be significant, as it will support the business and investment case for steelmaking with lower emissions.

GPP could support the wider **green transition in the EU** by giving preference to lower-carbon and more energy- and resource-efficient solutions, thereby expanding the market for more sustainable, climate-neutral products.

Other impacts

GPP could increase the expenditure for public procurement projects and therefore have an **impact on member states' budgets**. Adding criteria for public procurement beyond cost-efficiency, such as those based on carbon content, can increase costs so long as the lower-carbon products are costlier and less competitive.

Impacts on other policy areas

- ***Availability of RES-E for the steel sector***

GPP supporting demand for green steel would not directly lead to greater **availability of RES-E** for the steel sector. However, just as GPP can mandate the use of lower-carbon materials – including steel – also an increased use of RES-E could be mandated. The use of carbon accounting conventions focusing on Scope 2 and Scope 3 emissions would make this more likely. Supporting green steel demand through public procurement would also increase the business case for steel production methods that rely on large quantities of RES-E, such as the secondary steelmaking route. Therefore, GPP can indirectly lead to an expansion of RES-E capacity over time.

- ***Interaction with carbon pricing policies in the EU***

By increasing demand for products with lower embedded emissions, the **demand for allowances under the EU ETS** can indirectly decline. If GPP is successful in generating investment in lower-carbon production, this could eventually be reflected in the ETS benchmarks, which are based on the most emission-efficient installations. Both the ETS benchmarks, as well as the carbon price in general, could provide data points to be used as a basis for public procurement standards.

- ***The business case for green hydrogen***

The business case for green hydrogen should indirectly improve if GPP practices supported the demand for green steel. Green hydrogen is, in fact, one of the decarbonisation routes for the steel industry, therefore its demand would increase. However, the exact scope of its impact depends on the extent to which steelmaking facilities will develop direct reduced iron technologies that use hydrogen as a reducing agent, as well as on the availability and costs of other types of hydrogen and decarbonisation routes, such as CCUS.

- ***The business case for CCUS***

The business case for CCUS should indirectly improve if GPP practices supported the demand for green steel, as CCUS is one of the decarbonisation routes for the steel industry.. However, the exact impact depends on the deployment of carbon capture technology and infrastructure, as well as on the availability and costs of other steel sector decarbonisation routes, such as hydrogen.

- ***The availability of high-quality scrap for the steel sector***

GPP can make it more attractive to invest in the collection of scrap and in technologies to recover scrap with higher purities, thus enabling more secondary steelmaking. The impact, however, is indirect, and depends on the availability and support for alternative decarbonisation options as well.

9.1.3. Policy option: developing a green label for low-carbon steel

Economic and competitiveness impact

A green label for low-carbon steel would not lead to immediate changes to the **costs of doing business for the steel industry**. However, demand for green steel could be supported by a green label. This can subsequently improve the business and investment case for green steel production. It thereby supports more **sustainable production and consumption**.

A green label could increase **transaction costs** for businesses. These costs are related to the information requirements of the label (e.g. data collection such as emissions intensity) and the adjustment to marketing material.

Environmental impact

A green label supports more **sustainable consumption** of climate neutral goods. This should have a positive impact on **GHG emissions** over time.

A green label could apply to many different industrial goods and products and thereby **support the green transition in the EU** in general. Green labels may also support the functioning of other policies, such as green public procurement.

Impacts on other policy areas

A green label for low-carbon steel would not have a direct **impact on the deployment of RES-E, green hydrogen, CCUS or scrap collection**. However, green labels could conceivably contain information about production methods, which enhance customer information on the products' carbon content. This could have an indirect positive impact on the business case for these decarbonisation options.

Green labels may also be developed by other countries pursuing a deep decarbonisation in industry. In so far as the green labels are just there for consumer information, this should not pose problems. However, should the green labels form part of a larger standardisation policy, compatibility between different labels (and the data contained therein) could **affect trade**.

9.1.4. Policy option: CCfDs

Economic and competitiveness impact

CCfDs could have a direct positive impact on the **costs of doing business** for the steel industry by providing a premium for green steel production. CCfDs can cover CAPEX and in theory OPEX costs as well. CCfDs would likely be designed as a cross-sectoral funding instrument available to multiple industrial sectors. As such, they could likewise have a positive impact on the **costs of doing business for other industries** as well.

CCfDs could **attract investment** in green industrial production by defraying part of the investment costs. As such, they have a positive impact on inward **investment flows**. As CCfDs are linked to expansion of climate neutral production capacity, **trade flows** could also be affected over time.

The capacity of the EU steel industry to innovate should be significantly positively impacted by CCfDs. The CCfD-subsidy would be made available conditional on investments in low-carbon production capacity. By expanding low-carbon production capacity, **sustainable production** will grow.

CCfDs are an industrial policy measure aimed at supporting investments in climate neutral production. In doing so, they also **support industrial competitiveness**, especially in the longer-term. While CCfDs are not intended to mitigate carbon leakage risk, indirectly they may still do so by making it attractive to produce in the EU in order to be eligible to receive funding through CCfDs. In so far as global steel markets shift to lower-carbon steel, EU producers should benefit in terms of **market share vis-à-vis non-EU competitors**.

Environmental impact

GHG emissions could be significantly reduced by CCfDs as they support expansion of climate neutral production capacity. The effect will only materialise in the mid-to-long term, however, as it requires investments with long lead times.

As an instrument potentially applicable to industrial sectors in general, CCfDs can accelerate the industrial decarbonisation dimension of the **green transition**. Conversely, CCfDs – and the broader climate-neutral industrial expansion – are not likely to benefit other environmental goals, with the exception of air quality in case fossil fuels are displaced.

Other impacts

As a form of subsidies, CCfDs need to **comply with the WTO rules on subsidies**. Given the environmental imperative of the measure, this should not pose problems, although the measure should be designed to minimise distorting trade, just as CCfDs implemented by EU member states should be designed in line with EU State aid rules to **minimise distortions to the internal market**.

CCfDs can carry a significant price tag and therefore have a **large potential impact on member states' budgets**. However, due to their interaction with the ETS carbon price, this impact can be mitigated. The higher the carbon price is, the lower the expenditure required for CCfDs.

Impact on other policy areas

CCfDs have a built-in **positive interaction with the EU ETS,** as they are designed to stabilise the carbon price component in an investment decision (through strike prices). If the ETS price equals the strike price, in principle, the premium offered drops to zero. This limits the potential expenditure for the issuer of the CCfD.

Business case for green hydrogen and CCUS: CCfDs would only be issued for investment projects compatible with the EU's decarbonisation objectives. For the steel industry, this means that green hydrogen and CCUS are likely to benefit significantly, as they provide pathways for green steelmaking. The impact should be a direct one, with part of the funding provided through CCfDs fostering the expansion of hydrogen or CCUS capacity.

Availability of RES-E and high-quality scraps: the availability of RES-E would be supported by CCfDs both directly and indirectly. Technologies that have higher CO_2 mitigation potential require greater volumes of RES-E, as does hydrogen-based steelmaking in so far as the hydrogen is produced through electrolysis. CCfDs could in theory also support projects making increased use of scraps. However, as scrap-based steelmaking does not require the same type of large-scale breakthrough investments as with other technology pathways, the impact may be more limited.

9.1.5. Policy option: higher carbon price due to increased scarcity in the EU ETS

Economic and competitiveness impact

A higher carbon price increases carbon costs and therefore the **costs of doing business**. This is true for the steel industry and for other industries covered by the EU ETS. The actual carbon costs also depend on the volume of the free allocation given. Even with free allocation, however, the opportunity costs of holding allowances increases with a higher ETS price.

With a higher carbon price, investments in climate neutral production technologies have a higher chance of being "in the money". At the same time, the carbon compliance costs for existing assets increase. Therefore, the **impact on investments** depends on the costs and availability of emission reduction technologies and other policies (such as CCfDs), that support breakthrough investments.

Trade and investment flows can be affected both positively and negatively by higher carbon prices. While higher carbon price could reduce exports by EU steel producers due to carbon leakage risk, there are measures in place to mitigate this risk. Without effective and proportional carbon leakage risk mitigation, higher carbon prices would adversely impact the market share and competitive position of EU producers vis-à-vis non-EU producers.

All else unchanged, a higher ETS price would lead to **more sustainable production and consumption**, by making comparatively lower-carbon products a competitive advantage. This will decrease the relative price of environmentally-friendly goods. Higher carbon prices can increase the need to reduce emissions, which can attract investment in abatement technology.

Environmental impact

Higher carbon prices should lead to **lower emissions of GHGs**. If the higher carbon prices are the result of increased scarcity in the ETS, this impact will be certain, as the cap will always be met.

Higher carbon prices can have a signal effect for the **green transition in the EU** in general. Although the carbon price does not affect environmental indicators beyond GHGs, it can serve as a benchmark for other climate policies, such as for sustainable finance, internal carbon prices of companies, or for GPP.

Other impacts

Higher carbon prices or increased scarcity as such should not impact **regulatory convergence with third countries**. However, if the EU wants to link its ETS to carbon markets in other jurisdictions, the two parties should find an agreement on what constitutes an appropriate supply.

Higher carbon prices have a significant **positive impact on member states' budgets**. As auctioning is the default method of allocation in the ETS, applicable to over 55% of ETS emissions, a higher carbon price will increase revenues for member states.

Impact on other policy areas

A higher carbon price and increased scarcity in the EU ETS can have a positive impact on the **business and investment case for green hydrogen**. The EU ETS covers different types of hydrogen production. Green hydrogen is covered via the provisions applicable for the power sector and electrolysis. Grey and blue hydrogen are covered as stand-alone industrial sectors. If CCS is used, the compliance obligation for the captured emissions disappears. For now, green hydrogen is less competitive than other types of hydrogen. Higher carbon prices would make green hydrogen relatively more competitive vis-à-vis production methods associated with higher GHG emissions. **The business case for CCUS** also increases with higher carbon prices by increasing the cost of unabated emissions. In addition, higher carbon prices promote higher capture rates, as the residual emissions still carry a compliance obligation.

Higher carbon prices and increased ETS scarcity can support the **increased availability of RES-E**. With higher carbon prices, carbon-intensive electricity will be pushed down the merit order and becomes less competitive. At the same time, higher carbon prices increase the wholesale electricity price. This strengthens the investment signal for renewables investment. The impact on **availability of scraps** can indirectly be positive, by increasing the costs of relatively more carbon-intensive steelmaking processes.

9.2. Comparative assessment

9.2.1. Effectiveness

Policy option on GPP

GPP is considered to be a very effective policy option that can support the steel sector's decarbonisation across the value chain. GPP is seen as most effective when considered as a complementary policy to address weaknesses of carbon pricing through the ETS: by inducing demand for green steel through policy, investments in climate neutral production methods become more attractive. Over time, this will lower the abatement costs and increase the role of the carbon price in decarbonising steel. GPP is considered a moderately effective policy to attract funding. By promoting the use of climate neutral materials such as green steel, decarbonisation options that enable green steelmaking are indirectly supported as well. For CCUS in particular, GPP is considered an effective method to support a market. The effectiveness of green public procurement can be limited due to information asymmetries and transaction costs along the value chain.

Policy option: developing a green label for low-carbon steel

A green label is considered a moderately effective way to support the decarbonisation of the steel industry. It is most effective in so far as it helps to distinguish between low-carbon and high-carbon intensive steel products. Such market differentiation can support demand for green steel specifically and thereby attract investment. As a second-order effect, increased demand for green steel can indirectly support the deployment of green hydrogen and CCUS, as well as RES-E and steel scrap, although this effect may be modest.

Policy option: introducing CCfDs

The introduction of CCfDs is considered to be the most effective policy option to ensure that carbon pricing policies in the EU contribute to emissions reduction in the steel sector. CCfDs are designed to complement the ETS price, while, at the same time, making funding available (which directly leads to emissions reductions). CCfDs support investments that enable climate-neutral steelmaking, while also supporting the competitiveness of greener steelmaking in the long term.

CCfDs could also achieve some of the goals that other funding instruments aim to achieve, such as mobilising private capital, de-risking investments (by stabilising the carbon price component) and providing funding for capital investments. CCfDs are also considered to be a highly effective instrument to support green hydrogen deployment (similar to financing the deployment of electrolysers). They could have a similarly positive impact on the deployment of CCUS and RES-E as well.

Policy option: higher carbon price due to increased scarcity in the EU ETS

A higher carbon price in the EU ETS would be moderately effective in supporting the decarbonisation of the steel industry. Several stakeholders see higher carbon prices as a necessary but not sufficient condition to increase green steel investments and emission reductions. For the deployment of currently costly options such as CCUS, a higher carbon price can improve the investment case. A higher carbon price can, likewise, improve the investment case for green hydrogen, and foster greater RE deployment by increasing the costs of carbon-intensive electricity generation.

9.2.2. Efficiency

Policy option: GPP

GPP may carry direct costs due to the procurement of costlier products that satisfy the 'green' requirements. Indirectly, administrative and transaction costs may reduce the efficiency of GPP. The more different stakeholders are involved, the more transaction costs may play a role.

In spite of these costs, however, GPP is inherently efficient as it ensures that governmental spending contributes to other long-term public policy objectives. The cost reductions that can arise as a result of an increased market for green steel (and other climate neutral products) will have a positive impact on both industrial competitiveness and climate policy.

Policy option: developing a green label for low-carbon steel

A green label is considered a moderately effective way to support the decarbonisation of the steel industry. It is most effective in so far as it helps to distinguish between low-carbon and high-carbon intensive steel products. Such market differentiation can support demand for green steel specifically and thereby attract investment. As a second-order effect, increased demand for green steel can indirectly support the deployment of green hydrogen and CCUS, as well as RES-E and steel scrap, although this effect may be modest.

Policy option: introducing CCfDs

In spite of the potentially significant costs, CCfDs can be a highly efficient tool to support the deployment of cleaner steelmaking technologies. CCfDs can de-risk investments, provide stability and contribute to covering CAPEX and OPEX costs. Their interaction with the ETS price ensures that the exposure of the issuer of CCfDs remains limited. CCfDs can also build on other design elements of the ETS to determine how they should be deployed (e.g. sector or benchmark definitions).

Policy option: higher carbon price due to increased scarcity in the EU ETS

A higher carbon price in the EU ETS would be a highly efficient instrument to promote additional emission reductions in the steel industry. Carbon pricing is considered a first-best instrument to address externalities such as GHG emissions, even if other policy tools may remain necessary to achieve deep decarbonisation. The auctioning of allowances can create an additional 'dividend' which can be used to fund other climate policy actions, or to defray the costs of certain policies. Higher carbon prices can increase carbon leakage risk. The mitigation of carbon leakage risk can result in less efficient policy design.

9.2.3. Feasibility

Policy option: GPP

Greening public procurement is seen as a moderately feasible policy option. In principle, existing EU legislation could be amended to pursue GPP. Member states can also change domestic practices. When seen from the perspective of creating demand with the aim of supporting CCUS deployment, the feasibility is considered high by many stakeholders.

Policy option: developing a green label for low-carbon steel

A green label would be a comparatively light-touch policy intervention that falls within the EU's internal market competences. As such, it is a feasible policy option, even if there may be political disagreements on the data to be used.

Policy option: introducing CCfDs

Introducing CCfDs is seen as a highly feasible policy option. The instrument is already deployed in some member states. CCfDs could be applied to existing instruments such as the EU ETS IF. However, CCfDs would have the greatest impact if the funding they provide is additional, not that the CCfD is merely used as a means to allocate existing financing. Finding the budget for new financing streams may be politically challenging.

Policy option: higher carbon price due to increased scarcity in the EU ETS

Increasing scarcity in the EU ETS is a highly feasible policy option. The EU ETS is considered the cornerstone of EU climate policy. The EU ETS will be revised in any case to reflect the new "at least -55%" emissions reductions target for 2030.

9.2.4. Coherence

All proposed policies are coherent with existing EU climate strategies and policies. Some policy options, such as green labels or GPP, could contribute to multiple dimension of the European Green Deal, including environment and circularity. Several policy options strengthen or make use of already existing measures, such as carbon pricing in the EU ETS. Compatibility with the functioning of the internal market can also be assured in the design of the policy measures.

10. Monitoring indicators

Based on the comparative assessment of the policy options under each thematic chapter, a few options stand out in in terms of effectiveness, efficiency, feasibility and coherence. The following set of indicators can be used to measure the progress and achievement of these policy options.

10.1. Funding

Indicators for option FD1 (promoting the use EU funding programmes to finance OPEX of low-carbon steel)

- The number of calls and applications (and funding allocated and awarded) to the ETS IF. This indicator can provide information on future trends in corporate investments aimed to green the steel industry.

Indicators for option FD4 (introducing risk mitigation and loan guarantee instruments for investments in decarbonisation technologies)

- The impact of the recent revisions introduced by the EC or the EIB for risk alleviation in the steel industry. This indicator can immediately provide information concerning the availability of risk mitigation instruments.

Indicators for option FD5 (integration of compulsory low-carbon standards)

- The impact of the recent revisions introduced by the EC on compulsory low-carbon standards in steel manufacturing and in the manufacturing of products using steel. This indicator can immediately provide information concerning possible future changes in the regulation.
- The embedded carbon contents of steel, expressed in kg of CO_2 per tonne of product. This indicator can provide an expectation of what an appropriate standard could be. The average carbon intensity of steel producers in the EU can, likewise, provide information on a possible standard to be set.

Indicators for option FD6 (promotion of low-carbon steel products in public procurement)

- The number of new EC public procurement calls[88] specifically require green steel. This indicator can provide an insight about whether or not the public sector is supporting the demand for this product. Economic trends should be considered, especially in the light of the recent cuts in public investments because of the Covid-19 pandemic.

10.2. Carbon pricing

Indicators for option CP2 (reducing steel sector abatement costs)

To monitor the change in abatement costs for the steel industry, both an absolute value as well as a relative value can be used.

- The abatement costs can be monitored for the technology pathways discussed in WP1.

[88] For further information on EC tendering opportunities, please see: https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/how-to-participate/tenders

- As a relative indicator, the learning rates for key technologies (including those of interest to industries beyond steel) can be monitored.

Indicators for option CP5 (introducing CCfDs)

- The amount in EUR of funding provided through CCfDs that benefit the steel industry.
- The number of CCfDs concluded, both at member-state and EU level, that benefit the steel industry.

At member state level, some national policies may not be explicitly called CCfDs, even if they otherwise have the characteristics of one. Hence, a formal definition of what a CCfD is is required, which could be provided through the guidance of DG COMP. When tracking the number of CCfDs and the amount of funding provided through them, it should also be monitored if they benefit the steel sector directly or only indirectly, as it may happen whenever cross-cutting technologies such as hydrogen or CCUS are supported.

Indicators for option CP6 (implementing a CBAM)

- The relative market share of EU producers versus non-EU producers (this can be supported by monitoring trade data on imports and exports as reported in the Comext database).
- Carbon intensity of production of EU steel producers versus non-EU steel producers;
- The average effective carbon price paid by steel producers in non-EU countries exporting steel into the EU market.

10.3. Renewable electricity

Indicators for option RE1 (EU funding for RE technologies)

- The amount of guarantees issued by the EIB and national public investment banks for RE projects (€) relative to a baseline year (yearly increase). This indicator measures the EU and member states' financial support to de-risk private investments in RE projects. The use of yearly increase is helpful in tracking the trend of public support for RE projects. This indicator can be built through yearly collection of data from the EIB and national public investment banks.
- The number of public-supported demonstration projects of RE technologies (e.g. for TRL7-9). This indicator shows EU's support to bridge the funding gaps between research and commercialisation of innovative RE technologies. One limitation of this measure is that it does not measure the amount of funding provided or assess the quality of such support. Some alternatives to this measure can be i) the amount of funding provided relative to a baseline year, or ii) the number of projects that achieve the desired TRL.

Indicators for option RE5 (PPAs or green energy offers)

- The number of member states that have set up public-supported guarantee mechanisms for PPAs. This indicator reflects member states' progress in supporting the financial costs that steel producers or energy sellers bear when entering long-term PPAs. It does not, however, measure the advancement and effectiveness of such guarantee mechanism. An alternative indicator would therefore be the amount of steel projects that received public-supported guarantees.

- The development of an EU guideline on GOs for RE. This is a binary indicator that receives a yes/no value. It measures the EU's effort to harmonise the GO systems across member states, reducing the administrative burden of managing, transferring, and cancelling GOs.
- The percentage of member states' electricity cables that allow the electricity produced by their power plants to be transported across their borders to neighbouring countries. This indicator shows member states' progress towards achieving the 15% interconnection targets, which is a crucial element to promote cross-border PPAs. This indicator can continue to be collected under the EC report on the State of the Energy Union.[163]

Indicators for option RE7 (energy storage policies)

- The amount of EU funding (e.g. Under the CEF) allocated to energy storage projects (€) relative to a baseline year. The indicator can focus on energy technologies that are specific for the decarbonisation of steelmaking processes, e.g. power-to-X technologies.
- The average duration of the permitting-granting process for storage projects classified as IPCEIs and therefore eligible for CEF funding. This indicator measures whether member states' authorisation process shortens and simplifies the permitting process for these projects, as stipulated by the TEN-E Regulation. The information on permits can be collected from the national or local authorities which issue the permits.

10.4. Green hydrogen

Indicators for option GH1 (supporting member states' initiatives towards early deployment)

As this option contributes more to the strategic guidance that the EU can offer to member states, an indicator quantifying the extent of this contribution is more difficult to design.

- A potential indicator could measure the total capacity of electrolysers under development following the publication of EU strategic documents.
- In addition, price targets for new electrolyser capacities (measured in €/MW) could be monitored periodically, to assess whether they meet the goals outlined in strategic documents such as the Hydrogen Strategy. Benchmarks can be established for multiple types of electrolyser technologies. Similarly, a stocktaking can be done regarding member states' ambitions manifested through strategic plans proposed under EU guidance (such as the National Energy and Climate Plans and the National Recovery and Resilience Plans) and see how they evolve over time. For instruments such as IPCEIs, an adequate indicator could be installed capacity measured in MW.

Indicators for option GH4 (offering a premium to producers of green hydrogen, through CCfDs)

- As this option would directly provide funding for specific projects, the main indicator could be electrolyser capacity installed measured in MW.
- A likewise important indicator, especially from an efficiency perspective, is the strike price for the green hydrogen produced from the installed electrolysers, measured in €/MWh. This is particularly relevant for premiums awarded on a competitive tendering process which should be designed to deliver the lowest possible strike price.

- As the purpose of this option is not only to foster the deployment of new electrolyser capacity, but also to potentially offer support for promising technologies, a separate indicator may also be needed for the development of technologies that have not yet reached commercial readiness. This could be measured either by considering capacity for specific technologies (e.g. PEM), or by measuring the cost savings achieved compared to previous projects using similar installations.

10.5. CCUS

Indicators for option CCUS8 (supporting clusters/industrial symbiosis - e.g. through IPCEIs)

- Whether or not an IPCEI has been established would be a direct and simple indicator to measure aspects of CCUS8. As an IPCEI is a proposed way to achieve the objectives, measuring if one has been established can be a direct way to see whether collaboration between companies is taking place. However, such an indicator would not be able to measure to what extent clustering or industrial symbiosis take place. Additional indicators could be apt to measure the degree to which this takes place both inside and outside of establishing an IPCEI, which may require using, adapting or developing a model combining different indicators.

Indicators for option CCUS5 (providing increased public support and funding for R&D&I to optimise capture at high rates)

- Public funding provided for R&D&I for optimizing CO_2 capture (€) relative to a baseline year (% change). The indicator is directly relevant to policy option CCUS5, as it would provide a direct measurement of whether an increase in funding for R&D&I aimed at optimizing capture at high rates would take place. By establishing a baseline of funding provided for R&D&I towards optimizing capture, it would be possible to measure the relative change in funds provided for this purpose. Tracking such specific directions for public funds could, however, become an additional administrative burden.
- Number of active R&D&I projects relevant to optimising capture at high rates receiving public support. Notably, however, this indicator would not be able to evaluate the quality of such support, and neither the amount of funding provided. It would also entail some administrative burden in collecting such detailed data. Combined with the first indicator, however, it could provide a comprehensive picture of the public support provided for CCUS5.

10.6. Steel scrap

Indicators for option SC2 (Improving the quality of steel scrap in the EU)

Several indicators can be used to track the achievement of this policy option, such as:

- The amount of EU funding (€) for R&D&I of technologies that improve the quality of steel scrap relative to a baseline year. This indicator could particularly measure the funding available to support the demonstration and deployment of these technologies. One limit of this measure is that it does not evaluate the quality of such support. An alternative indicator can be the number of projects that achieve the desired TRL.

- The updates of the BATs that include the most modern scrap sorting and handling technologies. This is a binary indicator that receives a yes/no value.

10.7. Cross-cutting options

Indicators for GPP:

- The percentage of public procurement spent in line with activities considered compatible with the Paris Agreement under sustainable finance taxonomy (lower bound).
- The percentage of total public procurement targeting green products of top 10 industrial EU ETS sections as measured by GHGs in the EU Transaction Log. For steel products specifically, this would be NACE code 24.10.
- The number of GPP projects per MS.
- The increase in the demand for green steel in longer-term. This could be measured as the share of the volume of production of total steel production that fulfils the criteria to be considered ‘green steel’. (NACE code 24.10 in Eurostat Comext).

Indicators for EU ETS:

- The volume of allowances, reflecting ETS scarcity. The linear reduction factor and updated baselines for the cap specifically.
- The removals by the MSR and invalidations.
- Carbon price.

Indicators for CCfDs:

- The amount in € of funding provided through CCfDs.
- The number of CCfDs concluded, both in MS and at EU level that benefit the steel industry. At the member state level, some national policies may not be explicitly called a CCfD, even if they otherwise have the characteristics of one. Hence, a formal definition of a CCfD is required, which could be provided through DG COMP guidance.

Indicators for standards:

- The number of products for which standards (kg of Co2 per tonne of product) have been established.
- The aggregate steel sector emissions (EUTL) and trade volumes covered (Comext) (NACE24.10).

11. Recommendations

All cross-cutting options are recommended, although the introduction of low-carbon standards should receive a lower priority, and should rather be seen as a long-term option.

The cross-cutting policy options have the potential to contribute to multiple relevant areas for the decarbonisation of the steel sector at once. Moreover, the policy options represent approaches that could also be applied to other major energy-intensive sectors. Therefore, the coherence of these options in contributing to the Green Deal and the EU's 2050 climate objectives is considerable.

GPP can support demand for green steel but does not state how green steel is produced or how the emission reductions from its actual use are achieved. It can therefore indirectly contribute to low-carbon steelmaking processes and also increase circularity and reduce the demand for steel.

A green label for green steel would be a lighter touch measure that could send a clear signal to the market that there is differentiation in the market for steel. It would also require a clear definition of what green steel actually is, which can, in turn, support dissemination of technology solutions throughout the value chains where steel is used. Green labels could also strengthen GPP by making it easier to create a demand for green materials.

CCfDs would apply to specific investments in the steel industry. However, the mechanism could also be used to finance climate-neutral production processes in other sectors that currently still face high abatement costs. The interaction with the ETS price makes CCfDs an attractive complement to the already existing carbon pricing regime in the EU. In addition, CCfDs can be created at both MS and EU level. The greatest impact from CCfDs would, however, require to allocate the funding provided through these instruments to the support of investments in climate-neutral industry.

Increasing scarcity in the EU ETS on its own would not be sufficient to trigger immediate investment in climate-neutral steelmaking. Nevertheless, if increasingly scarce allowances make carbon prices go up, then reducing emissions in the most carbon-intensive steel production facilities would become more appealing. A stronger carbon price signal could also be used to guide procurement choices while, at the same time, the amount of funding needed to provide CCfDs would decline with higher carbon prices.

The introduction of low-carbon standards could be an attractive option to protect the competitiveness of EU steel producers, once the capacity of green steel production in the EU has expanded. Such a standard would be an internal market measure applying to both domestic producers and importers, therefore EU producers would only face competition from producers who can produce steel with a sufficiently low carbon footprint.

In addition to the cross-cutting policy options, a number of policy options pertaining to specific policy areas are recommended. Funding options – while being the focus of a dedicated chapter in this report – nevertheless have the potential to cut across different areas and positively impact multiple areas at once. Policy options for funding can be divided into three categories: technology push, demand-pull, and options affecting the playing field for steel producers. In addition to GPP and low-carbon standards, two specific options are recommended. The first is the promotion of EU funds to cover increased OPEX costs. While operational costs are generally expected to not be (fully) compensated, temporary and limited support for increased OPEX while the steel industry starts producing climate-neutral steel can help making green steel more competitive over time. Similarly, to boost what are considered to be risky investments in climate-neutral steelmaking technologies, de-risking instruments and loan guarantees are recommended. However, private investments still depend on a bigger market for green steel specifically, hence the importance of some of the lead market and demand-side measures proposed.

Regarding RES-E, continued support for innovation and deployment of RE is recommended. Electrification often represents an efficient and attractive decarbonisation pathway for the steel industry, whether directly or indirectly through green hydrogen. However, the volumes of RE needed are vast, and include also other industrial sectors and sectors outside industry and electricity generation itself, such as road transport and heating. Therefore, innovation and commercialisation support for not-yet-mature RE technologies can help increase the supply of RE for steel and other sectors in the future.

PPAs also provide a good approach for industrial electricity consumers, as it allows for longer-term investment signals in renewables capacity. In addition, they can also make electricity costs more predictable. Instruments such as CCfDs allow for public support in managing electricity prices, thereby supporting steel producers' competitiveness. Finally, with increased shares of variable RES-E generation, the importance of energy storage will grow. EU instruments such as the Connecting Europe Facility can support the early deployment and market uptake of electricity storage capacity.

Green hydrogen is closely linked to expanding RES-E capacity. Nevertheless, some specific actions are recommended to increase its availability in the EU. The first is to support MS initiatives towards early deployment of electrolysers. This requires coordination of EU policies, for example through national energy and climate plans or through State aid guidance. A second, more direct EU intervention would be to offer a premium to producers of green hydrogen. This could be done through CCfDs, which are already recommended and which could therefore apply to multiple dimensions of a green steel value chain, but also through other targeted subsidies. With increased scale and learning, the costs of electrolysers will decrease, thereby making green hydrogen more competitive.

For CCUS, similar cost reductions are needed to make the technology more competitive. Any cross-cutting instrument that can achieve this would be an option, but there are some specific issues pertaining to CCUS specifically that policy makers should be aware of. The first one is the importance of industrial clusters and symbiosis: CCUS is a technology group that could be available to more (industrial) sectors, beyond the steel sector. In carbon-intensive areas, where significant volumes of emissions could be captured, transported, and stored, the efficiency of CCUS as a decarbonization pathway could increase considerably. A policy focus on clusters can also address in advance some of the coordination problems that may arise between different actors of the CCUS value chain. Secondly, CO_2 needs to be captured at the highest possible rates (to limit residual emissions) with a low energy penalty. To achieve this, increased R&D efforts to optimise the efficiency of capture technology are recommended.

The secondary steelmaking route also provides promising options towards the decarbonisation of the steel industry. For this, high-quality steel scrap should become far more widely available. Not all steel produced through (more efficient) secondary processes can substitute steel from primary steelmaking. Even if primary steelmaking will always remain necessary for some steel products, increasing the collection of high-quality scrap would allow for a greater share of secondary steelmaking.

Regarding carbon pricing, the EU ETS has generally functioned well since the revision of the system in 2017-18 and after the introduction of the MSR in 2019. A further revision of the EU ETS is foreseen under the Green Deal to account, inter alia, for the new “at least net -55%” emission reduction target for 2030. A tighter ETS cap will strengthen the carbon price signal, but some additional measures increasing the ETS price are nevertheless recommended to accelerate industrial decarbonisation. CCfDs and GPP have already been mentioned. These measures can ultimately reduce abatement costs in the steel industry, thus allowing the ETS system to have a greater impact without the need for it to reach exceedingly high prices. Finally, the CBAM, in spite of its complexity, can provide an alternative to free allocation, therefore mitigating carbon leakage risk.

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