Coalition On Materials Emissions Transparency

A Market Mechanism for the Creation of a Climate-differentiated Market in the Steel Industry

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About

The Coalition on Materials Emissions Transparency (COMET) accelerates supply chain decarbonization by enabling producers, consumer-facing companies, investors, and policymakers to better account for greenhouse gas (GHG) emissions throughout materials supply chains, in accordance with existing GHG accounting and disclosure methods and platforms.

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Acronyms and Abbreviations

AIB	Association of Issuing Bodies
BF-BOF	Blast Furnace-Basic Oxygen Furnace
CAPEX	Capital Expenditures
CCfD	Carbon Contracts for Difference
CCS	Carbon Capture and Storage
CfD	Contract for Differences
CSRD	Corporate Sustainability Reporting Directive
DRI	Direct Reduced Iron
DRI-EAF	Direct Reduced Iron-Electric Arc Furnace
EAC	Energy Attribute Certificate
EAF	Electric Arc Furnace
EECS	European Energy Certificate System
EPA	Environmental Protection Agency
EMTS	EPA Moderated Transaction System
EPD	Environmental Product Declarations
ERC	Emissions Reduction Certificate
ERCOT	Electric Reliability Council of Texas
ESG	Environment, Social, and Governance
FMC	First Movers Coalition
GHG	Greenhouse Gas
GO	Guarantee of Origin
GSC	Green Steel Certificate
GSF	German Steel Federation
I-REC	International Renewable Energy Certificates
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
IDDI	International Deep Decarbonization Initiative
IEA	International Energy Agency
IRENA	International Renewable Energy Agency
ISO	International Organization for Standardization
LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
MOU	Memorandum of Understanding
MWh	Megawatt Hour
OPEX	Operating Expenditures
PCR	Product Category Rules
PPA	Power Purchase Agreement
R&D	Research and Development
REC	Renewable Energy Certificates
RGGO	Renewable Gas Guarantee of Origin
RIN	Renewable Identification Number
RPS	Renewable Portfolio Standards
SABA	Sustainability Aviation Buyers Alliance
SAF	Sustainable Aviation Fuel
SAFc	Sustainable Aviation Fuel Certificate
EEC	Energy Efficiency Certificate
SBT	Science-based Targets
UNIDO	United Nations Industrial Development Organization
VOA	Voluntary Offtake Agreement
VOAS	Virtual Offtake Agreement for Steel
VPPA	Virtual Power Purchase Agreement
WTO	World Trade Organization

Executive Summary

The heavy industry sector accounts for around 25% of the global energy system CO_2 emissions annually. Despite this substantial environmental footprint, demand for materials from these industries is projected to steadily grow through 2050, particularly in developing countries seeking to expand their infrastructure to support development and transition towards net-zero emissions. The sector's ongoing reliance on traditional, high-emission technologies, particularly in steelmaking, underscores the critical need to shift towards innovative, low-emission alternatives. This transition faces obstacles such as the lack of commercially viable low-emission options and the high costs of new technologies. Overcoming these challenges requires a mix of policy support and market-based incentives to foster the adoption of near-zero emissions technologies in heavy industries.

Current policies and regulations around the world are insufficient to drive emissions reductions adequately in this sector, highlighting a significant gap in global climate strategies. Market mechanisms can help fill this policy gap by fostering the creation of a climate-differentiated market that spurs demand for products manufactured through the development of green technologies in heavy industry. Market mechanisms involve the monetization of environmental attributes separate from their underlying physical product, thereby enabling consumers to claim emissions reductions. Market mechanisms have been implemented in the electricity and gas industries to enhance the adoption and scalability of green alternatives by stimulating demand through the creation of a climate-differentiated market. However, these traditional market mechanisms often exhibit significant shortcomings. They often lack additionality, meaning it is unclear whether they lead to effective new emissions reductions. Transparency and traceability issues further undermine their efficiency and credibility. Without standardized reporting systems and with risks of double counting, concerns arise about their contributions to decarbonizing the real economy. Moreover, price volatility and oversupply hinder the establishment of a mature, liquid market for these mechanisms. Low prices resulting from oversupply often lead to greenwashing, where companies claim sustainability without demonstrating real environmental benefits.

A market mechanism tailored to the heavy industry sector must not only tackle the challenges of current market mechanisms but also be finely attuned to the unique sector requirements. For instance, the steel sector is characterized by the high capital intensity necessary for deploying and scaling innovative green technologies. This imposes a significant green premium on initiatives aiming to introduce less carbon-intensive practices within this sector, often hampering their viability and deployment. In this context, there is a need for a market mechanism that ensures GHG emissions reductions are genuinely additional. This means ensuring that reductions are incremental beyond what would occur without the mechanism, rather than allowing that the monetization of environmental attributes merely offsets current practices of downstream buyers.

In this paper, we propose the implementation of a twofold market mechanism designed to facilitate the transition from traditional BF-BOF steelmaking methods to more sustainable technologies like the EAF-DRI route. This shift is critical as BF-BOF technologies, (in particular without carbon capture and storage (CCS)), due for phase-out within 20 years, lock in high carbon emissions. On the other hand, EAF-DRI, especially when powered by green hydrogen, offers a near-zero emissions technology-proven and near commercially viable alternative despite its higher costs. Our market mechanism aims to absorb these additional costs, making green steel more competitive and viable. It will be particularly useful for steel producers developing new EAF-DRI capacities that meet stringent GHG emission thresholds set by international standards and for whom the physical offtakes do not cover all the necessary demand to grow.

The first component of this market mechanism is a Green Steel Certificate (GSC) designed both (i) to verify the emissions intensity of the steel produced so it complies with GHG emissions thresholds to be considered "green", and (ii) to monetize the benefits of producing "green" steel. This certificate should be transferred through a robust book and claim system, where third-party verification of GHG accounting precedes the issuance of the GSC, ensuring compliance with established green standards and allowing the environmental attributes of steel to be marketed separately from the physical product, allowing buyers to claim Scope 3 emissions reductions by purchasing these certificates. GHG emissions calculations for the GSC steel should follow fixed boundaries, ensuring cradle-to-gate emission measurements. Additionally, the certificate transfer must be linked to a coherent corporate decarbonization strategy, ensuring that revenue from certificate sales funds emission reduction projects that are ambitious and feasible rather than supporting practices that will lock-in emissions, thereby maintaining the integrity of decarbonization efforts.

The second component of this initiative is the Virtual Offtake Agreement for Steel (VOAS), which enhances the effectiveness of the GSC by tying it to a long-term commitment from buyers. This commitment ensures consistent cash flow for steel producers and supports the additionality necessary for effective decarbonization in steel production. The VOAS is a long-term financial contract that delivers the GSC in exchange for the green premium payment when the green steel is produced. This allows buyers to support the transition to sustainable practices by securing the environmental attributes of green steel production while giving producers the future revenue certainty to acquire project finance to implement new decarbonization technologies. The VOAS's structure includes a Contract for Difference (CfD) financial settlement mechanism, which adjusts cash flows between steel producers and corporate buyers to reflect price variations. This mechanism compensates for the cost differences between conventional steel's market price and the higher strike price set to cover the extra costs of decarbonization technologies. If the market price surpasses the strike price, buyers are reimbursed for the excess; if it falls below, they compensate the producers to ensure projected earnings are maintained.

The enhancement of the GSC through integration with a VOAS requires a robust, independent registry to ensure transparency, integrity, and credibility. This registry, managed by an independent third party, is critical for overseeing both the GHG emissions intensity verification and the book and claim processes. Existing practices in the steel industry, namely unverified transactions of certificates, highlight the need for this registry to address issues such as double counting and enhanced credibility.

The proposed market mechanism faces its own challenges. Regulatory uncertainty due to non-standardized definitions of "low-carbon" and "green" steel complicates transparency and consistent implementation across global regulatory frameworks. Additionally, the accumulation of multiple certificates in non-integrated steel production processes adds administrative burdens. Skepticism towards environmental certificates, due to their history and confusion with carbon offsets, undermines their credibility and acceptance. Financial uncertainties about market growth and the emergence of new demand for physical steel production, coupled with the high costs of advanced technologies like EAF-DRI—which still require government subsidies—pose significant barriers to securing the necessary financing. Addressing these challenges requires regulatory frameworks that not only mandate but also support technologies like EAF, ensuring a sustainable transition to green steel production, so mechanisms such as the one proposed here remain a much needed but temporary solution.

Introduction

The heavy industry sector plays a pivotal role in global economic development, yet its environmental impact, particularly in terms of greenhouse gas (GHG) emissions, remains a critical concern. According to the International Energy Agency (IEA), as of 2022, the industrial sector accounted for approximately 30% of total global CO_2 emissions.[1] Heavy industry in particular, which includes steel, cement, and chemical production, is a major contributor responsible for emitting 6 Gt of CO_2 (70% of all industrial emissions).These emissions accounted for 25% of global energy system CO_2 emissions, including process emissions but not including indirect emissions from electricity used for industrial processes[2].

1 Richard Simon, Paul Hugues, Peter Levi, and Tiffany Vass, *Industry* (Paris: International Energy Agency, July 2023), https://www.iea.org/energy-system/industry.

2 *Achieving Net Zero Heavy Industry Sectors in G7 Members* (Paris: International Energy Agency, May 2022), https://www.iea.org/reports/achieving-net-zero-heavy-industry-sectors-in-g7-members.

Moreover, the demand for materials in heavy industry is poised for a steady increase in the next two decades. By 2050, it is expected that globally, the demand for these materials will continue to be strong under existing policies. While advanced economies may see some reduction in demand, this decrease will likely be balanced by significant growth in developing and emerging economies, which will need to build infrastructure and services to support their development. More specifically, these products play a crucial role in the global shift towards achieving net-zero emissions. They are essential for producing clean energy technologies and infrastructure, including wind farms, transmission lines, and electric vehicles.[3] Such projections accentuate the urgency of addressing emissions from heavy industry, as the anticipated surge in material demand implies a corresponding rise in energy-intensive production processes.

3 Laura Cozzi, Timur Gül, Araceli Fernández, and Thomas Spencer, *Net Zero Roadmap: A Global Pathway to Keep the 1.5 °C Goal in Reach 2023 Update* (Paris: International Energy Agency, 2023), https://www.iea.org/reports/net-zero-roadmap-a-global-pathway-to-keep-the-15-0c-goal-in-reach.

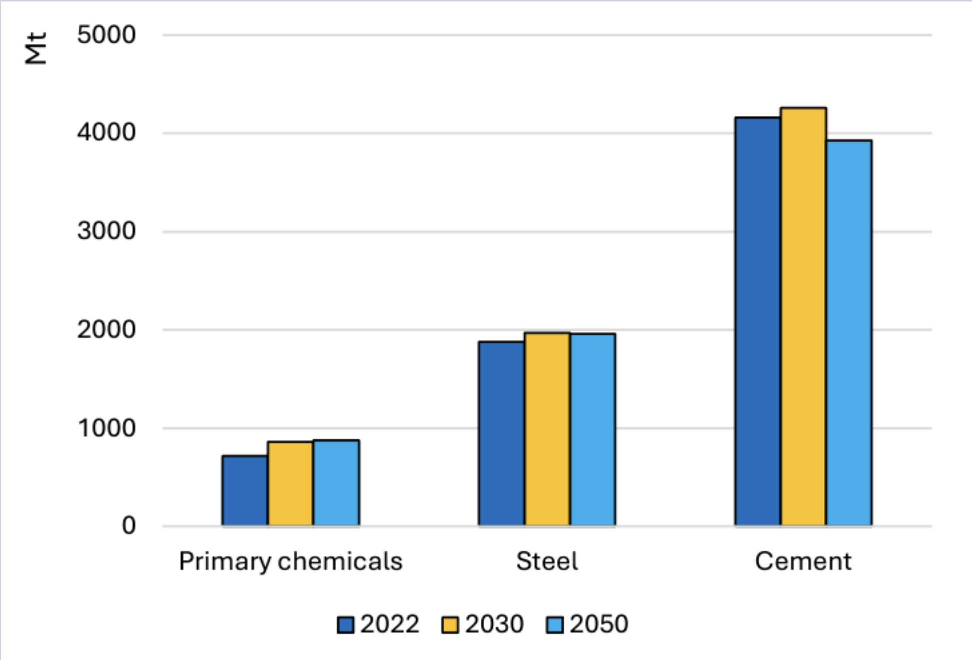


Figure 1. Demand for primary chemicals, steel and cement under the Net Zero Emissions by 2050 Scenario, 2022-2050

Source: IEA (2023). Net Zero Roadmap: A Global Pathway to Keep the 1.5 °C Goal in Reach.

Despite the imperative to mitigate GHG emissions, the current state of affairs in heavy industry reveals a persistent reliance on conventional high-emission technologies. The World Economic Forum highlights that the majority of industrial processes continue to be powered by fossil fuels, thereby leading to substantial carbon footprints.[4] For instance, in the steel sector, around 160 million tons of capacity are under construction or announced, at least half of which will use emissions-intensive processes for steelmaking such as blast furnaces with basic oxygen furnaces.[5] This reliance on traditional methods not only exacerbates environmental degradation but also underscores the pressing need for innovative, low-emission technologies to reshape the landscape of heavy industry.

While the necessity of transitioning to low-emission technologies in heavy industry is evident, the current lack of commercially available options poses a significant challenge. For instance, even though several initiatives aimed at producing low-emission steel had been announced globally, a significant portion of these endeavors remain in the initial phases of pilot or demonstration, even as conventional steelmaking capacities persist in their expansion concurrently.[6] The International Renewable Energy Agency (IRENA) notes the insufficiency of widespread adoption of near-zero emission production technologies across various heavy industry sectors.[7] Additionally, the high cost associated with implementing such technologies acts as a deterrent for industry stakeholders, hindering the swift transition to sustainable production routes.[8] In light of these challenges, it becomes evident that a strategic combination of policies and market-driven signals is essential to propel the scalability of near-zero emissions production technologies in heavy industry.

4 *Future Scenarios and Implications for the Industry* (Cologny: World Economic Forum and Boston Consulting Group, March 2018), https://www3.weforum.org/docs/Future_Scenarios_Implications_Industry_report_2018.pdf.

5 *Massanobu Nakamizu, Latest Developments in Steelmaking Capacity 2023* (Paris: OECD Publishing, 2023), https://www.oecd.org/industry/ind/latest-developments-in-steelmaking-capacity-2023.pdf.

6 Green Steel Tracker," Leadership Group for Industry Transition, 2024, https://www.industrytransition.org/green-steel-tracker/.

7 Paul Durrant, Carlos Ruiz, Padmashree Gehl Sampath, Sean Ratka, Elena Ocenic, Seungwoo Kang, and Paul Komor, *A Summary of Reaching Zero With Renewables: Eliminating CO_2 Emissions from Industry and Transport in Line with the 1.5 °C Climate Goal* (Abu Dhabi, International Renewable Energy Agency, 2020), https://www.irena.org/publications/2020/Sep/Reaching-Zero-with-Renewables.

8 Hana Mandová, Tiffany Vass, Araceli Fernandez Pales, Peter Levi, and Timur Gül, *The Challenge of Reaching Zero Emissions in Heavy Industry* (Paris: International Energy Agency, September 2020), https://www.iea.org/articles/the-challenge-of-reaching-zero-emissions-in-heavy-industry.

I. Current Landscape of Market Mechanisms

A. Defining the Importance of Market Mechanisms in Industry Decarbonization

Market mechanisms are often defined as economic strategies or tools through which market participants' interaction happens, and which encourage the efficient allocation of resources through supply and demand forces.[9] Market mechanisms offer a promising avenue for addressing the pressing environmental concerns associated with heavy industry. In the context of creating a new climate-differentiated market for green heavy industry materials, market mechanisms can play a pivotal role in driving the adoption of low-carbon technologies.

Current policy and regulatory measures aimed at reducing emissions in the heavy industry sector globally are inadequate, representing a critical gap in global climate strategies.[10] This absence of comprehensive policies addressing the environmental impact of heavy industry impedes progress toward achieving climate targets, highlighting the urgent need for coordinated action to mitigate emissions in this sector. In the absence of robust public policy, integrating market mechanisms into the heavy industry landscape can help bridge this policy gap and drive the adoption of green technologies.[11]

9 Georgios Tsaousogloua, JuanS.Giraldo, and Nikolaos G. Paterakis, "Market Mechanisms for Local Electricity Markets: A Review of Models, Solution Concepts and Algorithmic Techniques," *Renewable and Sustainable Energy Reviews* 156 (2022), https://www.sciencedirect.com/science/article/pii/S1364032121011576.

10 *Achieving Net Zero Heavy Industry Sectors in G7 Members*

11 Tom Kerr, with significant support from Aditi Maheshwari and Jagabanta Ningthoujam, *Creating Markets for Climate Business: An IFC Climate Investment Opportunities Report* (Washington D.C.: International Finance Corporation, 2017), https://www.ifc.org/content/dam/ifc/doc/mgrt/ifc-climate-investment-opportunity-creating-markets.pdf.

B. Overview of Most Common Market Mechanisms

A diverse range of market mechanisms has been established worldwide, spanning different sectors and jurisdictions, with the intention of stimulating investment in emerging green technologies across different industries. These mechanisms are intended to foster the development or expansion of a climate-differentiated market in their respective industry, thus generating the essential demand needed to scale these technologies for commercial viability. These instruments are usually designed to incentivize the production of a low-carbon or green product, not only by providing a financial boon to projects that produce that specific product but also by making it more feasible for investors and developers to commit to such endeavors. They encompass a diverse array of approaches, each customized to suit specific sectors and geographic regions, reflecting the nuanced challenges and opportunities present in different contexts.

While the forthcoming section aims to offer an overview of the most common market mechanisms, it is essential to note that it is not an exhaustive list. Instead, its focus lies in delineating the common design features shared by most of these mechanisms and identifying potential risks inherent in their design that may hinder their efficacy in achieving their intended goals. These risks include complexities in market design, uncertainties stemming from regulatory frameworks, and challenges related to ensuring additionality, traceability, and transparency within these mechanisms. Therefore, understanding these common pitfalls is crucial for designing robust market mechanisms capable of effectively spurring investment in green technologies for materials in the heavy industry sector.

Table 1: Overview of Most Common Market Mechanisms

Market Mechanism	Applicable Sector	Geographic Scope	Purpose	Additionality	Transparency/ Traceability
Energy Attribute Certificate (EAC)[12]	Energy General	Global	Broad category of certificate that certifies the generation of a specific amount of energy (ranging from electricity to fuel) from renewable sources, providing proof of the environmental attributes of the energy produced.	Not guaranteed	Depending on the jurisdiction
Renewable Energy Certificate (REC)[13]	Electricity	United States	Represents proof that one megawatt-hour (MWh) of electricity was generated from a renewable energy source, facilitating the tracking and trading of the environmental benefits associated with the power.	Not guaranteed	Not guaranteed No central independent registry
International Renewable Energy Certificates (I-REC)[14]	Electricity	Global	Represents proof that one MWh of electricity was generated from a renewable energy source across international borders, facilitating the tracking and trading of the environmental benefits associated with the power.	Not guaranteed	Has an NGO independent registry
Guarantee of Origin (GO)[15]	Electricity	European Union	Represents proof that one MWh of electricity was generated from a renewable energy source, facilitating the tracking and trading of the environmental benefits associated with the power.	Not guaranteed	Not guaranteed despite having an independent private registry
Renewable Identification Number (RIN)[16]	Renewable fuel	United States	A unique identifier assigned to biofuel production and imports to track its production, use, and trading as part of regulatory compliance and incentives for renewable fuel use.	Not guaranteed	Has a central governmental registry with the EPA. Not enough info to assess transparency

12 “Energy Attribute Certificates (EACs),” United States Environmental Protection Agency, March 6, 2024, https://www.epa.gov/green-power-markets/energy-attribute-certificates-eacs.
13 “Renewable Energy Certificates (RECs),” United States Environmental Protection Agency, January 15, 2024, https://www.epa.gov/green-power-markets/renewable-energy-certificates-recs#one.
14 “I-REC for Electricity,” The International Tracking Standard Foundation, https://www.trackingstandard.org/product-code/electricity/.
15 European Parliament and Council of the European Union, Directive 2018/2001 on the Promotion of the Use of Energy from Renewable Sources (Recast), December 11, 2018, (EU Directive on the Promotion of the Use of Energy from Renewable Sources), Art. 19, https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018L2001.
16 “Renewable Identification Numbers (RINs) Under the Renewable Fuel Standard Program,” United States Environmental Protection Agency, January 23, 2024, https://www.epa.gov/renewable-fuel-standard-program/renewable-identification-numbers-rins-under-renewable-fuel-standard.

Market Mechanism	Applicable Sector	Geographic Scope	Purpose	Additionality	Transparency/ Traceability
Renewable Gas Guarantee of Origin (RGGO)[17]	Renewable Gas	European Union	Certifies that a specific quantity of gas, such as biomethane, was produced from renewable sources, facilitating its traceability and supporting claims of renewable energy use.	Not guaranteed	Has an NGO independent registry
Sustainable Aviation Fuel Certificate (SAFc)[18]	Aviation Fuel	Global	Verifies the production and supply chain integrity of sustainable aviation fuels, allowing the buyer to claim Scope 3 or Scope 1 (depending on the buyer) emissions reductions when there is no physical offtake.	Only regulatory	Guaranteed by verification process plus an NGO independent registry
Maritime Book and Claim System[19]	Maritime Fuel	Global	Allows shipping companies to purchase credits representing a reduction in greenhouse gas emissions, enabling them to offset the emissions from their operations without directly using cleaner fuels in their vessels.	Only regulatory	NGO independent and fully electronic registry. Not enough information to assess transparency
CertifHy[20]	Hydrogen	European Union	A hydrogen certification scheme based on a Guarantee of Origin that tracks hydrogen's origin and environmental attributes.	Not guaranteed	Not guaranteed despite having an NGO independent registry
Energy Efficiency Certificate (EEC) / White Certificate[21]	Energy Efficiency	Global	Represents a quantifiable amount of energy savings achieved through efficiency measures, incentivizing and verifying reductions in energy consumption and carbon emissions.	Not guaranteed	Registries vary depending on jurisdiction. Not enough information to assess transparency

Source: Prepared by the authors

17 "About Renewable Gas Guarantees of Origin (RGGOs)," Green Gas Certification Scheme, https://www.greengas.org.uk/certificates.

18 *Sustainability Framework for Sustainable Aviation Fuel (SAF): Version 2* (New York: Sustainable Aviation Buyers Alliance, September 2023), https://flysaba.org/wp-content/uploads/2023/09/SABA-SAF-Sustainability-Framework-9-23.pdf.

19 *Maritime Book & Claim: Design Decisions and Justifications* (Copenhagen, Mærsk Mc-Kinney Møller Center for Zero Carbon Shipping, April 2023), https://cms.zerocarbonshipping.com/media/uploads/documents/Book-Claim-Design-decisions-and-justifications.pdf.

20 "Definition and Benefits," CertifHy, https://www.certifhy.eu/go-definition/.

21 Emma Schwentner, "Price Formation in European White Certificate Markets: Theoretical and Empirical Insights from Italy, France, and the UK," *SciencesPo European Chair for Sustainable Development and Climate Transition,* September 12, 2023, https://www.sciencespo.fr/psia/chair-sustainable-development/2023/09/12/price-formation-in-european-white-certificate-markets-theoretical-and-empirical-insights-from-italy-france-and-the-uk/.

C. Basic Design Principles

In this diverse landscape of market mechanisms spanning various sectors and jurisdictions, each one of them is tailored to address specific challenges and objectives within their respective industry or jurisdiction. However, it is possible to identify fundamental design principles common to all such mechanisms. In this section, we aim to highlight and analyze these core design principles, shedding light on their characteristics as well as concrete examples of how they materialize in some market mechanisms.

1. The Certificate Structure

These market mechanisms exist in the form of certificates that validate the generation or production of a certain quantity of renewable energy, renewable gas, sustainable fuel, green hydrogen, or other low-carbon products. These certificates are often twofold; they serve as tangible evidence of the production process of a given quantity of a specific product and convey ownership rights over the environmental, social, and other non-physical attributes of the certified product.[22] In essence, these certificates are different from (and should not be confused with "green labels"), as they not only quantify the volume of the product generated but also signify the ownership of the associated environmental benefits such as reductions in GHG emissions or contributions to sustainable development goals.

Energy Attribute Certificates (EACs) represent a broad category of mechanisms that include Renewable Energy Certificates (RECs), Guarantees of Origin (GOs), and others serving a similar purpose in different jurisdictions. For instance, RECs are widely utilized in renewable energy markets (in the United States, Canada, Australia, and India) to track and trade the environmental attributes of renewable electricity generation. A REC is a market-based instrument that signifies the ownership rights to renewable electricity generation's environmental, social, and other non-power attributes. These certificates are issued when one megawatt-hour (MWh) of electricity is generated and delivered to the grid from a renewable energy source.[23] Similarly, Guarantees of Origin (GOs) are energy certificates for each MWh produced that provide energy customers with information regarding the source of their energy within the European Union. GOs, however, also include information about the type of renewable energy technology used (e.g. wind, solar, hydro), the identity, location, type, and capacity of the installation where the energy was produced, the date on which the installation became operational, and the date and country of issuance.[24]

For some certificates, following the establishment of the primary market, where buyers get the certificate coupled with the physical product directly from the producers, a secondary market can emerge wherein these certificates are traded and resold among secondary buyers. This secondary market, in theory, adds a layer of liquidity and flexibility that allows for broader participation and investment in a particular sector.[25] However, it is critical to recognize that not all market mechanisms are accompanied by a secondary market. For example, emerging mechanisms such as SAFc currently lack a secondary market, primarily due to their nascent stage of development.[26] In contrast, RECs have a well-established secondary market facilitated by the maturity and widespread adoption of the primary market for RECs. The emergence of a secondary market is contingent upon the primary market's stability and maturity, indicating a well-developed infrastructure that supports the trading and resale of these environmental commodities. The implications of a secondary market for these kinds of market mechanisms will be further discussed in Section III-D.

22 For instance, RECs encompass a range of data attributes, including certificate data, type, tracking system ID, renewable fuel type, facility location, nameplate capacity of the project, project details such as name and vintage (build date), certificate generation vintage, a unique identification number, the utility to which the project is connected, and eligibility for certification or compliance with renewable portfolio standards (RPS).

23 "Renewable Energy Certificates (RECs)," United States Environmental Protection Agency.

24 EU Directive on the Promotion of the Use of Energy from Renewable Sources, Art. 19.

25 Capcade Inc, "Secondary Markets in Private Equity: Unlocking Liquidity and Flexibility," *Medium,* December 13, 2023, https://capcade.medium.com/secondary-markets-in-private-equity-unlocking-liquidity-and-flexibility-80a4504d350e.

26 Interview with expert at RMI Aviation, February 2024

2. Emissions Reductions Claims

The demand for these types of market mechanisms is driven by both (i) voluntary purchases from companies and individuals wanting to reduce their GHG emissions and (ii) mandatory regulatory requirements or quotas set by governments (i.e., renewable energy standards requiring utilities to produce a certain percentage of their electricity from renewable sources).

The certificate structure of these mechanisms allows consumers and businesses to substantiate their emissions reduction claims. The common characteristics of these market mechanisms make them attractive for companies and businesses that are either more interested in the emissions benefit than the physical product itself or that would prefer physical offtake but cannot access it for logistic reasons. These companies can then use this claim in their corporate sustainability reporting as evidence of their Scope 2 and Scope 3 emissions reductions.

Along the same line, another attractive feature of these market mechanisms for businesses and companies is the fact that by purchasing them, they can offer businesses a way to meet mandatory regulatory requirements such as renewable energy targets. For instance, in the United States, the Environmental Protection Agency (EPA) supports the use of RECs as a way for utilities to meet their renewable energy goals and demonstrate compliance with Renewable Portfolio Standards (RPS) (state-level policies that require or encourage electricity suppliers to provide their customers with a stated minimum share of electricity from renewable resources).[27] Following this federal acquiescence, many U.S. states with RPS, such as California, Texas, and New York, allow companies to use RECs to comply with their minimum renewable energy requirements.[28]

27 *EPA Clean Energy-Environment Technical Forum: Renewable Energy Certificates: Background & Resources* (Washington D.C.: United States Environmental Protection Agency, October 2008), https://www.epa.gov/sites/default/files/2016-03/documents/background_paper_3.pdf.

28 "Renewables Portfolio Standard – Certification," California Energy Commission, https://www.energy.ca.gov/programs-and-topics/programs/renewables-portfolio-standard/renewables-portfolio-standard-0; Public Utility Commission of Texas, Review of Renewable Portfolio Standard, project no. 55323, https://www.puc.texas.gov/agency/rulesnlaws/subrules/electric/25.173/55323adt.pdf; "LSE Obligations," New York State Research and Development Authority, https://www.nyserda.ny.gov/All-Programs/Clean-Energy-Standard/LSE-Obligations.

3. Bundling with Underlying Product

All of these market mechanisms, in the form of certificates, assign economic value to the environmental attributes of renewable energy or other sustainable products (also known as green premiums), thereby allowing these certificates to be sold and purchased. The market for most of these market mechanisms is set for two main approaches to transferring the certificates: bundling and unbundling with the underlying product.

Bundling the market mechanisms with the underlying product means that the environmental attributes of the green or low-carbon product are sold having a direct connection to the physical product as part of the same contract or transaction between two same parties. For example, in the case of EACs, a bundled EAC means that the certificate sold is directly tied to the project that produced the electricity and it is transferred at the same time as the physical electricity is being generated and sold, meaning that the purchase of renewable attributes under a certificate is directly related to a renewable energy project. In the electricity market, bundled EACs are associated with Power Purchase Agreements (PPA), a long-term offtake agreement between an electricity producer and an electricity consumer, either in their physical or virtual form (see section IV-E).

On the other hand, unbundled market mechanisms are sold without any type of connection to the physical underlying product. Unbundled market mechanisms are generally tradable, sold by a third-party retailer who does not provide physical electricity, and entail the existence of a spot (secondary) market, where prices are regulated by supply and demand. This flexibility allows producers of the underlying low-carbon product to sell the product to one party and the environmental attributes to the spot market, potentially increasing revenue streams through market effects. Unbundled market mechanisms can be aggregated and sold to a wide variety of customers without committing to long-term contracts, making them accessible to a broader market. This enlarges the market itself while providing end consumers with the flexibility to procure power and renewable attributes from different providers. However, this disconnect between the environmental attributes and the underlying product poses several risks that have affected the credibility of unbundled certificates, which will be further discussed in section D below.

Irrespective of whether market mechanisms are bundled or unbundled, through them, producers can benefit from the income of two different product streams: (i) the physical product and (ii) the underlying attributes as represented by the certificate. From the buyers' perspective, this means that they have the flexibility to decide between (i) purchasing both the underlying product together with its environmental, social, and other non-physical attributes or (ii) purchasing just either one of them (i.e.: only the physical product or only the underlying environmental attribute).

4. The Independent Registry Oversight

a. Third-party Management

These types of market mechanisms are typically tracked within dedicated registries. These registries serve as centralized databases where certificates are registered and managed to provide their issuing, buying, selling, and retirement with transparency, accountability, and the prevention of double counting.

For example, in the United States, the EPA[29] oversees the generation, tracking, and trading of Renewable Identification Numbers (RINs) through the EPA Moderated Transaction System (EMTS), a central database that records all the transactions related to this market mechanism.[30] Similarly, the International REC Standard operates a global tracking system for international renewable energy certificates (I-REC), intending to provide integrity and transparency of renewable energy transactions across international borders.[31] In Australia, the Clean Energy Regulator manages the REC Registry which oversees the creation, registration, transfer, and retirement of RECs.[32]

Additionally, Renewable Gas Guarantees of Origin (RGGOs) are tracked and managed within national or regional gas certificate registries, such as the Green Gas Certification Scheme (GGCS) in the United Kingdom, administered by the Renewable Energy Association (REA).[33] Moreover, the standardization and management of GOs that account for renewable energy generation are facilitated through the European Energy Certificate System (EECS), which is managed by the Association of Issuing Bodies (AIB). The European Energy Certificate System sets standardized procedures for the trade, retirement, and utilization of GOs among AIB members, aiming at uniformity in the process.[34]

These registries may be managed by official government agencies, such as the EPA in the United States and the REC Registry in Australia, or by non-governmental organizations (NGOs) like the I-REC Standard or the REA, depending on the jurisdiction and specific market requirements. Using a centralized registry system can, in theory, provide stakeholders with transparency by allowing them to trace the origin of the renewable energy they purchase and ensure their sustainability claims are accurate and verifiable. The registry should act as a ledger recording the issuance, trade, and retirement of certificates, thereby providing a clear trail from production to end-use.

Even though the intention of having official government agencies or reputable NGOs manage these registries is to enhance their credibility and ensure compliance with regulatory standards, thereby fostering trust and transparency in trading environmental certificates within the market, this may not always be the case. Transparency and double-counting risks are further discussed in section II-B.

b. Certificate Retirement as a Traceability Tool

When final consumers purchase these types of market mechanisms as proof of the specific product consumed or delivered, these certificates should be electronically retired within the same registry system. This process, also known as "certificate cancellation," means that the entity that purchased the certificate has claimed to own the environmental attributes of the low-carbon product that the certificate represents. Once the certificate is canceled or retired, it can no longer continue to be traded in the market. This is a crucial step for maintaining the integrity and transparency of the mechanism.

29 The Environmental Protection Agency is a United States Government Agency.
30 "Reporting RFS RIN Transactions in the EPA Moderated Transaction System," United States Environmental Protection Agency, August 24, 2023, https://www.epa.gov/fuels-registration-reporting-and-compliance-help/reporting-rfs-rin-transactions-epa-moderated.
31 "I-REC for Electricity," The International Tracking Standard Foundation.
32 "About the REC Registry," Australian Government Clean Energy Regulator, https://www.rec-registry.gov.au/rec-registry/app/public/about-the-registry.
33 "The Green Gas Certification Scheme," Green Gas Certification Scheme, https://www.greengas.org.uk/.
34 "AIB," Association of Issuing Bodies, https://www.aib-net.org/aib.

The electronic retirement ensures that each certificate, representing a specific amount of low-carbon product produced, is uniquely accounted for and decreases the risk of double counting or selling the same certificate more than once and having two different entities claiming the emissions reduction derived from it. For instance, in the case of RINs in the United States, obligated parties, such as refiners and gasoline/diesel importers, acquire RINs and ultimately retire them in the EMTS when they decide to use them to comply with renewable fuel mandates. This retirement serves as evidence of their compliance with the program's requirements.[35]

Thus, in theory, the electronic retirement is a critical step in the oversight process of a registry that should act as a ledger, recording certificate issuance, trade, and retirement, thereby providing a clear trail of the environmental attributes contained in the certificate from production to end-use.

D. Design Risks

As we delve into the impact and efficacy of these market mechanisms, it is crucial to assess whether they are genuinely meeting their intended objectives. In the forthcoming section, we will explore this question by analyzing the inherent risks associated with these mechanisms. Specifically, we will examine how certain market mechanisms manifest these risks more significantly than others, potentially affecting their effectiveness in supporting the growth of a climate-differentiated market for green or low-carbon products. This analysis will provide a clearer understanding of the dynamics at play within the market for renewable energy certificates and similar instruments, shedding light on their real-world impact on the development of new renewable energy projects.

1. Additionality

a. Defining Additionality

The concept of "additionality" in market mechanisms presents a considerable challenge due to the absence of an official, universally accepted definition. The lack of consensus on what precisely constitutes additionality makes it nearly impossible to demonstrate its presence in a project unequivocally.[36] This ambiguity and lack of standardized definition is the first risk derived from this matter, leaving the concept open to individual interpretations and complicating the assessment of projects' genuine contributions to emission reductions beyond what would have occurred in their absence.

Additionality is fundamentally about ensuring that GHG emissions reductions are genuinely incremental to what would have occurred without the project. It refers to the principle that a given project or mechanism should result in additional environmental benefits that would not have occurred without the intervention or investment being made.[37] In the realm of market mechanisms, additionality is a measure that should ensure that the purchase of these certificates supports the financing and development of low-carbon product production projects that: (i) entail additional costs for the company that do not have another financial source to cover them; and (ii) effectively displace fossil fuel-based conventional operations. This concept is crucial in this context for achieving real reductions in GHG emissions, avoiding greenwashing, and supporting the growth of the low-carbon products market – which in turn encourages innovation and the reduction of costs over time.

However, establishing this additionality is fraught with difficulties because it requires comparing a project's outcomes against a hypothetical baseline scenario of what would have happened without the project. This comparison involves predictions about future developments, such as energy prices or technological advancements[38], making the process inherently speculative and subject to information asymmetry, where project developers may have incentives to portray their projects as additional regardless of the reality. Moreover, criteria and methodologies for assessing additionality vary so much that there are several types of additionality and specific tests that end consumers can consider when determining if the use of these market mechanisms is truly additional.

35 Brent D. Yacobucci, *Analysis of Renewable Identification Numbers (RINs) in the Renewable Fuel Standard* (Washington, DC: Congressional Research Service, April 2014), https://crsreports.congress.gov/product/pdf/R/R42824/6.

36 Interview with expert at Arcelor Mittal, February 2024.

37 *The Greenhouse Gas Protocol: A Corporate Accounting and Reporting Standard: Revised Edition* (Washington D.C.: World Resources Institute and World Business Council for Sustainable Development, March 2004), chapter 8, https://ghgprotocol.org/sites/default/files/standards/ghg-protocol-revised.pdf.

38 *Clean Development Mechanism: CDM Methodology Booklet* (Bonn: United Nations Framework Convention on Climate Change, December 2022), https://cdm.unfccc.int/methodologies/documentation/meth_booklet.pdf.

b. Types of Additionality and the Different Tests

In an attempt to have a standardized definition of additionality, several types thereof have emerged, each addressing different aspects of how a project contributes additional environmental benefits beyond what would have occurred in the absence of the project or mechanism. Understanding all types of additionality is crucial for evaluating the genuine impact of market mechanisms and ensuring that a market mechanism scheme does not pay for emissions reductions that would have occurred anyway. Several organizations have created different tests to assess the existence of each type of additionality within a specific project. Assessing each type of additionality will ultimately give a sense of the project's additionality.[39]

- **Financial Additionality:** focuses on whether the project required additional financial support to be viable. The test to assess financial additionality questions if the project would have been implemented without the financial revenue from these market mechanisms. In other words, this test looks at the project's economics and tests whether expected returns without the sale of market mechanisms would have been sufficient to justify the investment in the project and make it viable.[40] Financial additionality can also manifest as accelerated capital investment. For example, a decarbonization project might be viable yet postponed until the existing conventional asset reaches its end of life, thereby delaying capital expenditures. If revenue from a market mechanism allows for early retirement of this asset, thus accelerating capital investment, the mechanism has financial additionality.
- **Regulatory Additionality:** considers whether a project goes beyond what is required by law or regulation. The test for regulatory additionality questions whether the project was implemented to comply with existing legal or regulatory requirements. If the answer to that question is yes, then it may not be considered additional because it would have happened anyway due to regulatory requirements. Projects that exceed regulatory requirements or that are implemented in areas where no such regulations exist can be considered additional.[41] For instance, the Sustainability Aviation Buyers Alliance (SABA) supporting the development of SAFs through market mechanisms is particularly attentive to regulatory additionality given the range of established mandates on the use of sustainable fuels in aviation (this will be discussed in more depth in Section E below).[42]
- **Common Practice Additionality:** refers to projects that employ new or innovative technologies that are not common practice in a given sector or region. These projects contribute additional environmental benefits by advancing the adoption of cutting-edge technologies that reduce emissions or enhance sustainability beyond what would occur through the normal course of technological development. If the project's activities are already widespread, it might not be considered additional. However, if the project introduces practices or technologies that are not commonly adopted in its context, it can be seen as contributing additional environmental benefits.[43]
- **Barrier Additionality:** addresses the specific barriers (i.e., financial, technical, cultural, or informational) that a project overcomes to be implemented. If these barriers would have prevented the project from occurring under normal circumstances, the project can be considered additional. This type emphasizes the challenges projects face and how their implementation addresses these challenges to achieve environmental benefits.[44]

The variation in methodologies and the subjective nature of additionality assessments underscore the complexity of ensuring that market mechanisms genuinely contribute to additional environmental benefits. These efforts highlight the ongoing challenge of defining and verifying additionality in a way that supports the integrity of market mechanisms while fostering genuine contributions to environmental sustainability.

c. The Risk of Lack of Additionality of Market Mechanisms

One of the main objections raised against these market mechanisms, particularly manifest in EACs, revolves around whether they genuinely contribute to the creation of projects that generate new emissions reductions beyond what would have occurred anyway, which is at the heart of the additionality concept.

39 *The Greenhouse Gas Protocol: A Corporate Accounting and Reporting Standard: Revised Edition,* chapter 8.
40 Interview with expert at Arcelor Mittal, February 2024.
41 Interview with expert at RMI Aviation, February 2024.
42 "Atmospheric Benefit Principle Evaluation Tool," Sustainable Aviation Buyers Alliance, September 6, 2023, https://flysaba.org/atmospheric-benefit-principle-evaluation-tool/.
43 *Clean Development Mechanism: Tool for the Demonstration and Assessment of Additionality.*
44 *Clean Development Mechanism: Tool for the Demonstration and Assessment of Additionality.*

This risk is especially materialized when these market mechanisms can be unbundled from their underlying product, signifying a disconnect between the underlying project that generates electricity and the certificates that contain the environmental attributes. This disconnect means that unbundled market mechanisms cannot claim complete additionality as they represent only a redistribution of existing renewable energy supply rather than driving the development of new projects. While bundled EACs offer a clearer path to supporting the expansion of renewable energy by directly linking the purchase of renewable energy with its generation, thereby contributing to the additionality of renewable energy capacity, unbundled EACs are currently generated by existing projects that would operate regardless of market mechanisms sales and therefore rarely have a direct impact on additional renewable energy development.[45] Furthermore, unbundled EACs allow companies to claim the use of renewable energy without ensuring that their investment supports additional generation capacity beyond what would have been developed anyway.

The additionality of market mechanisms in their current state and form is also questioned when there is a mismatch between where and when the renewable energy is generated and where and when the EACs are consumed. For example, if a company in a region with little renewable infrastructure purchases EACs generated in a distant location where renewable energy is already abundant, the direct impact on increasing renewable capacity in the company's region may be negligible.[46]

Another risk to consider regarding additionality is that markets often focus on the quantity of renewable energy generated rather than the quality or impact of the projects generating this energy. This focus can lead to prioritizing established, lower-cost renewable technologies that might have been deployed anyway rather than supporting emerging technologies or projects in areas most in need of renewable infrastructure development.[47]

45 Anders Bjørn, Shannon M. Lloyd, Matthew Brander & H. Damon Matthews, "Renewable Energy Certificates Threaten the Integrity of Corporate Science-Based Targets," *Nature Climate Change 12, (2022): 539–546,* https://doi.org/10.1038/s41558-022-01379-5.

46 J.A.M. Hufen, "Cheat Electricity? The Political Economy of Green Electricity Delivery on the Dutch Market for Households and Small Business," *Sustainability* 9(1), no. 16: (2017), https://doi.org/10.3390/su9010016.

47 Ákos Hamburger and Gabor Harangozo, "Factors Affecting the Evolution of Renewable Electricity Generating Capacities: A Panel Data Analysis of European Countries," *International Journal of Energy Economics and Policy* 8, no. 5: (2018), https://www.researchgate.net/publication/327688474_Factors_Affecting_the_Evolution_of_Renewable_Electricity_Generating_Capacities_A_Panel_Data_Analysis_of_European_Countries.

Since the sale of these types of market mechanisms generates additional revenue for producers, this revenue can potentially finance different costs associated with decarbonization projects, such as capital expenditures (CAPEX), operating expenditures (OPEX), or financing costs. A notable shortcoming of unbundled market mechanisms, especially EACs, in their current form (i.e. sold on a spot market, often suffering from low prices due to oversupply, and without long-term commitments) is that they do not provide the long-term certainty that is needed to ensure successful raising of the upfront capital costs required to create additional capacity.[48]

In conclusion, the widespread use of EACs can distort the perception of progress towards meeting science-based targets (SBTs). By including these market mechanisms in their emissions reduction strategies, companies may appear to be making significant strides in reducing their carbon emissions. However, without additionality, these efforts do not translate into tangible environmental benefits, challenging the integrity of SBTs and the overall effectiveness of corporate sustainability initiatives in contributing to global decarbonization goals.[49]

2. Transparency and Traceability

Obstacles associated with transparency and traceability have compromised the efficiency and credibility of these market mechanisms. Such risks have notably manifested within EACs, the most established market mechanisms. Issues of transparency and traceability pertain to the degree of openness and clarity concerning both the quality of the information and the ability to follow an EAC's lifecycle, which includes its issuance, trading, and retirement.

Several factors have contributed to the lack of transparency of these mechanisms, presenting a multifaceted challenge. Firstly, the complexity and variability inherent in the diverse rules and methodologies applied across regions and certification schemes obscure stakeholders' comprehension of the environmental impact of EAC purchases. This diversity greatly complicates the ability of consumers and investors to accurately evaluate the genuine environmental benefits derived from their EAC investments. For instance, the most common international standard utilized to account for these market mechanisms, the Greenhouse Gas Protocol,

48 Bjørn, Lloyd, Brander & Matthews, "Renewable Energy Certificates Threaten the Integrity of Corporate Science-Based Targets."

49 Bjørn, Lloyd, Brander & Matthews, "Renewable Energy Certificates Threaten the Integrity of Corporate Science-Based Targets."

advises companies to disclose both market-based and location-based data regarding their electricity use for Scope 2 emissions accounting purposes and provides criteria for integrity when market-based mechanisms are used. The Protocol also advises companies to report emissions associated with bundled certificates in order for the utility to calculate the residual mix (i.e., grid emissions averages excluding claims) for use in location-based calculation to avoid double-counting.[50] In practice, all remains voluntary guidance and it remains unclear what companies really do.

Additionally, the scarcity of publicly available information exacerbates this issue, particularly the lack of detailed data concerning EAC transactions—including the mechanisms by which prices are established and trades are executed— and the specific renewable projects generating these certificates. This deficiency in accessible information severely restricts informed decision-making processes for potential buyers, who are left without crucial insights into these projects' environmental and social advantages, potentially discouraging their engagement and undermining trust in the system.[51]

In the absence of stringent regulatory frameworks, there exists a considerable risk associated with the potential for EACs to be accounted for multiple times, a phenomenon known as double counting. Without adequate tracking mechanisms, there arises a significant uncertainty regarding the possibility of EACs being reused inappropriately, thereby compromising their intended purpose.[52] Moreover, challenges related to geographical alignment (where EACs are claimed in a different region than where the electricity was actually produced, sometimes not even having an interconnection of the power grids) and temporal alignment (where there is no direct timing link between when electricity is generated and when it is consumed, such as using winter electricity offset by summer solar production) further exacerbate the double-counting issue (further discussed below). The intricate task of accurately tracing the specific details of renewable energy production may lead to discrepancies between the locations and timings of consumption and generation.[53]

All these risks combined have materialized in Europe when countries like Iceland—whose renewable sources predominantly power the energy grid—sell the green attributes of their electricity separately from the physical power itself to final users in other countries in Europe. This system has led to a practice where the electricity producers in Iceland sell GOs, which final consumers claim in another country in mainland Europe, which has no grid connection to Iceland, and their local consumers at the same time claim to use renewable energy despite not holding the certificates.[54]

The issue was formally brought to the attention of the AIB, the organization responsible for overseeing the issuing, selling, purchasing, and retirement of GOs. In response, the AIB opted to address the matter privately, choosing not to publicize the findings or reports related to the situation. When pressured to disclose the findings of their investigation, the AIB issued a communication admitting there was an issue but justifying it as "double claiming" instead of "double counting." This distinction suggests that while the renewable attribute of electricity is claimed by more than one party, it does not necessarily involve the improper issuance or accounting of GOs; therefore, the framework they oversee was not directly breached.[55]

To address the issue, the AIB initially implemented a temporary ban on the export of GOs from Iceland as a measure to address the concerns. However, this ban was subsequently revoked, with the AIB providing no public explanation for the reversal of their decision. Despite regulatory efforts from different governments in Europe (especially in Germany and France) and discussions on the risks of transparency, concrete solutions to prevent double counting and ensure the integrity of these market mechanisms remain elusive, and situations like the one in Iceland are replicated in other countries such as Norway and Denmark, where even though there is interconnection with the European electricity grid, significant issues with double

50 *The Greenhouse Gas Protocol: A Corporate Accounting and Reporting Standard: Revised Edition.*

51 Jaap Jansen, "Does the EU Renewable Energy Sector Still Need a Guarantees of Origin Market?" *CEPS Policy Insights,* July 2017, https://cdn.ceps.eu/wp-content/uploads/2017/07/CEPS%20Policy%20Insights%202017-25%20Guarantees%20of%20Origin%20J%20Jansen.pdf; Hanno Böck, "The Trouble with European Green Electricity Certificates," *Industry Decarbonization Newsletter,* December 15, 2023, https://industrydecarbonization.com/news/the-trouble-with-european-green-electricity-certificates.html.

52 A.Hast, S. Syri, J. Jokiniemi, M. Huuskonen, and S. Cross, "Review of Green Electricity Products in the United Kingdom, Germany and Finland," *Renewable and Sustainable Energy Reviews* 42, (2015): 1370–1384, https://doi.org/10.1016/j.rser.2014.10.104.

53 Hanno Böck, "Double Counting and other problems with Green Electricity Certificates," *Industry Decarbonization Newsletter,* June 5, 2023, https://industrydecarbonization.com/news/double-counting-and-other-problems-with-green-electricity-certificates.html.

54 Ole Lofsnaes, "Guarantees of Origin for Renewable Power Set for (Overdue) Scrutiny," Euractiv, *September 22, 2017,* https://www.euractiv.com/section/energy/opinion/guarantees-of-origin-for-renewable-power-set-for-overdue-scrutiny/.

55 Böck, "The Trouble with European Green Electricity Certificates."

counting have emerged. For instance, Norway is currently the largest exporter of GOs in Europe, being almost entirely powered by renewable electricity; studies have found that, like Iceland, numerous companies in Norway also employ location-based accounting for their advertising purposes, yet they do not receive GOs.[56]

The transparency and oversight concerns in the EACs markets are not unique to Europe, and similar double counting and credibility issues have been raised in the United States. The REC market in the U.S. lacks a single governing body to oversee transactions, leading again to concerns about the potential for double counting and the integrity of claims made by REC purchasers. There are ten different tracking systems active in the United States and Canada that act as registries and facilitate REC issuance and trading of RECs. Each registry oversees a different state or region. Even though these multiple "registries" create some level of oversight, each one of them operates under its own rules, and in some cases, there is geographical overlap among them (with some generators registering in systems outside their geographical limits). With no single federal governing body to oversee the issuing, trading, and retirement of RECs in the country, the market is left with on-the-spot bilateral transactions that are difficult to verify. This lack of unified oversight is translated in the fact that today in the United States, where there are three separate operating grids[57], it is admissible to purchase a REC from a grid outside where the consumption occurs or beyond the state or region's borders. This situation contributes to both transparency and additionality risks in the sense that given limited transfer capacity and matching phase challenges, these grids transfer virtually no power to each other, meaning that power generated in the Electric Reliability Council of Texas (ERCOT) grid can only be consumed within the ERCOT grid. Therefore, it has been proposed an ERCOT REC should only be allowed to be claimed within the ERCOT region as it cannot physically reduce Scope 2 emissions beyond those physical boundaries.[58]

For end consumers, all these challenges associated with transparency and traceability translate into difficulties in comprehending the impact of their EAC purchases. These issues not only foster trust concerns regarding the purported environmental benefits but also act as a deterrent to market participation and investment within the renewable energy sector. Consequently, a general perception has emerged that equates these market mechanisms with offsets, further complicating the landscape. This perception of EACs merely as offsets diminishes their perceived value in advancing renewable energy objectives and makes the emissions benefit for end consumers difficult to harness.

3. Excess of Supply

The market dynamics of these market mechanisms, in particular EACs, present a complex landscape of supply, demand, and price volatility. For instance, despite an uptick in the certification rate in the European market in the last two years, the GO certificate market remains challenged by poor liquidity and significant price fluctuations.[59] An example of this volatility is the recent situation in Europe where, in January 2022, GOs sold at 1.7 EUR/MWh. However, the combined impact of the conflict in Ukraine, a season of low rainfall, and more stringent environment, social, and governance (ESG) standards have influenced the market prices for GOs, closing 2022 with GO prices peaking above 9 EUR/MWh, later adjusting to 7 EUR/MWh at the outset of 2023.[60]

Additionally, this market has consistently faced an oversupply issue, with a substantial volume of certificates going unused, signaling difficulties in achieving mature and liquid market status.[61] This often occurs when the capacity for renewable energy generation eligible for EACs expands rapidly without a corresponding increase in consumer demand to purchase EACs to substantiate renewable energy usage; a trend that is generally reinforced by governmental financial aid for renewable energy and regulatory mandates on utilities. This situation of market saturation, where the supply of EACs outstrips demand, leads to lower prices.

56 Böck, "The Trouble with European Green Electricity Certificates;" Hufen, "Cheat Electricity? The Political Economy of Green Electricity Delivery on the Dutch Market for Households and Small Business."

57 The Western Interconnection, the Eastern Interconnection and the Texas Interconnected System or Electric Reliability Council of Texas (ERCOT), three separate power grids that are almost completely isolated from one another.

58 Spenser Robinson and George Sullivan, "Proposed Guidelines for US Scope 2 GHG Reduction Claims with Renewable Energy Certificates," *The Electricity Journal* 35, no. 7 (2022), https://doi.org/10.1016/j.tej.2022.107160.

59 Marijn van Diessen, "Guarantees of Origin: Playing a Vital Role in Decarbonization," *Mckinsey & Company* (interview), January 16, 2024, https://www.mckinsey.com/industries/electric-power-and-natural-gas/our-insights/guarantees-of-origin-playing-a-vital-role-in-decarbonization.

60 Ecohz, "Guarantees of Origin Could Drive Record Investments in Renewables," press release, February 28, 2023, https://www.ecohz.com/press-releases/a-booming-guarantees-of-origin-market-could-drive-record-investments-in-renewable-energy-production-in-europe.

61 Daan Hulshof, Catrinus Jepma, and Machiel Mulder, "Performance of Markets for European Renewable Energy Certificates," *Energy Policy* 128 (2019): 697–710, https://doi.org/10.1016/j.enpol.2019.01.051.

Between 2012 and 2018, the prices for unbundled RECs in voluntary markets ranged from $0.3 to $1.2 per MWh, while GO prices varied between €0.1 and €2.35 per MWh, indicating an oversupply in the market.[62]

The implications of low EAC prices are multifaceted. First and foremost, when low prices are a structural problem in a market-based system, it does not result in an acceptable return on suppliers' investments. Financial incentives for new projects are undermined when the additional revenue generated by EAC sales does not suffice to cover the incremental costs or risks associated with new renewable energy developments. This lack of financial incentive deters investment in new capacity. Therefore, additionality is compromised when low prices indicate a market saturated with certificates from existing projects, which do not require EAC sales for financial viability, undermining their intended purpose.[63]

Moreover, markets flooded with low-cost EACs that do not clearly support new renewable energy projects create skepticism about the validity of environmental claims made by organizations that purchase them. This skepticism erodes trust in EACs as a market mechanism. This situation can lead to greenwashing, where companies may purchase cheap renewable certificates to claim renewable energy usage without contributing to actual emissions reductions or renewable capacity expansion. Furthermore, it can discourage internal projects aimed at reducing carbon footprints, as buying cheap GOs appears more cost-effective than investing in on-site improvements.[64]

Generally, RECs operate within two distinct markets: the voluntary market and the compliance market; this is the case in various jurisdictions such as the United States, Canada, and Australia. The risk of oversupply is particularly present in the voluntary market. For instance, in the United States, the compliance market –mandated by regulatory requirements– consistently exhibits higher prices than the voluntary market. In 2022, the average cost for compliance RECs was $33.94 per credit, markedly higher than the $3.00 per credit observed in the voluntary market.[65] This price disparity suggests that the compliance REC market, unlike its voluntary counterpart—which serves primarily as a supplementary option for meeting beyond mandated RPS quotas—plays a more critical role in driving investments toward renewable energy projects. This is due to its more balanced supply-demand dynamics and the higher prices, which help finance the upfront costs of new (or "additional") renewable energy capacity.[66]

Despite historical trends of oversupply and the GO prices remaining below €2/MWh for many years, the supply and demand dynamics of the European GO market have significantly shifted in the last two years.[67] Projections suggest a conservative estimate of the GO prices averaging around 5.5 EUR/MWh towards 2030, attributed to an expanding corporate consumer base.[68]
With more consumers committing to GOs, demand is expected to stay strong, raising GO prices and driving the market to grow up to €57 billion by 2030.[69] Similarly, in the U.S., the gap between voluntary and compliance REC market prices has been narrowing. Voluntary REC prices reached historical highs in 2021, almost $8/MWh, after consistently staying below $1/MWh before 2018.[70] This change indicates a closing supply-demand gap, pointing towards a more balanced market. These trends underscore the importance of considering evolving market dynamics when analyzing the implementation of new market mechanisms in the renewable energy sector.

62 *Guarantees of Origin, Renewable Energy Certificates, the Residual Mix and carbon offsetting in LCA* (Delft: Delft University of Technology, 2021), https://www.ecocostsvalue.com/lca/gos-and-recs-in-lca/.

63 Machiel Mulder and Sigourney P.E. Zomer, "Contribution of Green Labels in Electricity Retail Markets to Fostering Renewable Energy," *Energy Policy* 99 (2016): 100–109, https://doi.org/10.1016/j.enpol.2016.09.040.

64 Gautam Naik, "Problematic Corporate Purchases of Clean Energy Credits Threaten Net Zero Goals," *S&P Global,* May 5, 2021, https://www.spglobal.com/esg/insights/problematic-corporate-purchases-of-clean-energy-credits-threaten-net-zero-goals.

65 Adam Wilson and Tony Lenoir, "US Renewable Energy Credit Market Size to Double to $26 Billion by 2030," *S&P Global,* December 16, 2022, https://www.spglobal.com/marketintelligence/en/news-insights/research/us-renewable-energy-credit-market-size-to-double-to-26-billion-by-2030.

66 Michael Gillenwater, Xi Lu, and Miriam Fischlein, "Additionality of Wind Energy Investments in the U.S. Voluntary Green Power Market," *Renewable Energy* 63 (2014): 452–457, https://doi.org/10.1016/j.renene.2013.10.003.

67 Kyrylo, "The Rising Price of the European Guarantees of Origin and Future GO Market Outlook," *Future Energy Go* (blog), Feburary 6, 2022, https://futureenergygo.com/the-rising-price-of-the-european-guarantees-of-origin-and-future-go-market-outlook/.

68 Ecohz, "Guarantees of Origin Could Drive Record Investments in Renewables."

69 "What is the Difference Between Bundled and Unbundled EACs?" *Ecohz* (blog), April 21, 2023, https://www.ecohz.com/blog/bundled-vs-unbundled-eacs.

70 "Increasing REC Prices: Is There an Impact on Clean Energy Development?," Leyline Renewable Capital, https://www.leylinecapital.com/news/increasing-rec-prices-is-there-an-impact-on-clean-energy-development#:~:text=REC%20prices%20were%20previously%20coming,to%20build%20clean%20energy%20projects.

E. Addressing the risks

As highlighted in the previous section, most of the risks posed by current market mechanisms are particularly materialized in the case of EACs. The reason behind this is the fact that they have a longstanding presence and established structure in the market, and have been around since the late 1990s[71]. These mechanisms were the pioneers in the use of market-based tools to stimulate investment and market development in the renewable energy industry. Their development has been a road of trial and error that has resulted in the multiple shortcomings analyzed in the previous section.

However, with the purpose of tackling these risks and applying the lessons learned from EACs, newer mechanisms have emerged in other sectors. For instance, Sustainable Aviation Fuel certificates (SAFc) or RGGOs incorporate the common basic design principles outlined in Section C but introduce specific improvements. These enhancements aim to address the identified risks of Section D more effectively and achieve the overarching goal of fostering a climate-differentiated market for their underlying products.

1. Improvements in Transparency

SAF certificates allow for the decoupling of environmental benefits from the physical sustainable aviation fuel (SAF), enabling airlines and corporate consumers to claim reductions in direct (Scope 1 for airlines) and indirect (Scope 3 for corporate consumers) emissions, even without physical access to SAF. The certification process for SAF includes a comprehensive assessment of the fuel's lifecycle emissions from production through to consumption. This lifecycle approach to accounting for emissions provides a clear and transparent basis for the environmental benefits associated with each SAFc. While RECs represent a unit of renewable energy generated, the focus is not always on the lifecycle emissions reductions, which can vary significantly depending on the source and method of renewable energy production.[72]

Moreover, the implementation of SAFc leverages advanced digital platforms and blockchain technology to enhance the traceability of the certificates from issuance to retirement. This technology ensures that each certificate is unique and securely tracked throughout its lifecycle, minimizing the risk of double counting or fraud. Given the aviation industry's regulatory environment, SAFc systems are designed to align with international standards and regulatory requirements. This alignment not only enhances transparency but also boosts consumer and stakeholder confidence in the environmental integrity of SAFc. The certification process for SAF ensures that the fuel reduces GHG emissions by a significant margin compared to conventional jet fuel which often requires a reduction of up to 80% in lifecycle emissions as defined by the International Air Transport Association (IATA).[73] This process is overseen by credible organizations such as the International Civil Aviation Organization (ICAO).[74]

2. Improvements in Robustness

The SAF certificate system leverages the foundational principles of the mass balance certification system as defined by the Roundtable on Sustainable Biomaterials (RSB) and the International Sustainability and Carbon Certification (ISCC) systems. These systems play a critical role in independently verifying the sustainability criteria of SAF supply chains, encompassing every step from feedstock production to fuel blending and delivery.[75] By adopting this dual approach—mass balance verification followed by a book and claim system—the SAFc mechanism enhances its robustness. This enhanced robustness is pivotal in fostering a high degree of transparency and credibility within the mechanism. It ensures that stakeholders can have confidence in the environmental integrity of SAF, knowing not only that the fuel's sustainability criteria are independently verified but also that the environmental attributes of the fuel are meticulously tracked and accounted for throughout the supply chain.

Moreover, RGGOs also provide a more robust system than other market mechanisms such as EACs used in the electricity industry. RGGOs are issued to renewable gas producers for each unit of renewable gas injected into the gas pipeline that displaces units of fossil gas. Even though RGGOs, similarly to other EACs, do not track the

71 "History of Voluntary Markets," United States Environmental Protection Agency, January 15, 2024, https://www.epa.gov/green-power-markets/history-voluntary-markets.

72 *SAFc Registry Guide* (New York: Sustainable Aviation Buyers Alliance, December 2022), https://rmi.org/wp-content/uploads/2022/12/safc_registry_guide_saba.pdf.

73 *Net Zero 2050: Sustainable Aviation Fuels* (Montreal: International Air Transportation Association, December 2023), www.iata.org/en/iata-repository/pressroom/fact-sheets/fact-sheet---alternative-fuels/.

74 *CORSIA Sustainability Criteria for CORSIA Eligible Fuels* (Montreal: International Civil Aviation Organization, June 2019), https://www.icao.int/environmental-protection/pages/SAF_Sustainability.aspx.

75 *SAFc Registry Guide.*

physical flow of renewable gas, they must link producers and consumers of gas that are part of the same network.[76] By matching the gas that a consumer has withdrawn from a distribution network to a unit of renewable gas that was produced and placed into the same network by the producer, RGGOs introduce a safeguard that is not present in other EACs previously analyzed. This provides the system with improved robustness and transparency as it eliminates the double counting and lack of transparency claims associated with RECs and GOs, where certificates allow the environmental attributes of electricity produced in one region to be claimed in another region that has no grid connection whatsoever.

3. Improvements in Regulatory Additionality

EACs have traditionally found their place within the voluntary market, operating alongside compliance systems but not necessarily seeking to achieve regulatory additionality. In contrast, the design of the SAF certificates inherently incorporates the concept of regulatory additionality, setting a distinct standard for the environmental contribution of these market mechanisms. A critical aspect of this approach involves requiring fuel providers to disclose whether the production of their fuel met any legal or regulatory mandates, thereby distinguishing whether the actions were purely voluntary or just in pursuit of regulatory compliance. This distinction is crucial in assessing the actual environmental value added by the SAFc market, particularly because it focuses on whether the certificates are driving the production of sustainable aviation fuel or if they are simply a means to meet regulatory obligations. By scrutinizing the motivations behind fuel production in this manner and striving to achieve regulatory additionality, the SAFc system aims to guarantee that its impact is additive and fosters tangible progress in the aviation sector's decarbonization.[77]

4. The case and potential of CCfDs

Carbon Contracts for Difference (CCfDs) are a financial mechanism designed to support the transition to low-carbon technologies by covering the cost difference between emitting and non-emitting technologies. These are long-term contracts between the signing parties that mitigate the uncertainty related to changing climate policies, carbon pricing and carbon markets (on the supply side), and the advancement of low-carbon technologies (on the demand side).[78] The signing parties involved, generally the public sector and a company, agree on a fixed price over the period of time covering the contract, which intends to provide the company with a certain future compensation for the incremental costs derived from investing in low-carbon technology.

CCfDs are designed around several key principles: they provide long-term price security for investors in green technology, reduce the financial risk of new low-carbon projects, and are flexible enough to adapt to changing market conditions and carbon pricing mechanisms.

In countries like Germany and the Netherlands, CCfDs are being used to stimulate demand growth in sectors with traditionally high carbon footprints, such as steel and aluminum production. By covering the green premium—the additional cost of producing green products—these contracts act as a subsidy, making it economically feasible for heavy industries to invest in cleaner technologies. For instance, Germany's "Decarbonization in Industry" program[79] and the Netherlands' SDE++ scheme[80] are examples of how national strategies incorporate CCfDs to support the production of green steel and aluminum. These initiatives not only contribute to reducing industrial carbon emissions but also enhance the competitiveness of industries transitioning to green production processes.

Exploring CCfDs between private parties presents a novel approach to scaling up low-carbon technologies. In such arrangements, the producer (Actor A) and another company (Actor B) could enter into a CCfD, where Actor B agrees to cover the green premium for Actor A's low-carbon products. While this model extends the benefits of CCfDs beyond government-private partnerships, it could introduce significant financial and operational risks. Considerable challenges include the substantial investment required for transforming production processes and operational costs, the volatility of CO_2 prices and energy carriers, the potential lack of necessary

76 "About Renewable Gas Guarantees of Origin (RGGOs)," Green Gas Certification Scheme.

77 Interview with expert at RMI Aviation, February 2024.

78 Tim Gerres, and Pedro Linares, Carbon Contracts for Differences: *Their Role in European Industrial Decarbonization* (London: Climate Strategies, September 2020), 1, https://climatestrategies.org/publication/carbon-contracts-for-differences-their-role-in-european-industrial-decarbonisation/.

79 *The German Carbon Contracts for Difference (CCfD) Scheme* (Berlin: Federal Ministry for Economic Affairs and Climate Action of Germany, June 2023), https://www.bmwk.de/Redaktion/DE/Downloads/klimaschutz/introduction-ccfd_en.pdf?__blob=publicationFile&v=6.

80 *SDE++2023: Stimulation of Sustainable Energy Production and Climate Transition* (Zwolle: Netherlands Enterprise Agency, August 2023), https://english.rvo.nl/sites/default/files/2023-09/BrochureSDE2023English.pdf.

infrastructure or energy supplies, and the need to precisely match supply and demand between the two parties.

Nonetheless, the possibility of creating multiple CCfDs with different counterparts for various shares of production could mitigate some risks by spreading the financial burden and reducing dependency on a single project's success. For this approach to work, it would have to overcome administrative complexities and the challenge of securing multiple partners willing to engage in such agreements before committing to substantial investments.

II. The Particular Context of the Heavy Industry: A Focus on Steel

Despite the emergence of several new market mechanisms in sustainable aviation fuel and biogas industries aimed at improving transparency, traceability, and robustness, the critical issue of additionality (in particular financial additionality) remains inadequately addressed. This creates a gap where there is a need for market-based tools that foster investments in decarbonization technologies and stimulate demand for low-carbon products, thereby creating a differentiated market that prioritizes climate-friendly options.

The decarbonization of industries such as steel, cement, and aluminum not only requires significant CAPEX, but also heavily relies on research and development (R&D) for technological innovations that are still under exploration. For instance, transitioning to low-emission steel production is anticipated to require a substantial financial commitment estimated at $4.4 trillion over the next 30 years. This estimate breaks down to an average investment of approximately $164 billion every decade, with the highest expenditure expected between 2030 and 2040.[81] Such a significant outlay reflects both the upfront capital required for the development and implementation of cleaner production technologies, including carbon capture and storage (CCS) and hydrogen-based methods, as well as the increased operational costs associated with these greener alternatives, increasing unit production costs by at least 30%.[82]

Addressing financial additionality in this context is crucial, as it guarantees that investments are channeled into technologies and projects that offer real, measurable progress toward lowering global carbon emissions rather than merely offsetting business-as-usual practices. This focus on financial additionality is especially pertinent for heavy industries, where the path to decarbonization is fraught with financial and technical hurdles, underscoring the need for market mechanisms that ensure genuine and substantive contributions to climate change mitigation.

A. Current Use of Certificate-structured Mechanisms in the Steel Industry

Within the steel industry, companies are increasingly adopting innovative strategies to address the financing of carbon emissions from their operations. Among the range of certificate-based strategies, one such strategy is a variant of the mass balance approach, which allows companies to account for and manage emissions reductions achieved through improvements in their manufacturing processes or the implementation of new decarbonization technologies. These reductions are then internally reshuffled and utilized to issue a certificate based on the free and direct allocation of emissions reduction to specific product lines, thereby creating "virtually decarbonized" products.

Examples of this approach include ArcelorMittal's XCarb®, Nippon Steel NSCarbolex™ Neutral, Tata Steel Zeremis® Carbon Lite Steel Thyssenkrupp bluemint® pure, Voestalpine greentec steel green steel certificates, which customers can buy to offset their Scope 3 emissions.[83] This practice involves the concept of balancing emissions reductions achieved anywhere within the company's operations against the emissions associated with specific products. In this system, a steel producer can take any emissions reductions, no matter how minor, from any part of their operations and freely allocate them all to one specific product. This allocation can occur even if the product was not produced in the area where the emissions reductions were achieved. This allows for flexibility in claiming emissions reductions, as they do not need to be directly linked to the product's own manufacturing line provided the total emissions that are reduced and then allocated to the product balance out.

81 Mekala Krishnan, Hamid Samandari, Jonathan Woetzel, Sven Smit, Daniel Pacthod, Dickon Pinner, Tomas Nauclér, Humayun Tai, Annabel Farr, Weige Wu, and Danielle Imperato, *The Net-Zero Transition: What it Would Cost, What it Could Bring* (New York: McKinsey, January 2022), https://www.mckinsey.com/capabilities/sustainability/our-insights/the-net-zero-transition-what-it-would-cost-what-it-could-bring.

82 Thomas Koch Blank, *The Disruptive Potential of Green Steel* (Basalt: Rocky Mountain Institute, September 2019), https://rmi.org/wp-content/uploads/2019/09/green-steel-insight-brief.pdf.

83 These low-carbon steel brands have been analyzed in the context of CCSI's report: John Biberman, Perrine Toledano, and Chloe Zhou, *GHG Accounting for Low-Emissions Branded Steel and Aluminum Products (New York: Columbia Center on Sustainable Investment, October 2023),* https://ccsi.columbia.edu/sites/default/files/content/docs/ccsi-GHG-accounting-steel-aluminum.pdf.

This variant of the mass balancing approach has been particularly pursued by steel companies with blast furnace facilities, as it offers a method to market the environmental benefits of incremental process improvements. However, the actual volume of emissions reductions represented by these certificates is relatively small when compared to the companies' total production volumes and GHG emissions.

For instance, Tata Steel Nederland's Zeremis Carbon Lite certificates, sourced from efficiency projects at its Ijmuiden blast furnace plant, represent a fraction of the company's overall GHG emissions.[84]

84 Biberman, Toledano, and Zhou, *GHG Accounting for Low-Emissions Branded Steel and Aluminum Products.*

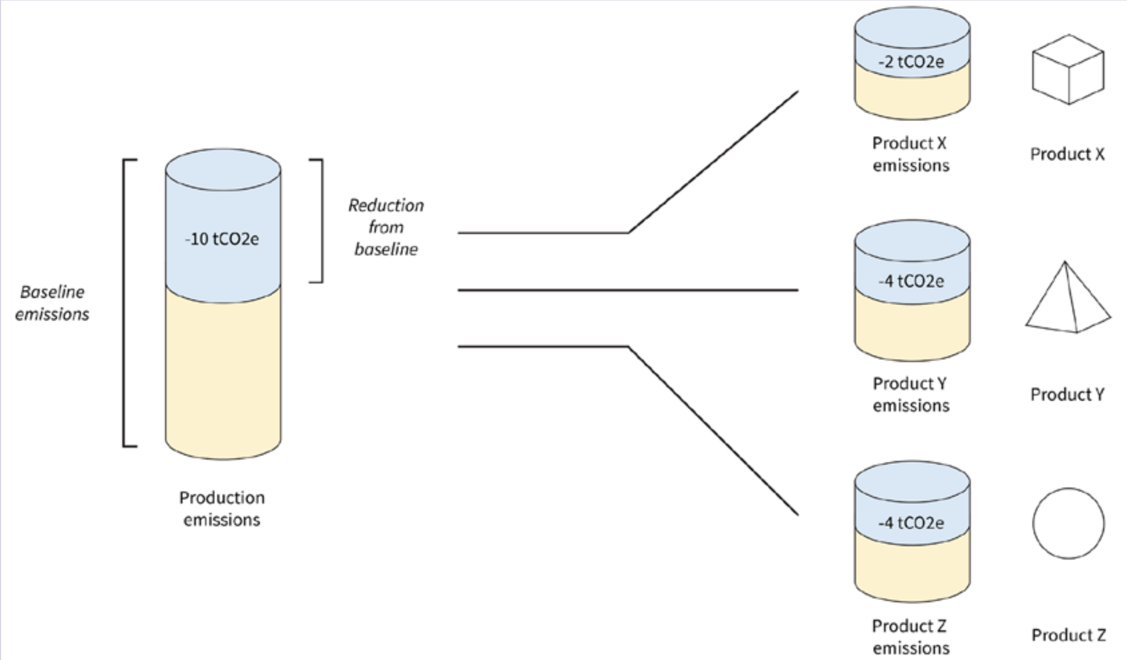


Figure 2: Internal Mass Balancing Approach

Source: GHG Accounting for Low-emissions Branded Steel and Aluminum Products. CCSI

While purchasing emissions reductions certificates allows customers to claim their steel purchases are "low carbon," it is important to recognize that these reductions typically originate from the more emissions-intensive Blast Furnace-Basic Oxygen Furnace (BF-BOF) production route. Despite the real emissions reductions achieved, the GHG intensity of steel produced via the BF-BOF route (without CCS) remains significantly higher than the benchmarks for sector decarbonization set by international bodies like IEA.[85]

There are several challenges associated with this variant of the mass balance/certificate approach. One major challenge is establishing and updating a credible baseline for emissions to account for the reductions accurately. This process is complicated by the lack of specific requirements and standards, leading to potential variability and inconsistency in how reductions are calculated and claimed (this will be discussed in more depth in the following section). Additionally, there is a high risk of double counting, where emissions reductions might be claimed both as part of a product's carbon footprint and sold separately as certificates, as highly documented in other types of market mechanisms such as RECs and GOs, explained in Section II. This issue is compounded by the absence of settled rules for reporting emissions reductions via certificates and is currently mitigated through auditing and verification processes.[86]

85 *Achieving Net Zero Heavy Industry Sectors in G7 Members.*

86 Biberman, Toledano, and Zhou, *GHG Accounting for Low-Emissions Branded Steel and Aluminum Products.*

Ultimately, fragmented accounting equates to bad accounting, as it hinders the attainment of an accurate representation of an entity's GHG emissions, thereby obstructing informed decision-making and effective decarbonization strategies. Furthermore, this fragmented accounting approach manifests the risks associated with the traditional market mechanisms highlighted in Section I. These include a notable lack of transparency, where the purchaser of these certificates lacks clear insight into the actual environmental benefits or level of 'greenness' of the steel. Additionally, there is a marked absence of additionality, where the sale of these certificates fails to drive investments towards projects that yield genuine, incremental emissions reductions and instead merely reshuffles existing reductions.

B. Lack of Standard Definitions

The terms "green steel" and "low-carbon steel" are often, and mistakenly, used interchangeably in the context of decarbonization efforts in the steel industry. However, they signify different approaches, technologies, and emissions reduction levels. Low-carbon steel generally refers to steel produced with technologies that emit lower GHG emissions than conventional steel production methods. This encompasses a range of innovative practices and technologies aimed at reducing the carbon burden of steel, such as using alternative energy sources or CCS technologies.[87]

On the other hand, the term "green steel" could appear as leaving less room for interpretation is a more precise term, but in fact, it has been more difficult to reach a consensus on its definition. This concept has been used to describe steel manufactured in ways that minimize their GHG emissions to a near-zero level. This might include, among other technologies, steel produced through the direct reduced iron (DRI) route using green hydrogen produced through the electrolysis of water using renewable electricity. However, the term "green steel" can be interpreted in various ways by different stakeholders, sometimes leading to confusion due to its diverse meanings. For instance, it can also be interpreted as covering broader sustainability considerations than just emissions.

The discourse surrounding the definition of "green" or "near-zero emissions" steel has seen a considerable expansion, with various organizations proposing different threshold definitions. Despite the diversity of proposals, some convergence in the core concepts underlying these definitions can be observed. For instance, the IEA suggests a definition that ties the near-zero emission intensity threshold for crude steel production to the proportion of scrap metal used. This approach recognizes the emission reduction potential inherent in the use of scrap metal, advocating for a sliding scale that adjusts the threshold based on scrap usage. The more scrap metal utilized, the lower the emissions intensity threshold, with a proposal to classify steel production as primary or secondary near-zero emission based on a specified percentage of scrap use, tentatively set at 30%. For crude steel production with zero scrap use (iron ore provides all the metallic inputs), the proposed threshold is 400 kg of CO_2 equivalent per ton ($kgCO_2e/t$) of crude steel. For crude steel production with 100% scrap inputs (zero iron ore used for metallic inputs), the proposed threshold value is 50 $kgCO_2e/t$ of crude steel.[88]

Similarly, the IEA's methodology echoes Responsible Steel's guidelines,[89] which also employ a sliding scale that accounts for the volume of scrap metal in production. This consensus highlights a broader industry move towards integrating scrap use as a critical factor in defining low-emission steel production standards. Moreover, the German Steel Federation (GSF) in Germany recently published the Low Emissions Steel Standard (LESS) that builds on the IEA's scheme and aims to implement it in a practical manner by focusing on the product rather than the production process.[90] Meanwhile, the Global Steel Climate Council (GSCC) has introduced standards that deviate significantly from the IEA's framework, suggesting a method that eliminates the scrap sliding scale and measures emissions reduction irrespective of the production methods.[91] Finally, the World Trade Organization (WTO) has led an effort under the COP agenda, where they endorse a set of Steel Standards Principles that contribute with emissions measurement methodologies.[92]

87 Andrew Purvis and Nicholas Walters, "Blog: What We Mean When We Talk About Low-Carbon Steel," *World Steel* (blog), April 12, 2021, https://worldsteel.org/media-centre/blog/2021/blog-low-carbon-steel-meaning/.

88 *Achieving Net Zero Heavy Industry Sectors in G7 Members.*

89 *ResponsibleSteel International Standard Version 2.0* (London: ResponsibleSteel, September 2022), https://www.responsiblesteel.org/standards.

90 Wirtschaftsvereinigung Stahl, "Low Emission Steel for "Green" Lead Markets: New Label System Creates Transparency," press release, April 22, 2024, https://www.stahl-online.de/wp-content/uploads/20240422_LESS_Low_Emission_Steel_New-Label-System.pdf.

91 *The Steel Climate Standard: Framework for Steel Product Certification and Corporate Science-Based Emissions Targets* (Global Steel Climate Council, August 2023), https://globalsteelclimatecouncil.org/wp-content/uploads/2024/02/GSCC-Standard-August2023-TM.pdf.

92 *Steel Standards Principles: Common Emissions Measurement Methodologies to Accelerate the Transition to Near Zero (Geneva: World Trade Organization, April 2024),* https://www.wto.org/english/tratop_e/envir_e/steel_standards_principles_e.pdf.

The proliferation of multiple proposals highlights the need and relevance of harmonizing definitions and establishing a universally accepted framework for categorizing "near-zero emission" steel. Opportunely, there is currently a collective industry aspiration to reach this global harmonization. The IEA, through its Working Party on Industrial Decarbonization and roles in the Secretariat of the Clean Energy Ministerial and the International Deep Decarbonization Initiative (IDDI) –hosted by the United Nations Industrial Development Organization (UNIDO)–, as well as hosting the Secretariat of the recently launched Climate Club, is at the forefront of facilitating ongoing discussions aimed at achieving clarity and consensus on these definitions.[93]

The lack of globally accepted standards for defining "near-zero emissions" or "green" in steel production significantly complicates the transparency and integrity of market mechanisms within the industry. This absence of consensus allows for confusion and a broad interpretation of what constitutes "green" steel, enabling jurisdictions and companies to adopt self-determined thresholds that may align more closely with their interests rather than rigorous decarbonization benchmarks. Consequently, this situation can lead to claims of selling "green" steel that, in reality, may only represent conventional steel produced in facilities with marginally reduced emissions, cleverly presented to appear more environmentally friendly than it is. This practice not only misleads buyers but also dilutes the impact of efforts aimed at genuinely reducing the industry's carbon footprint. This should be addressed so that market mechanisms such as these are not being used counterproductively.

Furthermore, the current absence of standardized definitions for "near-zero emissions" or "green" steel significantly impedes the establishment of clear legal and regulatory frameworks globally, which are crucial for determining the regulatory additionality of market mechanisms within the steel industry. The lack of uniformity in defining low-emission steel production thresholds hinders the ability to assess whether the intervention of market mechanisms in the steel sector contributes to additional emissions reductions beyond existing regulations. This ambiguity undermines the potential for market mechanisms to be recognized as valid and effective tools for advancing industrial decarbonization efforts. Without universally accepted benchmarks for what constitutes "near-zero emissions" or "green" steel, aligning market-based initiatives with regulatory objectives becomes challenging.

C. What Is Missing to Increase Demand

Governments and companies have been working towards scaling up demand for "near-zero emissions" or "green" steel by jointly making procurement commitments since COP26 under the Breakthrough Agenda, and since then, through other similar initiatives.[94] This collaborative effort has led to a significant increase in procurement commitments, reflecting a growing consensus on the importance of transitioning to sustainable steel production. The IDDI, the First Movers Coalition (FMC), RMI's Steel Buyers Platform, and SteelZero are pivotal platforms facilitating these commitments today, with IDDI's membership expanding from 5 to 9 members, and FMC and SteelZero witnessing an increase in participating companies by 5 and 13 respectively since the end of 2021. Moreover, 19 additional companies have engaged in commitments often through direct offtake agreements with steel producers.[95] Similarly, several automotive industry buyers have recently entered in binding direct offtake agreements with H2 Green Steel for the supply of "near zero emissions" steel starting in 2026, when the company expects to have the largest "green" steel mill ready to operate in Sweden.[96]

Despite these advancements, the geographic distribution of these commitments remains largely concentrated, with 88% originating from European-based companies, indicating a regional skew in the commitment landscape. To address this disparity and foster a more globally inclusive approach, FMC has initiated in-country workshops in India, Brazil, the United States, and the United Arab Emirates. At the same time, SteelZero has marked its presence

93 "IEA Supports Faster Industrial Decarbonisation Through New Climate Club," *IEA News,* December 1, 2023, https://www.iea.org/news/iea-supports-faster-industrial-decarbonisation-through-new-climate-club.

94 "The Breakthrough Agenda was launched by 45 world leaders at COP 26 and is a commitment to work together this decade to accelerate innovation and deployment of clean technologies, making them accessible and affordable for all this decade"

95 *The Breakthrough Agenda Report 2023* (Paris: International Energy Agency, September 2023), https://www.iea.org/reports/breakthrough-agenda-report-2023.

96 H2 Green Steel, "Purmo Group in 7-year Agreement with H2 Green Steel for Near Zero Emission Steel Supply," press release, November 6, 2023, https://www.h2greensteel.com/latestnews/purmo-group-in-7-year-agreement-with-h2-green-steel-for-near-zero-emission-steel-supply.

in India in 2022 and is actively extending its reach to the United States, Korea, and Japan. These efforts, though substantial, have yet to translate into new commitments from companies in these regions.[97]

The commitments for direct offtake of "near-zero emissions" or "green" steel represent an optimal scenario for boosting demand within the steel industry. This direct offtake approach, underpinned by specific pledges, directly aligns buyers with producers of green steel, facilitating a streamlined path towards increasing the consumption of "green" products and guarantees both the payments of the green premium required to produce "green" steel and a market for the "green" product itself. Ideally, if the entire demand for green steel could be satisfied through direct offtake agreements stimulated by these pledges, it would mark a significant stride toward the industry's decarbonization goals. This model not only ensures a market for green steel but also encourages producers to invest in and accelerate the development of low-emission steel production technologies. By bypassing risks and challenges typically associated with market mechanisms, direct offtake agreements provide a clear, direct incentive for the production and procurement of green steel, thereby fostering a more sustainable steel industry.[98]

However, these initiatives, commitments, pledges, memorandums of understanding (MOUs), and direct offtake agreements currently do not generate enough demand to create a climate-differentiated market for "near zero emissions" or "green" steel that will propel a scaled production of green steel. Therefore, a second, however nascent, approach within the steel industry aimed at fostering demand for green steel involves their variant of the mass balance/certificate approach, as detailed in section III-A. While this method could be considered as an initial test of market demand for "green" products by allowing companies to claim lower emissions for their products and explore buyer willingness to pay a premium, it is teeming with shortcomings. Notably, this approach currently falls short of ensuring transparency and guaranteeing additionality. Firstly, this method, as explained before, enables producers to use marginal emissions reductions from their whole operation and freely allocate them to one product, claiming it is a "green" product. This introduces misaligned incentives between steel producers and buyers. If buyers can claim their purchases are carbon-neutral without any material decarbonization efforts from the producers, there is little motivation for them to pay the premium that genuinely decarbonized production warrants. This lack of incentive stifles the economic drive needed for producers to invest in and adopt cleaner technologies. Secondly, relying on what essentially amounts to an accounting maneuver does not test the market's willingness to support environmentally sustainable practices. Since the approach does not involve real costs for the producers, buyers are not inclined to pay a premium, further entrenching the status quo. Lastly, the compatibility of this accounting method with the International Organization for Standardization's (ISO) Life Cycle Assessment (LCA) rules is questionable. This ambiguity can lead to regulatory challenges and skepticism about the integrity of environmental claims, potentially damaging trust in sustainability initiatives within the industry.

The prevalence of such claims by companies highlights the critical need for establishing a robust, independent market mechanism that is anchored in a third-party auditable standard. This framework should include clear rules regarding the retirement of certificates and any associated environmental claims. An independent standard would ensure that claims of decarbonization and sustainability are verifiable and meet internationally accepted thresholds, thereby preventing the exploitation of accounting loopholes and enhancing the credibility of the steel industry's environmental efforts. Ultimately, this would foster transparency, hold companies accountable, and guarantee that sustainable practices are genuinely contributing to environmental conservation, as discussed below.

Given the substantial challenges in achieving the volumes of offtake necessary to support near-zero emissions steel production at scale, relying solely on broad direct offtake pledges is impractical and limits the pool of buyers for "green" products. While these international commitments for direct offtake should continue to expand as they are critical in building momentum, they alone are not enough. A dual strategy that continues to reinforce these agreements and pledges but also implements a robust market-based mechanism would address the current limitations in spurring demand for "green" steel and scaling up its production.

97 *The Breakthrough Agenda Report 2023.*
98 Interview with expert at the International Energy Agency, February 2024

III. Design Principles of a Market Mechanism for the Heavy Industry: A Focus on Steel

In this section, we outline the design principles that should underpin the architecture of such a market mechanism. Our focus is on articulating a structured framework that incorporates both theoretical and practical considerations essential for the effective functioning of the multiple elements of this mechanism.

The imperative for phasing out BF-BOF technologies in steelmaking is rooted in their significant carbon footprint (emitting approximately 2.3 tons of CO_2 per ton of crude steel as shown in Figure 3)[99] and the lack of feasible and commercially-proven decarbonization pathways and processes –such as CCS–, making conventional steelmaking a significantly hard-to-abate sector. Moreover, projections suggest that transitioning away from the BF-BOF will happen within the next 20 years, taking into account the current range of ages of the fleet. This phase-out aligns with the typical lifespan of blast furnaces, which require relining every 20 years. The investment in relining a blast furnace at the end of its lifetime provides a strategic opportunity to phase out and replace them with more sustainable technologies, thereby avoiding further carbon lock-in and supporting a shift towards cleaner steel production methods.[100]

99 Mimi Khawsam-ang, Max de Boer, Grace Frascati and Gernot Wagner, *Decarbonizing Steel* (New York: Columbia Business School Climate Knowledge Initiative, March 2024), https://leading.business.columbia.edu/climate/steel/decarbonizing-steel.

100 Valentin Vogl, Olle Olsson, and Björn Nykvist, "Phasing Out the Blast Furnace to Meet Global Climate Targets, *Joule* 5 (2021): 2646-2662, https://www.cell.com/action/showPdf?pii=S2542-4351%2821%2900435-9.

	1 Blast Furnace-Basic Oxygen Furnace (BF-BOF)	2 Scrap Electric Arc Furnace (Scrap EAF)	3 Natural Gas-Based Direct Reduced Iron – Electric Arc Furnace (NG DRI-EAF)
Description	**Iron ore, coke, and limestone** produce pure iron in a **blast furnace**, which **is turned into steel in an oxygen furnace**	**Scrap metal** is **melted in an EAF** using **electrical energy**	**Iron ore** is turned **into iron** using **natural gas**, which is then **melted in an EAF** to **produce steel**
Main inputs	**Iron ore, cooking coal**	**Scrap steel, electricity**	**Iron ore, natural gas**
% of global steel production	72%	21%	7%
CO2 per tonne of crude steel	**2.3 tonnes**	**0.7 tonnes**	**1.4 tonnes**
Energy intensity per ton of crude steel	**~24 GJ**	**~10 GJ**	**~22 GJ**
Average cost per tonne of crude steel	**~$390**	**~$415**	**~$455**

Figure 3: Current Steel Production Methods

Source: Columbia University 2024[101]

101 Khawsam-ang, de Boer, Frascati and Wagner, *Decarbonizing Steel.*

On the other hand, the electric arc furnace (EAF) route appears much closer to full decarbonization by relying on a package of different technologies that are feasible to implement, technology proven, and approaching full-scale commercial deployment[102] including renewable energies, green hydrogen and scrap (see both Figures 3 and 4 for the different EAF technologies, their maturity, and cost competitiveness). As shown in Figure 3 above, the EAF-scrap route is already a mature and cost-competitive technology but is reliant on the availability of scrap.

102 Projects like HYBRIT and H2GS are among the leaders in using green hydrogen for steelmaking, showing significant progress and nearing commercialization. H2GS is already proceeding into full commercial operations (H2 Green Steel, H2 Green Steel Raises More Than €4 Billion in Debt Financing for the World's First Large-Scale Green Steel Plant," press release, January 22, 2024, https://www.h2greensteel.com/latestnews/h2-green-steel-raises-more-than-4-billion-in-debt-financing-for-the-worlds-first-large-scale-green-steel-plant), while HYBRIT has entered the demonstration phase (HYBRIT, "HYBRIT: LKAB Will Be Responsible for the Construction of the Demonstration Plant in Gällivare," press release, November 1, 2023, https://www.hybritdevelopment.se/en/hybrit-lkab-will-be-responsible-for-the-construction-of-the-demonstration-plant-in-gallivare/.)

	1 100% Green Hydrogen (H2) DRI-EAF	2 Iron Ore Electrolysis	3 Carbon Capture, Utilization, and Storage (CCUS)
Description	• **Green hydrogen** replaces **natural gas** as an iron ore reductant in DRI shaft; the rest of the process remains the same • Generates **water as a byproduct** instead of CO_2	• **Two different processes** are possible**:** **Molten oxide electrolysis:** High current runs through mixture of iron ore and liquid electrolyte to split ore into pure molten iron **Electrowinning-EAF:** Iron from iron ore is dissolved in acid. Iron-rich solution is then electrified to form pure solid iron	• **CCUS equipment** can be added to **existing steel-producing infrastructure** to **capture** emitted CO_2 • Captured CO_2 is then **sequestered underground** or **reused**
Real-time sector initiatives	HYBRIT 100% fossil fuel-free DRI-EAF production with green H_2 used for DRI	Electra Electrowinning to produce high-purity iron plates ready for EAF input (no DRI or MOE step)	ArcelorMittal Carbalyst® captures carbon from a blast furnace and reuses it as bio-ethanol. However, technology not proven at scale
Applicability to conventional routes	**Applicable to existing DRI-EAF route**, with minor retrofitting	**Full overhaul** of BF-BOF equipment required; **replacement** of DRI shaft in DRI-EAF	**Retrofitting** of capture technology is possible on **conventional BF-BOF and DRI-EAF**
Decarbonization potential (vs. BF-BOF)	**~90%**	**~97%**	**~90%** Hypothetical best-case scenario
Estimated production cost (excl. CapEx)	**<$800 per tonne of steel**	**~$215 per tonne of iron + cost of 'stranded' iron ore**	**~$380 – 400 per tonne**

Figure 4: Decarbonization Routes for Steelmaking

Source: Columbia University 2024[103]

103 Khawsam-ang, de Boer, Frascati and Wagner, *Decarbonizing Steel.*

On the other hand, the Direct Reduced Iron-Electric Arc Furnace (DRI-EAF) route reliant on green hydrogen is a proven technology but is suffering from a "green premium" or incremental costs that compromise its cost competitiveness compared to conventional steelmaking process such as BF-BOF (see Figure 5 below).

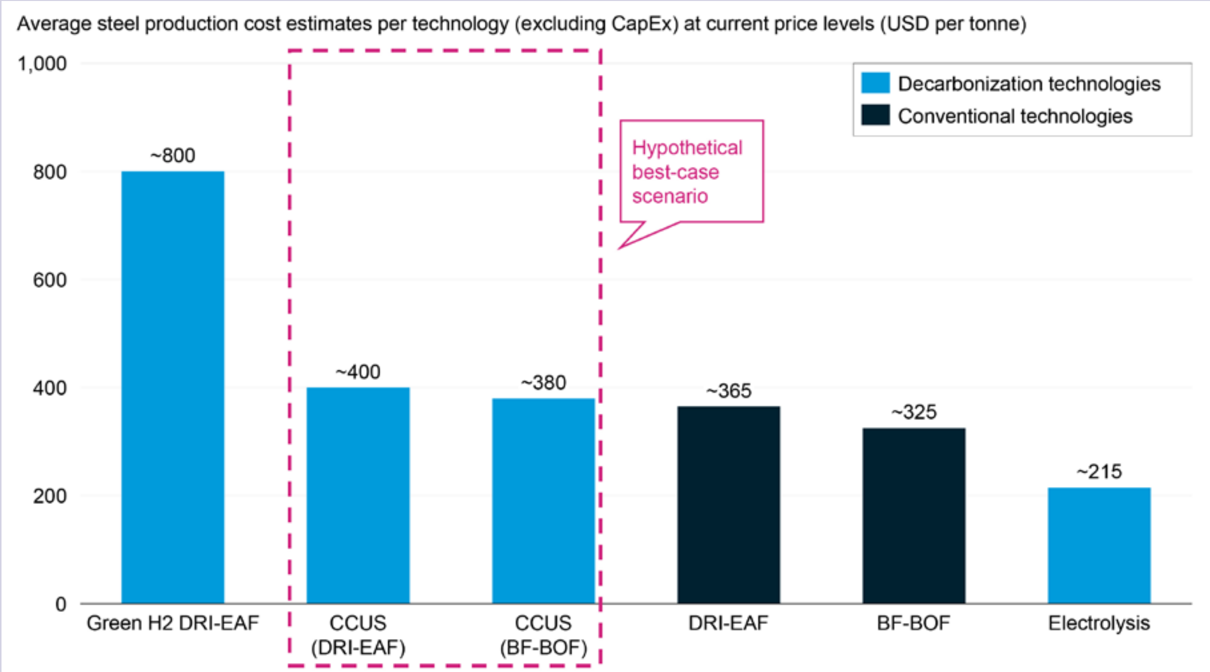


Figure 5: Green Premium of Steel Decarbonization Technologies

Source: Columbia University 2024[104]

104 Khawsam-ang, de Boer, Frascati and Wagner, *Decarbonizing Steel.*

Against that backdrop, our proposed market mechanism is designed to support the uptake of the DRI-EAF technology route by absorbing its green premium and supporting the demand that physical offtake cannot satisfy. Therefore, the proposed market mechanism is intended to be implemented by steel producers that are looking to develop new capacity of DRI-EAF technology that will produce steel that is compliant with "near zero" or "green" standards or thresholds. This means that all the steel produced at a specific facility adheres to the GHG emissions thresholds stipulated by either local regulations (i.e., EU taxonomy) or respected international standards, such as those set by the IEA or similar organizations. However, facilities and operations where DRI-EAF technologies are already operational and compliant "green" steel is already being produced, can also benefit from this market mechanism, given that companies relying exclusively on virtual offtakes cannot run a viable business model in the long run (as explained in section V-D below).

As mentioned in the previous section, we also assume that the first requisite for such a market mechanism to be successfully developed is having globally accepted harmonized standards and threshold definitions for what constitutes "near-zero emissions" or "green" steel.

A. A Robust Certificate Structure

The blueprint of an additional market mechanism for technologies in the steel industry that produces steel compliant with internationally accepted thresholds to be considered "green" requires a certificate structure that, similarly to RECs, GOs, SAFc, or RGGOs, is designed to fulfill a dual purpose: certifying the environmental integrity of the steel production process and monetizing the environmental benefits accrued from producing "green" steel. However, for these certificates to genuinely drive additionality, they must incorporate specific enhancements compared to their electricity and energy sector peers as detailed below. These improvements are crucial for ensuring that the certificates not only signify compliance with emissions intensity standards but also stimulate tangible advancements in the steel industry's decarbonization efforts.

1. Chain of Custody Model

Various systems are in place to trace the origin and environmental attributes of commodities, including their GHG emissions and other impacts. These systems, known as 'chain of custody' models, track a product and its characteristics through the supply chain to the end user. There are four main types of chain of custody models based on the degree of traceability of the physical product.[105]

105 *Chain of Custody – General Terminology and Models* (Geneva: International Organization for Standardization, 2019), https://www.iso.org/obp/ui/#iso:std:iso:22095:dis:ed-1:v1:en.

Box 1: Chain of Custody Models Explained

- **Identity Preservation:** Ensures complete segregation of a product batch from a specific source from those of different origins throughout the supply chain, maintaining strict adherence to sustainability standards. This method offers the highest level of product traceability, allowing for the identification of a product's origin, characteristics, and documentation to a single source. However, this meticulous separation generally results in higher costs due to specialized logistical needs.
  - Currently, in the green hydrogen market, this is the only accepted model due to the lack of harmonization of standards, which results in the fact that green hydrogen is unable to leverage the established grey hydrogen pipeline infrastructure, which in turn raises its green premium even more.[106]
- **Segregation:** Allows products that comply with sustainability standards from different sources to be mixed while preventing the blend of compliant and non-compliant items throughout the supply chain. This approach offers a balance between strict traceability and operational flexibility, operating at a lower cost compared to the identity-preserved system.
- **Mass Balance:** Tracks sustainability-compliant and non-compliant products mixed within the supply chain before reaching consumers. It monitors the production process and the inputs and outputs, ensuring that over a specific period of time, the quantity of compliant product leaving the supply chains and delivered to the end consumers is equal to the amount added to the supply chain, irrespective of it blending with non-compliant product. This system can utilize different units like mass, volume, energy content, or even emissions reductions for calculation. Key variables include the system's size, the timeframe for calculating mass balance (e.g., monthly, quarterly), and how compliance claims are matched with physical deliveries. For this last variable, there are two options: (i) proportional allocation, where all consumers receive products containing an equal share of compliant product; or (ii) free allocation, where only a portion of consumers receive 100% compliant products.
  - Current certificates being issued in the steel industry are utilizing a variant of this chain of custody model, where they freely allocate any minor reduction of emissions in their whole operation to one specific product to achieve virtual decarbonization (refer to Section III-A).

106 Interview with expert at GH2, January 2024.

- **Book and Claim:** Focuses on markets rather than supply chains, severing the direct link between a product's physical flow and its environmental attributes. In this model, certificates representing specific environmental qualities of goods are issued and decoupled from the actual products, allowing for their independent trade, often through online platforms, especially when a physical offtake of the product is not possible or too difficult. When making a purchase, the buyer "books" a specific amount of emissions reductions or savings in one place, and later, they "claim" the emissions reduction benefits to contribute to their sustainability objectives somewhere else. Consequently, the buyer gains ownership of the environmental benefits without physically having the underlying product and obtains an independently verified certificate to substantiate their claim.
    - Traditional market mechanisms of the electricity industry, such as RECs and GOs, are based on this chain of custody model.
    - The SAFc, a more modern market mechanism, provides a robust structure by integrating both the mass balance and book and claim models (refer to Section II-E(2)).

Given the current intricate nature of the supply chain from the producer adopting near-zero emissions technologies to the buyer who values these emissions reductions, employing identity preservation or segregation methods for chain of custody proves unfeasible. The lack of uniformity in defining what qualifies as "green" steel further complicates the traceability and verification of claims throughout the supply chain. This complexity makes it impractical to employ identity preservation or segregation chain of custody models. Therefore, a mass balance or book and claim chain of custody should be implemented.

The mass balance method of free allocation, which involves internally reshuffling emissions and is currently employed by some steel producers, has proven to be ineffective for achieving transparent and additional decarbonization, as explained above. Moreover, book and claim systems where certificates are completely unbundled (detached) from the underlying product or project and are sold on the spot and a very low prices, generate risks and challenges such as ensuring additionality, maintaining transparency, and preventing excess of supply.

In light of the foregoing considerations, the optimal approach for establishing a chain of custody system for this market mechanism involves implementing a robust book and claim system, reinforced by prior third-party verification of the product's GHG accounting and boundary analysis, to ensure compliance with accepted thresholds and definitions of greenness.
The initial step in the issuance of this certificate involves establishing a robust GHG accounting system (which will be detailed in section 3 below). This foundational measure ensures that the product's production processes are accurately measured against established and accepted environmental benchmarks, boundaries, definitions and thresholds. Following this, it is crucial to engage a third-party verifier to certify the product's emissions intensity adheres to the accepted definitions or thresholds of "green" standards. This first step will provide the transparency and credibility of the environmental claims associated with the product for the following book and claim phase.

Subsequently, through the book and claim system, the company will separate the environmental attributes from the already verified physical product and transfer them in the form of a certificate that we will hereinafter call a Green Steel Certificate (GSC). The company reports the emissions intensity of one ton of the product, but it is the registry (as discussed further below) that is in charge of issuing the GSC, which will then be transferred to the buyer. By integrating both a third-party emissions intensity verification and a book and claim method, the system gains robustness, with the initial certification process ensuring the sustainability of the physical supply chain and the product's acceptable emission intensity, while the subsequent transfer of certificates enables stakeholders to leverage the environmental attributes of the "green" product.

The efficacy of this dual integrated chain of custody model, observed in nascent industries like SAF, underscores its potential for driving meaningful change within the steel industry.[107] Nevertheless, to address any remaining challenges associated with the implementation of chain of custody models, the adoption of the complementary elements proposed for this particular market mechanism in the following sections is imperative.

2. Certificate Information Provided

The information contained in the certificate should be grounded in clarity, transparency, and scientific evidence. This level of rigor and transparency is crucial not only for informing policy and consumer choices but also for fostering trust in market mechanisms as helpful tools to increase demand and develop a climate-differentiated market for heavy industry.

The minimum information that the certificate of this market mechanism structure should have is:

- **Issuer Details:** Information about the body or organization that issued the certificate, including its name and contact details, in case the issuer is a different entity than the producer.
- **Producer Information:** Details about the steel producer, including the name and the location of the production facility where the steel was produced.
- **Batch Identification:** A unique identifier for the specific batch of steel, facilitating traceability from cradle to gate and preventing double counting.
- **Product Information:** Detailed description of the steel product(s) covered by the certificate, including type, grade, and possibly dimensions or other relevant specifications.
- **Production Period:** The date or period during which the steel was produced.
- **Quantity:** The amount of steel covered by the certificate, typically measured in tons.
- **Technology:** Detailed information about the technology implemented within the producer's operation that resulted in the emissions reductions leading to production of "green" steel.
- **Carbon Intensity:** specific information on the carbon intensity of the steel product, expressed as kilograms of CO_2 emissions per ton of steel produced. This includes both direct and indirect emissions associated with the production process.
- **Certification Standards:** Reference to any standards that the steel complies with.
- **Verification:** Details about the verification process, including the name of the independent third-party verifier and the standards or methodologies used to assess the carbon intensity and validate the emission reductions.
- **External Funding:** reporting if there are any subsidies, grants, or financial incentives from other sources different from the companies' own investments that are funding the emissions reductions where the steel was produced.
- **Decarbonization Strategy:** Report the company's overarching decarbonization strategy to ensure that revenue from the certificates is being used to genuinely contribute to reducing carbon emissions in a cost-effective and proven manner (see section IV-D-4).

3. The Right Carbon Accounting

The process for calculating the GHG emissions of the "green" steel should adhere to ISO 14044 standards and rules. This set of guidelines outlines the procedure for performing an LCA, an essential component of which involves detailing the Life Cycle Inventory (LCI) at a granular process level. The life-cycle boundaries should be cradle-to-gate.[108]

Establishing clear boundaries for GHG accounting is a key element of the certificate. Precise GHG accounting within defined boundaries ensures that emissions are accurately measured, reported, and subsequently claimed by the buyer. In this context, RMI's Steel GHG Emissions Reporting Guidance (the "Guidance")[109], as well as the ResponsibleSteel International Standard (the "Standard")[110] can be considered in tandem as a reference for the steel industry. The development of both the Guidance and the Standard benefited from a comprehensive public consultation process involving key industry stakeholders, including manufacturers, environmental groups, and regulatory bodies. This inclusive approach ensured that the guidance was both practical and robust, addressing the specific needs

107 *SAFc Registry Guide.*

108 Lachlan Wright, Xiyuan Liu, Iris Wu, and Sravan Chalasani, *Steel GHG Emissions Reporting Guidance* (Basalt: Rocky Mountain Institute, June 2023), https://rmi.org/wp-content/uploads/2022/09/steel_emissions_reporting_guidance.pdf.

109 Wright, Liu, Wu, and Chalasani, *Steel GHG Emissions Reporting Guidance.*

110 *ResponsibleSteel International Standard: Version 2.0* (London: ResponsibleSteel, September 2022), https://assets-global.website-files.com/6538e481169ed7220c330f0a/66034300556ac7c2610cd8d0_ResponsibleSteel-Standard-2.0.pdf.

and challenges of the steel industry while aligning with global best practices for GHG accounting.

The Guidance suggests the adoption of a fixed system boundary in GHG accounting within the steel industry. This methodology mandates a cradle-to-gate assessment, which means the inclusion of all process steps from iron and coal mining to crude steel product (whether hot rolled or casted) in total emissions reporting, regardless of the steel companies' ownership structures (see Figure 6). Such an approach mitigates inconsistencies arising from the differential reporting of emissions-intensive processes like sintering and coke production. In vertically integrated operations, these processes are typically accounted for as Scope 1 emissions under the GHG Protocol, directly reflecting the company's operational control.

Conversely, for non-integrated steelmakers, emissions from the same processes might be classified as Scope 3, often leading to underreported emissions due to differing reporting standards and practices. Furthermore, as the industry evolves, particularly with the increasing adoption of DRI and shifts towards hydrogen-based steelmaking, the distinctions between Scopes 1, 2, and 3 emissions are expected to become more fluid, potentially complicating comparability across the sector. The fixed boundary system thus ensures a uniform framework for emissions reporting, enhancing both transparency and the ability to gauge progress towards decarbonization effectively.

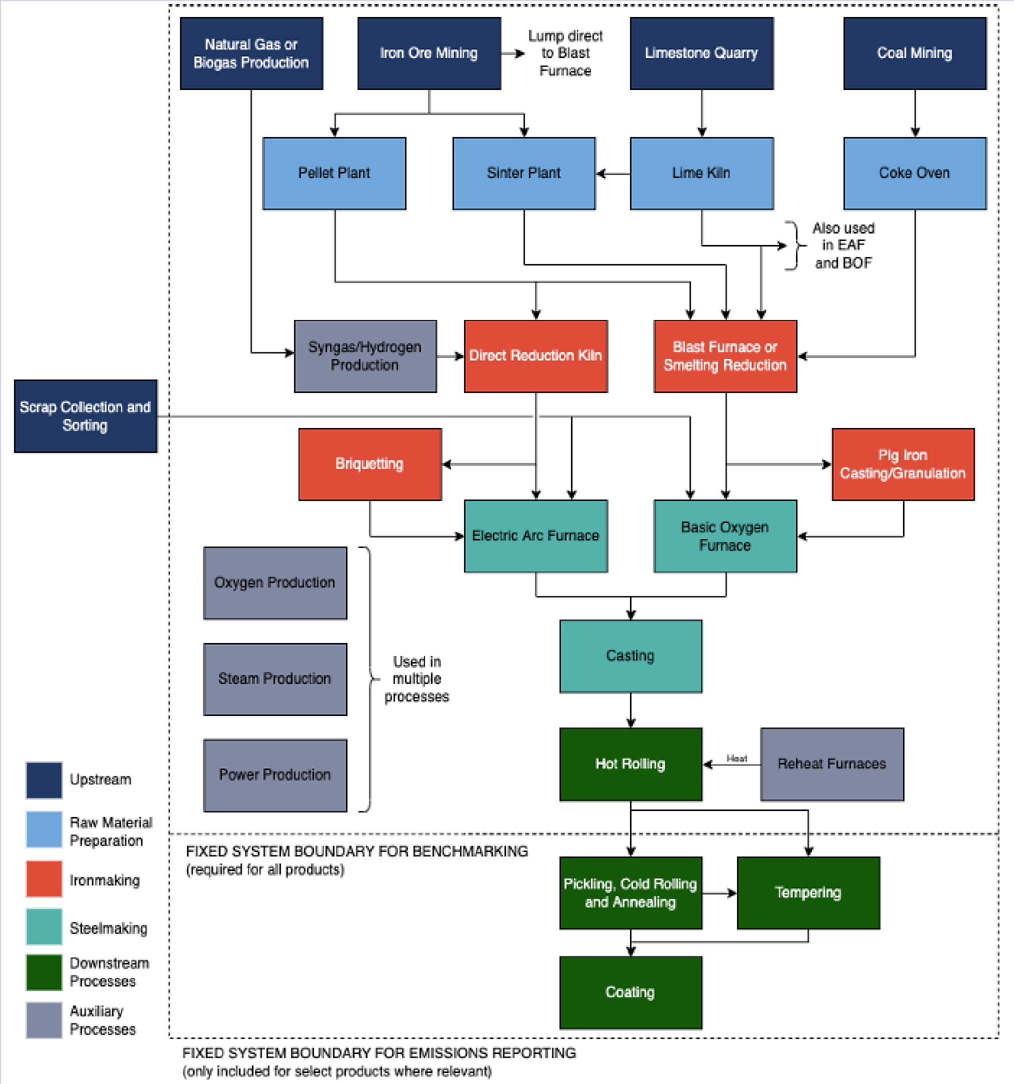


Figure 6: Fixed system boundaries for steel products

Source: RMI. Steel GHG Emissions Reporting Guidance

On the other hand, in Criterion 10.4, the Standard provides a broader and third-party verified guideline to determine site-level GHG emissions for the purpose of reporting the GHG emissions intensity for the production of crude steel. According to the Standard, the scope boundaries for determining GHG emissions during crude steel production encompass Scope 1, Scope 2 and Scope 3 emissions. The endpoint of the scope boundary for the determination of the total GHG emissions related to crude steel production is defined as the point where crude steel is initially produced, excluding any emissions from further processing like hot rolling or coating. Additionally, the data used to calculate the greenhouse gas emissions intensity for crude steel production, as outlined in Criterion 10.4, has been independently checked and confirmed to meet the standards of ISO 14064-3:2019.

For steel products, co-products, and by-products exported from the site, the scope boundary for carbon footprint calculation aligns with relevant international or regional standards, and it may differ from the boundary used for assessing the site's crude steel emissions intensity.[111]

Moreover, when implementing decarbonization technologies that entail the use of renewable energy electricity, it is important to consider addressing temporal differences in measuring the carbon intensity of renewable electricity supplies—distinguishing between annual and hourly averages—which presents a significant challenge for accurately assessing the overall carbon footprint of steel production. The fluctuating nature of renewable energy sources, such as wind and solar power, means that the carbon intensity of the electricity grid can vary considerably throughout the day and year. Relying solely on annual average figures may obscure these variations, leading to potential inaccuracies in the GHG accounting of steel manufacturing processes that are increasingly reliant on renewable electricity. Recognizing and accounting for these temporal differences is something to be eventually considered in the future when assessing Scope 2 emissions of "green" steel production and thus measure its carbon footprint accurately. Incorporating hourly average calculations could potentially allow companies to achieve a more precise understanding of their emissions, especially during production peaks and troughs, thus facilitating more informed decisions regarding energy sourcing and consumption.[112] However, since there is ongoing academic debate regarding whether hourly matching or time-of-use pricing represents the optimal path forward, this should be a point of future research and something steel producers should bear in mind when accounting for their Scope 2 emissions and issuing emissions intensity of their "green" products within the discussed boundaries.

4. Decarbonization Strategy

The structure, contents, chain of custody, and GHG accounting method of this certificate and market-based mechanism should be linked to the company's comprehensive and coherent decarbonization strategy and transition plan. It is essential that the revenue resulting from these certificates is invested in technologies that genuinely contribute to the reduction of carbon emissions in a cost-effective and proven manner. Without this alignment, companies might allocate funds from the sale of these certificates towards projects that ultimately aim to prolong the lifetime of high-emitting conventional technologies, such as the implementation of an excessively large CCS system, rather than exploring technologies that are aimed are phasing out conventional BF-BOF technologies and striving for more sustainable options within EAF alternatives. Such an approach to decarbonization, driven by the potential for misaligned incentives rather than effectiveness and efficiency towards decarbonization, undermines the primary goal of these mechanisms and risks diverting valuable resources away from more impactful decarbonization initiatives.

To safeguard against the financing of suboptimal decarbonization strategies, it is crucial for companies to transparently communicate to consumers and investors that their use of market mechanisms is part of a rigorous corporate transition plan. This plan should articulate clear, measurable goals and outline the strategic deployment of technologies and practices that are recognized for their efficacy in reducing GHG emissions. By ensuring transparency and accountability in how the proceeds from certificate sales are used, companies can reinforce the confidence and credibility of these types of mechanisms and enhance their reputation as contributing to industrial decarbonization. This approach ensures that market mechanisms serve their intended purpose of fostering genuine and effective decarbonization efforts within the industry.

It is important to disclose this information on the certificate element of this market mechanism to enhance transparency and accountability. Such disclosure is consistent with

111 *ResponsibleSteel International Standard: Version 2.0.*

112 Gregory J. Miller, Kevin Novan, and Alan Jenn, "Hourly Accounting of Carbon Emissions from Electricity Consumption," *Environmental Research Letters* 17, no. 4 (2022), https://www.researchgate.net/publication/359490448_Hourly_accounting_of_carbon_emissions_from_electricity_consumption.

evolving regulation requirements in different jurisdictions, including the European Union's Corporate Sustainability Reporting Directive (CSRD)[113] as well as the California legislative landscape that includes the Climate Corporate Data Accountability Act, the Climate-related Financial Risk Act, and the Voluntary Carbon Market Disclosure Act[114] that require businesses to disclose information on the corporate decarbonization strategy. Having this information in the certificate will allow both the buyer and the Registry (see more in section F) to verify the additionality of the mechanism. Moreover, the decarbonization strategy disclosed herein should align with at least one sectoral decarbonization pathway to ensure that producers' efforts are not just compliant with current and evolving regulations but are also heading towards benchmarked decarbonization goals.

B. A Virtual Offtake Agreement

Our GSC offers an improved approach over similar certifications found in the steel industry and elsewhere, yet it alone does not fully ensure additionality in emissions reductions that decarbonization projects need to achieve. Integrating this certificate into a long-term offtake agreement will tie this standalone certificate to the underlying decarbonization project and will offer a long-term commitment from the buyer to purchase the environmental attributes of the "near zero emissions" or "green" steel, ensuring cashflow certainty associated with the "green premium" for the producer. This provides the structural enhancement needed to eliminate the risk of lack of additionality of unbundled mechanisms.

1. Definition and Precedent

Offtake agreements are legally binding contracts where a buyer commits to buy a significant portion, if not all, of a producer's future production over several years. This type of deal is negotiated and entered into before the project is operational, effectively securing a steady revenue stream for the project ahead of time. It is a mutually beneficial arrangement as the supplier gets a guaranteed income, making it easier to get non-dilutive financing (without giving up equity), while the buyer locks in a long-term supply, usually at a fixed price, hedging the uncertainties of future pricing of the commodity. These agreements are especially useful for smoothing out the financial viability of a project, reducing the risk for lenders, and making it easier to secure project finance, as they substantiate the financial forecasts that lenders rely upon to assess the feasibility of a facility still in the planning stages and not yet producing cash flow.

For emerging decarbonization technologies, securing offtake agreements is often a critical step toward obtaining project financing and ensuring long-term viability. Demonstrating existing demand for the output of a novel technology can open doors to non-dilutive capital, which is crucial for the development phase. Additionally, a company that showcases a successful project track record effectively reduces its risk profile, enhancing its appeal to potential investors.[115] This dynamic has proven effective for offtake agreements in the electricity industry through PPAs, which have been commonly used in the market for decades. These agreements are gaining growing traction within the renewable energy sector, with 36 GW of the over 220 GW of operational renewable energy capacity in the United States being transacted through PPAs by the end of 2022.[116]

In more recent developments, the renewable electricity sector has seen the advent of a novel form of PPA known as Virtual Power Purchase Agreement (VPPA). A VPPA is a financial contract. Unlike PPAs, it does not involve the physical transfer of electricity but rather the exchange of environmental attributes of the electricity generated and financial payments based on the market price of electricity. The design of a VPPA involves a buyer nominally buying the electricity for a fixed price but not receiving it physically, instead obtaining a REC that accounts for the environmental attributes of that electricity. The seller sells the electricity generated at the current market price into a wholesale market. The difference between these prices is settled through a financial mechanism explained in

113 European Parliament and Council of the European Union, Directive 2022/2464 Amending Regulation (EU) No 537/2014, Directive 2004/109/EC, Directive 2006/43/EC and Directive 2013/34/EU, as Regards to Corporate Sustainability Reporting, December 14, 2022, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32022L2464.

114 State Government of California, Climate Corporate Data Accountability Act, SB-253, October 7, 2023, https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=202320240SB253; State Government of California, Greenhouse Gases: Climate-Related Financial Risk, SB-261, October 7, 2023, https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=202320240SB261, State Government of California, Voluntary Carbon Market Disclosures, AB-1305, October 7, 2023, https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=202320240AB1305.

115 Kobi Weinberg, *Everything You Need to Know About Offtake Agreements: A Tool for Early-stage Climate Technology Infrastructure Projects* (New York: CREO, October 2023), https://www.creosyndicate.org/store/an-introduction-to-climate-offtake-agreements.

116 *Clean Energy Powers American Business* (Washington D.C.: American Clean Power Association, 2022), https://cleanpower.org/clean-energy-powers-american-business/.

section IV.B.4 below. Because the VPPA is purely financial, the buyer still needs to meet its electricity load by buying it from its usual utility at the retail level.

The uptake of VPPAs has been noteworthy in the last few years. One key reason both PPA types have been successful is because they allow corporate buyers to demonstrate a direct link between their actions and new renewable energy-generating capacity. When buyers sign long-term contracts guaranteeing the price for renewable electricity, they act as "guaranteed off-takers," an essential element to enable financing for new renewable energy projects, which provides the scheme with the additionality that certificates alone, such as RECs, GOs, and even mass balance certificates used in the steel industry lack.[117]

2. General Structure

Considering the precedent, the second element of our proposed market mechanism is a Virtual Offtake Agreement for Steel (VOAS). This agreement should take the form of a legally binding financial contract between a steel producer and a buyer. Notably, it does not involve the physical delivery of steel. Instead, it facilitates the exchange of the GSC for financial payments based on a mutually agreed strike price aiming at covering the green premium.

For steel producers, the VOAS guarantees having a buyer for the green premium for their "low-carbon," "near-zero emissions," or "green" steel products. This allows the producer to sell the "green" steel products at a conventional steel price, securing the physical offtake of the "green" product from its current buyers. This, in turn, makes it easier to secure financing for projects aimed at decarbonizing their production processes. On the other hand, buyers benefit from the VOAS as it allows them to support the steel industry's shift towards decarbonization, provides a mechanism to hedge against fluctuations in future steel prices, and allows them to achieve Scope 3 emission reductions in a manner that is both transparent and accountable.

117 Rachit Kansal, *Introduction to the Virtual Power Purchase Agreement* (Basalt: Rocky Mountain Institute, November 2018), https://rmi.org/insight/virtual-power-purchase-agreement/.

The following are the main elements of a VOAS:

Table 2: Elements of a VOAS

Element	Considerations
Parties	• **Steel Producer:** Develops and implements decarbonization technologies for steel production that result in steel production that can account for a verifiable reduction in GHG emissions. • **Buyer (Offtaker):** A company within the steel value chain looking to reduce its carbon footprint.
Main Obligations	The green steel supplier sells the buyer the exclusive right to claim all Scope 3 reductions, including all of the rights to make claims under any legal programs related to GHG emissions reduction and supply chain emissions reduction related to the steel produced under the virtual offtake. The buyer agrees to make payments according to the price settlement mechanism agreed upon in the agreement.
Term	The VOAS should have a duration of five to ten years and be designed to outlast the term of the loan needed to build the project, ensuring stable cash flows. More detailed considerations on the term of the agreement in section 3 below.
Price and financial settlement	The buyer agrees to pay the steel producer a fixed price for the "green" steel generated. The actual steel is sold by the producer locally at the steel market price. Financial settlements between the parties are based on the difference between the market price of steel and the fixed price agreed in the VOA. If the market price is higher than the fixed price, the producer pays the buyer the difference, effectively giving the buyer a financial credit. If the market price is lower, the buyer pays the producer the difference, ensuring the developer receives a predictable income. More detailed considerations on the pricing settlement of the agreement in section 4 below.
Green Steel Certificates	Bundled with the agreement, the buyer should receive GSCs from the producer, which can be used to claim and report Scope 3 emissions reductions according to international standards (i.e. The Greenhouse Gas Protocol) and following the Registry protocols. The GSCs also represent proof that steel was produced within a facility that is currently producing "green" steel according to widely accepted international standards and thresholds.
Risk Management and Allocation	The VOAS should include provisions for managing risks such as electricity price volatility, non-delivery risk, project performance, changes in law and scale risk. Risk management strategies might include price floors, caps, and other financial hedging instruments.
Timing	For the producer, it is essential to enter into the VOAS before seeking a loan or any other type of project financing. The ideal time for this varies based on the company's technology-level readiness. Sometimes, companies commit to these agreements prematurely, settling for less than what is necessary for success due to the novelty of their projects. Delaying the VOAS can lead to better pricing, but waiting too long may hinder the ability to secure non-equity financing. Industry practice suggests negotiating the VOAS 6-18 months in advance and finalizing them 3-15 months before needing the loan, although terms can be adjusted closer to loan finalization. The overall process, from agreeing on offtake to financing, can span from 9 to 33 months depending on project scale and technology readiness.[118]

Source: Prepared by the authors

118 Weinberg, *Everything You Need to Know About Offtake Agreements.*

Both the contract and the certification are complementary elements of our proposed market mechanism; the contract outlines the parties' obligations of the virtual transaction, including the price of the whole mechanism, while the certificate independently verifies that the product meets specific green criteria. This dual approach ensures robustness, additionality, accountability, and credibility in emissions reductions, while fostering trust in the effectiveness of the mechanism among consumers, investors, and stakeholders.

3. Term

The term of the VOAS is crucial to ensuring the additionality of this market mechanism. We recommend that the VOAS be structured to have a term of 5 to 10 years, following the success of other virtual offtake agreements, such as VPPAs, which typically extend through a similar period of time. The long-term structure provides mutual benefits. For steel producers, it secures upfront capital to implement a new decarbonization technology (either retrofitting an existing facility or constructing a new one) by ensuring a continuous revenue stream. From the perspective of corporate buyers, it serves as a hedge against the potential volatility of steel prices, providing budget certainty, financial stability, and more accurate forecasting of steel costs along their supply chain.

The strategic structuring of a long-term VOAS also instills confidence in the market, sending a strong signal about growing demand for "green" products in the industry. This support is critical in contributing to additionality, as it fosters further investments and development of new decarbonization projects in the steel industry rooted in the assurance of a continuous revenue stream over a decade or more. The financial certainty provided by these long-term agreements generates a cycle of investment and development that demonstrates to financiers and stakeholders the economic feasibility of decarbonization projects; it also underpins the financial models that justify the initial capital investment into the steel transformation process. This way, a long-term VOAS enables steel producers to make the substantial upfront investments required to bring these decarbonization projects to fruition, accelerating the deployment of decarbonization technologies in the steel industry and other heavy industry sectors.

4. Pricing

The price settlement mechanism within a VOAS represents a critical element, orchestrating the financial interactions between the steel producer and the corporate buyer. This process is chiefly facilitated through a financial instrument known as a Contract for Differences (CfD), which plays a pivotal role in managing the agreement's fixed price, also referred to as the strike price—a pre-agreed fixed price for steel procurement within the VOAS framework.

A Contract for Differences, in essence, is a financial arrangement designed to compensate for the difference between the prevailing market price of steel and the VOAS's predetermined strike price. The direction of this financial exchange is contingent upon the relative position of the market price to the strike price at the time of settlement. This mechanism ensures that if market prices surpass the strike price, developers are obliged to pay the difference to the buyers, thereby offsetting the buyers' expenditure for procuring steel at rates higher than the market price. Conversely, should the market price fall below the strike price, buyers are required to compensate producers, guaranteeing them a stable revenue reflective of the agreed strike price and safeguarding their financial interests against market price reductions.

Negotiating the strike price itself is a critical process and should be done at the outset of the VOAS, aiming to establish a value that is equitable for both parties involved. This negotiation should consider two important aspects. Firstly, it should consider the incremental cost implications of implementing decarbonization technologies (as compared to using conventional technologies) and the purchasing entity's budgetary constraints, setting a price per ton of steel that the buyer commits to pay irrespective of fluctuating market prices. Secondly, as financial settlements are done by comparing the contract's strike price with the market price, it is crucial to include the specific steel market price in the contract. Currently, steel spot prices and indexes vary widely across different types of steel, different forms of steel products, and different geographical markets.[119] Therefore, during contract negotiations, it is essential for the parties to agree on and specify the exact steel market price that will serve as the reference price thereof.

119 "Weekly Steel Prices," SteelOrbis, 2024, https://www.steelorbis.com/steel-prices/weekly-steel-prices/.

The CfD price settling mechanism also serves as a crucial risk management tool. By offering protection against the volatility of energy market prices, it provides a buffer for producers against the potential financial instability caused by low market prices and shields buyers from the unpredictability of high market costs. Furthermore, this mechanism fosters the promotion of decarbonization technologies in the steel industry by ensuring a fixed income for producers, thereby encouraging new investment in and deployment of these technologies and thus fostering additionality. It is important to bear in mind that accurate forecasting and financial modeling are essential to determine a feasible strike price for the project that also provides value to the buyer.

C. A Reliable Registry

So far, the design of a bundled GSC integrated with a VOAS enhances the mechanism's robustness and addresses the lack of additionality risk. The third element of the proposed market mechanism is a reliable registry. The creation of a robust and reliable registry that tracks and oversees this market mechanism through all steps and elements of its formation is crucial for providing transparency and reliability of this structure, which spurs credibility and adoption.

A reliable registry in this context is one managed by an independent third party. This structure is vital for ensuring the integrity and credibility of the certification process. In the steel industry, the current practice involves the sale of a variant of mass balance certificates as spot transactions directly between the steel producer and the certificate buyer. The absence of an independent body to oversee these transactions compromises the certificates' credibility and undermines overall market transparency.

Two different elements must be verified in our proposed market mechanism–the GHG emissions intensity verification followed by the book and claim phase. For the verification process of these two phases, the ideal scenario would include two different verification bodies for each phase, thereby following the successful SAF certificate model.[120] Nonetheless, as mentioned throughout this paper, the current lack of harmonized and widely accepted standards for what constitutes "low-carbon" and "green" steel translates into the fact that, currently, there is no independent body that can accurately (and in a globally accepted manner) perform the verification of the GHG emissions intensity to certify that this process actually resulted in the emissions reductions material enough to allocate to specific products in a given facility, making the steel products "greener." Since setting up an independent, robust registry to verify the process is already a challenge itself, we propose that efforts be concentrated in this regard and assign the Registry the task of verifying the accuracy of emissions reductions and their allocation in the mass balance process.

120 Reference Section II-E for further details.

Box 2: EPD Standardization and Registry as GHG Emissions Intensity Verification

On Feb. 15, 2024, the EPA announced that it had issued a Notice of Availability to seek public input on the Agency's Draft Label Program Approach, through which the EPA proposes to standardize and improve the quality of data used in Environmental Product Declarations (EPDs), which disclose key environmental impacts of a product's lifecycle. It also proposes a process to use data from EPDs and other sources to set thresholds for the amount of embodied carbon a product can have related to similar products to qualify for the label. The final phase of the draft approach is for the program to certify materials and products and to create a central registry of certified products. Moreover, On March 5, EPA published a Notice of Availability to seek public input on draft Criteria for Product Category Rules (PCRs) to support the Label Program for Low Embodied Carbon Construction Materials through a 30-day comment period.[121]

Current EPDs lack the necessary robustness to certify the "greenness" of products and materials.[122] Therefore, these draft regulations by the EPA for a Label Program Approach for low embodied carbon construction materials and Criteria for PCRs to support the Label Program would represent a valuable step toward having robust EPDs that could serve as the verification system for the GHG emissions intensity of our proposed market mechanism, especially considering that the EPA is proposing to create a central registry of certified products, who could act as the third-party verification body that our market mechanism's Registry would need. However, in order for this to be successful, specific PCRs for this category of "green" steel products would need to be clearly codified.

121 "Label Program for Low Embodied Carbon Construction Materials," United States Environmental Protection Agency, March 28, 2024, https://www.epa.gov/greenerproducts/label-program-low-embodied-carbon-construction-materials.
122 Biberman, Toledano, and Zhou, *GHG Accounting for Low-Emissions Branded Steel and Aluminum Products.*

Subsequently, the Registry should also be in charge of guaranteeing the transparency and traceability of the GSC once it is issued and transferred through the book and claim system. This should be done by assigning a unique tracking number to the GSC. Ideally, these two different verification phases should be performed by differentiated divisions of the Registry to avoid any possible conflict of interest. By involving an impartial third party to verify all the elements of this market mechanism, stakeholders can be assured of their authenticity and accuracy, thereby boosting confidence in the sustainability claims made by steel producers.

There are emerging discussions among various stakeholders of the steel industry about enhancing the transparency and traceability of the current mass balance certificates used in the steel industry. The current practice of on-the-spot transactions and individual company-based accounting for certificates has sparked interest in exploring the creation of an independent third-party organization to oversee certificate trading. This shows that there is already appetite in the industry to avoid issues related to double counting and issuance, thus lending even more credibility to the system. Therefore, the idea of having an independent organization manage the registry, akin to practices in bioplastics or biogas markets, is being explored for its potential to reinforce credibility beyond government-operated registries.[123]

Moreover, as a third-party verification entity, the registry should always monitor "double accounting." For companies benefiting from a green premium, whether from government subsidies or other sources, there should be a clear disclosure of these external funding incentives. This ensures that companies do not gain disproportionate benefits by aligning with the principle that if they receive subsidies or financial aid to offset the green premium, the value obtained from certificate schemes should exclude the green premium. This approach also aims to prevent an unjust increase in input costs for the consuming industry, ensuring adjustments are made accordingly. The inclusion of this information in the certificate should be verified by the Registry to transparently manage the benefits and ensure that the pursuit of sustainability targets is conducted in an equitable and accountable manner.

123 Interview with expert at Arcelor Mittal, February 2024.

Finally, this registry should require rigorous retirement processes. These registry processes are essential in preventing fraud and ensuring that claims about renewable energy are both credible and reliable. The implementation of these registries, coupled with the requirement for the electronic retirement of certificates, significantly boosts market transparency. This transparency, in turn, will instill confidence among consumers, investors, and regulators in the authenticity of the proposed market mechanism.

D. The Role of a Secondary Market

The establishment of a secondary market for this market mechanism has the potential to increase market liquidity. Such a market would facilitate the trading of these certificates and enhance the accessibility and affordability of green investments, thereby attracting a broader range of investors and capital. This has proven to be an attractive feature of secondary markets in the electricity industry.[124] Secondary markets can also help mitigate the scale risk when a buyer doesn't have the capacity to virtually consume the procured green steel production through the VOAS. Engaging with financial institutions to explore the creation of a secondary market could be a useful step toward mobilizing additional financial resources for climate action and decarbonization initiatives in heavy industry.

However, the development of a secondary market for environmental certificates is accompanied by a set of challenges, particularly concerning the integrity and credibility of the certificates being traded. The main concern is that increased trading and liquidity might lead to the environmental or sustainability claims associated with certificates becoming diluted or disconnected from their original purpose. This risk is particularly acute if certificates are traded multiple times, potentially leading to double counting of environmental benefits or the support of projects with less stringent sustainability criteria, as well as the fact that trading unused certificates on the secondary market does not impact the project's capacity to generate capital because such secondary transactions are separate from the project developer.

These risks could be potentially mitigated by implementing strict regulatory measures and validity timeframes for certificates. For example, SAF certificates have a two-year validity timeframe, which helps to ensure that the environmental benefits they represent are timely and relevant[125]. This stringent validity timeframe could prevent the accumulation of outdated certificates in the market, thereby maintaining their value and credibility. Additionally, robust tracking and verification mechanisms could be implemented to ensure that each certificate accurately reflects the environmental benefits it claims to represent and that these benefits are not counted more than once.

Moreover, establishing the price for a GSC in a spot market presents a significant challenge. This difficulty arises because the primary market pricing of the GSC, as proposed in our market mechanism, is completely dependent on the VOAS and the CfD pricing mechanism within the agreement. Detaching the certificate from the VOAS complicates matters, as the price of the standalone GSC, when considered independently, would need to be determined by the supply and demand dynamics of a spot market, which currently does not exist. Setting its price becomes problematic without an existing index price for an Green Steel Certificate (GSC) alone. To overcome this, introducing a clearing house to act as a neutral third-party mediator between buyers and sellers would be necessary, ensuring the establishment of the standalone certificate's price is transparent and fair. However, this would entail (i) a market maturity that is lacking today and (ii) administrative and logistic burdens that are not easily resolvable.[126]

124 Interview with expert at RMI Aviation, February 2024.

125 Interview with expert at RMI Aviation, February 2024.
126 Interview with expert at CREO, March 2024.

E. Summary Timeline Table

Table 3: Market Mechanism Timeline

#	Step	Considerations
1	The steel producer begins the development of the project that entails the implementation of steel production through EAF.	Consider at this phase recommendations in sections IV-A-4 and IV-A-1, notably: • The intended project should be aligned with the company's overarching decarbonization strategy (which in turn should be guided by a sectoral decarbonization pathway). • The GHG emissions accounting boundaries and standards should be clear at this point.
2	The buyer and the steel producer sign the VOAS, which defines all the terms and conditions of the long-term relationship and the transfer of GSCs.	Consider, at this phase, recommendations in section IV-E to structure a VOAS that has a minimum term of 5 years and a clear price settlement mechanism.
3	The steel producer obtains financing and begins construction of the project.	The VOAS will serve as a project finance instrument for the steel producer to raise non-dilutive project funding, as it will demonstrate to lenders that there is actual demand for the technology output.
4	Once the project is operational, the steel producer sells the steel from the EAF facility to a steel buyer in their area at whatever the index steel price is at the time, depending on the type of steel produced and the geographical market.	Considering that this is a virtual offtake, the buyer, who cannot access the physical steel coming from this specific facility due to supply chain difficulties, will not receive the physical steel resulting from the implementation of this decarbonization project. A steel consumer in the local geographical market will receive the physical delivery of the steel without being able to claim the Scope 3 reductions derived from it.
5	At the end of the settlement period, the steel market price vs. the fixed VOAS price will be calculated, and the steel producer or the buyer will pay the difference, depending on whether it was higher or lower than the VOAS price.	At this phase, consider the recommendations in section IV-B-4 regarding the importance of agreeing on a specific steel index and including it in the VOAS during the agreement's negotiation phase. Several different steel price indexes depend on the steel type, quality, and geographical market.
6	The steel producer calculates GHG emissions intensity and sends for third-party verification to ensure it complies with internationally accepted thresholds or standards.	It is crucial that this process is made with the recommendations set in section IV-A-3 regarding system boundaries and is also verified by a third party.
7	The steel producer issues one GSC for every ton of steel actually produced from the facilities where the emissions reductions were achieved and verified. The GSC will be immediately transferred to the buyer.	The GSC can only be transferred to the buyer when the steel has been actually produced by the new facility.
8	The buyer can immediately use the GSC to claim the equivalent amount of Scope 3 emissions reductions.	The Registry should oversee the whole process and ensure that the GSC is retired once the buyer has claimed it.

Source: Prepared by the authors

IV. Challenges of this Market Mechanism Structure

This paper proposes a market-based mechanism designed to stimulate investment in decarbonization technologies within heavy industries from the supply side, with the overarching goal of spurring and generating sufficient demand for the creation of a climate-differentiated market. This market would predominantly feature near-zero emission products and materials from heavy industries, aligning with broader sustainability objectives and decarbonization strategies. The outlined approach aims to bridge the gap between the current market supply and the increasing demand for industrial products and materials, ensuring the most additional reduction of GHG emissions. However, it is important to acknowledge that the framework we are suggesting is not devoid of challenges. The following hurdles are critical factors that must be navigated to ensure successful implementation and uptake of this proposed mechanism.

A. Regulatory Uncertainty

As previously highlighted, one of the pivotal challenges in promoting decarbonization within the heavy industry lies in the lack of standardization of terms such as "low-carbon" and "green" steel. The heavy industry is currently facing a barrage of proposals for definitions, leading to confusion and a lack of transparency regarding the actual GHG emissions reductions achieved. This ambiguity extends into the policymaking and regulatory realm, where the absence of clear and consistent regulation by governments exacerbates the difficulty of confidently deploying market mechanisms aimed at reducing emissions. The proliferation of multiple, sometimes conflicting, definitions hampers the ability to effectively communicate and quantify the environmental benefits of low-carbon products and undermines efforts to foster a transparent and trustworthy market for sustainable industrial materials.

This challenge is further compounded by geographical uncertainty. The global nature of heavy industry supply chains, which span countries with varying degrees of regulatory frameworks — from proposed to non-existent — adds layers of complexity to the consistent implementation of any kind of market mechanism. The disparate regulatory landscapes not only pose international trade challenges but also hinder the global adoption of standardized GHG emissions definitions, thresholds, and reporting methodologies. Without a harmonized approach to regulation across jurisdictions, it is nearly impossible to ensure that a market mechanism, such as the one proposed, could be uniformly applied. It is necessary to establish clear, standardized environmental metrics as a foundational step towards global implementation.

Moreover, regulatory uncertainty manifests as temporal uncertainty, highlighting the risks associated with long-term commitments in an evolving regulatory environment. For instance, if a producer enters into a 15-year offtake agreement, there is no guarantee that the regulatory definitions of acceptable environmental certifications will remain unchanged over that period. This uncertainty can undermine the value of such agreements, as final consumers seek assurance that the environmental attributes for which they are paying indeed correspond to green, rather than "brown," steel that may exploit loopholes in definitions. While existing regulations such as the EU taxonomy represent steps in the right direction by defining emissions intensity thresholds for green (i.e., taxonomy-aligned) economic activities, the current global landscape is characterized by a lack of globally agreed standardized regulation around acceptable emissions thresholds and GHG accounting methods, which also differ significantly in their system boundaries.[127] This unharmonized proliferation of regulations and methodologies fosters insufficient confidence in the market for these types of certifications. Consumers and producers alike are left navigating a landscape where long-term commitments may not align with future regulatory standards, underscoring the urgent need for regulatory clarity to build trust and facilitate the transition towards sustainable industrial practices.

B. Accumulating Certificates

Navigating the intricate road to reach a final Green Steel Certificate is challenging in situations where steel production processes are not integrated. This results in multiple certificates as each step is represented by one towards low emissions, resulting in an accumulation of administrative steps that overloads producers with additional administrative, financial, and logistical burdens. When it

127 John Biberman, Perrine Toledano, Baihui Lei, Max Lulavy, and Rohini Ram Mohan, *Conflicts Between GHG Accounting Methodologies in the Steel Industry* (New York: Columbia Center on Sustainable Investment, December 2022), https://ccsi.columbia.edu/sites/default/files/content/docs/publications/ccsi-comet-conflicts-ghg-accounting-steel-industry.pdf.

comes to validating the environmental credentials of steel, this chain of market mechanisms requires harmonization, especially considering that the steel certificate must be in line with the criteria set for green hydrogen certificates. Nevertheless, global variation in regulations on green hydrogen certificates poses another challenge as they must also meet standards for renewable energy certificates. Additionally, these requirements often lay one atop another and produce a maze-like regulatory environment that frustrates a smooth emission steel production.

Addressing this challenge necessitates a holistic approach wherein steel manufacturers might consider taking control of the entire production process. By producing the necessary inputs themselves—specifically, generating the renewable energy required for green hydrogen production and subsequently using this green hydrogen in DRI plants—manufacturers can ensure a more seamless and integrated path to achieving low emissions certification. This strategy not only simplifies the certification process by reducing dependence on external certificates but also aligns with the overarching goal of streamlining criteria across different stages of production. By taking ownership of the entire chain, from renewable energy generation to steel manufacturing, companies can mitigate the complexities associated with accumulating certificates by facilitating an efficient route to sustainable steel production.

C. Low Acceptance and Credibility

The credibility and acceptance of environmental certificates, such as EACs, have generally been low due to the various issues these certificates have encountered in the past, as detailed in this paper. Consequently, there is a risk that similar certificates, including the Green Steel Certificate, might also be viewed skeptically as mere offsets. This perception could potentially foster doubts among buyers and other key stakeholders such as financial institutions.

This skepticism is exacerbated if we consider that there is also technological heterogeneity in the steel industry, where there are varied starting points from which different producers embark on the journey of decarbonization and market creation.[128] For instance, companies such as ArcelorMittal have already developed and implemented some form of certificates,129 distinguishing them from firms that have yet to adopt such measures. This variation in technological and operational starting points could result in uneven progress across the industry when implementing this proposed new market mechanism. Certain players may be able to leverage advanced decarbonization strategies and market mechanisms, while smaller firms face the dual challenge of catching up with industry technology advancements while also navigating the implementation of new market mechanisms, lowering the mechanism's acceptance rate.

Our proposed mechanism aims to directly tackle the credibility issue by introducing a more transparent and accountable framework than traditional environmental certificates such as EACs, thereby garnering broader additionality. However, the lack of acceptance and consensus within the industry itself presents a remarkable obstacle. Reaching an industry-wide agreement on the validity and effectiveness of certificates, as well as their design features contributing to this validity and effectiveness is crucial for moving forward. Without a unified stance, efforts to implement new mechanisms risk being fragmented or outright rejected. Therefore, addressing the challenge of low acceptance and credibility not only involves improving the certification system itself but also building a consensus within the industry. This requires engaging with all stakeholders to develop a certification mechanism that is both rigorous in its environmental standards and flexible enough to be broadly accepted. Only through such collaborative efforts can we aim at the wide acceptance of this market mechanism in a way that ensures an uptake significant enough to achieve the overarching goal of creating a robust climate-differentiated market for "green" products in the heavy industry.

Adding to this is the frequent confusion between these mechanisms and carbon offsets. This confusion is not limited to industry stakeholders but is also evident in regulatory frameworks, further compounding the issue. The conflation of direct emissions reduction strategies, such as those aimed at producing green steel, with carbon offsetting—where emissions are compensated for through external projects rather than reduced at the source—muddles each approach's understanding and perceived effectiveness. This misunderstanding can lead to skepticism about the actual environmental benefits of this mechanism, as stakeholders may perceive them as indirect or less impactful measures. The mischaracterization of these mechanisms as offsets dilutes their credibility and

128 *The Heterogeneity of Steel Decarbonisation Pathways* (Paris: OECD Publishing, 2023), https://doi.org/10.1787/fab00709-en.

129 Interview with expert at Arcelor Mittal, February 2024.

undermines efforts to establish them as legitimate tools for decarbonization. To overcome this barrier, regulatory clarity to differentiate these concepts will be crucial in building trust and acceptance for these mechanisms designed to drive the steel industry's decarbonization.

D. Potential Lack of Financing

Given the intricacies of the proposed market mechanism, financial institutions could face significant challenges in providing financing. Without a comprehensive understanding of the project dimensions and potential impacts, banks and investors are hesitant to commit substantial funds. Particularly, the uncertainty surrounding the emergence of new buyers and the expansion of demand poses another formidable challenge. By relying on a virtual offtake agreement, the proposed mechanism assumes that there will be a guaranteed physical off-take for the current steel demand. This is because the green premium is absorbed by the buyer of the mechanism through the virtual offtake, thereby allowing the physical off taker to buy the "green" steel at conventional prices. While this might be an accurate assumption, the proposed mechanism would fall short on guaranteeing additional demand on top of a business-as-usual situation. Being able to evidence market growth or new demand attraction is a critical factor for financial institutions to step in and provide finance for a new green steel facility. Banks require secure and tangible growth projections to justify investments, and merely maintaining the status quo with conventional demand offers little assurance of the financial viability or the potential for market expansion that lenders seek. This uncertainty makes it difficult for financial institutions to provide funding through this mechanism, limiting the reach and effectiveness of environmental initiatives in high-impact sectors like steel production.[130] A possible solution to address this challenge is to have producers secure both the physical offtake of steel production from the new facility and the virtual offtake (through this market mechanism) to absorb the green premium hedging against the market volatility risk.

Moreover, as evidenced in section IV above, the DRI-EAF green premium remains too high for both market acceptance and bank financing. It means that government subsidy is still required at the current level of maturity of DRI-EAF before a market mechanism can be enough to cover the green premium. Fortunately, a number of governments have unlocked public finance to support the steel industry green transformation. See Figure 7 for an estimation of the public investment in current green DRI-EAF projects.

130 Interview with expert at Goldman Sachs, April 2024.

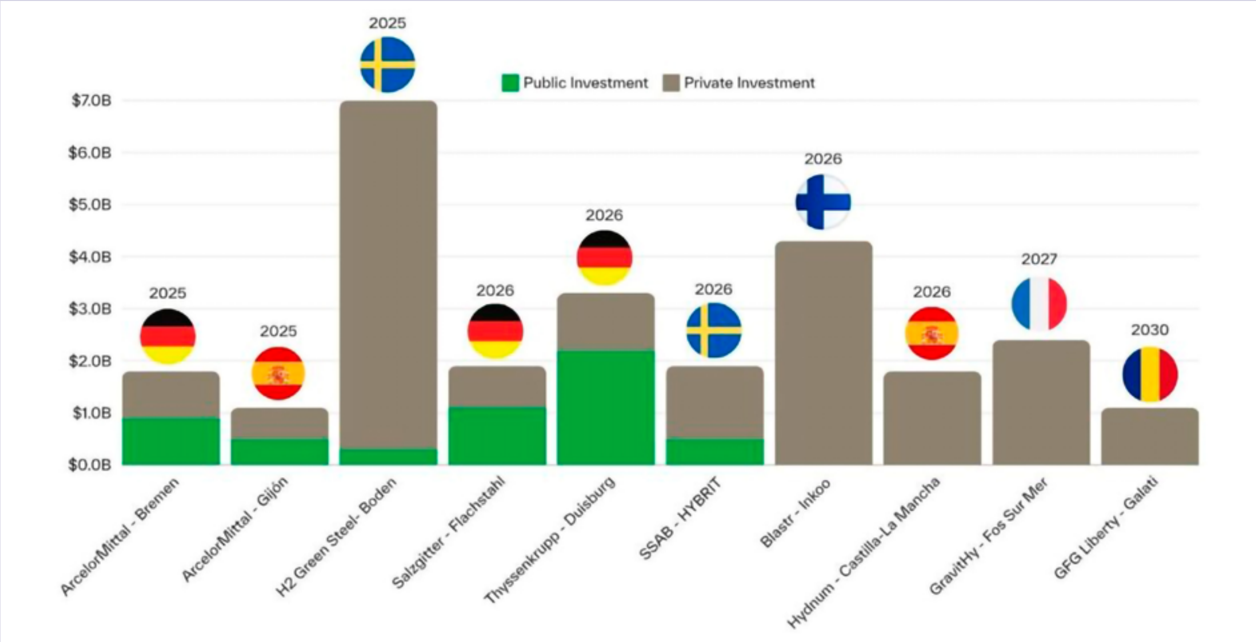


Figure 7: Total Public and Private Investment in USD for green H2-DRI projects by startup year

Source: Government Subsidies for the Green Steel Transition[131]

131 Industrious Labs and Public Citizen, *Government Subsidies for the Green Steel Transition (Washington, DC: Public Citizen, March 2024),* https://www.citizen.org/article/government-subsidies-for-the-green-steel-transition/.

V. Conclusion: The Importance of Evolving with the Market

Three essential elements should be brought into alignment in order to achieve meaningful decarbonization within the heavy industry, particularly with respect to the steel sector. First, there is an indisputable need for uniform and globally accepted policy and legal frameworks that require steel producers to take clear and stringent actions toward steel decarbonization. It was noted through this paper that much progress has to be made in standardizing and harmonizing regulations guiding decarbonization measures. There have been steps taken in the right direction, such as the EU taxonomy, but the current landscape is generally characterized by a proliferation of regulations that do not form the comprehensive and unified approach required to implement effective market mechanisms that contribute to creating a climate-differentiated market for green products in the steel industry.

Secondly, the direct offtake of green products within the heavy industry is a critical driver towards achieving decarbonization goals. With the commitments they have announced, initiatives such as the First Movers Coalition, SteelZero, and Climate Club play a key role in stimulating demand for green products. These commitments send out important signals to the market, indicating that sustainable industrial practices are gaining importance and spurring demand-side engagement in decarbonization.

Finally, it is crucial to spur new investments directly on the supply side, hence making a clear business case for producers and investors that showcases the economic attractiveness of decarbonizing the steel industry. In this sense, market-based solutions such as this paper's proposed mechanism form part of the overall solution and are not meant to crowd out advanced market commitment with direct physical offtakes. Such mechanisms create an incentive for companies to invest in technologies aimed at reducing carbon emissions in steel production processes by proving that adopting decarbonization technologies is economically viable and thus contributing to broader efforts to reduce carbon emissions from heavy industry.

In the development of a market-based mechanism that contributes to the creation of a climate-differentiated market for green products and materials in heavy industry, it is important to note the dynamic nature of these mechanisms and their need to adapt to evolving market and regulatory conditions. Like any other market-driven solution, the proposed market mechanism in this paper is not a one-size-fits-all solution but rather a blueprint of a tool that can be implemented in different stages over time to suit best the changing landscape of the steel industry and its sectoral decarbonization pathways and responds to technological advancements, changes in policy, or market needs so that it remains effective and up-to-date at all times.

Moreover, the proposed market mechanism should be considered a temporary measure as it is a voluntary solution needed due to the current absence of regulatory mandates that require steel producers to adopt near-zero emissions practices and downstream consumers to adopt near-zero emissions inputs. Therefore, we recommend that governments establish global policy and legal frameworks to regulate steel production in a way that promotes and supports (both legally and financially) EAF technologies, thereby enhancing the market for "green" steel. This proactive approach would ensure a more sustainable future for the steel industry, transitioning from voluntary market-based initiatives to a regulated, mandated, and systemic change.

Appendix: A Case for the Gradual Decarbonization of BF-BOF Steelmaking Technologies

In the principal text of this paper, we delved into the formulation of a market mechanism specifically tailored for companies currently deploying DRI – EAF technologies capable of producing steel that complies with internationally recognized standards for being labeled "green" or "near-zero emissions." This market mechanism focuses exclusively on facilities that consistently produce 100% green steel, as defined by rigorous LCA with fixed boundaries to determine the emissions intensity per ton of steel produced. Consequently, each ton of steel manufactured under these conditions at a DRI- EAF facility qualifies for the issuance of a green steel certificate, reflecting its low emissions profile.

However, it is crucial to acknowledge the significant presence BF-BOF technologies within the current global steel production landscape. These conventional steelmaking technologies still contribute to approximately 70% of the world's steel production.[132] Transitioning away from BF-BOF technologies poses substantial challenges, particularly in regions where alternatives like Green H2-based DRI-EAF are less viable due to logistical, regulatory, and technological constraints.

For example, in Japan, the steel industry faces obstacles such as difficulties in procuring high quality iron ore, a lack of available green hydrogen and renewable energies, and regulatory frameworks that do not support the swift adoption of DRI-EAF technology. Moreover, the IEA has identified CCS as a pivotal technology for the steel sector, particularly for retrofitting existing blast furnaces and in regions with limited potential for hydrogen-based DRI.[133] Current projects are exploring CCS for blast furnaces, and though proven efficiency and commercial viability is still years away—a timeline consistent with many other emerging technologies crucial for steel decarbonization such as iron-electrolysis[134] or the use of sustainable biomass or high hydrogen in injection in BOF[135]—it represents a critical pathway for reducing emissions for the legacy BOFs for which the phasing out is particularly constrained.

In light of the foregoing, the development of a market mechanism that includes BF-BOF operations, as discussed herein, does not imply an endorsement of practices that could be construed as greenwashing, nor does it advocate for the prolonged use of BF-BOF technologies that could be phased out. Instead, this proposal aims to acknowledge and address the complexities and temporal realities associated with phasing out these technologies. By incorporating transitional steps that enhance the decarbonization of BF-BOF operations, this mechanism seeks to provide a pragmatic approach to reducing emissions while broader technological and infrastructural transformations are underway.

We fully support the imperative of phasing out BF-BOF technologies. However, recognizing that complete transition may take longer for certain regions or facilities, this market mechanism is proposed as an intermediate solution to promote more decarbonized operations within conventional high-emitting technologies. This approach aims to balance immediate actionable steps against the ideal long-term outcomes, facilitating a more sustainable transition pathway for the current BF-BOF technology.

The structure of this proposed market mechanism is also dual-faceted, encompassing both a certificate system and a long-term virtual offtake agreement, all of which should be administered by a third-party registry. The registry and the long-term virtual offtake agreement will mirror the design explained in this paper for the Green Steel Certificate, thereby ensuring both additionality and transparency within the mechanism.

However, the primary distinction lies in the nature of the certificate itself. In this context, this certificate will be called an ERC. The characteristics of the ERC are crafted to specifically address the nuances of emissions reduction in traditional steelmaking processes by implementing technologies that decarbonize the BF-BOF processes. This certificate will be based on a

132 *The Breakthrough Agenda Report 2023.*

133 Interview with expert at the International Energy Agency, February 2024.

134 *Fact Sheet: Electrolysis in Ironmaking (Brussels, World Steel Association, May 2021),* https://worldsteel.org/wp-content/uploads/Fact-sheet-Electrolysis-in-ironmaking.pdf.

135 Zhiyuan Fan and Julio Friedmann, *Low-Carbon Production of Iron & Steel: Technology Options, Economic Assessment, and Policy (New York: Columbia Center on Global Energy Policy, March 2021),* https://www.energypolicy.columbia.edu/publications/low-carbon-production-iron-steel-technology-options-economic-assessment-and-policy/.

combination of both a mass balance and a book and claim system. The certificate will be issued in two phases: the first phase will entail a reformed version of the mass balance variant currently used by steel producers, followed by a second book and claim phase.

The current use of the "mass balance" approach to allocate and reshuffle emissions within the steel industry poses several significant issues, discussed extensively in the main text of this paper, that create misaligned incentives between steel producers and buyers, do not genuinely test the market's willingness to support environmentally sustainable practices, and generate ambiguity in the Scope 3 reduction claims made by buyers. This ambiguity can lead to skepticism about the integrity of environmental claims, potentially undermining trust in the sustainability initiatives within the industry. The prevalent practices, as they are currently executed by companies, often lead to greenwashing, and thus, we do not endorse them. Maintaining such a system could also impede the transition towards more sustainable technologies like EAF steelmaking.

To address these challenges, we propose a reformed and more robust variant of the currently used "mass balance system". By refining this system, we aim to realign incentives, promote genuine environmental accountability, and facilitate a smoother transition to greener steel production technologies. This revised system will be designed to ensure clearer communication of environmental impacts and encourage both producers and buyers to make more informed, responsible decisions that reflect true decarbonization efforts.

Illustrating the global momentum toward more rigorous mass balance systems, the Japan Iron and Steel Federation revised its Guidelines on Mass Balance in October 2023, which should be considered as an example to be followed for the mass balance system of our proposed market mechanism. This updated version delineates a three-step methodology for implementing the mass balance system, where the first step is creating a baseline by measuring the GHG emissions of a given steel product. In the second step, a project with additionality needs to be conducted, and the number of emissions reduced needs to be determined. In the final step, a reduction certificate is issued based on the number of emissions reduced. Moreover, it emphasizes the critical importance of project additionality, providing a stringent definition of what constitutes additionality. In this case, they define additionality exclusively as emissions reduction projects that are new, that the company has committed to on its own, and that result in cost increases, even excluding projects that, even though they lead to cost increases, are being conducted by many companies in the industry (therefore will not pass the common practice additionality test). Moreover, it stipulates that all certificates must be affixed to "low-carbon" steel products, further underlining the industry's commitment to traceability.[136] Unfortunately, these guidelines haven't reached international acceptance.

To ensure the integrity of the enhanced mass balance system, adherence to stringent rules and principles is necessary. These principles include:

1. Adopting a proportional allocation approach to ensure that all consumers receive products containing a proportional share of compliant material. Such a measure mitigates the risk of consumer deception regarding the environmental credentials of steel products to which all emissions reductions would be attributed and, as a result, would be inaccurately claimed as being completely "green" or "near zero emissions."[137]
2. Through a proportional allocation approach, this allocation would occur within the same production site rather than across multiple sites.
3. Having a limited and relatively short timeframe to do the mass balancing, meaning the verification of the composition of the output versus the input of emissions reductions. For instance, the timespan for mass-balancing biofuels in the EU may not exceed three months.[138] The timeframe for performing the mass balance of emissions reductions in this certificate should not exceed one year to reinforce the system's reliability and efficiency.
4. The exclusive issuance of emissions reduction certificates from facilities undertaking projects that secure additionality, measured by a test in which only new decarbonization projects that the company

136 *Guidelines for Green Steel Upon the Application of the Mass Balance Approach Version 2.0 (Tokyo: Japan Iron and Steel Federation, October 2023),* https://www.jisf.or.jp/en/activity/climate/documents/Guidelines_231117.pdf.

137 Biberman, Toledano, and Zhou, *GHG Accounting for Low-Emissions Branded Steel and Aluminum Products.*

138 "Renewable Energy – Recast to 2030 (RED II)," European Commission, https://joint-research-centre.ec.europa.eu/welcome-jec-website/reference-regulatory-framework/renewable-energy-recast-2030-red-ii_en.

has committed to on its own and that result in cost increases will be considered for the mass balance. This is paramount to guarantee a commitment to genuine emissions reduction efforts.[139]

5. The GHG accounting to define both the baseline scenario and the emissions reductions achieved after the implementation of the decarbonization project will be done following fixed boundaries and the methodology outlined in section III-A-3 of this paper.
6. The mass balance phase would be linked to the company's clear and public decarbonization pathway, as outlined in section III-A-4 of this paper.
7. Comprehensive third-party verification would be mandatory throughout the process, as outlined in section III-C of this paper.

Building on the proposed reform of the current mass balance system, the outcome will be a novel type of certification. This certificate will quantify the emissions reductions achieved through the implementation of decarbonization technologies at the facility, applicable across all its products. Unlike the GSC, which quantifies emissions in terms of tons of green steel produced, this new certificate will express reductions in terms of the number of emissions reduced per ton of steel produced. This metric provides a more precise measure of environmental impact than the current mass balance approach implemented by some steel companies as it directly correlates the number of reduced emissions with the steel output. This novel approach ensures that each unit of steel's environmental footprint is clearly communicated, fostering a more sustainable and responsible steel production sector.

Following the establishment of this enhanced mass balance system, the subsequent phase entails the introduction of a book and claim system, equal to the system proposed above for the GSC.

As mentioned above, the VOAS to which the ERC will be attached should follow the exact same principles explained in the main text of this paper. Finally, the introduction of an independent third-party Registry should also follow the same principles outlined in the main text of this paper, with the only consideration that following the Japanese Iron and Steel Federation's Guidelines[140], which has proposed a scheme where the GHG emissions reduction certificate has to be verified by a third party in all its stages, a reliable registry for this particular market mechanism should verify both the mass balance phase and the book and claim phase, independently.

139 Erwin Cornelis, *The True Face of Hydrogen: How Robust Definitions and Chain of Custody Systems Can Help Unmask Fossil Hydrogen in Disguise (Brussels: Environmental Coalition on Standards, April 2023),* https://ecostandard.org/wp-content/uploads/2023/04/ECOS-Paper-The-true-face-of-hydrogen.pdf.

140 *Guidelines for Green Steel Upon the Application of the Mass Balance Approach Version 2.0.*

Summary Timeline Table:

Table 4: Market Mechanism Timeline

	Step	Considerations
1	The steel producer begins the development of the project that entails the implementation of a new decarbonization technology to reduce emissions reductions in the production of Steel	Consider at this phase: • The intended project should be aligned with the company's overarching decarbonization strategy (which in turn should be guided by a sectoral decarbonization pathway). • The baseline GHG emissions before the implementation of the project should be clear at this point.
2	The buyer and the steel producer sign the VOAS, which defines all the terms and conditions of the long-term relationship and the transfer of ERCs.	Consider, at this phase, recommendations in section IV-E to structure a VOAS that has a minimum term of 10 years and a clear price settlement mechanism.
3	The steel producer obtains financing and begins construction of the project.	The VOAS will serve as a project finance instrument for the steel producer to raise non-dilutive project funding, as it will demonstrate to lenders that there is actual demand for the technology output.
4	Once the project is operational, the steel producer sells the steel from the facility where the decarbonization technology was developed to a steel buyer in their area at whatever the index steel price is at the time, depending on the type of steel produced and the geographical market.	Considering that this is a virtual offtake, the buyer, who cannot access the physical steel coming from this specific facility due to supply chain difficulties, will not receive the physical steel resulting from the implementation of this decarbonization project. A steel consumer in the local geographical market will receive the physical delivery of the steel without being able to claim the Scope 3 reductions derived from it.
5	At the end of the settlement period, the steel market price vs. the fixed VOAS price will be calculated, and the steel producer or the buyer will pay the difference, depending on whether it was higher or lower than the VOAS price.	At this phase, consider the recommendations in section IV-E-4 regarding the importance of agreeing on a specific steel index and including it in the VOAS during the agreement's negotiation phase. Several different steel price indexes depend on the steel type, quality, and geographical market.
6	The steel producer performs the mass balance phase of the formation of the ERC.	Taking into account the emissions baseline identified in Step 1 and the projects being developed as defined contractually in Step 2, a certificate is issued based on the amount of emissions reduced.
7	The steel producer issues one ERC for every ton of steel actually produced from the facilities where the emissions reductions were achieved and verified. The ERC will be immediately transferred to the buyer.	The ERC can only be transferred to the buyer when the steel has been actually produced by the facility that has implemented the emissions reduction technology.
8	The buyer can immediately use the ERC to claim the equivalent amount of Scope 3 emissions reductions.	The Registry should oversee the whole process and ensure that the ERC is canceled once the buyer has claimed it.

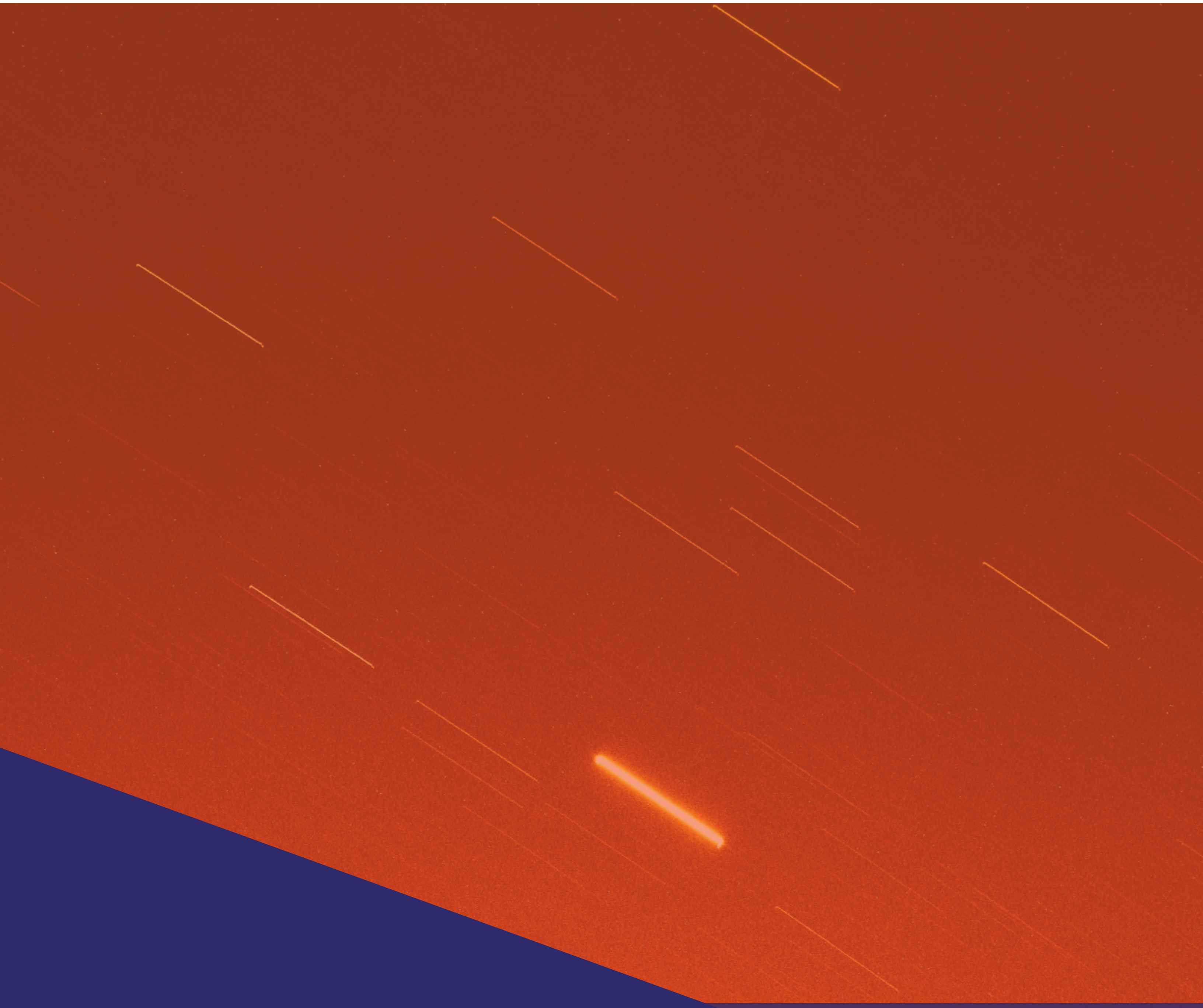
Source: Prepared by the authors

The greatest challenge that this particular version of a market mechanism will face is low acceptance and credibility, particularly among producers using DRI-EAF technology. These producers have voiced strong objections to the mass balance certificate system currently used by some steel producers within the steel industry. Their primary concern is that the current system serves as a pretext for continuing carbon-intensive practices, thereby hindering the industry's decarbonization efforts. This sentiment is not isolated to DRI-EAF producers alone; it extends to other actors critical of the mass balance approach. The lack of general confidence in the certificate system stems from its perceived inadequacy in driving genuine change, leading to a slow uptake of more sustainable practices. This skepticism is detrimental, as confidence is a cornerstone for the adoption of any new system designed to facilitate industry-wide transformation.[141]

141 Interview with expert at Arcelor Mittal, February 2024.

This particular version of the proposed market mechanism should be a temporary solution for producers that are unable to rapidly transition to EAF technologies and require transitioning their BF-BOF assets. Under no circumstances should this market mechanism be used as an excuse for producers to stall or delay the phase-out of their BF-BOF assets. Conversely, this version of the market mechanism should always be intended to quickly evolve into a purely book and claim system based on a GSC. Moreover, just as the GSC-based market mechanism outlined in the main text of this paper, this version of the proposed market mechanism should also be considered a temporary measure while governments establish global policy and legal frameworks to regulate steel production in a way that promotes and supports (both legally and financially) EAF technologies.

COMET Coalition On Materials Emissions Transparency



The Coalition on Materials Emissions Transparency (COMET) accelerates supply chain decarbonization by enabling producers, consumer-facing companies, investors, and policymakers to better account for greenhouse gas (GHG) emissions throughout materials supply chains, in harmony with existing GHG accounting and disclosure methods and platforms.

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