The Sustainable STEEL Principles: Alignment Zone Briefing

An envelope of net-zero scenarios for measuring climate-alignment in the steel sector

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Introduction

Purpose: The purpose of this document is to provide a detailed explanation and further information on the Alignment Zone approach of the Sustainable STEEL Principles. This benchmark, which consists of two net-zero scenarios, can assist lenders in determining the climate-alignment of their steel lending portfolios.

This document is organized into three sections: the Alignment Zone rationale, its application, and the methodology used for its development.

Background: The Sustainable STEEL Principles Working Group (WG), comprised of Citi, ING, Société Générale, Standard Chartered, and UniCredit, was launched in May 2021. The objective of the WG was to develop a measurement and disclosure framework to assess the climate alignment of their steel lending portfolios. Over the course of several months, the WG developed and tested various scenarios to measure the climate-alignment of their steel lending portfolios.

To assess climate alignment, the Sustainable STEEL Principles utilizes an Alignment Zone to benchmark progress towards a net-zero steel sector by 2050. Rather than consisting of a single benchmark, the Alignment Zone comprises two, the combination of which confers several benefits. First, it ensures that sectoral targets set by banks are consistent with limiting global temperature rise to 1.5°C. Second, it provides needed granularity, critical to enabling client engagement, and bolstering advocacy. Third, in the absence of regional sector-specific models, it reflects a range of decarbonization pathways that may be pursued by steelmakers globally.

Consultation Process: In November 2021, the WG launched a consultation process to share the initial proposal for the Alignment Zone with stakeholders. Based on feedback, the WG then adjusted the Alignment Zone and in January 2022, the WG launched a second round of consultations and amended the Alignment Zone again. All feedback collected during these consultations is outlined in Appendix I, although not attributed to any one entity. Based on the stakeholder support to the amended approach, the WG ultimately adopted the Alignment Zone to serve as the benchmarking tool of the Sustainable STEEL Principles.

The consultations on the Alignment Zone built on two previous consultations: one on the fixed system boundary and a second on the rationale for differentiating between emissions from primary and secondary steel production. For further information, see "The Sustainable STEEL Principles: A Split Trajectory Approach" and "The Sustainable STEEL Principles: Fixed System Boundary Approach."

SECTION 1: Rationale

1. What is an "Alignment Zone"?

The Alignment Zone consists of two scenarios. The lower scenario, or emissions reduction trajectory, is the International Energy Agency Net-Zero by 2050 Scenario (IEA NZE), while the upper scenario is the Mission Possible Partnership's Technology Moratorium scenario (MPP TM), one of several scenarios within the Steel Sector Transition Strategy Model (ST-STSM).

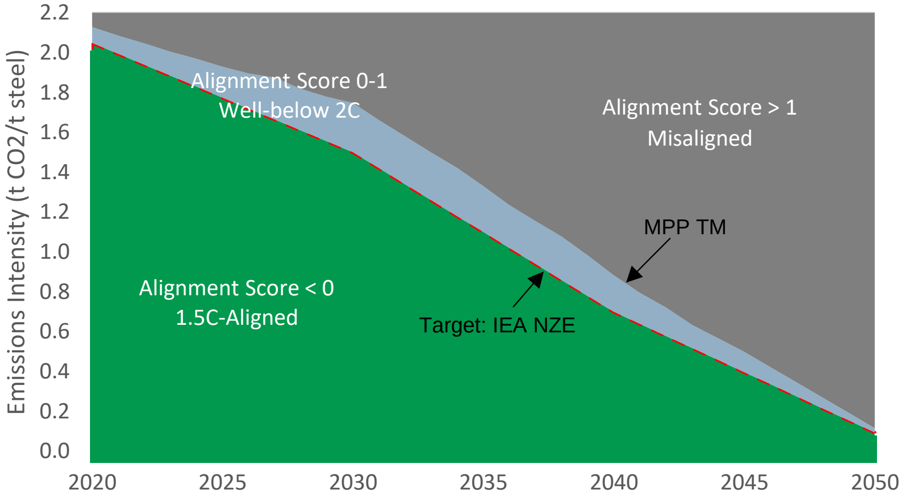
Under the Alignment Zone, the IEA NZE unambiguously serves as the target scenario because it has a greater chance of achieving 1.5°C, and due to its wide acceptance and clear compliance with the Net-Zero Banking Alliance (NZBA) target setting guidelines.

While the IEA NZE serves as the target for lenders and their clients, there are several uncertainties surrounding decarbonization of the steel sector. In particular, in order to reduce emissions from the sector at the pace proposed by the NZE, a supportive policy environment will be essential. However, these conditions do not exist yet, presenting challenges to the decarbonization of steelmaking in all geographies, particularly in emerging economies.

Therefore, the Sustainable STEEL Principles measure steelmakers against an additional scenario, the MPP TM (see question 6 for further explanation). While the IEA NZE is a top-down model of the global economy, providing a critical tool for policy making, the MPP TM is a granular bottom-up model that reflects the technological and economic conditions of the prevailing regulatory framework. Together, these two trajectories form three categories (Figure 1). These categories include:

- 1.5°C-Aligned: Steelmakers with an annual emissions intensity lower than the IEA NZE
- Well-below 2°C: Steelmakers with an annual emissions intensity above the IEA NZE, but below the MPP TM
- Misaligned: Steelmakers with an annual emissions intensity above the MPP TM

Figure 1. Alignment Zone for a sample steelmaker



Note: Trajectories based on the sample steelmaker's inputs to production consisting of 20% scrap.

Signatories to the Sustainable STEEL Principles report annually on the aggregate emissions intensity of their steel loan book according to the Zone in a manner that is compliant with NZBA target setting guidelines. (See Section 2 for the use of the Alignment Zone in determining the alignment of individual steelmakers and financial portfolios).

2. Which roadmap models did the Sustainable STEEL Principles consider?

The WG selected the two target scenarios within the Alignment Zone by identifying key criteria for selection (Table 1), examining various roadmap models against the criteria, and then deciding upon the target scenarios for the Alignment Zone.

Table 1: Key criteria for selecting a scenario

Key Criteria	
Climate-alignment	Does the model reach net-zero emissions from the steel sector by 2050 and is it no-to-low overshoot of 1.5°C?
Granularity	Does the model include granular data for the sector, including yearly data on emissions reductions through 2050? Does the model incorporate various technology options and sensitivities?
Openness	Are the model's full assumptions and results available to the Signatories and other stakeholders?
Industry Validation	Has the model been informed or endorsed by industry?
Adaptability	Can the model be tailored and updated if necessary?
Legitimacy	Has the model gone through a process of validation from key stakeholders?
Standardization	Is the model being used by other voluntary or mandatory initiatives?

In addition to the IEA NZE and MPP TM, the WG considered the University of Technology Sydney's OneEarth Climate Model (OECM), a top-down model of twelve sectors, including steel. Due to differences in the underlying assumptions across the three models under consideration, the sector carbon budget and global carbon budget varied greatly (Table 2).

Table 2. Comparison of carbon budgets across models

	OECM	IEA NZE	MPP TM
Steel sector emissions in 2050 (Gt CO_2e) (scope 1 and 2)[1]	19	54.5[2]	69.6
Global economy emissions in 2050	400	500	640[3]
Portion of steel emissions of total carbon budget	4.75%	10.9%	10.9%[4]

Sources: International Energy Agency, *Net Zero by 2050*, IEA, 2021; Net-Zero Steel Initiative, *Net-Zero Steel Sector Transition Strategy*, October 2021; and University of Technology Sydney, Institute for Sustainable Futures, *Sectorial Pathways for Industries – OneEarth Climate Model 2021,* November 2021

[1] See question 13 for a further explanation of the scope and boundary of the IEA NZE trajectory.
[2] This value is not disclosed by the IEA NZE. Value calculated based on a linear interpolation to estimate annual steel production and direct (scope 1) emissions based on the stated production and emissions values for 2020, 2030, 2040 and 2050 from the IEA NZE. Annual scope 2 emissions are estimated based on the technology mix stated in the IEA NZE for 2020, 2030 and 2050.
[3] This value is not calculated by MPP, since it is a sector specific model. Figure calculated by assuming the same portion of emissions for the steel sector of the global carbon budget as the IEA NZE (10.9%) and then applying this amount to determine a global emissions value.
[4] Assumed to be the same portion of carbon budget as the IEA NZE.

A key trend emerged in the consideration of various roadmaps: the differences in and complementarity of top-down models such as the IEA NZE, as well as bottom-up models, such as the MPP TM.

Top-down models were defined as those that provide a global economy roadmap which model inter-sectoral interactions. Top-down models derive sectoral pathways as part of integrated assessment models for transitioning the global economy to net-zero emissions by 2050 in line with the goal of limiting warming to 1.5°C with no-to-low-overshoot. As a result, these models can be useful for target-setting as they ensure targets are consistent with the decarbonization of the entire economy in line with 1.5°C.

By comparison, bottom-up models outline a transition pathway for specific sectors but are built independent of a global economy roadmap. Bottom-up models, such as the MPP TM, were recognized for their granularity and ability to provide necessary insights to inform and sharpen client engagement and policy advocacy.

The Alignment Zone utilizes *both* the top-down IEA NZE and bottom-up MPP TM. Each selected scenario serves functions which are key to the Sustainable STEEL Principles' overall objectives and meet several of the criteria set forth by the WG (Appendix II). The WG decided not to select the OECM model due to how it compared against the selection criteria (Table 1).

The IEA NZE is widely used and readily accepted as legitimate by various stakeholders, a key criterion in the work to create a standard for the steel sector. On the other hand, the MPP TM has several advantages as compared to the NZE. For one, the MPP TM contains highly granular, publicly available data on its assumptions and results, in particular on the technology archetypes applied, which enables financial institutions to glean insights from the model to support the sector's transition (Appendix III).

Additionally, cost optimization is a central driver of the MPP TM trajectory, which industry indicated is necessary to make transition pathways realistic and actionable. Lastly, the policy assumptions modelled by the MPP TM are more reflective of the current policy landscape, whereas the policy assumptions of the IEA NZE reflect the changes that will be needed for a smooth and rapid transition to a net-zero global economy (Table 3).

Table 3. Key drivers of the IEA NZE and MPP TM models

	IEA NZE	MPP TM
Transition driver	Assumes a range of drivers including policies, mandates/ standards, industry investment and carbon pricing/ market reforms	• 2020 – 2030: Steel asset switches to technologies that optimize for lowest total cost of ownership • Post-2030: Investments limited to near-zero-emissions technologies. With average relining cycles of ~20 years, this achieves net-zero emissions by 2050 and avoids stranded assets
Carbon price	Advanced economies: • \$75/tCO_2 in 2025; \$250/tCO_2 in 2050 China, Brazil, Russia, South Africa: • \$45/tCO_2 in 2025; \$200/tCO_2 in 2050 Other emerging markets/ developing economies: • \$3/tCO_2 by 2025; \$55/tCO_2 by 2050	None
2050 coal consumption	22% in 2050 from 75% in 2020 as a share of total steel sector energy use	25% of total steel sector energy use in 2050
Additional investment	Unknown	\$215B between 2020 and 2050
Government action	Governments fund the R&D for critical near-zero emissions industrial technologies and mitigates investment risks.	Scenario could be realized through various interventions, including government regulation on environmental standards for new plants.
Action from financial institutions	• Private sector is central to finance higher investment needs, requiring collaboration between developers, investors, public financial institutions and governments. • Private sector actors engage with policy makers, including those in emerging markets, to reform regulatory frameworks	Adopt practices to de-risk and scale new low-carbon steelmaking technologies, including: • Developing/offering sustainable finance instruments • Developing risk management frameworks that accelerate the adoption of net-zero steelmaking technology • Adopting systems that can scale voluntary carbon markets
Industry action	Radical technological transformation of iron & steel infrastructure to support the shift from coal to electricity.	• Investigate options to decarbonize existing steel sites • Engage with stakeholders to get the needed infrastructure (i.e. carbon-free energy grids, carbon transport and storage networks etc.) in place on time • Enter into long-term off-take agreements for low-CO2 steel products

Sources: International Energy Agency, *Net Zero by 2050*, IEA, 2021; and Net-Zero Steel Initiative, *Net-Zero Steel Sector Transition Strategy*, October 2021.

3. What assumptions underpin the MPP Steel Sector Transition Strategy Model (ST-STSM) and how does it achieve net-zero emissions by 2050?

The ST-STSM model, which includes the Technology Moratorium (TM) scenario, adopts a bottom-up, asset-by-asset approach that evaluates the cost-effectiveness of technology switching by steel producers in a particular country and region to achieve net-zero CO_2 emissions by 2050. The model includes twenty technology archetypes (Appendix III) and estimates direct (i.e., scope 1) and indirect (i.e., scope 2) emissions from the steel sector, in line with the Sustainable STEEL Principles' fixed system boundary approach for emissions accounting.[5] The model includes two scenarios to achieve net-zero emissions in the sector by 2050, the Carbon Cost scenario and TM scenario, each of which employ various assumptions about steelmaking technologies, scrap usage, and policy frameworks.

Pre-2030, the TM optimizes for the lowest total cost of ownership by selecting the most appropriate technologies at each major investment decision this decade. In the absence of measures to incentivize their adoption in the 2020s, lower-emissions technologies are initially only built where they can compete on cost with conventional steelmaking. These "transitional" or marginal emissions reduction measures can include energy efficiency improvements, such as upgrading blast furnaces to the best available technology, utilizing lower-emissions inputs where available (e.g., biogas, biochar), and switching to lower-emissions steelmaking processes (e.g., from blast furnace to DRI).[i]

After 2030, the model assumes a moratorium on investment in new carbon-intensive technologies, and new investments are only made in near-zero emissions steelmaking technologies (either due to regulatory measures or because financing is no longer made available for these assets). This ensures that all steel sector assets are net-zero compatible by 2050, due to the average industry relining cycles of approximately 20 years.

The model does not account for impacts of changing trade flows between regions, nor does it consider the likelihood of specific geographies achieving climate targets at different times. Additionally, the model does not account for the relocation of greenfield assets to more competitive locations, or the potential changes in energy prices due to shifting demand for fossil fuels resulting from a decarbonizing global economy.[ii]

Steelmakers who are part of the Mission Possible Partnership's Net-Zero Steel Initiative (NZSI) informed the model through interviews and workshops and endorsed the Sector Transition Strategy that was developed from the model's outputs[6]. The model's materials and analytics are open access, enabling transparency regarding its inputs and assumptions, and allowing for future iterations as data and insights evolve.

4. What assumptions underpin the IEA NZE and how does it achieve net zero emissions in the steel sector by 2050?

The NZE models the transition needed for the global energy sector to achieve net-zero CO_2 emissions by 2050 in a way that is consistent with a 50% probability of limiting global temperature rise to 1.5°C, without overshoot.[iii] The model delivers the optimal share of technology choices by country and region over time by optimizing emissions reductions and minimizing costs, while satisfying demand for steel. To do so, the model includes specific carbon pricing mechanisms where relevant (e.g., the European Union's Emissions Trading System).

The NZE discloses the inclusion of the following technologies and practices: BF-BOF, blast furnace retrofits, scrap-based EAF, hydrogen-based DRI-EAF and natural gas-based DRI-EAF, iron ore electrolysis, CCUS-based primary, smelting reduction, and technologies using bioenergy. In addition, the NZE models material and energy efficiency measures, assuming global demand for steel is 12% higher in 2050, compared to 2020. Additionally, the model includes carbon pricing assumptions starting in 2025 in advanced economies, emerging markets, and developing economies, which ramps up to 2025 (Table 3).

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[5] The ST-STSM estimates scope 3 (mining and transportation) emissions as well, but to align with the fixed system boundary adopted by the WG, these were not included in the TM emissions reduction trajectory. Please refer to the "The Sustainable STEEL Principles: Fixed System Boundary Approach" brief.

[6] Companies that endorsed the Sector Transition Strategy developed from the model's outputs include: ArcelorMittal, Boston Metal, Liberty Steel, Rio Tinto, Severstal, SSAB, Tata Steel, thyssenkrupp Steel Europe AG.

The NZE reports only direct (scope 1) emissions for the steel sector, while it attributes indirect (scope 2) emissions from electricity consumption from steelmaking to the power sector. The NZE is not fully open-access; emissions data for the steel sector is only reported in decadal increments and scrap utilization is only reported in 2020, 2030, and 2050. The model's assumptions are not fully disclosed.

Since the NZE scope of emissions is inconsistent with the MPP TM as well as the Sustainable STEEL Principles' approach for a fixed system boundary for the steel sector[iv], adjustments were made to include indirect (scope 2) emissions to the NZE trajectory (see question 13). In addition, since the NZE only reports on a decadal basis, emissions and scrap utilization data was interpolated linearly to generate yearly data from 2020 through 2050. See Appendix IV for a more complete comparison of the MPP TM and IEA NZE.

5. How do the NZE and TM differ in reductions in emissions intensity over time?

The two models differ in their projections of the future steelmaking technology mix, resulting in different rates of reduction in emissions intensity over time (Table 4).

Table 4. Emissions intensity reductions for the NZE and TM

Period	NZE Emissions Intensity Reductions	TM Emissions Intensity Reductions
2020 – 2030 (compared to 2020 baseline)	-33%	-24%
2030 – 2040 (compared to 2030 baseline)	-56%	-50%
2040 – 2050 (compared to 2040 baseline)	-79%	-80%

Sources: Net-Zero Steel Initiative, *Net-Zero Steel Sector Transition Strategy*, October 2021 & International Energy Agency, *Net Zero by 2050*, IEA, 2021.

Between 2020 and 2030, there are steeper reductions in emissions intensity under the IEA NZE. Although the MPP TM optimizes for total cost of ownership in the 2020s, emissions intensity still declines 24% under this scenario, due to assumptions for energy efficiency upgrades, the utilization of scrap in blast furnaces, and lower levels of off-gases.

Post-2030, a moratorium on non-net-zero-compatible technologies is applied, resulting in sharper reductions in emissions intensity under the MPP TM. As a result, the emissions intensity across the two scenarios begins to converge post-2040.

6. Why are the Sustainable STEEL Principles utilizing an Alignment Zone?

The Alignment Zone approach is designed to achieve two core objectives:

1) Target setting—ensuring that sectoral targets set by banks are consistent with limiting global temperature rise to 1.5°C and with the Net-Zero Banking Alliance target setting guidelines. To achieve this, the target trajectory for banks and their clients is the IEA NZE.

2) Real economy impact—providing a framework for maximizing real economy impact, achieved through the inclusion of a second trajectory, the MPP TM. These two scenarios, when used in tandem, provide banks with the tools they need for client engagement and policy advocacy, necessary for achieving real economy impact.

Through the inclusion of multiple scenarios, this approach more accurately represents the uncertainty faced by the steel sector in pursuit of 1.5°C due to economic, regulatory, and technological factors. In doing so, it better illustrates the need for policy, provide a framework for informing client engagement, and ratchet that engagement upward with policy.

Target setting:

The IEA NZE is consistent with a 50% chance of limiting long-term average global temperature rise to 1.5°C without a temperature overshoot. It is a global economy model, however, there is little transparency with regards to annual emissions or technology assumptions for the steel sector. This makes the IEA NZE a useful trajectory for target setting, but limits its utility for client engagement and advocacy.

Real economy impact:

On the other hand, since the MPP TM is a sector-specific scenario, not a top-down integrated assessment model, and since its emissions exceed the IEA NZE carbon budget, it is less useful for target setting. However, the TM scenario models global steel assets and its assumptions are fully disclosed, making it an effective technical roadmap and a highly beneficial tool for real economy impact.

Client engagement

Given that lending has been the largest source of capital to the steel sector over the past decade, banks have a key role to play in supporting the net-zero transition. The Sustainable STEEL Principles can provide lenders with the tools necessary to support the decarbonization efforts of their clients, enabling client engagement. This approach differs from one that might alternatively incentivize banks to exit client relationships—a strategy which may achieve portfolio alignment, but is unlikely to drive emissions reductions in the real economy.

Utilizing a single trajectory would result in a binary approach of categorizing steelmakers as either “aligned” or “misaligned”. Due to the cost implications of near-zero emissions technologies for the steel sector in many regions, assessing sectoral alignment in comparison to the IEA NZE only could result in categorizing a majority of companies as “misaligned”, at least in the near term. This might incentivize banks to exit client relationships, rather than engage clients to explore transition strategies and identify opportunities to support the transition. Utilizing the NZE as a single trajectory could run the risk of disadvantaging steelmakers who are unable to make the investments required to align with the emissions intensity of the NZE, due to the lack of a supportive policy environment.

A core assumption of the TM is a ban on new high carbon assets post-2030. Achieving this will require that low-carbon technologies become commercially feasible before 2030, necessitating investment in demonstration plants now. Therefore, in order for banks to align their portfolios, client engagement will be required to prepare for sectoral decarbonization, including decades of forward planning and investment by industry incumbents and newcomers alike.

Furthermore, the TM proves useful in its ability to guide decision-making to help avoid major value destruction through stranded assets. The TM scenario represents the slowest pace for decarbonization to reach net-zero by 2050 *without* stranding assets. Therefore, the TM is valuable for lenders as a guardrail for alignment.

Policy advocacy:

In the 2020s, the TM optimizes for total cost of ownership by selecting the most appropriate technologies at each major investment decision (i.e., major maintenance), in the absence of policy measures. Post-2030, the TM assumes a moratorium on investment in carbon-intensive technologies, ensuring that all steel sector assets transition to be net-zero compatible by 2050. Therefore, the TM provides two useful reference points: what can be expected under a close-to-current-policies scenario, and what a rapid but orderly transition of steel assets might entail. It should be noted that such a transition would be contingent upon the deployment of transition finance and the implementation of effective policy frameworks globally.

The IEA NZE, by contrast, assumes a global carbon price starting in 2025 and ramping up to 2050. The inclusion of the "Well-below 2°C" zone provides a useful framing for lenders to advocate for sector-specific policies capable of shifting the scales of their lending portfolios by noting the delta between the emissions intensity of their steel portfolios and the IEA NZE.

While the Alignment Zone is the current approach utilized by the Sustainable STEEL Principles, both trajectories may be updated as new modelling becomes available or as economic or policy conditions change.

7. Is the Alignment Zone considered compatible with no-to-low overshoot of 1.5°C?

To determine the temperature compatibility of the Alignment Zone, RMI conducted an analysis on the cumulative carbon emissions associated with the MPP TM and compared it to the carbon budget calculation methodology provided in the IPCC "Special Report on Global Warming of 1.5°C" (SR1.5). While the IEA NZE is constructed to limit the chance of exceeding 1.5°C to 50%, the chance of exceeding 1.5°C under the MPP TM scenario is 60%, which falls within the IPCC definition of "low-overshoot" of 1.5°C.[v]

For the temperature analysis, a global carbon budget associated with the MPP TM had to be estimated, since the STSM is sector-specific and is not an integrated assessment model of the global economy. To do so, RMI assumed the same fraction of emissions for the steel sector as used by the NZE. The NZE implies that the steel sector emits 54.5 Gt CO_2 cumulatively between 2020 and 2050, equating to 10.9% of the total economy-wide carbon budget of 500 Gt CO_2e[7]. Assuming the same portion of emissions for the steel sector for the TM scenario results in a global carbon budget of 637.9 Gt CO_2e, rounded to 640[8] Gt CO_2e (Table 5).

Using the carbon budget calculation methodology provided in the IPCC SR1.5[vi], the MPP TM budget of 640 Gt CO2e was found to result in a 60% chance of exceeding 1.5°C and a 40% chance of limiting warming to less than 1.5°C.

Table 5. Cumulative emissions of NZE and TM

	IEA NZE	MPP TM
Cumulative steel sector emissions (Gt CO_2)	54.9	69.6
Total carbon budget (Gt CO_2e)	500	640
Steel sector fraction of global emissions	10.9%	10.9%
Chance of >1.5°C	50%	60%

Sources: Net-Zero Steel Initiative, *Net-Zero Steel Sector Transition Strategy*, October 2021 & International Energy Agency, *Net Zero by 2050*, IEA, 2021.

The SR1.5 defines scenarios as being consistent with limiting warming to 1.5°C-low-overshoot that contain cumulative carbon emissions (to the peak temperature year) of up to 670 Gt CO_2 and with a likelihood of exceeding 1.5°C of up to a 62% (Table 6). Across 37 modelled climate scenarios, the IPCC found that cumulative emissions of between 590 – 670 Gt CO_2 were consistent with no-to-low overshoot of 1.5°C.

[7] Since the IEA NZE only discloses steel sector emissions on a decadal basis, emissions data was interpolated linearly to generate yearly data from 2020 to 2050.
[8] It is common practice of the IPCC to round to the nearest 10 Gt.

Table 6. Geophysical characteristics of mitigation pathways derived at peak warming.[vii]

			Geophysical Characteristics at Peak Warming										
Category	# scenarios with climate assessment	Peak|Median warming	Peak|Year	Peak|CO_2 [ppm]	Peak|RF all [W m^{-2}]	Peak|RF CO_2 [W m^{-2}]	Peak|RF non CO_2 [W m^{-2}]	Net zero CO_2 |Year	Cumulative CO_2 emissions (2016 to peak warming) as submitted [$GtCO_2$]	Cumulative CO_2 emissions (2016 to peak warming) harmonized [$GtCO_2$]	Peak|Exeedance Probability 1.5°C [%]	Peak|Exeedance Probability 2.0°C [%]	Peak|Exeedance Probability 2.5°C [%]
Below-1.5°C	5	1.5 (1.5, 1.5)	2041 (2040, 2046)	423 (422, 424)	2.9 (2.8, 2.9)	2.3 (2.3, 2.3)	0.6 (0.6, 0.6)	2044 (2038, 2050)	480 (480, 490)	460 (460, 470)	45 (42, 46)	5 (5, 5)	1 (1, 1)
1.5°C-low-OS	37	1.6 (1.5, 1.6)	2048 (2045, 2050)	431 (429, 435)	3.0 (2.9, 3.0)	2.4 (2.3, 2.4)	0.6 (0.5, 0.6)	2050 (2047, 2055)	620 (600, 670)	620 (590, 670)	60 (56, 62)	10 (9, 12)	1 (1, 2)
1.5°C-high-OS	36	1.7 (1.6, 1.7)	2051 (2048, 2053)	447 (440, 454)	3.2 (3.1, 3.3)	2.6 (2.5, 2.7)	0.6 (0.6, 0.7)	2052 (2049, 2059)	840 (760, 930)	870 (760, 930)	75 (72, 78)	18 (14, 20)	3 (2, 4)
Lower-2°C	54	1.7 (1.7, 1.8)	2061 (2059, 2074)	454 (446, 458)	3.2 (3.1, 3.3)	2.6 (2.5, 2.7)	0.6 (0.5, 0.7)	2070 (2063, 2079)	990 (890, 1080)	1000 (900, 1070)	79 (75, 82)	26 (22, 28)	6 (6, 7)
Higher-2°C	54	1.9 (1.9, 2.0)	2078 (2069, 2100)	473 (464, 478)	3.4 (3.3, 3.5)	2.8 (2.8, 2.9)	0.5 (0.5, 0.7)	2084 (2070, post-2100)	1320 (1170, 1450)	1320 (1150, 1490)	87 (85, 89)	40 (38, 46)	13 (11, 15)
Above-2°C	182	3.1 (2.2, 3.8)	Post-2100	651 (520, 777)	5.4 (3.9, 6.6)	4.6 (3.4, 5.5)	0.8 (0.6, 1.2)	post-2100	3550 (2000, 4790)	3530 (1980, 4780)	100 (95, 100)	96 (69, 100)	84 (31, 97)

Source: IPCC, *Mitigation Pathways Compatible with 1.5°C in the Context of Sustainable Development Supplementary Material*, 2018

An additional analysis of temperature-compatibility examines the implied temperature rise of the MPP TM carbon budget with a 50% probability. Applying a transient climate response to cumulative carbon emissions (TCRE) of 0.45, a 0.07°C overshoot for the MPP TM scenario is calculated, resulting in 1.57°C of peak warming over pre-industrial levels[viii].

As depicted in Table 7, the IPCC SR1.5 defines scenarios or pathways as “1.5°C-low-overshoot,” which limit median warming to below 1.5°C in 2100 with 50 – 67% probability of temporarily overshooting that level earlier, implying less than 0.1°C higher peak warming. The MPP TM scenario is estimated to result in 0.07°C overshoot, which falls within the IPCC SR1.5 classification of “1.5°C-low-overshoot.”

Table 7. Classification of pathways by implied temperature rise[ix]

Pathway group	Pathway Class	Pathway Selection Criteria and Description	Number of Scenarios	Number of Scenarios
1.5°C or 1.5°C-consistent**	Below-1.5°C	Pathways limiting peak warming to below 1.5°C during the entire 21st century with 50–66% likelihood*	9	90
	1.5°C-low-OS	Pathways limiting median warming to below 1.5°C in 2100 and with a 50–67% probability of temporarily overshooting that level earlier, generally implying less than 0.1°C higher peak warming than Below-1.5°C pathways	44	
	1.5°C-high-OS	Pathways limiting median warming to below 1.5°C in 2100 and with a greater than 67% probability of temporarily overshooting that level earlier, generally implying 0.1–0.4°C higher peak warming than Below-1.5°C pathways	37	
2°C or 2°C-consistent	Lower-2°C	Pathways limiting peak warming to below 2°C during the entire 21st century with greater than 66% likelihood	74	132
	Higher-2°C	Pathways assessed to keep peak warming to below 2°C during the entire 21st century with 50–66% likelihood	58	

* No pathways were available that achieve a greater than 66% probability of limiting warming below 1.5°C during the entire 21st century based on the MAGICC model projections.

** This chapter uses the term 1.5°C-consistent pathways to refer to pathways with no overshoot, with limited (low) overshoot, and with high overshoot. However, the Summary for Policymakers focusses on pathways with no or limited (low) overshoot.

Source: IPCC, *Mitigation Pathways Compatible with 1.5°C in the Context of Sustainable Development*, 2018

8. What is the rationale for the names of the categories within the Alignment Zone?

1.5°C-aligned: The IEA NZE trajectory forms the upper boundary of the "1.5-aligned" category, since the IEA NZE "is consistent with limiting the global temperature rise to 1.5°C without a temperature overshoot (with a 50% probability)". As per the IPPCC Special Report 1.5, a 50% likelihood of limiting peak warming below 1.5°C qualifies as a pathway for the category of "Below-1.5°C", therefore, this is categorized as 1.5°C-aligned.[x]

Well-below 2°C: Although the MPP TM scenario can be considered aligned with a low-overshoot of 1.5°C, the zone between the IEA NZE and MPP TM is referred to as "Well-below-2°C". The rationale is twofold: first, since the MPP TM is sector-specific and not an integrated assessment model of the global economy, limiting global temperature rise will depend on the emissions reduction pathways of the broader economy. Therefore, it was considered prudent to apply a more conservative estimate of temperature rise. Second, referring to this zone as "Well-below 2°C" instead of "1.5°C-low overshoot" avoids potential confusion of utilizing pathways with similar terms.

Misaligned: Anything with an emissions intensity above the MPP TM boundary is categorized as "misaligned," since it exceeds established carbon budgets.

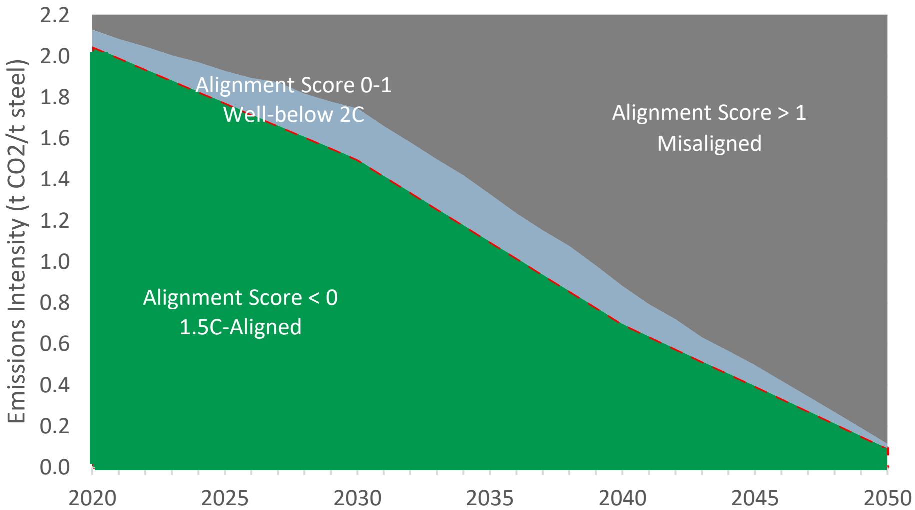
SUSTAINABLE STEEL PRINCIPLES

SECTION 2: The Alignment Zone in Practice

9. How is the Alignment Zone used to determine the alignment of steelmakers and financial portfolios?

Based on a borrower's emissions and use of external scrap, Signatories to the Sustainable STEEL Principles determine an Alignment Zone for each of their borrowers and calculate a score that indicates the borrower's alignment (Figure 2).

Figure 2: Alignment Zone for a sample borrower



Note: Trajectories depicted based on the sample borrower's inputs to production consisting of 20% scrap.

The Alignment Zone and score are generated according to the following steps:

1. Obtain annual data on a borrower's (i) use of external scrap by weight as a share of total metallic inputs, and (ii) CO_2 emissions on a comparable basis per ton of crude steel (Table 8, Step 1).
2. Generate a lower and upper target for the borrower for each year as the weighted sum of the two primary and secondary trajectories (determined from the NZE and TM), with the weights being the share of external scrap by weight (for secondary production) and other metallic inputs (for primary production) (Table 8, Step 2).
3. Calculate the borrower's alignment score as the ratio of the borrower's emissions delta (the difference between their actual emissions and their lower target) and zone delta (the difference between their upper target and lower target) (Table 8, Step 2).

A score greater than 1 reveals that the borrower is misaligned; a score between 0-1 reveals that the borrower is aligned with "well-below 2°C"; and a negative score indicates that the borrower is aligned with a 1.5°C scenario. The score is designed to: (i) define the borrower's emissions relative to these three zones; (ii) provide a normalized basis that can be used to compare borrowers' performance; and (iii) provide a continuous metric used to calculate the weighted average alignment of a bank's loan portfolio.

The Alignment Zone is specific to each borrower, based on their metallic input mix. The lower end of the zone (delineating 1.5-aligned from well-below 2°C) is determined by taking the weighted average of the emissions target for primary and secondary steel emissions as determined by the NZE, weighted by the amount of primary steel and secondary steel produced in the previous calendar year for that specific borrower. Similarly, the upper-bound of the zone (delineating well-below 2°C from misaligned) is determined by taking the weighted average of the emissions target for primary and secondary steel as determined by the TM, weighted by the amount of primary steel and secondary steel produced in the previous calendar year for that specific borrower.

Table 8. Sample calculation of alignment scores at the borrower (client) and portfolio level

Step	Parameter	Terms & Equations		Steelmaker A Primary	Steelmaker A Secondary	Steelmaker B Primary	Steelmaker B Secondary
Step 1 Reporting	Production mix 2022	P_p	P_s	0.90	0.10	0.10	0.90
	Emissions 2022 *(t CO2/t steel)*	E_i		2.40		0.35	
Step 2 Borrower-level calculations	IEA NZE Benchmark 2022 *(t CO2/t steel)*	B_{ap}	B_{as}	2.26	0.67	2.26	0.67
	MPP TM Benchmark 2022 *(t CO2/t steel)*	B_{bp}	B_{bs}	2.38	0.73	2.38	0.73
	Borrower Lower Target *(t CO2/t steel)*	$T_{li} = (P_p * B_{ap}) + (P_s * B_{as})$		(0.9 * 2.26) + (0.1 * 0.67) = 2.10		(0.1 * 2.26) + (0.9 * 0.67) = 0.83	
	Borrower Upper Target *(t CO2/t steel)*	$T_{ui} = (P_p * B_{bp}) + (P_s * B_{bs})$		(0.9 * 2.38) + (0.1 * 0.73) = 2.22		(0.1 * 2.38) + (0.9 * 0.73) = 0.90	
	Zone Delta *(t CO2/t steel)*	$Z_\delta = T_{ui} - T_{li}$		2.22 – 2.10 = 0.12		0.90 – 0.83 = 0.07	
	Emissions Delta *(t CO2/t steel)*	$E_\delta = E_i - T_{li}$		2.40 – 2.10 = 0.30		0.35 – 0.83 = -0.48	
	Borrower Alignment Score	$\mu_i = E_\delta / Z_\delta$		0.30 / 0.12 = 2.50		-0.48 / 0.07 = -6.86	
Step 3 Portfolio-level calculations	Steel-related Revenues *(% of total)*	R_i		100%		25%	
	Debt Outstanding 2022 *(USD)*	O_i		$100mn		$400mn	
	In-Scope Exposure 2022 *(USD)*	$X_i = R_i * O_i$		100% * $100mn = $100mn		25% * $400mn = $100mn	
	Exposure Weight	$w_i = X_i / X_{total}$		$100mn / $200mn = 0.50		$100mn / $200mn = 0.50	
	Portfolio Alignment Score	$\mu_t = \sum_{i=1}^{N} w_i \mu_i$		(2.50 * 0.50) + (-6.86 * 0.50) = -2.18			

-------- Publicly reported annually

10. Why is an Alignment Score being utilized?

The Alignment Score plots the emissions intensity of a borrower against the Alignment Zone, thereby identifying a borrower's proximity to the emissions intensity of the IEA NZE benchmark, in addition to indicating the distance from the emissions intensity of the MPP TM. NB: while lenders see the scores of individual borrowers, only aggregated portfolio scores are reported publicly.

An alternative metric, such as a percent deviation from the IEA NZE trajectory, was also as a viable approach to identifying the climate alignment of a borrower. However, on its own, this metric is less instructive. A percent deviation can indicate whether a borrower has a higher or lower emissions intensity than the IEA NZE, depending on whether the value is negative or positive, but a positive value alone does not reveal the degree of misalignment.

The Alignment Score, by comparison, is more informative. A negative value reveals a lower emissions intensity than the IEA NZE; a value between 0 and 1 indicates that a borrower's emissions are in line with net-zero but are associated with well-below 2°C; and a value greater than 1 reflects misalignment.

11. How are an individual borrower's alignment scores be interpreted over time?

While the Alignment Score is helpful in comparing the emissions intensity between borrowers in any given year, it is not an ideal metric to compare emissions intensity temporally.

The Alignment Score is calculated using the delta between a borrower's weighted upper and lower targets (Table 8, Step 2), referred to as the "zone delta". The zone delta changes annually, due to the differences in the assumptions in both the NZE and TM scenarios and how these evolve over time.

As a result, the Alignment Score is not intended to compare a borrower's score over time. While this is less of a concern from 2020 to 2030, since the delta between the scenarios is relatively consistent, it becomes more pronounced after 2030, due to a greater divergence between trajectories.

Consequently, the Signatories to Sustainable STEEL Principles will revisit the approach regularly.

12. Why is an emissions intensity metric applied, rather than absolute emissions?

An emissions intensity metric was selected due to its ease of use, widespread applicability, and ability to compare emissions within a portfolio. As opposed to absolute emissions, emissions intensity normalizes emissions by output, allowing for a more direct comparison of borrowers regardless of size.

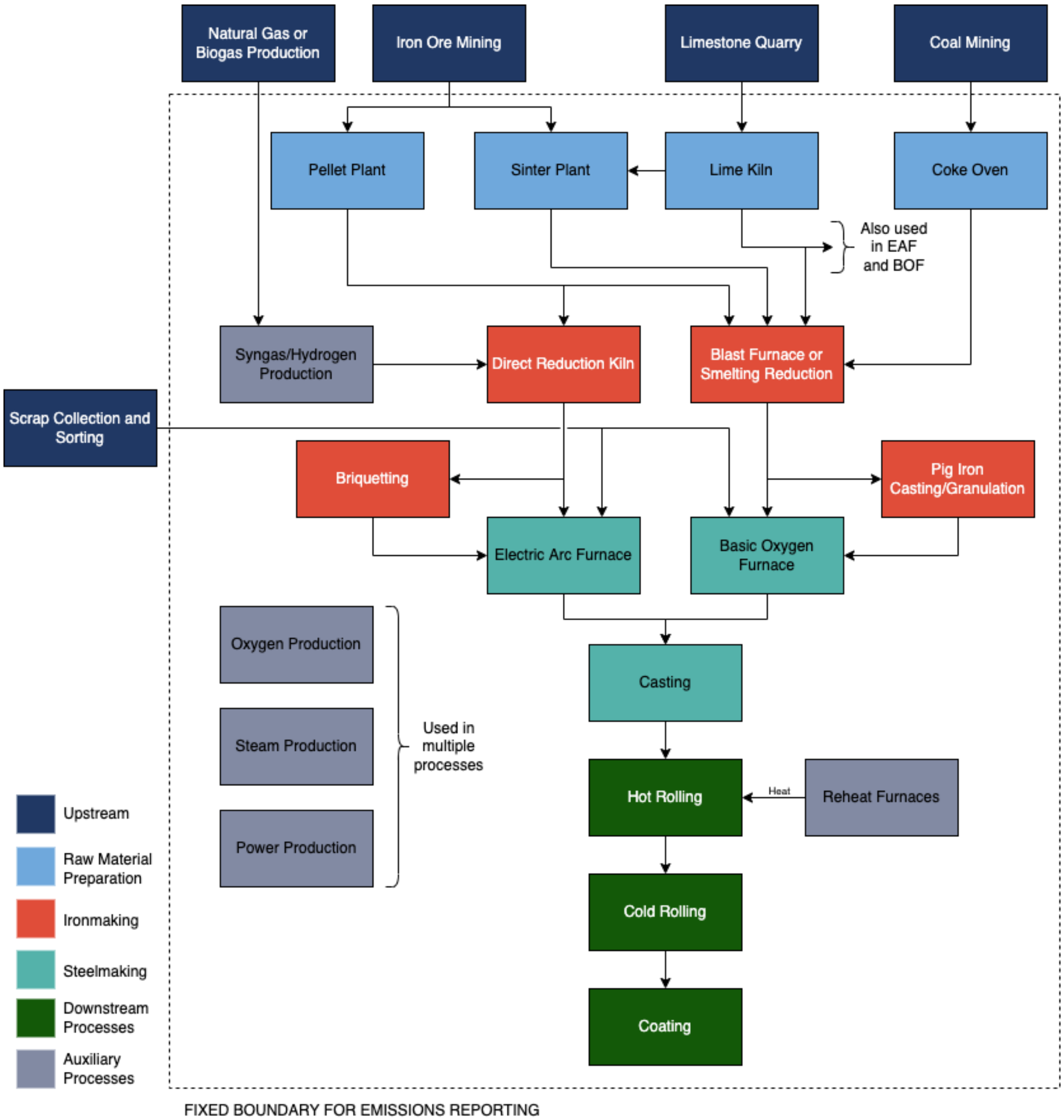
However, the selection of an emissions intensity indicator does not preclude future consideration of other indicators. For example, following feedback received from stakeholders on the value of forward-looking metrics, the Sustainable STEEL Principles WG opted to include a forward-looking indicator into the framework of the agreement.

SECTION 3: The Methodology Used to Construct the Alignment Zone

13. How was the scope of the IEA NZE adjusted to be consistent with the scope of the fixed system boundary—a methodology adopted by the Sustainable STEEL Principles to measure the alignment of steel lending portfolios?

The Sustainable STEEL Principles includes a fixed system boundary intended to improve emissions comparability in the steel sector.[9,xi] This approach requires borrowers to report on all emissions within the boundary (Figure 3), irrespective of ownership of various processes within the steel value chain.

Figure 3. Fixed system boundary



[9] The boundary was derived from the recommendations outlined by the Net Zero Steel Pathway Methodology Project (NZSPMP).

The IEA utilizes a similar system boundary for its Energy Technology Perspectives (ETP) report on the iron and steel sector[xii]. As the NZE's modelling assumptions are partially based on the ETP[10], the WG assumed a similar system boundary for the NZE scenario. Yet, while the system boundary for steel might be similar, the NZE attributes the steel sector's indirect (scope 2) emissions associated with electricity consumption to the power sector. As a result, the NZE trajectory needed to be modified to include a scope of emissions consistent with the fixed system boundary adopted by the Sustainable STEEL Principles.

To do so, scope 2 emissions for the NZE trajectory were estimated based on available information from the NZE (Table 9). The NZE discloses global scrap fraction and primary steel production by technology type. The amount of purchased and self-generated electricity required for each technology type were determined using the assumptions included in the MPP ST-STSM model.

Table 9. NZE steel production by technology type

Technology Type[11]	Share of Production (%)				Purchased Electricity (GJ/t)	Self-Generated Electricity (GJ/t)	Scrap Input (%)
	2020	2030	2040	2050			
Conventional primary steel production (BF-BOF and DRI-EAF)	80%	67%	32%	3%	0.4	0.8[12]	15%
Scrap-based EAF	20%	27%	34%	41%	2.2	0.0	100%
H2-DRI-EAF	0%	1%	10%	17%	6.1	0.0	0%
Electrolysis-based primary	0%	0%	4%	8%	12.1	0.0	0%
CCUS-based primary	0%	4%	19%	31%	7.0	0.0	15%

Source: International Energy Agency, *Net Zero by 2050*, IEA, 2021, as modified by RMI.

Purchased and self-generated electricity vary in their emissions intensity, so a different emissions factor was assigned to each source. The emissions factors for purchased electricity from now through 2050 were based on the global electricity grid emissions factors by decade published in the NZE[xiii] (Table 10).

Table 10. NZE emissions factors for purchased electricity

Year	Electricity Grid Emissions Intensity (kg CO_2/MWh)[13]
2020	438
2030	138
2040	-1
2050	-5

Source: International Energy Agency, *Net Zero by 2050*, IEA, 2021.

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[10] According to the International Energy Agency's Net-Zero by 2050 Scenario report (*International Energy Agency (2021), Net Zero by 2050, IEA, Paris*), "the projections in the NZE were generated by a hybrid model that combines components of the IEA's World Energy Model (WEM), which is used to produce the projections in the annual World Energy Outlook, and the Energy Technology Perspectives (ETP) model." See reports for further details.

[11] Since no information on scrap based EAF production is included in the IEA NZE, it is estimated by subtracting the scrap utilization of the other four technology routes from the fraction of total production derived from scrap provided by the IEA NZE. The scrap utilization of each technology route (not provided by the IEA NZE) is taken from the MPP TM model. The production shares of H_2 DRI-EAF, Electrolysis, and CCUS included in the IEA NZE are applied to the share of total production that remains after accounting for scrap based EAF production. The remaining share of total production is assigned to BF-BOF/DRI-EAF. Values for 2040 are based on a linear interpolation between 2030 and 2050. Based on data from International Energy Agency (2021) Net Zero by 2050: Net Zero by 2050 Scenario - Data product - IEA; as modified by RMI.

[12] It is assumed that this value is achieved in 2030, a 25% reduction (based on the data from MPP model for transitioning from an average to best-available technology blast furnace) in off-gases from 2020 values

[13] Negative emissions in 2040 and 2050 occur from the application of bioenergy with carbon capture and storage. Emissions intensity is from Table A5 in the IEA NZE.

Self-generation of electricity only applies to BF-BOF-based production technologies. The emissions factor for self-generation of electricity was calculated at 1908 kg CO_2/MWh, based on a 70/30 composition of blast furnace gas[14] and coke ovens gas being fed to onsite power generation with an assumed conversion efficiency of 37%[15]. The emissions factor was assumed to be constant since the only way to change it is to change the steel production process itself, which the NZE accounts for over time by shifting production technologies. This approach is consistent with the MPP ST-STSM model.

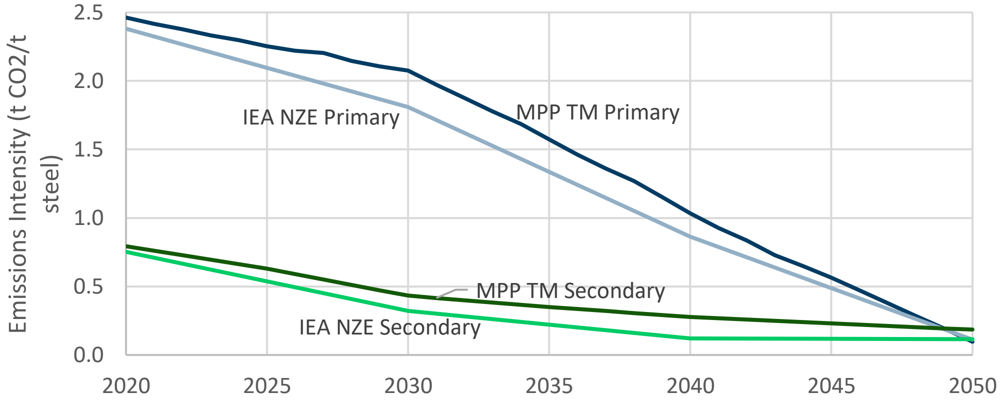
Once scope 2 emissions for steelmaking were estimated, these were added to the NZE's disclosed scope 1 emissions to generate the total emissions for the NZE trajectory in 2020, 2030, 2040, and 2050, allowing for a more accurate comparison between the NZE and TM scenarios.

14. How does the Alignment Zone differentiate between emissions from primary and secondary steel production?

In measuring climate alignment of borrowers and lending portfolios, the Sustainable STEEL Principles differentiate between emissions from the production of primary steel and the emissions from the production of secondary steel[xiv]. Therefore, defining the Alignment Zone while differentiating between primary and secondary steelmaking requires creating two decarbonization trajectories for the emissions intensity of primary steel production and secondary steel production from the NZE and TM trajectories (Figure 4). This is done by splitting the total carbon budget for the sector for each trajectory in the following way:

1. Determine the fraction of steel production by primary and secondary inputs (scrap charge) used in the NZE and in the TM (Appendix V).
2. Set the starting point of the decarbonization trajectories for secondary steel production for both models starting at an estimate for the 80th percentile of 100% scrap-based EAF emissions[16]. (See questions 15 and 16 for further methodological details).
3. Allocate remaining emissions from each model to primary steel production.

Figure 4. Resulting decarbonization trajectories for primary and secondary steel production



[14] The emissions factors for coke oven gas and blast furnace gas are 44 and 260 kg CO_2/GJ respectively, based on data from the EPA. (www.epa.gov/sites/production/files/2020-04/ghg-emission-factors-hub.xlsx).
[15] Based on assumptions by the World Steel Association.
[16] I.e., 80% of 100% scrap-based EAF steelmakers would meet the threshold.

15. How was the sector's carbon budget split to derive primary and secondary decarbonization trajectories?

To adhere to the Sustainable STEEL Principles methodology for differentiating between emissions from primary and secondary steel production, a threshold must be selected to apportion emissions to each. The threshold for splitting the carbon budget was selected to ensure the correct incentive structure, such that:

- Primary producers (mainly BF-BOF operators) have an incentive to increase their scrap use in the short-term, and
- Primary producers are incentivized to make capital investments in low-carbon steelmaking technologies in the medium-term

A typical BF-BOF operation can use 10-30% scrap as an input. The utilization of additional scrap can reduce a BF-BOF's emissions in the short-run. However, since there is a technological constraint on the total amount of scrap that can be used in BF-BOFs, and because the amount of scrap will fall short of meeting total projected steel demand in 2050[17], steel companies will need to invest in low-carbon technologies (including more scrap-based production) to reduce emissions in the medium- and long-run and ultimately achieve net-zero emissions by 2050.

To test the incentive structure, the emissions intensity of a BF-BOF operator with a range of scrap inputs (10-30%) was compared to the decarbonization targets steelmakers would have to meet based on the same scrap input range for two thresholds[18]:

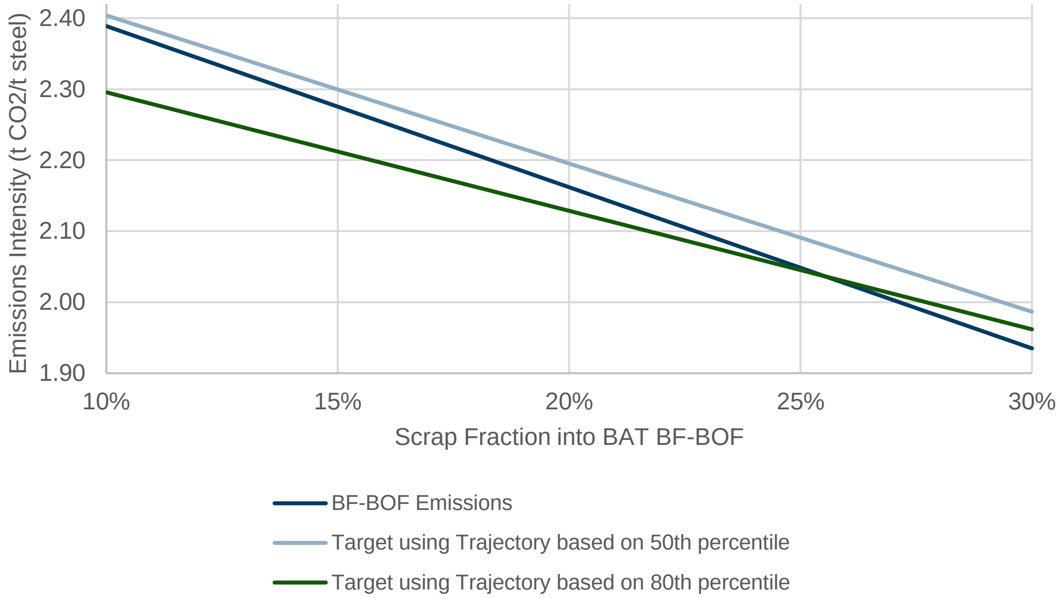
1. **Trajectory based on the 50th Percentile of 100% scrap-based EAF Emissions Intensity:** the primary and secondary decarbonization trajectories are derived by splitting the carbon budget at the average emissions intensity for 100% scrap-based EAF producers in 2020. This *results in a stricter decarbonization threshold for secondary steel production* because only 50% of EAF producers would align with the trajectory and a smaller share of the sector's total carbon budget is allotted to secondary steelmaking. Conversely, this *also results in a more lenient trajectory for primary steelmakers*, because a larger share of the sector's total carbon budget is allotted to primary steelmaking.

2. **Trajectory based on the 80th Percentile of 100% scrap-based EAF Emissions Intensity:** the primary and secondary decarbonization trajectories are derived by splitting the carbon budget using the 80th percentile of emissions intensity of 100% scrap-based EAF producers in 2020. This *results in a more lenient decarbonization trajectory for secondary steel production*, because 80% of EAF producers would align with the trajectory, meaning a larger share of the sector's total carbon budget is allotted to secondary steelmaking. This *results in a stricter trajectory for primary steelmakers*, because a smaller share of the sector's total carbon budget is allotted to primary steelmaking.

[17] A further analysis of the limitation of scrap availability is outlined in the "The Sustainable STEEL Principles: A Split Trajectory Approach" brief.

[18] The threshold was also tested at the 60th, 70th, and 90th percentile; at 70th and higher, the threshold did not result in material differences when compared to the 80th percentile shown in this analysis.

Figure 5. Incentives for emissions reductions across a range of scrap fractions for different thresholds



Source: Analysis using energy consumption and emissions factors for BAT BF-BOF from the MPP ST-STSM model

As depicted in Figure 5, if the sector's carbon budget was divided at the 50th percentile of EAF emissions intensity, a BF-BOF's emissions would be *below* their decarbonization target (i.e., they would be aligned) regardless of the level of scrap use. This implies that there would be little incentive for the BF-BOF operator to increase their scrap use to reduce their emissions in the near-term, since the decarbonization target would already be met.

Conversely, if the sector's carbon budget was divided at the 80th percentile of EAF emissions intensity, an BF-BOF steelmaker's emissions would be *above* their decarbonization target (i.e., misaligned) until ~25% scrap fraction, thereby incentivizing the steelmaker to utilize more scrap. The steelmaker would also be above their target over most of the scrap range, meaning an incentive is maintained for capital investments to reduce emissions.

16. How was the 80th percentile of emissions intensity for 100% scrap-based EAF producers determined?

The 80th percentile of 100% scrap-based EAF producer's emissions intensity is determined by:

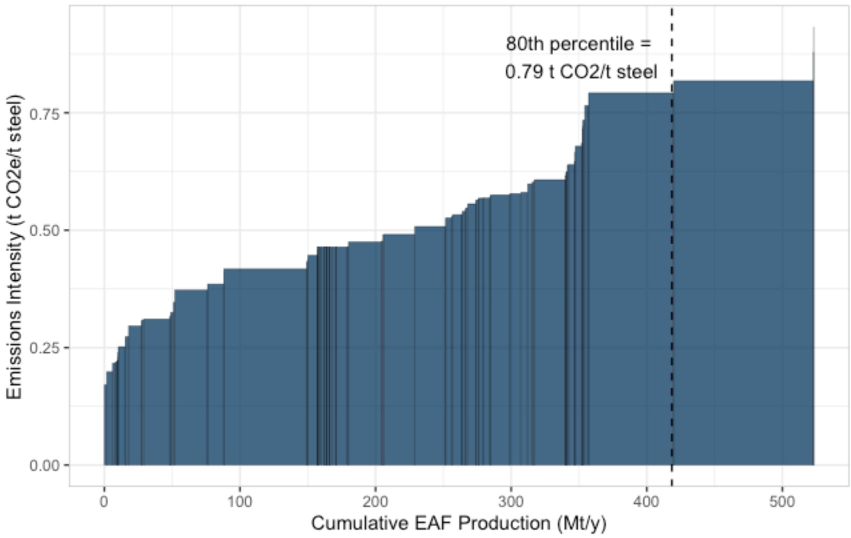
1. Identifying country-level steel production from EAFs using publicly-available worldsteel data.
2. Estimating the emissions for a 100% scrap-based EAF in each country using grid emissions factors[19] and electricity consumption data from the MPP model.

The same procedure was applied using the direct emissions assumptions from each of the MPP and IEA models for a 100% scrap EAF producer. The resulting estimated emissions intensity distribution using the MPP assumption is shown in Figure 6, from which the 80th percentile is selected to set the threshold for splitting the carbon budget. This threshold is used as the starting point for the MPP secondary trajectory.

[19] Grid emissions by country are sourced from IGES (https://www.iges.or.jp/en/pub/list-grid-emission-factor/), EU (https://www.eea.europa.eu/data-and-maps/daviz/co2-emission-intensity-8/download.csv), EPA (https://www.epa.gov/egrid), IEA (https://www.iea.org/reports/global-energy-co2-status-report-2019/emissions) or from data published directly by national governments or the UNFCCC.

A similar distribution was developed for the IEA trajectory, because the assumed direct emissions in the IEA model are lower (0.04 tCO_2/t steel compared with 0.08 tCO_2/t steel in MPP), the resulting initial threshold is slightly lower (0.75 t CO_2/t steel). The reduction rates for the NZE and TM secondary trajectories are based on the grid decarbonization rates from each model.

Figure 6. Emissions intensity distribution for 100% scrap-based EAFs



Source: Analysis using worldsteel country-level EAF production data from the Worldsteel Factbook 2019 and country-level electricity emissions factors from IGES, EU, EPA and UNFCCC.

Dividing the budget at this threshold results in most 100% scrap-based EAF producers being aligned initially, except for those operating on grids with the highest emissions (i.e., typically those relying on 65-70% of power from coal-fired sources).

17. Why does emissions intensity in 2020 differ between the primary trajectories of the IEA NZE and MPP TM?

Since the energy consumption assumptions of the IEA NZE are unknown, the assumptions from the MPP TM for energy consumption for each technology type were applied to the NZE scenario. This resulted in a consistent emissions intensity for the steel sector of 1.86 tons of CO_2 per ton of steel in 2020.

However, the two models include different assumptions on the amount of scrap used today—the IEA NZE assumes 32% and the MPP TM assumes 36% (Appendix V). Therefore, when the Alignment Zone is generated, a gap remains between the trajectories, since the creation of the Alignment Zone is determined by the relative amount of primary and secondary steel emissions.

SUSTAINABLE STEEL PRINCIPLES

APPENDIX

Appendix I. Stakeholder Feedback to the Alignment Zone (AZ), November 2021

The aim of the Sustainable STEEL Principles was to build consensus among financial institutions, steel producers, and technical experts on a vision for decarbonizing the sector by 2050. To achieve this, stakeholders in the Expert Committee, Industry Group, and Review Group were regularly consulted for their feedback on the WG's proposals for the various components of the Sustainable STEEL Principles. The following outlines a summary of feedback collected, the source of feedback, a response to that feedback, and accompanying documentation for further reference.

Category	Feedback	Source	Response	Response Document
Alignment Zone	The Alignment Zone (AZ) must be 1.5°C-aligned.	Expert Committee, Review Group	The AZ is aligned with no-to-low overshoot of 1.5°C. The IEA NZE is consistent with limiting the global temperature rise to 1.5°C without overshoot (with a 50% probability). The chance of exceeding 1.5°C under the MPP TM scenario is 60%, which falls within the IPCC definition of "low-overshoot" of 1.5°C.	"The Sustainable STEEL Principles: An Alignment Zone Approach"
Alignment Zone	The AZ approach must be ambitious enough to be accepted by the NGO community and align with NZBA.	Review Group	The IEA NZE benchmark was established as the unequivocal target of the AZ.	"The Sustainable STEEL Principles: An Alignment Zone Approach"
Alignment Zone	The term "industry leader" should be replaced.	Industry	The terms in the AZ were adjusted to reflect implied temperature rise. "Industry leader" was replaced with "1.5-Aligned".	"The Sustainable STEEL Principles: An Alignment Zone Approach"
Trajectories	The MPP TM trajectory is not ambitious enough and cannot be referred to as "climate-aligned" because its cumulative emissions exceed the IEA NZE.	Review Group	• The MPP TM is no longer a target. • RMI analysis of the implied temperature rise of the TM found it is compatible with 1.5°C low overshoot. However, the zone under the MPP TM is referred to as "well-below 2°C." • Adjusted categorization of the zone between the TM and NZE from "climate-aligned" to "well-below 2°C" to more accurately reflect the potential temperature rise of the trajectory.	"The Sustainable STEEL Principles: An Alignment Zone Approach"
Trajectories	• The IEA NZE is not realistic enough to be useful. • The IEA NZE trajectory should be replaced by an MPP trajectory for the sake of consistency.	Industry	• The IEA NZE is globally recognized as the standard for 1.5°C alignment. The WG acknowledges the importance of this trajectory for adhering to other frameworks, such as the Net-Zero Banking Alliance (NZBA) guidelines. • The WG believes that one of the advantages of the AZ is the combination a top-down global economy model (the IEA NZE), which can guide target-setting, with a bottom-up sectoral pathway (the MPP TM), which can guide engagements.	"The Sustainable STEEL Principles: An Alignment Zone Approach"
Trajectories	Additional clarity is needed on the global carbon budget and	Industry, Expert Committee	RMI analysis has shown the MPP TM trajectory to be in line with a 1.5°C low-overshoot scenario.	"The Sustainable STEEL Principles: An Alignment Zone Approach"

	temperature alignment of the MPP TM.			
Trajectories	The upper and lower bounds of the zone should reflect the same emissions intensity in 2020.	Industry, Expert Committee, Review Group	Emission factors and energy use assumptions were adjusted to increase consistency between the models. While emissions intensity values are consistent across scenarios, a gap remains in the AZ due to different assumptions on scrap utilization.	"The Sustainable STEEL Principles: An Alignment Zone Approach"
Methodology	Forward-looking metrics should be included in addition to emissions intensity.	Expert Committee, Review Group	The Sustainable STEEL Principles has adopted forward-looking indicators as part of the reporting framework	Sustainable STEEL Principles agreement text
Methodology	Steelmakers should be asked to report emissions by process.	Expert Committee	Due to the lack of an existing emissions accounting methodology to track emissions at the technology level, the methodology determines emissions by metallic input. The necessary framework to support this level of emissions accounting at the process level is currently under development by RMI and could be adopted by the Sustainable STEEL Principles in the future.	"The Sustainable STEEL Principles: Differentiating Between Primary and Secondary Steel Production"
Methodology	Splitting the carbon budget reduces the incentive to switch to scrap production. A single carbon budget should be used.	Expert Committee	The total sector carbon budget was split at a threshold determined to incentivize scrap optimization in the near term while also driving decarbonization of primary steel production in the long term. Each scenario used in the AZ incorporates significant growth in scrap utilization rates.	"The Sustainable STEEL Principles: Differentiating Between Primary and Secondary Steel Production"
Methodology	The methodology should utilize regional roadmaps instead of a global trajectory.	Industry, Review Group	While the WG noted the value of regional roadmaps, neither the IEA nor the MPP model include regional specificity at the time of development. As opposed to a single trajectory, the WG believes that the AZ is better positioned to accommodate regional variation.	NA
Methodology	Reporting should be aligned with existing standards published by the ISO and WSA.	Industry, Expert Committee	Technical guidance for reporting is based on ISO standard 14404. ISO 14404 is also aligned with worldsteel's current standardized emissions data collection too	NA
Fixed System Boundary	Internal scrap utilization should not be a part of the reporting.	Industry	Steelmakers are be asked to report on external scrap use only.	NA
Fixed System Boundary	Mining should be included within the reporting boundary.	Expert Committee	Mining was excluded for the following reasons: • The scenarios, utilized under this methodology do not include mining emissions within the steel sector boundary. • The CO_2 emissions that result from iron ore and coal mining represent a relatively small portion of total steel sector emissions. • The desire to align with various standards to the greatest degree possible.	Sustainable STEEL Principles Agreement

Appendix II. Comparison of IEA NZE and MPP TM trajectories against key criteria

Considerations		IEA NZE	MPP TM
1.5-no-to-low-overshoot		Yes	Yes
Granularity	*Data coverage*	Data for 2020, 2030, 2040, 2050	Annual data available for 2019-2050
	Scenario analysis	1 supply and demand scenario	3 supply scenarios and 2 demand scenarios
	Regionality	40 regions in the global model, results reported only on a global level	Demand modeled for 11 world regions; supply is modeled globally
	Technologies modeled	Fewer reported, total unknown	20 different technology archetypes
	Scopes covered	Scope 1	Scopes 1 and 2, in line with the fixed system boundary approach, adopted by the WG.
Openness	*Disclosure of assumptions and results*	Few assumptions and select indicators available	Fully open access
	Medium for disclosure	Report and select data	Report and full data in online interface
Industry Validation	*Steel producers and value-chain*	Peer-review by industry	Peer-review by industry
Adaptability		No	Yes
Legitimacy		Yes	Yes
Standardization		SBTi, TPI (both are updating IEA models to NZE)	

SUSTAINABLE STEEL PRINCIPLES

Appendix III. Technology archetypes employed by the MPP TM

Technology Group	Description and Archetypes evaluated per technology group
Blast Furnace – Basic Oxygen Furnace (BF-BOF)	The most emissions-intensive steelmaking technology today typically relies on coal both as a reductant and as an energy source, and on iron ore as the primary material input. Avg BF-BOF: Average BAT BF-BOF: Best Available Technology BAT BF-BOF+BECCS: + Bioenergy with carbon capture and storage BAT BF-BOF+CCS: + Carbon Capture and Storage BAT BF-BOF+CCUS: + Carbon Capture, Utilization and Storage BAT BF-BOF_bio PCl: Charcoal from biomass as Pulverized Carbon Injection BAT BF-BOF_H2 PCl: Hydrogen Injection
Electric Arc Furnace (EAF)	EAF: uses electricity to melt mostly steel scrap
Direct Reduced Iron – Electric Arc Furnace (DRI-EAF)	Today, mostly uses natural gas to produce DRI. Lower-carbon archetypes use CCS, or biomethane or hydrogen as opposed to natural gas, to produce DRI. The DRI is then melted and made into steel via EAF. DRI-EAF DRI-EAF+CCS: + Carbon Capture and Storage DRI-EAF_100% green H2: + 100% hydrogen produced via electrolysis using 100% renewable electricity (commonly known as H-DRI) DRI-EAF_50% green H2: + 50% hydrogen produced via electrolysis using renewable electricity (remainder natural gas or fossil methane) DRI-EAF_50% bio-CH4: + 50% biomethane (remainder natural gas or fossil methane)
DRI-Melt-BOF	DRI, produced with natural gas and/or hydrogen, is melted and then made into steel via BOF. DRI-Melt-BOF DRI-Melt-BOF_100% zero-C H2: + 100% hydrogen produced via electrolysis using renewable electricity DRI-Melt-BOF+CCS: + Carbon Capture and Storage
Electrolyzer	Electrolyzer-EAF: commonly known as molten oxide electrolysis (MOE), separates elemental iron and oxygen from molten iron ore at high temperatures.[xv]
Electrowinning	Electrowinning-EAF: at relatively low temperatures, separates solid state elemental iron by suspending iron ore particles in an alkaline electrolyte solution, and applying current which removes negatively charged oxygen molecules.[xvi]
Smelting Reduction	This process directly reduces iron ore into pig iron with slag and thermal coal, as opposed to metallurgical coal. The resulting iron is made into steel via BOF. Hisarna and Corex are common smelting reduction processes. Smelting Reduction Smelting Reduction+CCS: + Carbon Capture and Storage

Appendix IV. Comparison of IEA NZE and MPP TM in 2030 and 2050

2030 Comparison

Production and Scrap Mix	**IEA NZE**	**MPP TM**
Total steel production (Mt/y)	1,937	2,175
Iron ore consumption (Mt ore/y)	-	1,995
Scrap steel consumption (Mt scrap/y)	-	1,057
External scrap (% of metallics by weight)	38%	40%
Technology Mix for Primary Steelmaking		
Hydrogen-based DRI-EAF	2%	8%
BF-BOF and DRI-EAF	92%	91%
CCUS-equipped primary	6%	1%
Electrolysis	0%	0%
Emissions (direct + electricity emissions)		
Sector emissions (Mt CO_2/y)	2,409	3,090
Steel emissions intensity (tCO_2/tCS)	1.25	1.42
Captured CO_2 (Mt/y)	70	6.2
Energy Consumption		
Electricity including H_2 generation (TWh/y)	-	1,464
Hydrogen (PJ/y)	2,280	2,113
Natural gas consumption (including H_2 gen) (PJ/y)	-	2,948
Bioenergy consumption (PJ/y)	-	103
Met coal consumption (PJ/y)	-	9,943
Cumulative investment (USD bn)	-	345

2050 Comparison

Production and Scrap Mix	NZE	TM
Total steel production (Mt/y)	1,987	2,547
Iron ore consumption (Mt ore/y)	-	1,947
Scrap steel consumption (Mt scrap/y)	-	1,493
External scrap (% of metallics by weight)	46%	48%
Technology Mix for Primary Steelmaking		
Hydrogen-based DRI-EAF	29%	39%
BF-BOF and DRI-EAF	5%	0%
CCUS-equipped	53%	43%
Electrolysis	13%	18%
Emissions (direct + electricity emissions)		
Sector emissions (Mt CO_2/y)	226	355
Steel emissions intensity (tCO2/tCS)	0.11	0.14
Captured CO_2 (Mt/y)	670	621
Energy Consumption		
Electricity including H_2 generation (TWh/y)	-	4,853
Hydrogen (PJ/y)	6,480	4,493
Natural gas consumption (including H_2 gen) (PJ/y)	-	3,369
Bioenergy consumption (PJ/y)	-	0
Met coal consumption (PJ/y)	-	2,256
Cumulative investment (USD bn)	-	1,187

Appendix V. Scrap fraction comparison of the IEA NZE and MPP TM scenarios

Year	NZE	TM
2020	32%	36%
2030	38%	40%
2040	42%	43%
2050	46%	48%

Endnotes

[i] Net-Zero Steel Initiative, *Net-Zero Steel Sector Transition Strategy*, October 2021.
[ii] Ibid.
[iii] International Energy Agency, *Net Zero by 2050*, IEA, 2021.
[iv] RMI, *The Sustainable STEEL Principles: Fixed System Boundary Approach*, 2021.
[v] Forster, P., D. Huppmann, E. Kriegler, L. Mundaca, C. Smith, J. Rogelj, and R. Séférian, 2018: Mitigation Pathways Compatible with 1.5°C in the Context of Sustainable Development Supplementary Material. In: Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty [Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield (eds.)]. Available from https://www.ipcc.ch/sr15
[vi] IPCC, 2018: Global warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty [V. Masson-Delmotte, P. Zhai, H. O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J. B. R. Matthews, Y. Chen, X. Zhou, M. I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, T. Waterfield (eds.)]. In Press.
[vii] Forster, P., D. Huppmann, E. Kriegler, L. Mundaca, C. Smith, J. Rogelj, and R. Séférian, 2018: Mitigation Pathways Compatible with 1.5°C in the Context of Sustainable Development Supplementary Material. In: Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty [Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield (eds.)]. Available from https://www.ipcc.ch/sr15
[viii] Ibid.
[ix] Rogelj, J., D. Shindell, K. Jiang, S. Fifita, P. Forster, V. Ginzburg, C. Handa, H. Kheshgi, S. Kobayashi, E. Kriegler, L. Mundaca, R. Séférian, and M.V.Vilariño, 2018: Mitigation Pathways Compatible with 1.5°C in the Context of Sustainable Development. In: Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty [Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield (eds.)]. In Press.
[x] Ibid.
[xi] RMI, *The Sustainable STEEL Principles: Fixed System Boundary Approach*, 2021.
[xii] IEA (2021), Iron and Steel, IEA, Paris https://www.iea.org/reports/iron-and-steel
[xiii] International Energy Agency, *Net Zero by 2050*, IEA, 2021.
[xiv] RMI, *The Sustainable STEEL Principles: A Split Trajectory Approach*, 2021.
[xv] Boston Metal. "MOE Technology." 2021. https://www.bostonmetal.com/moe-technology/
[xvi] West, K. "Low-temperature electrowinning for steelmaking (ULCOWIN)." energy.nl. 2020. https://energy.nl/en/fact_sheet/low-temperature-electrowinning-for-steelmaking-ulcowin/