GREEN STEEL FOR EUROPE

Preliminary findings from stakeholder consultation

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List of acronyms and abbreviations

Alkaline Electrolysis:	Alkaline iron ore electrolysis
BF:	Blast Furnace
Biol. CCU:	Carbon Capture and Usage based on biological conversion processes
BOF:	Basic Oxygen Furnace
CAPEX:	Capital Expenditure
CCS:	Carbon Capture and Storage
CCU:	Carbon Capture and Usage
Chem. CCU:	Carbon Capture and Usage based on chemical conversion processes
EAF:	Electric Arc Furnace
Energy rec.:	Energy recovery and re-use - (Recover waste heat on intermediate products, slags and gases and re-use in production processes)
ETS:	Emissions Trading System
EU:	European Union
H2-DR:	Hydrogen based Direct Reduction
HPSR:	Hydrogen Plasma Smelting Reduction
IBRSR:	Iron Bath Reactor Smelting Reduction
Incr. Biomass:	Increased substitution of fossil fuels by Biomass
Incr. Scrap:	Increased scrap input into BF/BOF plants
MOE:	Molten Oxide Electrolysis
OPEX:	Operational Expenditure
R&D:	Research and Development
R&D&I:	Research and Development and Innovation
Slag processing:	Processing of steel plant slags
TGR-BF:	Top Gas Recycling Blast Furnace
TRL:	Technology readiness level

1 Introduction

This report summarises data and information collected from steel producers located in the EU via a short scoping questionnaire. In line with the proposed research approach of the Green Steel for Europe project, the questionnaire aimed to gather feedback on both technology (relevant to Working Package 1 (WP 1) and investment needs (relevant to WP2) to decarbonise the EU steel industry. In addition, it allowed to collect information on the expected industrial deployment of the needed technologies, decarbonisation drivers and barriers as well as available funding opportunities to meet the identified investment needs (relevant to WP1 and WP2).

This report presents data and information collected up to June 23th 2020. Some steelmakers, however, are still in the process of answering the scoping questionnaire. In addition, and in line with the consultation strategy set out for this project, additional details on the topic will be gathered via in-depth interviews with steelmakers and technology providers in the upcoming months and will be exploited to complete the draft deliverable D1.1 and D1.4 to the final deliverables D1.2 and D1.5. The preliminary results presented in this report, as well as any additional information provided by consulted stakeholders, will contribute to the following deliverables in the context of the Green Steel for Europe project:

- D1.1. Draft assessment and roadmapping of technologies
- D1.2. Assessment and roadmapping of technologies
- D1.4 Draft collection of possible decarbonisation barriers
- D1.5 Collection of possible decarbonisation barriers
- D2.1 Draft investment needs report
- D2.2. Investment needs report
- D2.3 Draft report on funding opportunities
- D2.4 Report on funding opportunities

The remainder of this report is divided into four main sections:

i) methodology, providing more details on the questionnaire, data collection methods and sample of respondents;

ii) technology assessment and investment needs,
   - first discussing decarbonisation technologies, covering the main steps from development to deployment, and
   - second presenting the financial needs to develop, demonstrate and deploy the decarbonisation technologies as well as the increase in capital expenditures (CAPEX) and operating costs (OPEX) stemming from the industrial deployment of such technologies;

iii) decarbonisation drivers and barriers, detailing both the factors that foster decarbonisation efforts by steelmakers (from development to deployment) as well as obstacles impinging on the decarbonisation of the steel industry; and

iv) funding opportunities, summarising the funding opportunities to decarbonise the EU steel industry that have been considered by the consulted stakeholders as well as barriers to use such opportunities.

v) concluding remarks.

2 Methodology

This section provides a brief overview of the methodology adopted within the scoping questionnaire to collect and analyse data and information from stakeholders as well as details on the consulted sample. The scoping questionnaire is divided into four parts:

1. The first part of the questionnaire aims to collect basic information on the company and person answering the questionnaire.
2. The second part focuses on innovative decarbonisation technologies and their maturity progress, from the expected period for demonstration (TRL = 8) to the deployment as first-of-a-kind on industrial level (TRL = 9). The second part further focuses on the investment and funding needs to develop and uptake such technologies, both for the period 2020-2030 and 2030-2050.
3. The third part focuses on drivers and barriers affecting the decarbonisation of the steel industry. A specific ranking consisting of 5 possible grades was given for assessment: (1) not at all; (2) to a limited extent; (3) to some extent; (4) to a high extent; or (5) to the fullest extent.
4. The fourth part gathers data and information from the stakeholders on their awareness of funding opportunities to support the required technologies and the experience achieved with them, if any, included possible barriers or experience of blending and/or sequencing of funding.

The responses to this scoping questionnaire will be used to develop a second questionnaire, which will be used to conduct more detailed in-depth interviews with selected stakeholders in the following months.

Among producers and technology providers, 34 stakeholders were consulted, distributed all over Europe (Italy, Spain, Austria, Belgium, Netherlands, Germany, Poland, the Czech Republic, Slovak, Sweden, Finland). The aggregate production corresponds to more than 80% of the CO_2 emission in Europe from steel industry as claimed in the Technical annex of the Proposal. The following Table 1 summarizes the state of the consultation activities by the scoping questionnaire on June 23th 2020.

Table 1: Summary of conducted scoping interviews

Status	Total	CO_2 share (of EU steel production)	Share (of contacted)
Contacted	34	83.5%	NA
Replied to contact (in any form)	26	83.1%	76.5%
Still ongoing	5	11.0%	14.7%
Sent filled questionnaire	15	71.1%	44.1%

The shares of CO_2 emissions of stakeholders involved in the consultations were calculated based on the 2020 allocations within the EU Emission Trading System (EU ETS).[1] Such an analysis is based on the assumption that the allocated CO_2 allowances reflect the current CO_2 emissions more accurately than the stakeholders' production capacity, as it is likely that they are operating at varying (not full) capacity. A more detailed approach, taking into account the reported verified emissions over multiple years, is going to be developed and utilized in the further evaluation process and the synopsis reports of consultation activities (D1.6, D2.6 and D3.3).

Until June 23th 2020 15 stakeholders answered the questionnaire in detail, corresponding to the 71% of the CO_2 emission share of EU steel industry. Additionally, three producers provided general, qualitative statements from which limited information (e.g. funding strategy) could be derived. However, additional stakeholders gave notices that they are still working on the questionnaire. The Covid-19 situation strongly effected this part of the consultation since it caused serious problems to the stakeholders in terms of urgent additional issues and short-time work. Concluding the remaining replies, the consortiums expects to receive additional replies which will – in sum – be consistent with the general target of the project "Green Steel for Europe" to cover at least 80% of the CO_2 emission in Europe from steel industry.

Data are presented in this report in aggregated form to ensure confidentiality.

For the data analysis the following approach has been used:

- In case of multiple answers, generally the most frequent answer was taken as representative. In other cases, a time range or an average was provided.
- In case that the producers provided multiple answers to single technologies, each information (TRL, investment needs, CAPEX, OPEX…) was allocated to each technology
- In other cases, the answers referred directly to a combination of technologies along the production chain the information gained was correlated to that combination.

[1] Data on CO_2 emission were achieved by performing a data analysis of the publicly available 2020 EU ETS allocations (via EU Transaction Log https://ec.europa.eu/clima/ets/), the allocated CO_2 emissions for iron and steel industry stakeholders were extracted. Thus, the specific share of EU steel industry CO_2 emissions was calculated for each stakeholder.

3 Technology assessment and investment needs

In the first part of the questionnaire, selected decarbonisation technology alternatives were proposed for assessment by the stakeholders.

This list comprised:

- Hydrogen-Direct Reduction (H2-DR),
- Iron Bath Reactor Smelting Reduction (IBRSR),
- Top Gas Recycling Blast Furnace (TGR-BF),
- Chemical/biological Carbon Capture and Usage/Storage (chem./biol. CCU),
- Alkaline Iron-Ore Electrolysis (Alkaline Electrolysis),
- Hydrogen Plasma Smelting Reduction (HPSR),
- Molten Oxide Electrolysis (MOE),
- Increased substitution of fossil fuels by Biomass (Incr. Biomass),
- Increased scrap input (Incr. Scrap),
- Energy recovery and re-use (Energy rec. / ER),
- Processing of steel plant slags (Slag processing), and
- Other technologies specified by the stakeholders (e.g. BF injection of H2 rich gases)

Combinations of technologies were accounted for as indicated in the questionnaire. They are listed as follows with use of the acronyms and abbreviations for each technology as above and in the Table of the report.

- H2-DR+ chem. CCU+ Alkaline Electrolysis+ Increased Biomass + Increased Scrap + Energy Recovery;
- H2-DR+chem. CCU+HPSR+ER+SP+SOEC;
- chem. CCU + hot charging;
- EAF in BOF route;
- Increased Biomass + Energy Recovery+ Slag Processing;
- Natural gas replacement with green hydrogen;
- H2-DR+ch.CCU+bio. CCU+ Increased Biomass +Energy Recovery +Slag Processing;
- H2-DR+Alcaline Electrolysis;
- Multifuel combined with H2;
- Increased Biomass+ Increased Scrap+ Energy Recovery +Slag Processing in EAF;
- Chem. CCU+ Increased Scrap + Increased Biomass;
- TGR-BF+ chem./bio CCU+ Increased Biomass +Energy Recovery+H2 use;
- H2-DR+ Slag Processing+ Alkaline Electrolysis.
- H2DR+ Increased Biomass+ Energy Recovery;
- Natural gas replacement with green hydrogen +Energy Recovery;
- bio. CCU+ Increased Biomass + Energy Recovery + Slag Processing + Metal Oxides Electrolysis +Alkaline Electrolysis,
- H2-DR + chem. CCU + Alkaline Electrolysis;
- H2-DR+ Slag Processing +Alkaline Electrolysis

The stakeholders were asked to assess one or more technologies which are relevant for their company and to give their estimation of the steps needed in terms of technology readiness level (TRL), time and financial resources to achieve the industrial deployment. At the end of this questionnaire section, information was asked on the expected share of production for the corresponding technology alternative and the cost effects (influence on CAPEX and OPEX as well as investment and funding needs).

An overview of the issues concerning technologies to reduce the emissions from the consulted EU producers' plant is shown for the period 2020-2030 in Table 2, for combinations of technologies in this period in Table 3. The correspondent information for the period 2030-2050 is given in Table 4 and Table 5. In some cases, different answers for the same technology were given and all of them are reported.

The legends are similar for all four tables and are described as follows. The **column headers** represent the questions posed in the questionnaire for the related content. They are indicated in a shortened form which are explained hereafter:

TRL 2019

TRL achieved for the technology in 2019.

TRL 8 year

Expected year when demonstration state at TRL8 is achieved:

TRL 9 year

Expected year of first industrial deployment at TRL9.

Full depl.

Expected year of full industrial deployment.

Dependence

Dependency of full industrial deployment start date on external boundary conditions, on a scale from 1 (not at all) to 5 (highly dependent)].

Share prod. 2030

Expected share (%) of production out of total production of your company in 2030 (as a best estimate).

Reduction CO_2 foreseen

Expected CO_2 reduction per tonne of crude steel (% decrease compared to 1990 emission levels, reference in the questionnaire).

Factors

External factors impacting on the development and industrial deployment of the technology.

Inv. Needs TRL7

Investment needs (include CAPEX + OPEX) for pilot scale tests at TRL6-7.

% needs (for TRL 7, 8 and 9)

Share of external financial support needed (%) (e.g. by public funding programmes).

Inv. Needs TRL8

Investment needs for demonstration plants at TRL 8.

Inv. Needs TRL9

Investment needs for first industrial deployment at TRL 9.

% Capex

Expected increase in annual CAPEX [% increase/decrease for the technology or combination thereof selected above compared to current CAPEX per tonne of steel].

% Opex

Expected increase in OPEX after industrial deployment (% increase/decrease for the technology or combination thereof selected above compared to current OPEX per tonne of crude steel).

The **row headers** represent the technology, or the combination of technologies, involved in the table for the period indicated. Such information is schematised with a number, whose legend as footer for the table explicitly indicates the type of technology and/or the combination of technologies, bases on the short labelling of the list in the initial part of the section.

The relevant data from the resuming tables can be summarised as follows.

a. In Table 2 no information is needed for TRL9 and CAPEX for the technologies, only in two cases for OPEX. This is different in table 3. The time period 2030–2050 addressed in Table 3 assumes (in consistency with the stakeholder replies) that TRL9 is already reached at that time.
b. In general, the most relevant technologies (CCU, H2-DR) are not yet at a TRL = 7. Only for technologies generally embedded in the pathway Process Integration (PI), such as "Increased scrap" and "Energy recovery", the reported TRL is higher and a start of industrial deployment within 2030 is expected.
c. No achievement of an industrial deployment level for the single technologies is foreseen within 2030.
d. Overall, a reduction of CO_2 emission of at least 50% is foreseen until 2030 compared to 1990 emission levels.
e. The dependency of full industrial deployment start date on external boundary conditions for the period 2020-2030 is claimed at a more stringent level for the combination of technologies than for technologies. In most case a mark was assigned with no motivation. Only for the H2-DR technology the maximum relevance was claimed (mark 5), motivated mostly by H2 availability. For the combinations of technologies, 5 is the prevailing mark for such period (50% of the answers). For the period 2030-2050, this mark is prevailing (again 50% of the answers) in both cases, technologies and combination of technologies. Among all the motivations given to justify the mark, very often the dependence on governmental policy on CO_2, and on the energy system, are cited.
f. The most evidenced factors that can help the technologies deployment, are the availability (volume, quality and price) of clean hydrogen, of renewable energy, of public funding opportunities and of synergies for industrial symbiosis. This holds for both the periods 2020-2030 and 2030 – 2050.
g. The investment needs for the considered technologies can reach values as high as 5 Million Euro for the achievement of TRL7 and 25 Million Euro for TRL 8 for the period 2020-2030, while for the period 2030-2050 upper limits of 25 Million Euro for TRL7, 1.4 Billion Euro for TRL 8, and 5 Billion Euro for TRL9.

h. With regard to the period 2020-2030 the information on the combination of technologies are scarce and the most recurring technologies involve increased use of biomass and scrap as well as energy recovery.

i. For the period 2030-2050, more ambitious targets are claimed for the technologies in the questionnaire answers, i.e., in several cases a CO_2 reduction greater than 90% is expected as a result of some technologies/combinations of technologies deployed (see the corresponding columns '**Reduction CO_2 foreseen'** in Tables 4 and 5)

j. In parallel, for the period 2030-2050 the investment costs for deployment at industrial level claimed can reach an order of magnitude of 4-5 Billion Euros and a CAPEX increase that in some cases can reach 100%.

Table 2: Overview of the issues concerning technologies to reduce the emissions from the consulted EU producers' plant between 2020 and 2030 – part 1

Technology	TRL 2019	TRL8 year	TRL9 year	Full depl. - year	share prod. to 2030	Dependence	Reduction CO_2 foreseen (%)	Factors (1)	Inv. Needs TRL7 - k€	% needs	Inv. Needs TRL8 - M€	% needs	% Opex
1	7	2028	2030	2035		5	80	CI, F, RE, DRI					
	4	2025	2026	2030	20	5	100	F, RE	120				
	5	2026	2030	2035	1	5	90	CI, F, RE, CCS	110	100	25	100	60
2	5	2030	2032	2035		4	80	CI, F, RE, DRI	1000	60		60	
3	2	2025	2030	2035	3	3	60						
	6	2022	2025	2028	10	4	50	CI, F, RE	100	0			
	7	2023	2024	2025		5	20	F, RE					
	7	2023	2025	2035			60	CI, F, RE, SYM	500	75	15	50	
4	8	2020	2021	2025	30	3	50	CI, F, RE, DRI					
	7	2023	2025	2035			60	CI, F, RE, SYM	1000	75	2	50	
5	8	2020	2021	2022	5	1		Ci, F, RE, DRI					
	7	2030	2040			5							
	7	2025	2026	2030	100	1		F, RE					20
	7	2023	2027	2035			60	CI, F, RE, SYM	5000	75	15	50	
6	7	2023	2025	2035			60	CI, F, RE, SYM					

Legend for the technologies (acronyms in the text of section 3):
1 = H2-DR, 2 = chem./biol. CCU, 3 = Increased Biomass, 4 = Increased Scrap, 5 = Energy recovery, 6 = Slag processing

(1) CI= Availability of clean hydrogen, RE = Availability of renewable energy, CCS = Availability of CCS, F= Availability of public funding opportunities, SYM = availability of industrial symbiosis synergies, DRI = availability of DRI

Table 3: Overview of the issues concerning combinations of technologies to reduce the emissions from the consulted EU producers' plant between 2020 and 2030 – part 2

Comb. of Techn.	TRL 2019	TRL 8 year	TRL 9 year	Full deploy. year	Share of prod to 2030	Dependence	Reduction CO_2 foreseen (%)	Factors (1)	Inv. Needs TRL7 - M€	% needs	Inv. Needs TRL8 M€	% needs	% Opex
7	6	2025	2026	2027	30	5			No info given in the questionnaires received for these issues				
8	3	2026	2029	2035		4	30	CI, F, RE, DRI					
9	7	2020	2021	2021	100			F, CCU					
10	9	2028	2030	2035	40	4	10	CI, RE, F					
11	9		2030	2035	20	5	30	F, RE, DRI					
12							30	F, RE					
13	6	2025	2030	2040	50	3	60	Ci, F, RE					
14	3	2023	2024	2025	50	3	30	F, RE, CCS					
15	7	2022	2029	2035			60	CI, F, RE, SYM					
16	7	2023	2025	2035			60						
17	5	2024	2026	2028	100	5	95	CI. F, RE					
18	5	2025	2028	2030	80	3	35	F					
19	6	2025	2030	2035	25	3	40	F, RE, CCS					
20	8	2019	2030	2050	40	5							

Legend for the combination of technologies (acronyms in the text of section 3): 7 =H2-DR+ chem. CCU+ Alkaline Electrolysis+ Increased Biomass + Increased Scrap + Energy Recovery; 8 =H2-DR+chem. CCU+HPSR+ER+SP+SOEC; 9 =chem. CCU + hot charging; 10=BF injection of H_2-rich gases; 11 =EAF in BOF route; 12 =Increased Biomass + Energy Recovery+ Slag Processing; 13 =Natural gas replacement with green hydrogen; 14 =H2-DR+ch.CCU+bio. CCU+ Increased Biomass +Energy Recovery +Slag Processing; 15 =H2-DR+Alcaline Electrolysis; 16 = Multifuel comb. With H2; 17 = Increased Biomass+ Increased Scrap+ Energy Recovery +Slag Processing in EAF; 18 = Chem. CCU+ Increased

Scrap + Increased Biomass; 19 =TGR-BF+ chem./bio CCU+ Increased Biomass +Energy Recovery+H2 use; 20 = H2-DR+ Slag Processing+ Alkaline Electrolysis

(1) CI= Availability of clean hydrogen, RE = Availability of renewable energy, CCS = Availability of CCS, F= Availability of public funding opportunities, SYM = availability of industrial symbiosis synergies, DRI = availability of DRI

Table 4: Overview of the issues concerning technologies to reduce the emissions from the consulted EU producers' plant between 2030 and 2050 – part 1

Techn.	TRL 2019	TRL8 year	TRL 9 year	Full depl. year	Share prod. To 2030	Dependence	Red. CO_2 foreseen (%)	Factors (1)	Inv. Needs TRL7 - k€	% needs	Inv. Needs TRL8 - M€	% needs	Inv. Needs TRL9 - M€	% needs	% Capex	% Opex
1	7	2028	2033	2035		4	90	CI, F, RE, DRI					2000		100	60
	4	2025	2026	2030	20	5	100	F, RE	12000							
	6	2030	2040	2050	100	5	95	CI, F, RE			100	60	5000	60	15	80
	8	2023	2030	2045	100	5	70									
2	5	2030	2050	2070	100	5	100	CI, F, RE			100	100	5000	60	15	80
3	6	2028	2033	2035		4	90	CI, F, RE, DRI					1200		100	60
4	7	2028	2033	2035		2	90	CI, F, RE, DRI					2000		1	1
5	7	2028	2033	2035		2	90	CI, F, RE, DRI					200		20	2
6	2	2045	2050		30	5	95	F, RE	25000	100	70	100	500			
7	5	2030	2035	2050	30	5	95	F, RE	2700		50	100	500		80	20
8	7	2028	2033	2035		2	90	CI, F, RE, CE					350		2	0

Legend for the technologies (acronyms in the text of section 3):
1 = H2-DR, 2 = HPSR, 3 = Increased Biomass, 4 = Increased Scrap, 5 = Energy recovery, 6 = Metal Oxides Electrolysis, 7 = Alkaline Electrolysis, 8 = Slag processing
(1) CI= Availability of clean hydrogen, RE = Availability of renewable energy, CCS = Availability of CCS, F= Availability of public funding opportunities, SYM = availability of industrial symbiosis synergies, DRI = availability of DRI

Table 5: Overview of the issues concerning technologies to reduce the emissions from the consulted EU producers' plant between 2030 and 2050 – part 2

Comb. Of Techn.	TRL 2019	TRL 8 year	TRL9 year	Full depl. year	Dependence	Share prod. to 2030	Red. CO2 foreseen (%)	Factors (1)	Inv. Needs TRL7 -k€	% needs	Inv. Needs TRL8 - M€	% needs	Inv. Needs TRL9 - M€	% needs	% Capex	% Opex
9	1	2037	2045	2050	5	25	50	CI, RE, F		50		60		60		
10	6	2025	2030	2040	3	50	*60*	Ci, F, RE	10000	100	100	70	150	30	15	10
11	2	2035	2042	2050	5		*80*	F, RE, CCS, CI	15000	100	250	85	45	65	10	
12	7	2025	2030	2040	3	100	95	Ci, F, RE					10		10	100
13							70	Ci, F, RE, CE								
14	6	2035	2040	2050	3	70	95	CI, F, RE, CCS, SYM	20000	100	1400	100	4000	100	50	50
15	6	2025	2026	2027	5	100	70									
16	9	2019	2030	2050	5	100	70									

Legend for the combination of technologies (acronyms in the text of section 3): 9 = H2DR+IB+ER; 10 = Nat. gas replacement. With green hydrogen +ER; 11 =bio. CCU+ Increased Biomass + Energy Recovery + Slag Processing + Metal Oxides Electrolysis +Alkaline Electrolysis; 12 = Multifuel comb. With H2; 13=Increased Biomass +Increased Scrap +Energy Recovery+ Slag Processing in EAF route; 14 =TGR-BF+ chem/bio CCU+ Increased Biomass+ Energy Recovery+H2 use; 15 = H2-DR + chem. CCU + Alkaline Electrolysis; Increased Biomass + Increased Scrap+ Energy Recovery, 16= H2-DR+ Slag Processing +Alkaline Electrolysis

(1) CI= Availability of clean hydrogen, RE = Availability of renewable energy, CCS = Availability of CCS, F= Availability of public funding opportunities, SYM = availability of industrial symbiosis synergies, DRI = availability of DRI

4 Decarbonisation drivers and barriers

The preliminary results displayed within this report are reflecting the state as of 23.06.2020, comprising the evaluation of 15 stakeholder responses reflecting a combined share of 71% of EU steel industry CO_2 emissions. Unfortunately, one stakeholder could not give specific ratings on decarbonisation drivers and barriers. Hence, the maximum number of answers elaborated is reduced to 14.

4.1 Drivers

In section DAB.1 of the scoping questionnaire it was asked for the importance of specific decarbonisation drivers to stakeholders. Five main drivers, previously elaborated by the project consortium, were included in the questionnaire. They are summarized in Table 6. This table also gives the abbreviations for these decarbonisation drivers as they will be used in the following figures. Furthermore, in addition to the above mentioned main drivers, the questionnaire provided an option to the respondents to report further drivers.

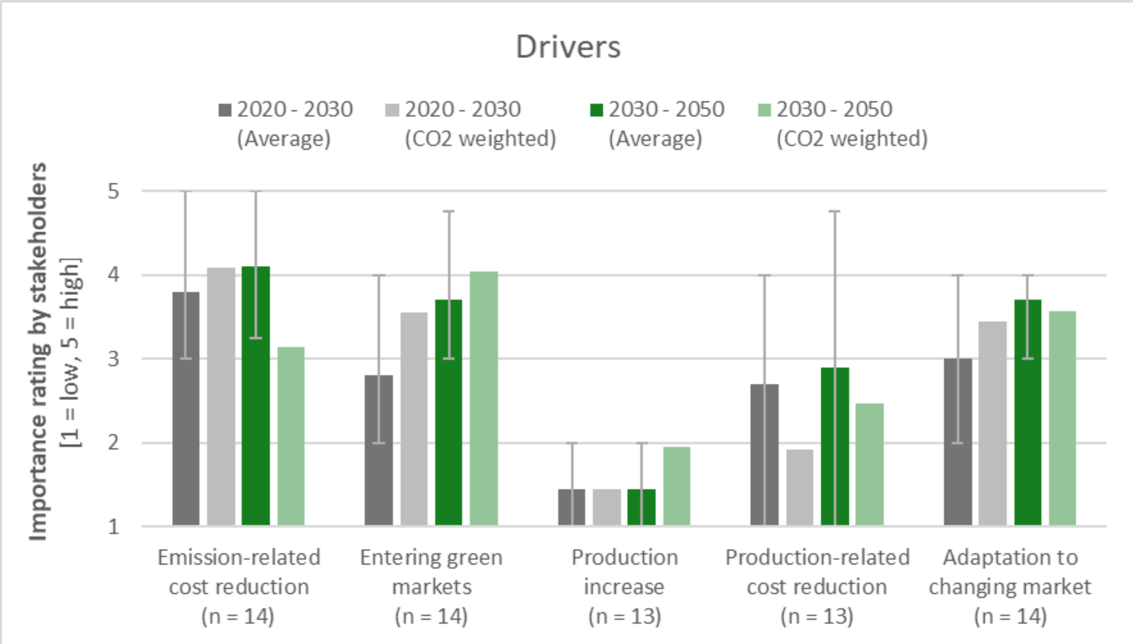
Table 6: List of decarbonisation drivers included in the scoping questionnaire and their specific abbreviations for further use

Decarbonisation Driver	Abbreviation
• **Avoiding or reducing costs stemming from EU or national rules (e.g. EU ETS costs)**	“Emission-related cost reduction”
• **Entering new markets (e.g. green value chains)**	“Entering green markets”
• **Increasing production levels**	“Production Increase”
• **Reducing production costs (e.g. via intensive use of circular economy actions)**	“Production-related cost reduction”
• **Adapting the production processes to changing energy markets**	“Adaptation to changing market”

The responses in terms of importance ratings by stakeholders were evaluated according to the methodology presented in chapter **Error! Reference source not found.**, with an importance rating scale from 1 (not important) to 5 (high importance). Based on these ratings, two specific metrics (simple averages & CO_2-weighted averages) are utilized distinguishing 2 time periods (2030 and 2050), leading to four values for each assessed decarbonisation driver. The results are displayed in Figure 1. The results in short term perspective (2020 – 2030) are displayed in grey colours, whereas those in long term perspective (2030 – 2050) are in green colours.

Darker colours represent simple averages of the stakeholders’ importance ratings. The CO_2-weighted averages (considering the stakeholders’ specific share of CO_2 emissions, see chapter **Error! Reference source not found.**) are displayed in light colours. The error bars display the area in which at least 50% of the answers were located, representing the borders of the 1st and 4th quartile. Thus, they are indicating the scattering of responses.

Figure 1: Stakeholder rated importance of decarbonisation drivers



The results show that avoidance/reduction of emission-related costs stemming from EU/national rules is the most important driver (i.e. rated between "relevant to some extent" and "relevant to a high extent") for decarbonising the steel industry, both in the short- (2030) and long-term (2050). Besides, the adaptation of the new production to new markets is a relevant aspect mainly in the long-term, once the developed technologies are expected to be deployed. The production-related cost reduction shows a wide scattering of responses, representing a differentiated stakeholder understanding or opinion on that.

The ranking of decarbonisation drivers based on their average rated importance by stakeholders is summarized in Table 7.

Table 7: Ranking of decarbonisation drivers by average stakeholder rated importance (sorted by 2030 average)

#	Decarbonisation Driver	2020-2030		2030-2050	
		Avg.	CO2	Avg.	CO2
1	Avoiding or reducing costs stemming from EU or national rules (e.g. EU ETS costs)	3.8	4.1	4.1	3.1
2	Adapting the production processes to changing energy markets	3.0	3.7	3.4	3.6
3	Entering new markets (e.g. green value chains)	2.8	3.7	3.5	4.0
4	Reducing production costs (e.g. via intensive use of circular economy actions)	2.7	2.9	1.9	2.5
5	Increasing production levels	1.4	1.4	1.4	1.9

Besides the drivers prepared by the project consortium, some producers pointed to other drivers for their industrial decarbonisation:

a) Social recognition / movement.
Its importance was assigned 4 up to 2030 and 5 up to 2050 by one stakeholder.

b) Implementation and definition of new skills.
Its importance was assigned 2 up to 2030 and 4 up to 2050 by one stakeholder.

4.2. Barriers

The information collected and hereinafter described refers to the answers in the section DAB.2 of the scoping questionnaire. There it was asked for the relevance ratings of 20 decarbonisation barriers previously selected by the project consortium both for short-term (2020-2030) and long-term (2030-2050) perspectives. These selected decarbonisation barriers are summarized in **Error! Reference source not found.**. Additionally, the possibility of adding further barriers and their importance grading was given in the questionnaire.

Similar to the assessment of decarbonisation drivers previously presented, the evaluation of decarbonisation barriers utilizes two different metrics. The simple average of importance rating of specific barriers is presented in dark colours in the following figures. The CO_2-weighted assessment is given in light colours. The results regarding the short-term perspective are given in grey, whereas the results for long term perspective are displayed in green. The error bars display the area which contains at least 50% of the answers, representing the borders of the 1st and 4th quartile. The importance rating is based on a scale from 1 (not important) to 5 (high importance). For visualisation purposes, the decarbonisation barriers are abbreviated in the following pictures. The used abbreviations are given for each selected barrier in **Error! Reference source not found.**. Each category of barriers (Technical, Organisational, Financial, Policy/Social) is presented separately in the following.

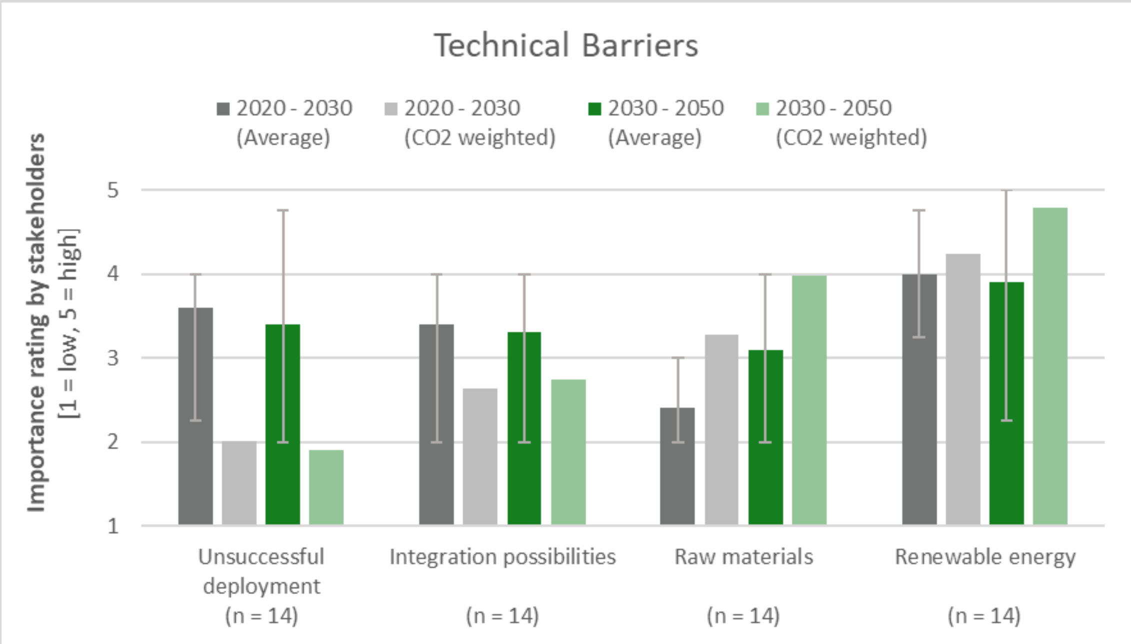
Table 8: List of possible decarbonisation barriers (as included in the scoping questionnaires)

Decarbonisation barrier	Abbreviation
Technical barriers	
• **Risk of unsuccessful deployment**	"Unsuccessful deployment"
• **Limited technical integration possibilities into existing plants**	"Integration possibilities"
• **Limited availability of raw materials**	"Raw materials"
• **Limited availability of renewable energy**	"Renewable energy"
Organisational barriers	
• **Availability of qualified staff (for both development and operation)**	"Qualified staff"
• **Bureaucracy (external) and other administrative burdens**	"Bureaucracy"
• **Management of industrial transformation**	"Transformation management"
• **Information exchange with other parties, collaborative research**	"Information exchange"
• **Intellectual Property Management**	"IPM"
Financial barriers	
• **Investments for demonstration plants**	"CAPEX Demo"
• **Investments for industrial deployment**	"CAPEX Deployment"
• **Limited access to funding opportunities**	"Funding access"
• **Increase in OPEX (costs of energy/renewable energy)**	"OPEX Energy"
• **Other increase in OPEX (costs of materials, CCS, CCU, etc.)**	"OPEX Other"
• **Unknown market conditions of clean steel**	"Market conditions"
Policy / Social Barriers	
• **Issuing of CO_2 storage permits for CCS**	"CO2 Storage"
• **Emission-related legislation (e.g. EU ETS)**	"Emission legislation"
• **Social acceptance of certain technologies (CCS, plants, infrastructure for H_2/electricity)**	"Social acceptance"
• **Local taxes and fees (e.g. German EEG)**	"Taxes & Fees"
• **National implementation of other framework conditions (e.g. "contract for difference")**	"National framework"

i. Technical barriers

The assessed relevance of technical barriers is displayed in **Error! Reference source not found.**.

Figure 2: Stakeholder rated importance of technical decarbonisation barriers



The most important technical barrier is the availability of renewable energy sources. Its importance rating is further increasing if assessed CO_2-weighted. This underlines the barrier relevance for stakeholders which are responsible for higher CO_2 emissions. The availability of raw materials appears to be less of an issue in short term, but of increasing relevance in long term.

The risk of unsuccessful deployment and integration possibilities into existing plants achieves a medium average importance rating. A significant difference between stakeholders assigned to smaller respectively larger terms of CO_2 emissions can be identified for these two barriers: It is of higher relevance to smaller stakeholders.

The assessed importance ratings are summarized in Table 9, ranked by their average importance in short-term.

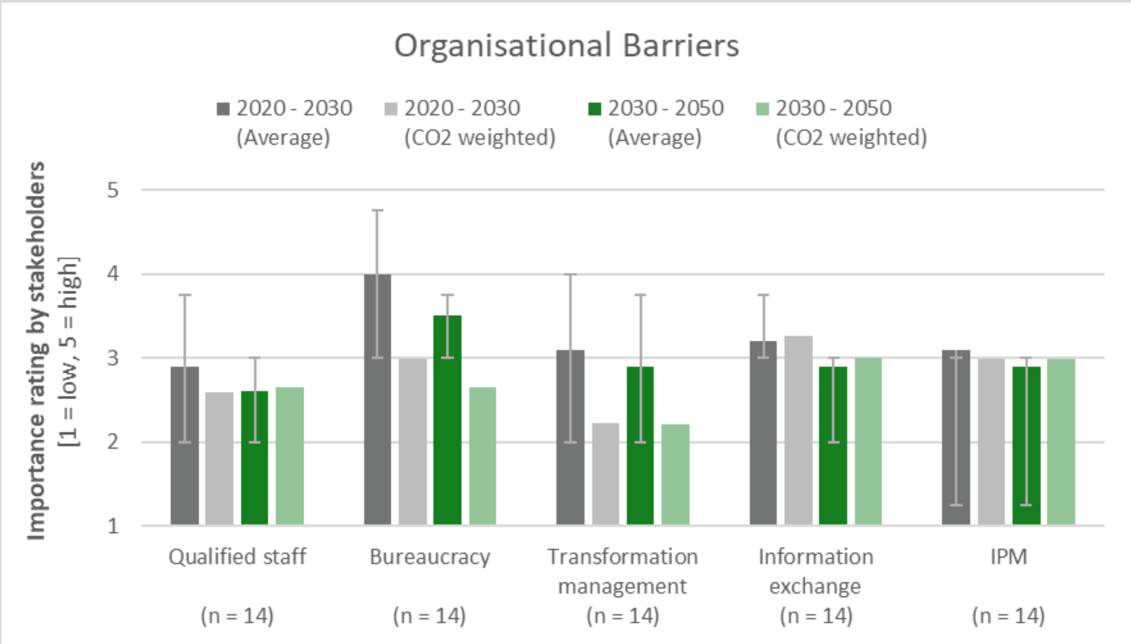
Table 9: Ranking of technical decarbonisation barriers by rated importance (sorted by 2030 average)

#	Decarbonisation Barrier	2020-2030		2030-2050	
		Avg.	CO2	Avg.	CO2
1	Availability of renewable energy	4.0	4.2	3.9	4.8
2	Risk of unsuccessful deployment	3.6	2.0	3.4	1.9
3	Integration of new technologies in existing plants	3.4	2.6	3.3	2.7
4	Availability of raw materials (primary or secondary)	2.4	3.3	3.1	4.0

ii. Organisational barriers

The elaborated results regarding organisational barriers are displayed in Figure 3.

Figure 3: Stakeholder rated importance of organisational barriers



Based on the evaluation of scoping questionnaire responses, currently bureaucracy is the most relevant organisational decarbonisation barrier with a ranking between "relevant to some extent" and "relevant to a high extent". The topics of information exchange and intellectual property management (IPM) are of medium relevance with a significant scattering of the rating. The importance of this topic is ranked differently by the stakeholders. The management of industrial transformation is also of medium importance in short term, significantly decreasing in relevance in long term. The availability of qualified staff is of lower importance to the stakeholders than other organisational barriers. The organisational barrier specific evaluation results are summarized and sorted by their short-term importance in Table 10.

Table 10: Ranking of organisational decarbonisation barriers by rated importance (sorted by 2030 average)

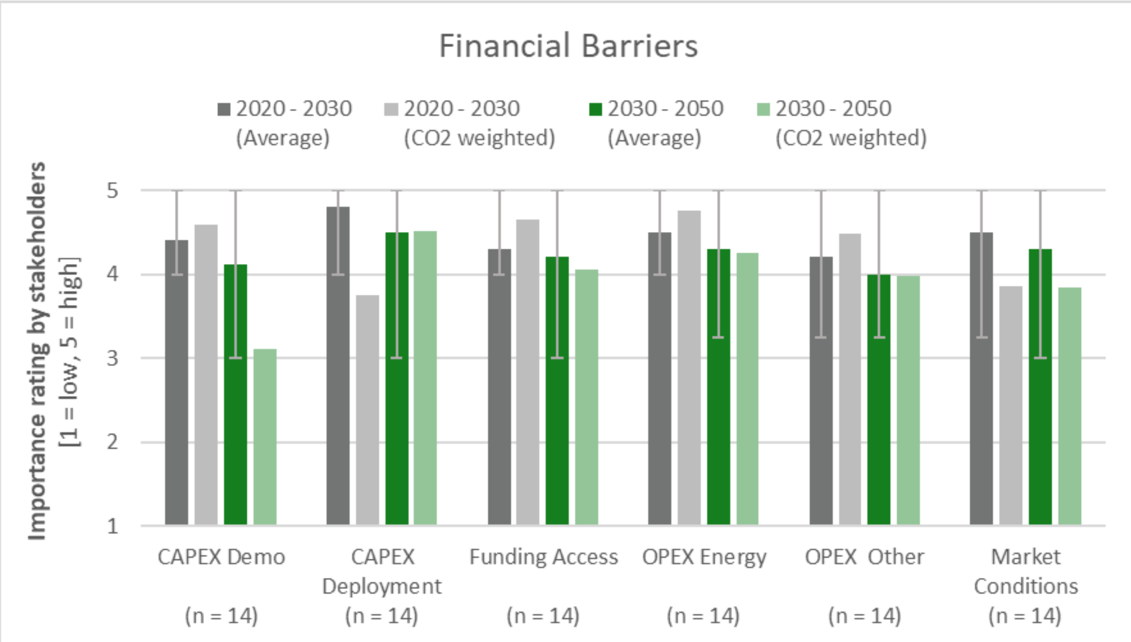
#	Decarbonisation Barrier	2020-2030		2030-2050	
		Avg.	CO2	Avg.	CO2
1	Bureaucracy (external) and other administrative burdens	4.0	3.0	3.5	2.7
2	Information exchange with other parties, collaborative research	3.2	3.3	2.9	3.0
3	Intellectual Property management	3.1	3.0	2.9	3.0
4	Management of industrial transformation	3.1	2.2	2.9	2.2

5	Availability of qualified staff (for both development and operation)	2.9	2.6	2.6	2.7

iii. Financial barriers

The importance ratings of financial barriers assessed by the stakeholders are visualised in **Error! Reference source not found.**.

Figure 4: Stakeholder rated importance of financial decarbonisation barriers



It can be identified, that all financial barriers are of higher relevance to the stakeholders compared to other barrier categories. All of them are rated to be “relevant to a high extent” or even “relevant to the fullest extent”. The respondents agree in the high short-term importance of CAPEX requirements for both demonstration plants and industrial deployment. This can be deduced from the low scattering of the given importance ratings for 2020-2030. This also applies for the access to available funding and the influence of OPEX caused by renewable energy requirements. The scattering increases if asked for the long-term perspective as well as for the influence of unknown market conditions, though still being on a high relevance level. The results in regard to financial barriers are summarized in Table 11 and ranked by their 2030 average rating.

Table 11: Ranking of financial decarbonisation barriers by rated importance (sorted by 2030 average)

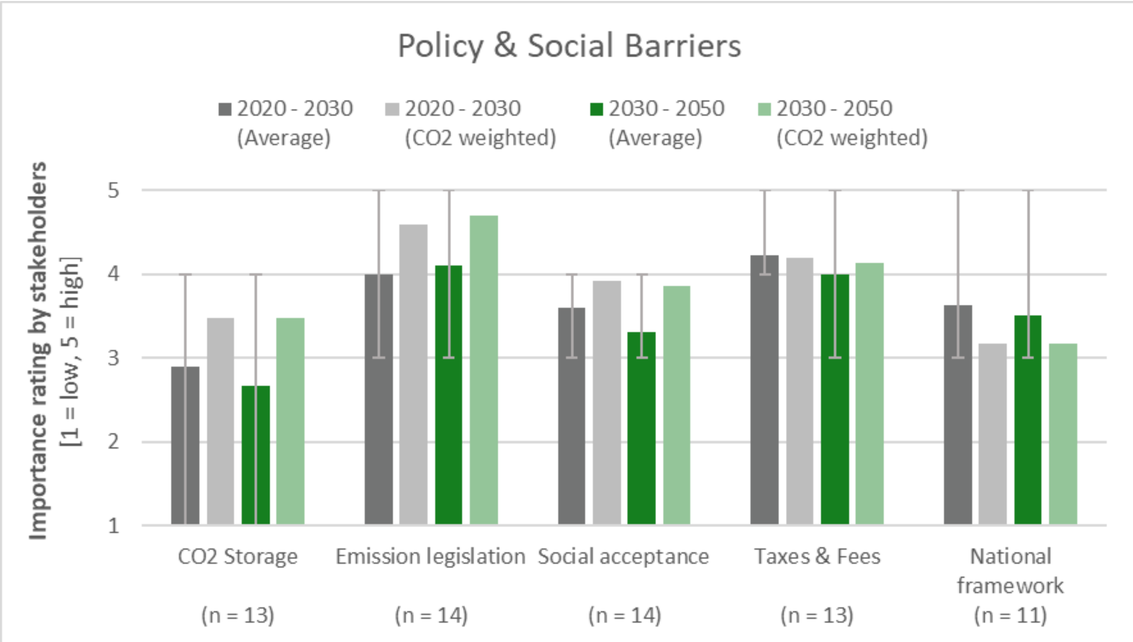
#	Decarbonisation Barrier	2020-2030		2030-2050	
		Avg.	**CO2**	**Avg.**	**CO2**
1	Investments for industrial deployment	4.8	3.8	4.5	4.5
2	Increase in OPEX (costs of energy/renewable energy)	4.5	4.8	4.3	4.3
3	Unknown market conditions of clean steel	4.5	3.9	4.3	3.8

4	Investments for demonstration plants	4.4	4.6	4.1	3.1
5	Limited access to funding opportunities	4.3	4.7	4.2	4.1
6	Other increase in OPEX (costs of materials, CCS, CCU, etc.)	4.2	4.5	4.0	4.0

iv. Policy and social barriers

The results of policy and social barriers importance assessment are displayed in Figure 5.

Figure 5: Stakeholder rated importance of policy and social decarbonisation barriers



The barriers of 'Additional taxes and fees' and 'emission-related legislation' (e.g. in terms of the EU ETS) are identified as most important policy and social barriers according to the stakeholders' responses. As both barriers also relate to financial impacts, these might also be classified as financial barriers with similar importance ratings. National implementations of framework conditions and social acceptance were identified as being relevant on a medium level. The importance of CO_2 storage conditions, containing e.g. their legal national permission, are rated to be of lower average relevance. The results for CO_2 storage permits differ significantly, so it can be interpreted that it is relevant to some stakeholders (intending to utilise it), while it is lesser important to other stakeholders.

The simple average and CO_2-weighted results for policy and social barriers are summarized and ranked (based on their 2030 average values) in Table 12.

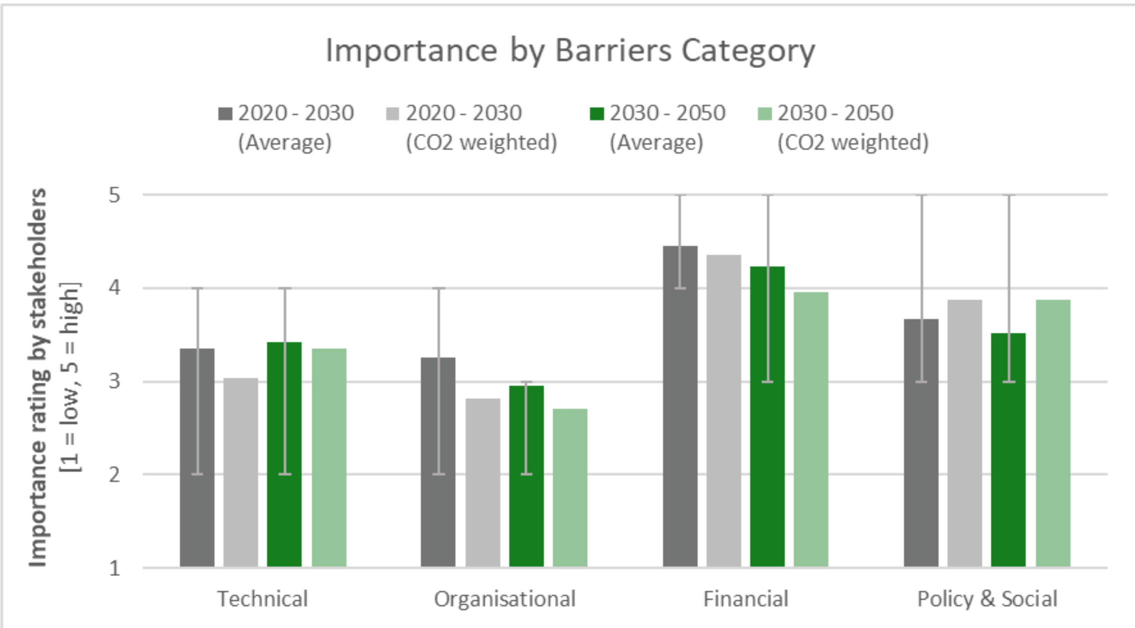
Table 12: Ranking of policy and social decarbonisation barriers by rated importance (sorted by 2030 average)

#	Decarbonisation Barrier	2020-2030		2030-2050	
		Avg.	CO2	Avg.	CO2
1	Local taxes and fees (e.g. German EEG)	4.2	4.2	4.0	4.1
2	Emission-related legislation (e.g. EU ETS)	4.0	4.6	4.1	4.7
3	National implementation of other framework conditions (e.g. "contract for difference")	3.6	3.2	3.5	3.2
4	Social acceptance of certain technologies (CCS, plants, infrastructure for H2/electricity)	3.6	3.9	3.3	3.9
5	Issuing of CO2 storage permits for CCS	2.9	3.5	2.7	3.5

v. Assessment of barriers categories

A comparison of the average importance ratings for decarbonisation barriers categories is given in **Error! Reference source not found.**.

Figure 6: Stakeholder rated importance of decarbonisation barriers categories



It can be identified that financial barriers clearly have the highest average importance rating by stakeholders both in short-term and long-term perspective. Policy / social barriers come second, however, with the most severe barriers of this category also being classifiable as financial barriers. Technical decarbonisation barriers are assessed to be relevant to some extent. The lowest average importance rating was given to organisational barriers. This ranking is summarised in Table 13.

Table 13: Ranking of decarbonisation barriers categories by rated importance (sorted by 2030 average)

#	Decarbonisation Barrier Category	2020-2030		2030-2050	
		Avg.	CO2	Avg.	CO2
1	Financial barriers	4.5	4.2	4.3	4.0
2	Policy / Social barriers	3.7	3.5	3.9	3.9
3	Technical barriers	3.4	3.4	3.0	3.4
4	Organisational barriers	3.3	3.0	2.8	2.7

5 Funding Opportunities

This section is focused on the evaluation of the stakeholder consultation with respect to existing funding opportunities to decarbonise the steel industry. The results from the questionnaire referring to the investment needs are hereinafter divided into:

i- stakeholders' experience with funding mechanisms, and

ii- barriers in making use of the available funding opportunities.

The section aims to identify possible improvements in the existing programmes and/or to suggest possible new approaches to funding the decarbonisation of the steel industry. The following parts give an overview of the results to the questionnaire answers from the points FUN1 to FUN8.

A short overview over the results is shown in table 8 below. This is related to the question 'FUN8' of the scoping questionnaire. The data reported refers to the most frequent answer provided in the forms received. The public funding (at national/local level at first, then at EU level) represents broadly the most referenced option. The typical TRL step of the R&D activities addressed varies from 5 to 7.

A typical project duration is 3 years, with participation request in a form of Consortium of applicants in most cases (75%) with a typical 60% co-financing rate (as occurs for example in RFCS projects). Based on the indications of the questionnaire in Section 3, where a funding rate up to 100% in some cases is envisaged, a stronger aid is expected from the stakeholders to support the decarbonisation investment needs related to the most challenging step forward in Technology Readiness Levels (from 7 onwards).

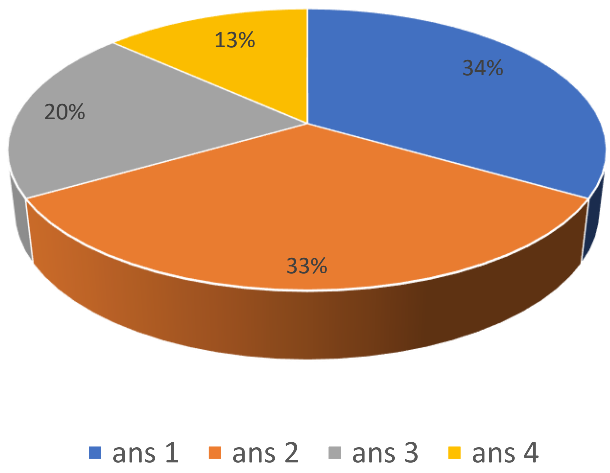
Table 14: Overall data on the application/awareness of the stakeholders about the main EU funding programmes available and related to decarbonisation technologies

Main funding programmes experience/awareness in the EU to R&D&I or activities related to decarbonisation technologies	
public, national	83% of the answers
EU public funding programmes, public	83% of the answers
Regional. Public	75% of the answers
Starting TRL	5 (50% of the answers)
Final TRL	7 (50% of the answers)
Duration (years)	3 (75% of the answers)
Consortium	Yes (75% of the answers)
Overall co-financing rate (%):	60 (75% of the answers)
Specific co-financing rate (if any) for purchasing assets (%):	60 % (60% of the answers)
Specific co-financing rate (if any) for R&D expenditures (%):	60% (90% of the answers)

5.1 Experience with funding mechanisms

Figure 7 shows the acquaintance of stakeholders with relevant EU funding programs which is obviously quite high: By summing up those making use of these opportunity on a yearly basis with those making use of them very often, a share of 67% is reached. Only 13% of the answers were given with “no use” of such funding opportunities. This definitively shows that producers look to funding programs as a sound basis for their R&D&I actions.

Figure 7: Application frequency for financial support in the EU to R&D&I activities related to decarbonisation technologies:(1 = on a yearly basis, 2 = often- more than 3/10y, 3 = seldom, 4 = never)



In Table 15, the typical TRL step accompanying the project development is shown which was rated to range from 5 to 7, up to just before the demonstration level. This furtherly evidenced the role of funding as enabler for producers to carry out innovation, issue of outmost importance for the new technologies.

Table 15: Data on the most prevailing TRL and range of production in the EU project approached.

Typical starting TRL:	5 (33% of the answers)
Typical target TRL:	7 (40% of the answers)
Typical target production (t crude steel/hour)	150 (average among the answers collected)

In Figure 8 the share of the main mentioned funding programmes is shown. Those directly relevant for steel industries are the most used (34%). Moreover, general programs for industries, addressed by producers on special R&D&I issues (21%) or aimed at decarbonisation (24%) are used. This evidences the effort of the stakeholders to take benefits at best from the opportunities offered by funding on issues of general interest.

Figure 8: Main programmes applied form the stakeholders consulted.

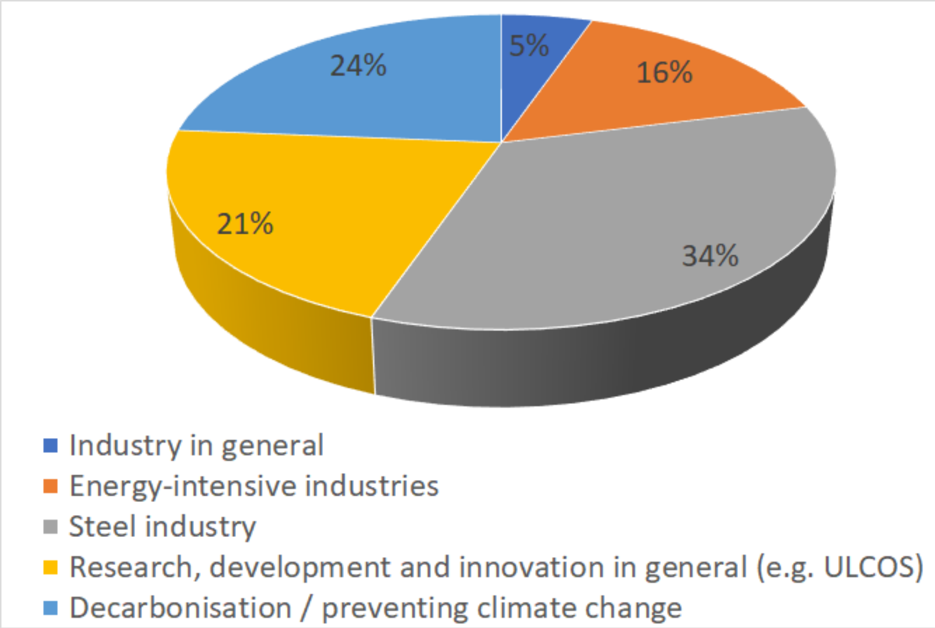


Figure 9 shows the share among the geographic source of the funding programmes. The prevailing source is of national type (41%). Besides, regional public funding programmes are used (25%). This evidences on one hand the broad effort of the companies to take benefit from funding opportunities at any level, on the other hand that support from national state still represents the most powerful lever the producers rely on in this field.

Info from the stakeholders on their experiences in blending funding programs is shown in Figure 10, while in Figure 11 their experience on sequencing the funding opportunities is evidenced.

Concluding Figure 10, in the most frequent case no blending of funding opportunities was experienced. In case of blending the most frequent cases refer to national and regional funds (27%) and EU and national funds (21%), with the national support still representing a sound backbone.

Figure 9. Type of the funding programme used by the stakeholders consulted.

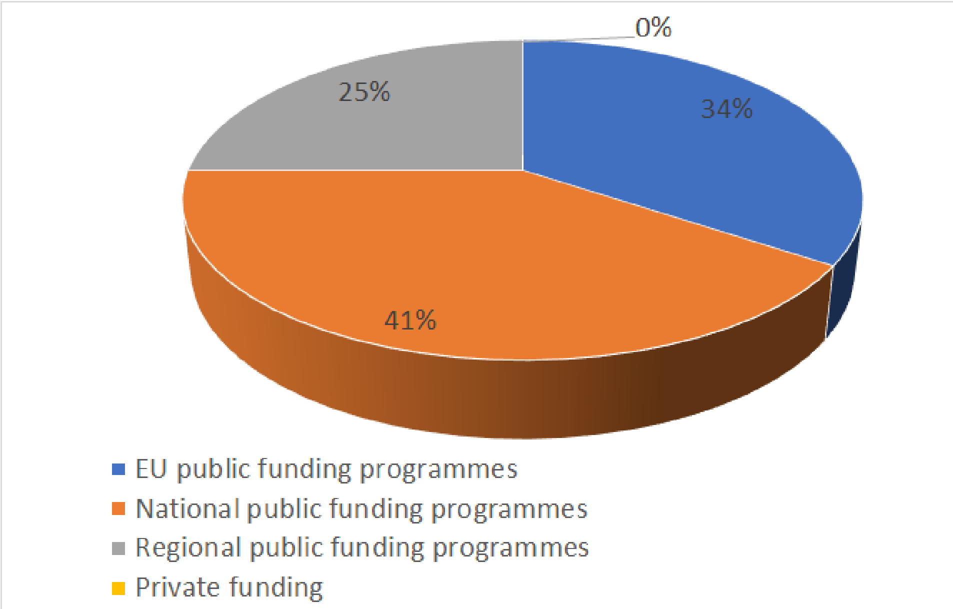
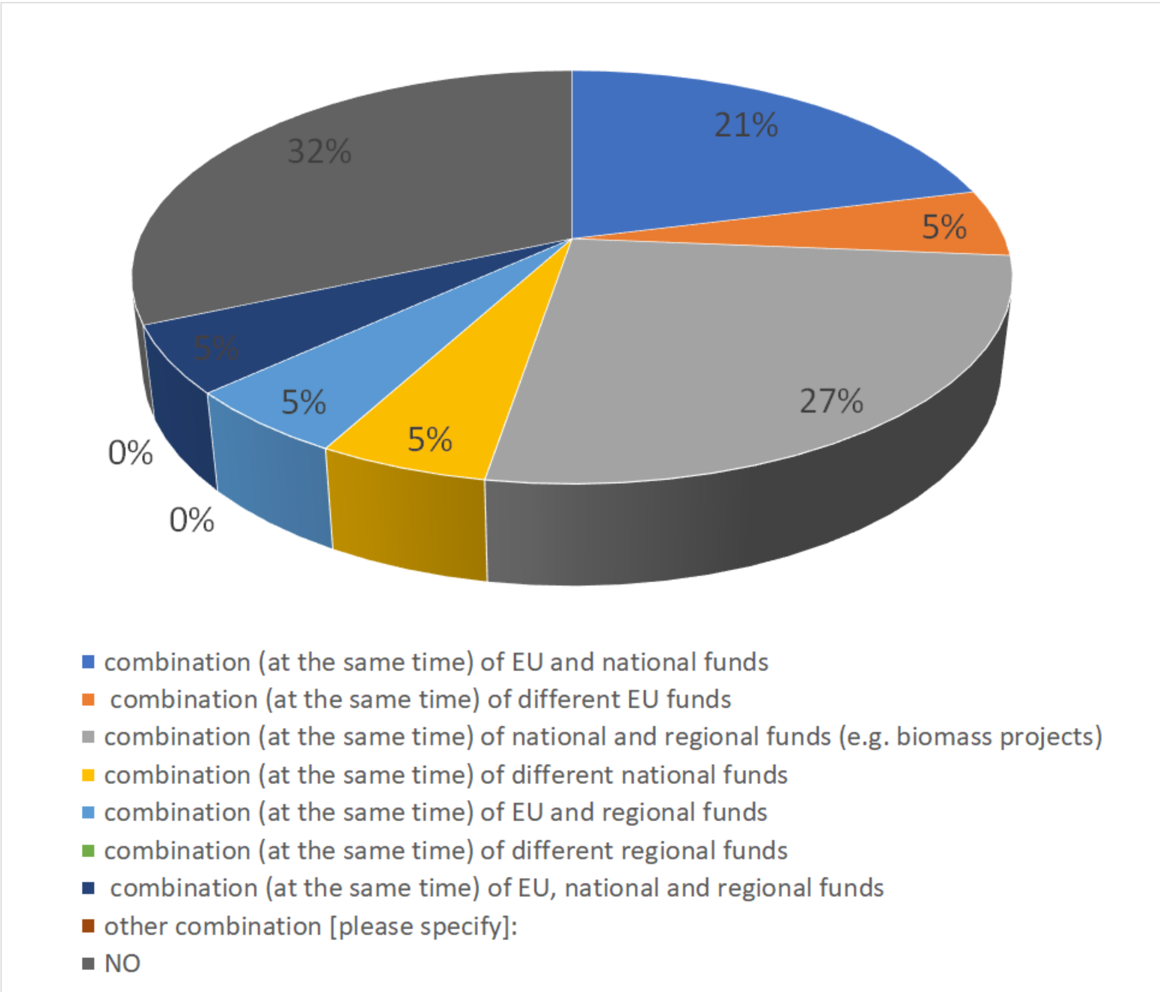


Figure 10. Stakeholders experiences in blending funding programs.



The blending experiences mentioned in the questionnaires are:

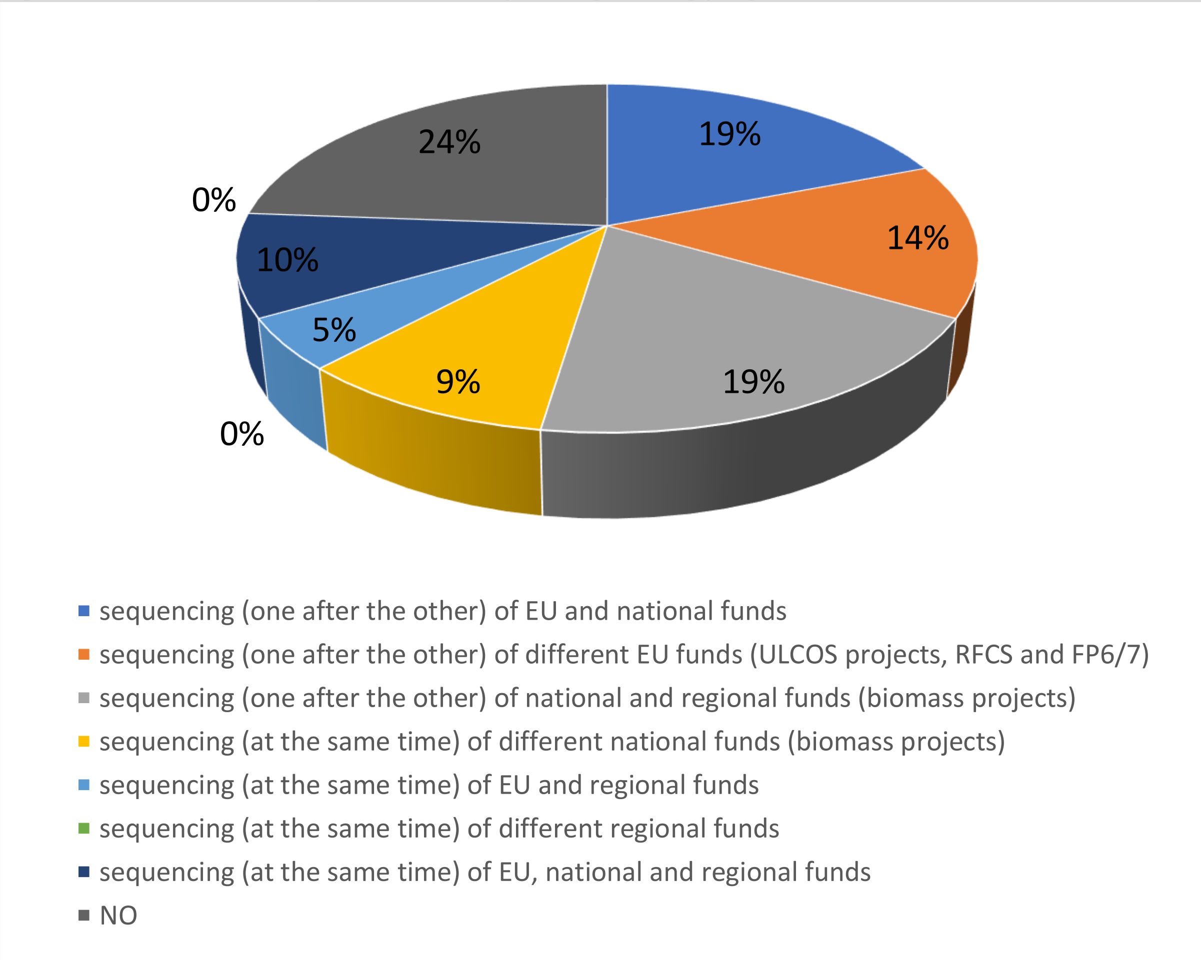
- RFCS (Research Fund for Coal and Steel) + LIFE (L'Instrument Financier pour l'Environnement) program;
- IPCEI (Important Projects of Common European Interest (IPCEI) with national funding;
- RFCS/HorizonEurope with Innovation Funding and IPCEI, also blended with initiatives from the national Government.

In Figure 11, the results on sequencing (one after the other) are shown. As for blending, the option of "no sequencing" is the most quoted (24%). The use on sequence of different EU funding is reported (14%). Among the sequencing experiences, the most reported are in the same way (19%) those involving EU and national funds, and those involving national and regional funds, again evidencing the role of the local support. In particular, the sequencing experiences claimed are:

- RFCS + H2020;
- Regional/National with Horizon Europe.

From these stakeholder replies, it can be concluded, that a great margin of improvement exists for more effective blending and sequencing of funding programmes.

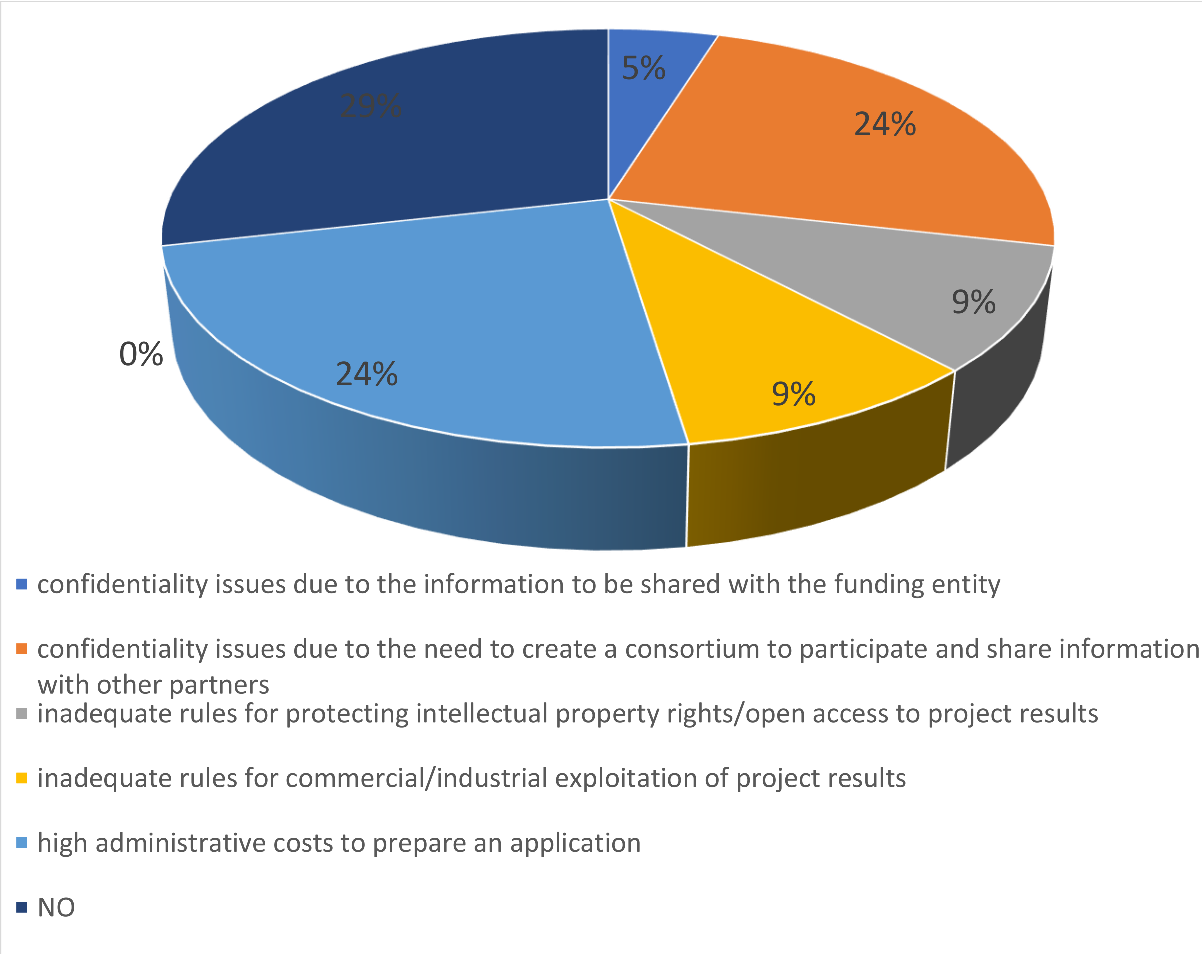
Figure 11. Stakeholders experiences in sequencing funding programs.



5.2 Barriers to access funding opportunities

An overview of the barriers found in accessing funding opportunities is shown in Figure 12.

Figure 12. Barriers claimed to be found by stakeholders in accessing funding opportunities.



6 Concluding remarks

The concluding remarks of this Deliverable 1.3 regarding the results of the first stage of the stakeholder consultation by a scoping questionnaire focused on main steel producers covering more than 80% of European CO_2 emissions are the following:

a) The level of technical readiness of the decarbonisation technologies is assessed to be TRL 5-7. Therefore, closing the technology gap towards demonstration level needs being initiated now.
b) This step forward is expected to generate major costs calling for significant public support to cover investment needs. As highlighted in Section 3, for the period 2030-2050 the investment costs for deployment at industrial level claimed can reach an order of magnitude of 4-5 Billion Euros and a CAPEX increase that in some cases can reach 100%.
c) Correspondingly, stakeholders clearly deem financial barriers to be the most severe barriers hindering decarbonisation. They are assessed with ratings between “relevant to a high extent” and “relevant to the fullest extent”.
d) High financial barriers are in particular linked to increases in CAPEX and OPEX and to the unknown market conditions for clean steel, given strong competition on the global steel markets.
e) The stakeholder replies concerning funding opportunities show that they already have a quite high awareness of the funding programmes. Most important are national programmes and EU programmes (covering 75% of the replies).
f) From the stakeholder replies regarding blending and sequencing of funding programmes, it can be concluded, that a great margin of improvement exists for more effective blending and sequencing of funding programmes.
g) As most important barriers regarding funding, high administrative costs and confidentiality issues were mentioned. This is highly relevant as innovation in breakthrough technologies at high TRL risks to fail without an appropriate innovation framework.

In-depth interviews, foreseen in the next steps of the project ‘Green Steel for Europe’, would allow a deeper insight on the main issues presented, as well as some success stories in making use of funding support. The findings presented in this deliverable furthermore provide the basis for the further investigations on investment needs and innovative funding approaches will be done within work package 2 of the project.