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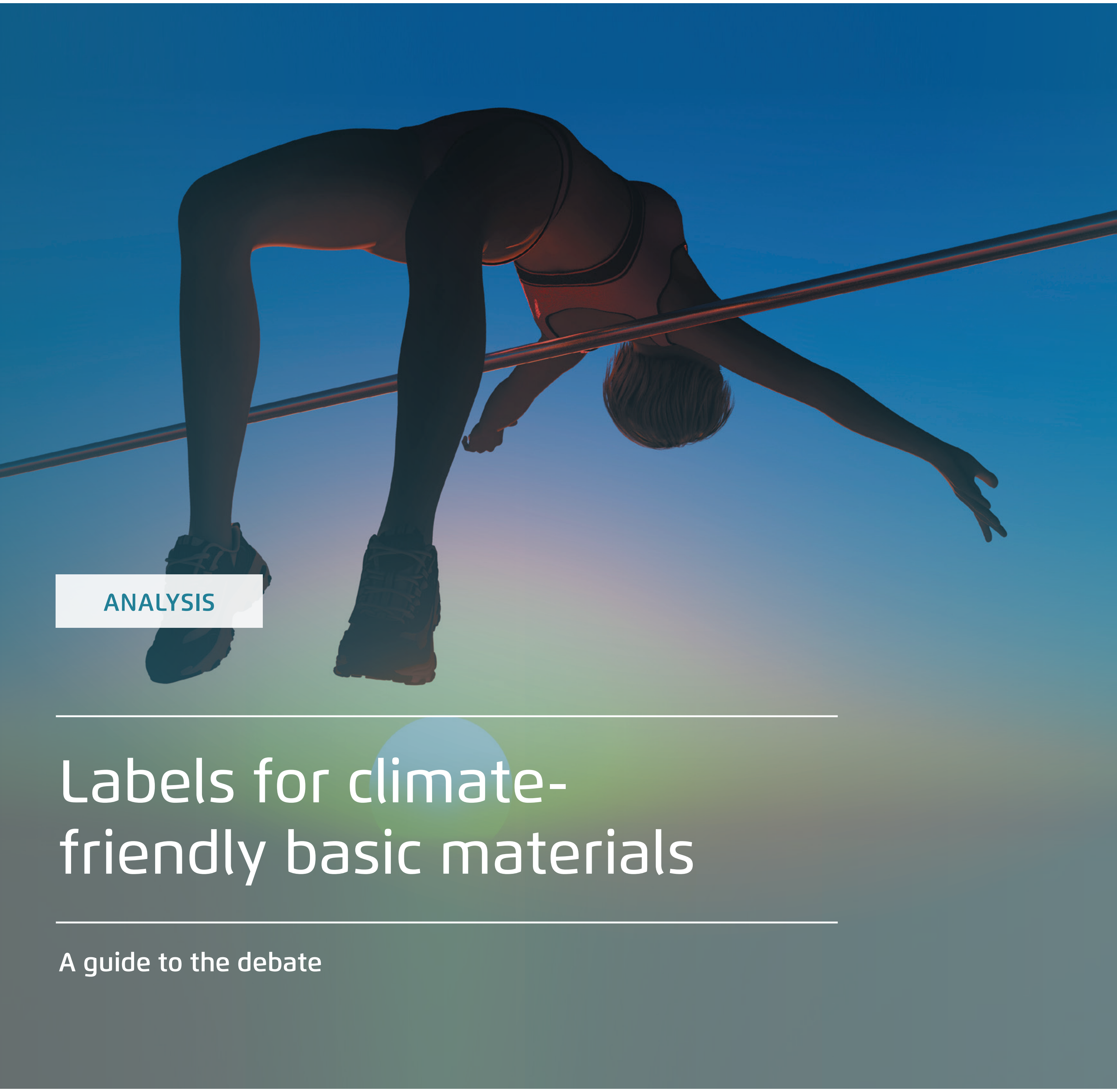

ANALYSIS

Labels for climate-friendly basic materials

A guide to the debate

Please cite as:

Agora Industry (2023): Labels for climate-friendly basic materials: A guide to the debate.

Analysis
Labels for climate-friendly basic materials: A guide to the debate.

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Acknowledgements
We would like to thank all Agora colleagues who made this project possible, in particular Sabine Zentek, Frank Jordans, Kaisa Amaral, and Anja Werner for their support; Frank Peter and Frank Jordans for their comments. We are also grateful to all the external reviewers who provided essential and constructive feedback to improve the quality of the report, in particular: Tiffany Vass and Peter Levi (International Energy Agency), Peter Hemingway (Industrial Deep Decarbonisation Initiative), Martin Theuringer and Gerhard Endemann (Wirtschaftsvereinigung Stahl), Shiva Kumar (ResponsibleSteel), Andrew Minson (Global Cement and Concrete Association), Daniel Boero Vargas (First Movers Coalition), Manuel Mohr and Christoph Müller (VDZ), Rob van der Meer and Koen Coppenholle (Cembureau), Jordana Baldoni and Sameen Khan (ClimateGroup), Karen Scrivener (EPFL) and Franco Zunino (ETH). These experts do not necessarily endorse the findings of this report.

Preface

Dear reader,

Steel and concrete are currently responsible for one-sixth of global greenhouse gas emissions due to the emissions intensity of their production processes and their widespread use.

Both sectors could make a tremendous contribution to bringing about a climate-neutral world if they transform their production processes and would fail to do so if business-as-usual continuess. Climate-friendly production processes exist in these sectors but need substantial scaling up in the coming years.

Coherent CO_2 pricing and the hedging of incremental costs through carbon contracts for difference can spur an initial development of climate-neutral steel and concrete production on the supply side.

Simultaneously, a market for green materials needs to be created to drive demand. To achieve this, the development of labelling for these materials is essential to provide information on their environmental properties and to set benchmarks for further emissions reductions.

I wish you pleasant reading!

Yours sincerely,

Frank Peter
Director, Agora Industry

Key findings at a glance

1. **Standardised emissions performance labels are an essential and urgently needed tool to kick-start demand for climate-friendly basic materials such as steel and concrete.** Labels can provide much-needed transparency and confidence in the environmental claims of basic-materials producers. A standardised labelling methodology is urgently needed to help support the business case for investments into key climate-friendly technologies in coming years.

2. **Labels should be nested within a broader mix of policies targeting a market creation for low-emissions basic materials.** Other demand-side related policies such as public procurement can use the definitions of low-emissions and near-zero basic materials provided in labels as a basis to formulate their own specific goals. Labels may also be a stepping stone towards CO_2 product requirements on certain basic materials, which could help align regulatory ambitions across countries.

3. **To support the industrial transition, labels must meet certain basic criteria.** They should differentiate the highest levels of ambition but also incentivise incremental steps along the way to climate neutrality. Labels should focus on certain production stages of basic materials, where the vast majority of emissions occur and that require deep transformation for sectoral decarbonisation. They must also adjust for factors that could significantly undermine incentives for transformation, such as the share of steel scrap in crude steel, or the strength of concrete.

4. **Labels for traded basic materials should ideally be developed at the international level and reflect the different starting points of low-, middle- and high-income countries.** If this cannot be achieved in due time, different national or regional – for example at the European Union (EU) level – pilot approaches need to be coordinated effectively. Venues such as the European Union, the OECD climate club, the IEA, the GASSA, or Global Arrangement on Sustainable Steel and Aluminium, and similar standardisation bodies and initiatives of the G20 Clean Energy Ministerial can help to promote this alignment.

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Glossary

Term	Explanation
Standard	A standard is a measure for the comparative evaluation of a product, the management of a process, the delivery of a service or the supply of materials. Standards exist at different geographical levels, for example EN at the EU level, and ISO at the international level. Standards for steel, cement or concrete can prescribe how to measure certain properties of these materials relevant for their environmental performance.
Definition	A definition expresses the nature or meaning of a certain word or subject. In this paper, a definition of near zero emissions steel or low emissions cement expresses what this means for the environmental performance of the material, and what it does not. This enables thresholds to be deducted.
Label	Generally, this term is considered synonymous with terms such as declaration, marking, and classification. In the context of this paper, a label provides relevant information on the environmental performance of a product. Labels and definitions are thus strongly linked, as the definition provides the reasoning behind the label.
Low emissions	Low emissions refers to a reduction in CO_2 emissions of a specific product compared to a baseline. This CO_2 reduction can be calculated in absolute numbers or in relative terms, e.g. percentages.
Net zero (emissions)	In the context of this paper, the term net zero, or net zero emissions refers to the compatibility of the environmental property of a material with climate neutrality, i.e. net zero CO_2 equivalent emissions are created by the material's manufacture within the relevant system boundary.
Near zero (emissions)	Near zero or near zero emissions refers to the reduction of net CO_2 equivalent emissions related to the material's manufacture to a level very close to net zero (compared to today's levels), while a small quantity of residual emissions remains.

Introduction

As momentum grows for the decarbonisation of industry, the question of how to create lead markets for basic materials is receiving greater attention. It is increasingly recognised that expanding the markets for climate-friendly basic materials – such as steel, cement and concrete – is an essential and urgent question. These markets are necessary to underpin the business case for investments in low emissions production technologies. The creation of a willingness to pay the "green premium" associated with producing climate-friendly materials is vital.

Creating demand for green basic materials requires standardisation of what is understood as "green". What exactly is a "low emissions" or "near-zero emissions" steel or concrete? To which products should the label be attached? And which emissions boundaries should be reported? Having standardised labels for such terms contributes to transparency, confidence and ease of communication and understanding about the relative environmental performance of products. The value of standardised CO_2 performance labelling schemes has been demonstrated already in other product markets, such as with energy performance labelling for appliances, CO_2 and fuel economy labels for vehicles, and bio/organic labels for food.

To this end, a number of initiatives –including ResponsibleSteel, ConcreteZero, SteelZero, Low Carbon Concrete Group (LCCG), the First Movers Coalition, the Climate Club and the Industrial Deep Decarbonisation Initiative among others – have emerged in recent years. At the EU level, recent legislative proposals such as the Construction Products Regulation suggest making it mandatory for European member states to apply CO_2 performance requirements as part of national and sub-national public procurement policies.[1] In North America, the US Government's Buy Clean Initiative and Canada's Federal Government have sustainable procurement benchmarks for CO_2 intensive basic materials. These initiatives are not all identical in aims, scope or geographical coverage, but a core purpose they share is to promote the emergence of demand for climate-friendly basic materials and they have grappled with the issue of how to label low-carbon basic material products.

Some of the initiatives mentioned above have proposed or adopted their own solutions to these questions or are in the process of doing so. So far, however, no definitive and universally accepted methodology has been established. Moreover, gaps exist. Some products, such as concrete, have tended to be ignored more than others (such as steel and cement) by existing proposals. The resulting lack of universally accepted labels for key products leaves policymakers with a challenge when it comes to designing their own lead markets policies – which label should they adopt and why? What are the trade-offs involved in choosing between different approaches that have been put out? And what are the environmental and policy implications of adopting one approach over another?

The purpose of this paper is to answer these questions. We focus on the three main materials under discussion today: steel, cement and concrete. For each of these products we survey the options that have been put forward, explain their motivation and rationale, their potential strengths and limitations, and the policy implications of certain choices made in their design. Building on these analyses, we also present our own suggestions for slight extensions to some existing proposals, such as those from the

1 Article 84 of the European Commission's proposed revision to the regulation, currently being debated, suggests that some environmental product requirements may become mandatory for public procurement purposes. This raises the question of what form these requirements should take and whether performance labelling – proposed elsewhere in the legislation – should be the basis for these requirements (see European Commission (2022)).

International Energy Agency, for an approach towards defining, ranking and labelling different classes of CO_2 emissions performance in steel, cement and concrete production, to illustrate how our analysis may be implemented in practice.

A core conclusion of this analysis is that there are a number of generally good, but often imperfect, labelling approaches that are currently being developed. Potentially with relatively minor adjustments (see our proposals), some of these methodologies already provide very a solid basis for national governments to move forward with lead market policies, such as green public procurement, etc.

Crucially for investors into the industrial transition, there is a trade-off between the ability to garner consensus on a specific approach and the speed of implementation of a standardised approach to labelling. In particular, extensive engagement with stakeholders during the preparation of this analysis suggests that full unanimous consensus on any one approach will not be possible. Governments and stakeholders themselves should therefore carefully assess the added value of long consultation processes on developing new labelling approaches that replicate debates that have already been played out during recent years and to which there is no perfect solution.

Rather, one can build on the best (but not the worst) of the approaches that currently exist: with labelling, environmental integrity is critical, but perfection is also the enemy of the good. In general this means: focusing the labelling emissions boundary on just the production process that needs deep transformation; setting net-zero and near zero emissions thresholds consistent with 2050 climate goals, while also including a large number of incremental steps from today's best performance benchmarks; and making adjustments for certain factors that could undermine incentives for deep transformation (e.g. for the share of scrap in the basic steel production process). Finally, adjustments by region of the world may be necessary to upper thresholds to kick start action.

This paper begins by clarifying in section 1 some basic principles of good practice for designing labels for basic materials. This section also briefly discusses some of the general controversies around labelling. Section 2 offers an analysis of some of the main existing labelling initiatives in the steel, cement and concrete sectors, the main relevant issues around labelling for these sectors and our recommendations for resolving them. Finally, Section 3 broadens the analysis by discussing some of the outstanding issues that remain unresolved or underdeveloped in the area of labelling for energy-intensive basic materials.

1 Why certain basic materials need standardised CO_2 performance ranking labels

1.1 Arguments for CO_2 performance ranking labels for basic materials

1.1.1 Helping to initiate and scale up demand for climate-friendly basic materials through lead markets

Key to achieving the transition to the use of climate-neutral materials is to create the relevant demand. However, this demand creation is often impeded by several factors, including the higher costs of climate-friendly materials, a lack of both transparency and knowledge regarding the environmental impact of materials, the absence of benchmarks to help identify and compare climate-friendly materials (CISL and Agora Energiewende, 2021) and a lack of confidence and trust in environmental performance claims.

Labels can help with overcoming many of these initial demand-related hurdles and are therefore a critical part of a broader policy package to drive demand for climate-friendly materials and products. They can provide reliable, comparable, and easily understandable information to purchasers about a product's environmental performance and thus create transparency and familiarity. In addition, labels also provide benchmarks for further emissions reductions by defining what constitutes a "low emissions", "near zero emissions" or even a "net zero emissions" ton of a material such as steel or cement. Thereby, they can also clarify where different decarbonisation solutions sit on the scale of performance needed and define the final landing point for the material's emissions intensity in a net zero industry world. Thus, they can help to guide and reward incremental progress, while signalling that such solutions can only be stepping-stones to the final destination. Only labels backed by credible standards for reporting and certification can also create confidence in the environmental performance claims made.

It is sometimes argued that labelling only makes sense for transactions between businesses and final customers, since only consumers will shift decision-making based on labels. However, for certain very CO_2-intensive basic materials, labels offering standardised performance rankings are essential, even though these goods are mostly traded business to business. Having a widely accepted set of benchmark definitions for ranking the relative emissions performance of products in these sectors can help to underpin investments in truly "net zero compatible" technologies and distinguish these from other products that are merely "better than average". This finding has been reported from research conducted with company representatives (see CISL and Agora Energiewende, 2021).

1.1.2 Creating incentives for investments in near zero emissions technologies

Creating transparency and confidence is often critical to the economics of developing markets for lower-carbon and more sustainable products. In basic materials sectors like steel, cement and concrete, investments in more sustainable production technologies and practices can only be justified if the products can command a higher purchase price (or green premium) with buyers. Research on net zero industrial technologies suggests that the incremental cost of decarbonising basic steel, cement and concrete and basic plastic and chemical products can be in the order of +20–100 percent of the relevant commodity prices today (Material Economics, 2019; Agora Energiewende, 2020; Agora Energiewende, 2021). Transparency and confidence in the green properties of these products is critical to buyers being willing to pay such a green premium.

Their significantly higher cost and capital intensity means that convincing companies and banks to finance these projects requires securing high-volume offtake agreements that guarantee future revenue streams paying the green premium, subsidies notwithstanding (Chiappinelli and Neuhoff, 2020; IDDRI, 2019). It is faster and easier to create large-scale, clear and strong demand signals to industry, if, say, public procurement agencies and private purchasing managers use common standardised benchmarks to determine what they will and will not buy in the future rather than each applying their own internal label. Global harmonisation of such labels across borders should be strived for wherever possible, especially in view of global or regional steel and cement trade.

1.1.3 Reducing unnecessary trade frictions and managing carbon leakage risks

Harmonisation and a common use of labels across borders are also potentially useful because, in the longer run, they might provide a stepping stone to harmonised product CO_2 requirements. Product CO_2 requirements, in turn, may be advantageous in the longer term because they may provide a way to limit carbon leakage and other trade frictions that result from different levels of policy ambition for CO_2-intensive basic materials. Even if policies such as the EU Carbon Border Adjustment Mechanism (CBAM) or green subsidies (e.g. in the US Inflation Reduction Act) can mitigate these issues in the short run, in the longer term such wide divergences in policy approaches are neither ideal nor sustainable.

The potential value of harmonised CO_2 performance labelling for carbon-intensive basic materials in such a context is relatively obvious: the introduction of standardised CO_2 performance benchmarks for certain materials can create the foundation for subsequent political agreements on aligning regulatory ambition across countries. The interest in such initiatives is already apparent, for instance looking at the "climate club" from the G7 group of nations (see G7 Statement on Climate Club, 2022), or in discussions around a transatlantic agreement between North America and Europe on a new set of standards for trade in green steel and aluminium (see for example Agence Europe, 2023 and European Commission, 2021). In the longer run, aligning such initiatives is key to avoid having different labels and ambition levels for same materials and products.

The fact that so many sectoral initiatives are trying to create standardised definitions and labels for products like steel, cement, concrete and aluminium is proof both of the value the private sector places on such tools and of the fact that there is a gap here that remains to be filled. However, what is important is that a critical mass of governments give official backing and credibility to a specific labelling approach. They can do this by adopting one and using it for their lead market policies for climate-friendly basic materials. To do this, however, they must navigate the complexities of the existing approaches that have been proposed and begin to align on a common approach.

1.2 Arguments against product labelling

Criticisms of product labelling for energy-intensive materials also exist. One such criticism is that upstream carbon pricing makes labelling redundant as low emissions materials become price-setting. This argument ignores the realities of what it takes to ramp up a worldwide pipeline of investments in very costly near zero emissions industrial production sites. Most nations currently do not (yet) have carbon pricing or a CO_2 price that would justify investments into low emissions production from an economic point of view. Moreover, one of the key components of what companies need in order to scale up investments is the assurance that they can market the resulting products accordingly. Carbon pricing helps in this regard, but it is also the result of a politically created market and therefore subject to significant uncertainty. Financial lenders therefore require companies to provide "back up" strategies against the risk of adverse carbon price fluctuations. Risk-hedging instruments, such as contracts for difference, can further help to de-risk revenues, but they are unlikely to provide a magic bullet, given limited government capacity to pay for them (or to bear the risk of paying). What can help in this context is the existence of markets that will buy the products at a green premium.

Another argument against standardised CO_2 performance product labelling is that the existing quality of reported emissions data is not sufficient to make reliable comparisons across products, especially regarding Scope 3 emissions (see for instance, CLC, 2023, CISL and Agora Energiewende, 2021). There is some truth to this criticism. For instance, existing reporting standards used in Europe and North America do not require product-specific data to be provided for all inputs and processes that go into making products such as cement, concrete and steel (Cf. EN 15804 and ISO 21930 on building products). Embodied carbon inventory databases are often used with generic sector average data; some databases are not compatible with each other; and some of the reporting requirements in existing standards do not require sufficiently robust information for quantifying the uncertainty inherent in the use of generic data (BPIE, 2021). Moreover, existing product category rules are not yet sufficiently strict or harmonised regarding the way that Scope 2 (electricity) emissions are to be reported, allowing for sometimes significant variances in reported product performance. There is also a general need for greater transparency in the way Environmental Product Declarations (EPDs) for specific products are prepared to enable better quality control and more fluid passage of data along value chains from the upstream to the downstream intermediate or final product (BPIE, 2021).

However, while these shortcomings related to data collection and standardisation are real, they do not in themselves constitute a compelling case against labelling. Many of the above-mentioned issues are solvable in principle and via iterative improvement in existing standards and practices. Nothing stops any given country implementing, say, a public procurement policy that requires competing companies to go above and beyond the existing disclosure standards in order to receive the low emissions label needed to win the tender.[2] Other measures could be used under lead market programmes to manage the risk created by the uncertainty in generic data. For instance, uncertainty weightings or penalties could be given to reporting mechanisms such as EPDs with less precise or less recent data on specific CO_2-intensive inputs. This is potentially a solution to the risk of "free riding" by the worst-performing companies in a given market.

1.3 Form should follow function: implications for labelling design

This section has put forward three arguments for why standardised emissions performance ranking labels are essential for decarbonising CO_2-intensive basic materials:

1. helping to initiate and scale up demand for green products through lead markets;
2. underpinning the business case for investments in near zero emissions technologies;
3. reducing unnecessary trade frictions and managing carbon leakage risks.

If these arguments constitute the rationale for having such labels, then this has implications for their design. Firstly, if an important goal is the rapid development of lead markets for green basic materials, then standardised labels providing benchmarks for different levels of relative performance compared to business as usual also matter. After all, such processes are likely to function by first rewarding incremental improvements relative to a baseline and then ratcheting up ambition in terms of near zero or net zero purchases over time. Environmentally meaningful incremental improvements should be recognised and rewarded via the labels.

Second, if a core goal is to underpin investments in near zero or net zero emissions breakthrough technologies, then labelling is not just about reporting on emissions but also about setting benchmarks and defining standardised labels consistent with a net zero industry sector in 2050. If another core goal is to support lead markets for certain kinds of clean investments, then adjustments are likely to be needed to avoid providing windfall gains to existing low emissions production with intrinsically limited po-

2 For instance, experience with the LCCG and Concrete Zero Initiatives in the UK has demonstrated that contractors (e.g. the purchasers of the concrete) often have a very detailed knowledge of product-specific data. Such data could also potentially be used for other purposes where reported data are not sufficient.

tentials. This has implications for the credit given to recycled steel, for instance, in comparison to primary steel.

Third, it can be a (longer-term) objective of implementing CO_2 performance ranking labels that they could serve as a basis for greater coordination of regulatory approaches to decarbonising energy-intensive and internationally traded sectors. This requires that the adopted methodologies strike a careful balance. On the one hand, they must be designed in a way that can be acceptable to many different jurisdictions and countries around the world in order to achieve sufficiently broad coverage over time. On the other hand, they must enable a gradual ratcheting up of ambition over time leading ultimately to a level consistent with the Paris Climate Agreement.

Lastly, concerns over the availability and accuracy of data and standards underpinning the labels (as outlined in chapter 1.3) should be taken seriously. Regulators should make sure that labels and their underlying data always reflect the latest available knowledge and authoritative standards to ensure maximum data quality and comparability across different materials at any given point in time.

1.4 Complementarities with LCA reporting and other forms of environmental information disclosure

It is important to note that standardised CO_2 performance labels for basic materials (and related products) do not necessarily preclude other information disclosures or negate their value. Rather, labels are complementary to other forms of disclosure in that they seek to isolate just a few key parts of the value chain (e.g. in steel or cement production) in order to place a specific emphasis on creating lead markets for green investment in these specific areas.

For instance, with regard to CO_2 emissions, other complementary forms of information disclosure – such as the reporting of the embodied emissions in terms of life cycle global warming potential – can still be highly valuable in addition to the simplified label. Such life cycle information is essential, for instance, for total embodied carbon reporting and accounting and for the regulation of the final products (an emerging practice in the buildings and automotive sectors). Larger and more sophisticated companies aiming to align sustainability policies with specific targets, such as the Science Based Targets Initiative, rely on the absolute emissions values disclosed by suppliers using such approaches.

Beyond carbon emissions, other product environmental information that is for example contained in Environmental Product Declarations can also be highly valuable. For CO_2-intensive basic materials, information on water resource intensity, toxicity, recyclability, recycled content, contribution to air or soil pollution and other environment-related factors may be also relevant – depending on the product concerned and the local regulatory environment. Thus, while this publication addresses "labelling on carbon emissions", in practice, this information may be nested within broader reporting tools involving a set of relevant environmental indicators, such as EPDs or Digital Product Passports (as currently under discussion in the EU).

Measuring and reporting life cycle emissions based on established ISO and EN standards

Life Cycle Assessments (LCA) measure the environmental impact of every process step of producing a product from cradle to grave. A Product Category Rule (PCR) measures the climate impact of a specific product and provides the rules for conducting an LCA by setting out system boundaries, functional units, definitions of the use phase and End-of-Life-options (EPD, n. d.). The PCR complements the General Programme Instructions (GPI), which forms the basis for administration and operation of a programme for a Type III environmental declaration. PCR-based LCAs and GPIs provide the basis for an Environmental Product Declaration (EPD), which is a globally used tool for reporting the environmental performance of products – in this context, cement, concrete and steel. Important standards underpinning the establishment of an EPD are ISO standards 14025, 14040 and 14044 among others. For the different sectors analysed in this study, a (non-exhaustive) list of relevant standards is provided below.

Cement and concrete: EN 15804 and ISO 21930, which substantiate ISO 14025 for building products. EN16908 is one of the most relevant standards for cement, and EN 16757 for concrete.

Steel: EN 15804 and ISO 21930 on building products are relevant for the steel sector, too. Among steel-specific standards, PrEN 17662 and ISO standards 20915 and 14067 are worth citing.

Other relevant mechanisms and tools for reporting emissions include CO_2 and energy reporting under the GCCA sustainability charter, the Concrete Sustainability Council, CO_2 and energy reporting under Worldsteel Sustainability Charter and the GHG Protocol.

Agora Industry (2023)

2 Overview of existing CO_2 performance ranking labelling initiatives

Several labelling initiatives have recently been introduced for the steel, cement and concrete sectors. The scope and level of inclusiveness of these initiatives vary widely. In the discussion on the different approaches, a certain level of convergence towards common design options can be observed, but at the same time differences with regard to certain key design questions remain. The following chapter provides a guide to the initiatives in the different sectors, the discussions around them and our recommendations on how to resolve outstanding issues.

2.1 Low emissions steel labelling

Traditionally, primary steel is produced from iron ore via the Blast Furnace-Basic Oxygen Furnace (BF-BOF) route. In a blast furnace, the iron ore is converted into liquid pig iron using coke both as a fuel and as a reducing agent. Alternatively, steel can be produced via the Electric Arc Furnace (EAF) route using recycled steel scrap. According to the IEA, steel produced via the PCI-BF-BOF route emits around 2 945 kg CO_2e/ton of crude steel (IEA, 2022). In contrast, the EAF-based production of recycled steel emits around 670 kg CO_2 per ton of crude steel on average globally (WorldSteel, 2022), but these emissions are largely determined by the source of power used. With clean power, the number can be as low as 100-150 kg CO_2/ton. In Europe and North America, the carbon footprint of EAF steel produced with 100 scrap steel is generally estimated to be around 400 kg CO_2/t crude steel (Material Economics, 2018).

While secondary steel production is much less emissions-intensive than steel produced via the primary production route today, it is still emissions-intensive and there is potential to further decarbonise this route, including by using decarbonised energy sources for electricity supply and by electrifying some parts of the process, such as rolling, which currently use fossil fuels, such as natural gas.

In practice, many steel products are a mix of both primary and secondary steel. Today, secondary steel represents only a minor share of the global demand for steel and is limited by the availability of steel scrap (iron ore-based primary steel still makes up around 74 percent of global production (WorldSteel, 2021)). Thus, secondary and primary steel are not perfect substitutes. Moreover, due to contamination of secondary steel by other metals such as copper, products with a high proportion of secondary steel tend either to be diluted with primary steel or else to be used for "lower grade" products, such as rebar for concrete reinforcement. However, in the future, better control of scrap quality and the advent of direct reduction processes for the primary steel route could allow for much higher blends of scrap and primary steel (Agora Industry, 2022). Typically, long products have higher proportions of recycled steel, while flat products tend to be aimed at more demanding product applications and thus use more primary steel, but this is not always the case.

Steel is often alloyed with other metals or elements, for instance to make stainless and higher-grade alloy steels. Non-ferrous metal alloying ingredients can themselves be highly energy- and carbon-intensive to produce. Therefore, if alloys are included within the product emissions boundary, and if steels contain significant proportions of alloys, then emissions from even basic steel alloy products can be significantly higher than they would be for pure crude steel products. Alloys are often mixed in with the steel during the crude steel production or subsequent stages of production such as hot rolling, and thus they are technically part of the basic system product boundary according to current reporting rules.

Establishing labels for steel products is also complicated by the fact that, if one goes beyond crude steel, then there are very many steel products. According to the World Steel Association, there are more than 3 500 different steel grades on the market, which can be differentiated by physical, chemical and environmental properties (WSA, n. d.). Steel can be differentiated according to many different parameters, including its finishing method (e.g. hot rolled, cold rolled), form (e.g. bar, tube) or heat treatment (e. g tempered, annealed) and many more. Each of these different products will currently tend to have slightly or significantly different emissions per ton of steel product, because the individual processes involved in making the products entail different levels of additional emissions, either because of different energy requirements or different additional material inputs. However, steel is most commonly classified according to its basic composition, i.e. whether alloy steel, carbon steel, stainless steel or tool steel. The variations in CO_2 emissions within these categories will tend to be more limited than between these categories.

The wide variety of steel sub-products and production processes thus raises a challenge for setting a common labelling threshold, and especially for doing so in a short timeframe in order to start developing lead markets. Typically, approaches therefore focus – at least as a first step – on crude steel (e.g. IEA, 2022), or on a limited set of product classifications, such as flat and long products (GSCC), or else on a specific type of steel grade (WV Stahl).

A variety of decarbonisation options are available in the steel industry. For primary steelmaking, these include the switch from the traditional coal-powered Blast Furnace-Basic Oxygen Furnace route either to hydrogen-based Direct Reduction of Iron (H_2-DRI), to electricity-based Molten Oxide Electrolysis, or to steelmaking routes based on the use of Bioenergy Carbon Capture and Storage (BECCS) to generate negative emissions. Secondary steelmaking – i. e. steelmaking using steel scrap – will also play a major role in future steel supply in a net zero world (Agora Industry, 2023). It is important to note that distinguishing between primary and secondary steelmaking will become increasingly difficult over time, since any proportion of DRI and steel scrap may be used to produce steel in the future in DRI plants and because there are likely to be technological options for improving the quality of scrap going into recycled steel, thus making it more competitive with primary steel.

2.1.1 Existing labelling proposals

Over recent years, several initiatives have been launched that put forward a framework to measure progress with regards to steel decarbonisation. The first proposal was released in 2019 by the multi-stakeholder initiative ResponsibleSteel (RS). The RS standard (see Figure 1) was developed adhering to World Trade Organisation (WTO) principles for standard development and targets a wide range of ecological and social aspects making it a comprehensive and globally applicable ESG certification scheme which can be used both for steel products and steel producing plants. As such, it is also wider in scope than other initiatives presented in this paper[3]. As part of the scheme a classification system for steel produced with reduced GHG emissions was introduced. This system takes into account GHG emissions during production and upstream processes as well as the scrap share used in the production. In particular, in order to take account of the limited supply of scrap steel, it makes an adjustment to the thresholds based on the share of scrap in the crude steel product – the so-called "sliding scale" idea. With rising scrap levels, thresholds become progressively tighter in order to incentivise further emissions reductions in scrap-based steel production, which has lower emissions already (ResponsibleSteel, 2022).

The classification consists of 4 levels, in which the basic level represents the threshold necessary for producers to be able to market their steel as RS certified. RS proposes a unit of measurement of kg CO_2e/ton of crude steel. As a basic threshold, RS proposes an emissions intensity of 2 800 kg CO_2e/t crude steel (for steel with 0 percent scrap content) and 350 kg CO_2e/t crude steel (for steel with 100 percent

3 Due to the nature of this paper, we only focus on the GHG emission-related requirements of the standard, acknowledging that the standard is broader in scope.

scrap content). As a near-zero emissions threshold, RS proposes 400 kg CO_2e/t crude steel (0 percent scrap content) and 50 kg CO_2e/t crude steel (100 percent scrap content). They propose two equally-spaced intermediate thresholds to get from the basic to the near zero threshold. The lower end of these thresholds, i.e. for near zero steel, is designed to be compatible with the IEA's Net Zero Emissions by 2050 scenario (ResponsibleSteel, 2022).

This standard lays important ground rules for measuring progress towards steel decarbonisation. It also includes guidance on system boundaries and principles for the emissions to be included. The measurement of emissions has to be done according to recognised standards. RS covers direct emissions (Scope 1 or onsite emissions from the steel plant), indirect energy emissions (Scope 2, i.e. indirect emissions from energy imported to the site) and upstream indirect emissions from material extraction, processing and transportation (Scope 3) (ResponsibleSteel, 2022).

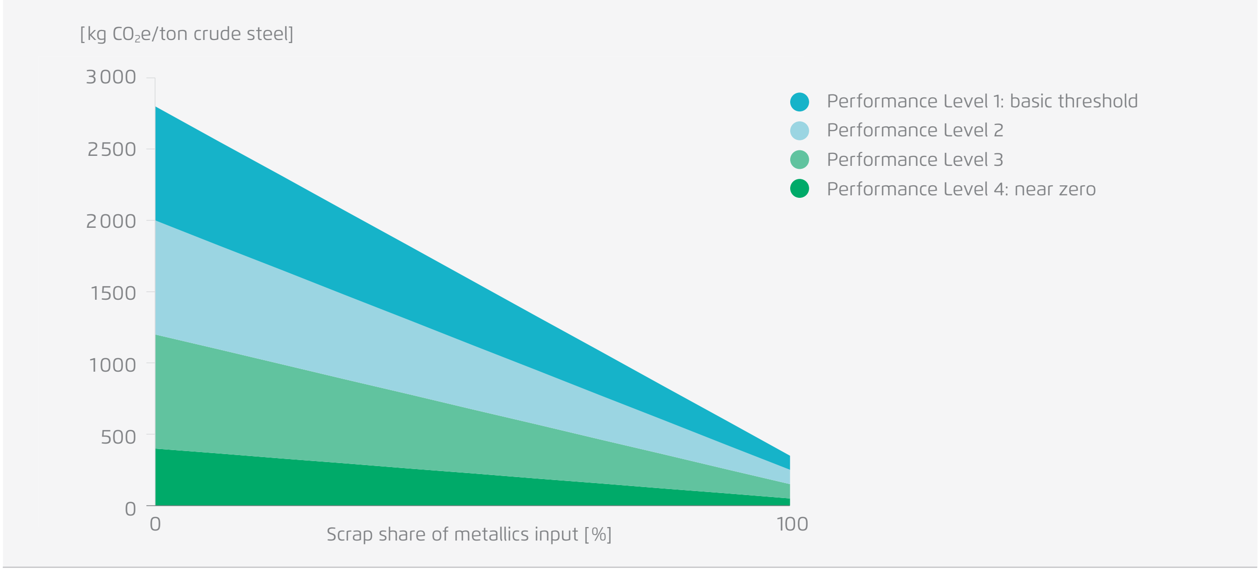
Notably, the RS thresholds have been calculated excluding sites that produce stainless and high alloy steel. Furthermore , upstream indirect (Scope 3) GHG emissions associated with the use of non-ferrous metal and ferro-alloys were also excluded (ResponsibleSteel, 2022, p. 118). However, steel sites that produce stainless or alloy steel may still apply for certification under the given thresholds as long as the steel contains less than 8 percent alloys. This was done because establishing thresholds for the use of alloys was not yet possible and remains a subject of further work for the RS standard (ResponsibleSteel, 2022). In the interim, a default value shall be used as a replacement value for the upstream scope 3 emissions for all non-ferrous and ferro-alloy additivies (ResponsibleSteel, 2022, p. 106).

RS proposes a number of standards for use in determining and reporting embodied emissions in steel and a range of broader environmental aspects to be considered, including: the GHG protocol; ISO 14067:2018; PAS 2050:2011; EN 15804:2012 + A2:2019; ISO 14025:2010; ISO 14040:2006; ISO 14044:2006; ISO 20915:2018; and ISO 21930:2017 (ResponsibleSteel, 2022, p. 119-120).

The RS standard contains several elements that can be evaluated positively. For instance, the near zero threshold is based on robust IEA scenarios for a 1.5 °C compatible global steel sector transition. The sliding scale adjustment for scrap – although controversial

The ResponsibleSteel standard

→ Fig. 1



ResponsibleSteel (2022)

with recyclers - is also arguably an essential element of a labelling certification scheme that provides the right incentives for investments in decarbonised production. The focus on crude steel, at least as a first step, provides a useful starting point that can be operationalised today, and captures the major sources of emissions, even if it does not include some downstream emissions that will ultimately need to be reflected in future iterations and additions to the standard (such as site certification for downstream processes). The current version of the standard excludes steels with alloy contents above 8 percent as more data requirements would be needed to include such steels. This is currently under review.

Finally, the standard includes a 5-yearly review in order to strike a balance between certainty and the need to enhance the methodology and potentially review certain thresholds in the light of technological developments. Indeed, some potential areas can already be identified where this initial version of the RS standard might be made stronger in future iterations. For instance, for a crude steel emissions boundary, the basic (Level 1) threshold of 2 800 kg CO_2/t crude steel for 100 percent primary steel roughly corresponds to the current global status quo. Even the Level 2 standard, beginning at 2 000 kg CO_2/t crude steel, is not particularly ambitious by European standards, meaning that RS certified products gaining this level of certification do not necessarily need to make significant transformative efforts to attain Level 2 – even if the standard will also include reporting on the actual emissions intensity number itself as an additional means of comparison. This contrasts with the more ambitious efforts demanded of recyclers compared to today's best practice at the 100 percent scrap level to meet the same Level 2 certification.

Secondly, setting only two, quite large, intermediate thresholds between the basic threshold and near zero offers little opportunity for differentiating between incremental emissions reduction achievements, so that these can be rewarded by policy makers. This is potentially a weakness compared to an alternative with more intermediate levels since it would potentially penalise actors making very significant additional investments to decarbonise primary production routes compared to those who invest in only more marginal improvements in order to scrape in just below the nearest threshold. The larger the thresholds, the more risk of threshold effects. Fewer thresholds also provide less opportunity for individual sites and companies (and their customers) to grade themselves accurately compared to their peers.

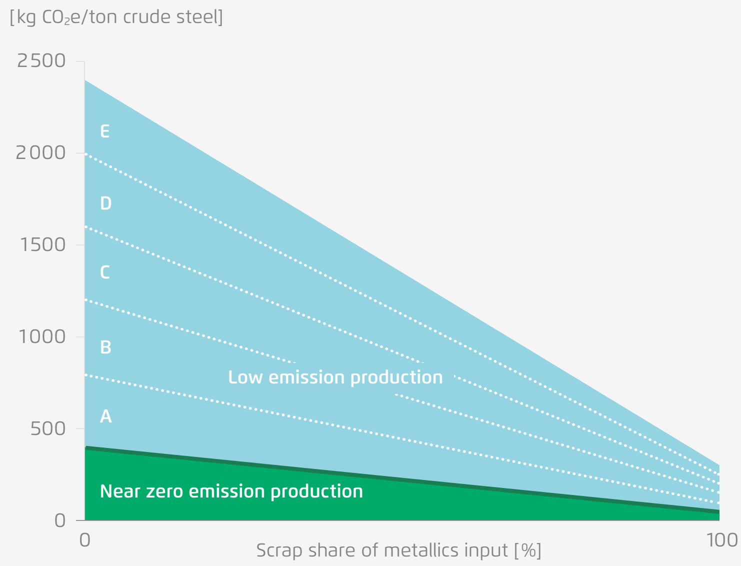
The approach to steel labelling proposed by the International Energy Agency (see Figure 2) in their report 'Achieving Net Zero Heavy Industry Sectors in G7 Members' resolves many of the potential areas for improvement of the RS approach, while building on its strengths. Like RS, the IEA approach defines classification thresholds in embodied CO_2 emissions per ton of crude steel (not final product, and prior to further processing such as hot rolling), which means the two approaches are easily comparable (see Figure 2). The advantage of this narrow boundary lies in limiting the data required and avoiding allocation loops. While the IEA does not specify what kind of steel grade the labelling is focused on, the Wirtschaftsvereinigung (WV) Stahl mention in their proposal that the IEA uses a generalised emissions value for the secondary route that is situated somewhere between construction and quality steel (WV Stahl, 2022).

Like the RS standard, the globally applicable approach of the IEA uses a sliding scale adjusting for the share of steel scrap. The intermediate low emissions thresholds are set in relation to the near zero threshold. The low emissions E band is six times higher than the near zero threshold, the D band five times, and so on. However, in contrast to the RS approach, the low emissions E label in the IEA's approach begins at a lower value of around 2 400 kg CO_2/t crude steel, which is intended to represent an improvement of around 10-20 percent below the current business-as-usual value of kg CO_2/t crude steel. Thus, the IEA does not provide a low emissions label category that covers business as usual. It also offers 5 different threshold bands between its low emissions E and its near zero thresholds.

As a methodology to determine the share of low emission production, the authors propose that "for a given volume of total production, a share would be

IEA steel label approach

→ Fig. 2



IEA (2022)

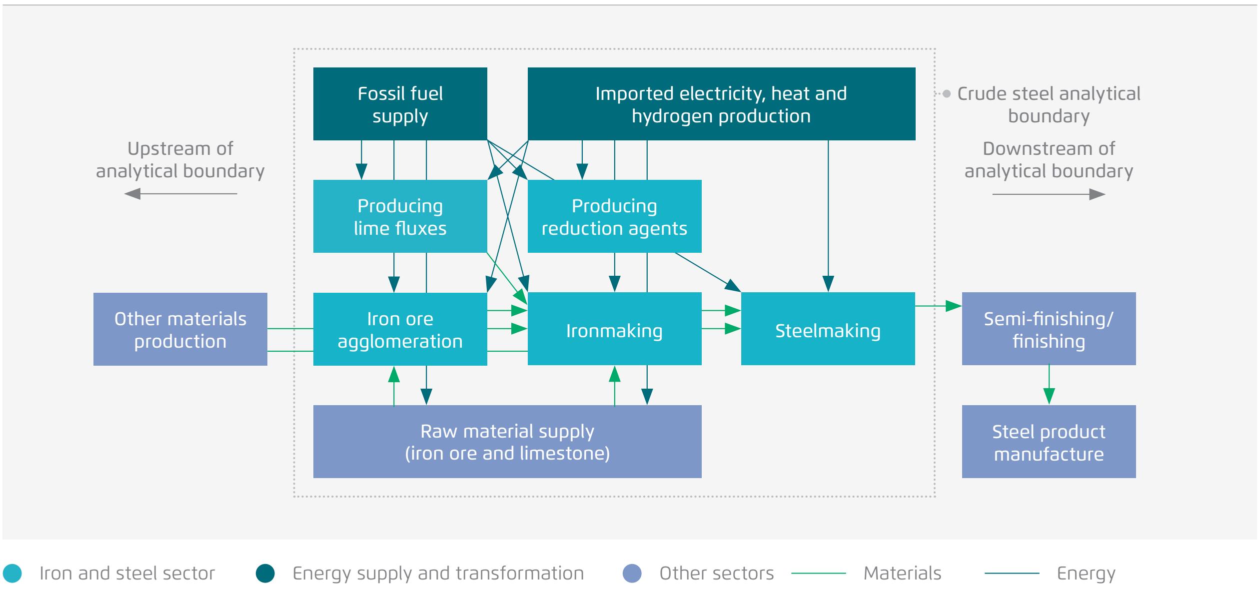
deemed low emission if the intensity lies between the near zero and low emissions production thresholds. This share is inversely proportional to the emissions intensity of total production" (IEA, 2022, p. 128). This means that a plant producing a ton of material with an emissions intensity that lies halfway between the near zero and low emission thresholds would achieve 0.5 tons of low emission production. When a share of production is at or below the near zero threshold, all the output would be near zero. With this approach, low emission production is progressively recognized, but the near zero threshold is binary.

It seems the reasoning behind this approach to calculate low emission and near zero emission outputs is to reward intermediary steps only partially to strengthen the relative reward given to deep cuts of near zero emission production. While this is a laudable aim, marginal performance improvements should also be incentivised alongside deep improvements, as all emissions count the same. Also, public procurers might well depend on production with an incrementally improved emission intensity at the outset. Partially rewarding incremental steps would maybe also hinder non-industrialised countries from joining initiatives such as IDDI given the high incremental costs of technologies with deep emission reduction potential. The proposal may even lead to disputes about unfair treatment, as it rewards the quantity of low emission production only proportionally to the degree of decarbonisation it achieves.

In their report, the IEA dedicates a whole section to describing relevant standards for measuring the emissions intensity in the steel and cement sectors. For the iron and steel sector, the organisation mentions ISO 14404 and ISO 20915 inter alia as relevant standards (IEA, 2022).

The IEA provides guidance on which direct and indirect energy-related emissions are to be included in the emissions boundary (see Figure 3). Emissions related to other inputs such as alloys, electrodes, refractory linings or their transport are excluded, though this is less a systematic choice and more a practical one driven by data availability and by the choice of the IEA to cover steel production, not (intermediary) steel products. The IEA avoids using the terminology of the GHG Protocol, as this may lead to confusion over which inputs are included and which are not. However, the analytical boundary specified by the IEA may be evaluated using the GHG Protocol's emissions categories and associated measurement standards (IEA, 2022).

IEA analytical boundary for defining near zero emissions steel production → Fig. 3



IEA (2022) Notes: "Other materials production" refers to the production of material inputs to the iron and steel sector besides iron ore and limestone, including electrodes, alloying elements and refractory linings.

The decision of the IEA not to use the existing GHG Protocol raises the issue of whether and how its approach might be reconciled with existing reporting standards. Some significant differences between the boundaries of the IEA approach and existing reporting standards are:

- → the production of other materials (notably the supply of alloys, processing of scrap, production of ferroalloys and refractory linings) is excluded from the IEA approach;
- → downstream processing of crude steel is excluded (requiring data to be collected at the level of the crude steel production prior to hot rolling, casting, cold rolling, and further processing).

As noted above, including these steps leads to significantly greater complexity because of the need to define additional benchmarks for these inputs and/or processes. As explained below, this could lead to additional significant complexities as it requires making a very number of differentiations in the labelling thresholds between similar but slightly different products. The downside is that a minor but sometimes still significant source of emissions can sometimes be excluded from the emissions boundary (the use of stainless steel alloys, for example, can add meaningful quantities of emissions). Excluding these emissions is also sometimes a concern for producers competing against products that use large amounts of alloys, or for recyclers who compete with integrated producers, as they fear that with a more restricted emissions boundary their competitors' products may appear to have lower emissions than they actually do. Another drawback from excluding alloys and sticking to crude steel production only is that existing reporting disclosures typically cover also these inputs to the (intermediary) product.

The impact of alloys on the total steel product footprint is illustrated in Figure 4, which shows that for several of the main alloying elements used in steel products, embodied carbon emissions per kg can range from 2 to up to 34 times the embodied carbon in an equivalent weight of pure primary steel. While in some cases the proportion of alloying elements may be relatively small in a given steel product, in others, it can be quite high. For instance, stainless steel can typically contain 10–20 percent chromium and up to 8–10 percent nickel (Unified Alloys, n.d.). Thus, total life cycle emissions of stainless steels can constitute more than 50 percent of the total steel product emissions. More generally, since most alloys are 2–4 times more carbon-intensive than steel itself, even a 5 percent share of alloys in the product can quickly account for more than 10-20 percent of total final steel product emissions.

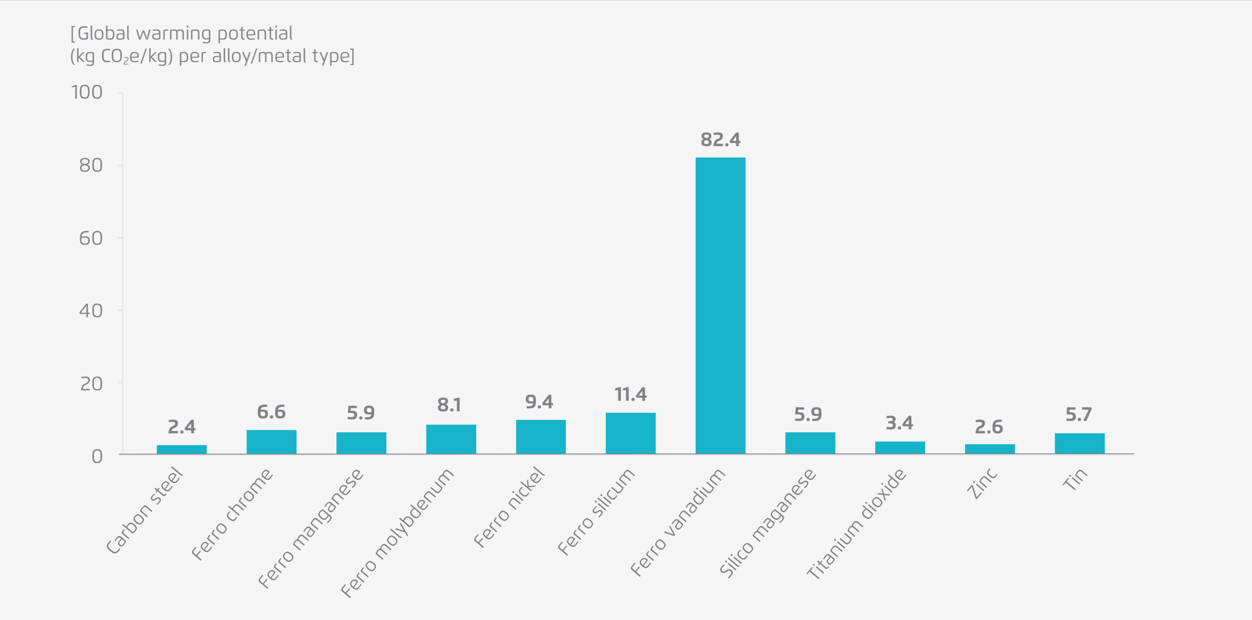
Since alloying inputs are typically taken into account under the dominant product category rules, reporting under steel labelling systems could also include them within the product boundary if these existing reporting disclosures were used. Indeed, ResponsibleSteel does this already for alloy steels with less than 8 percent alloy content. On the other hand, the IEA argues that including adjustments for alloys explicitly adds significant additional complexity to the labelling methodology and that these factors should be left out of scope and perhaps be assigned their own separate labels in future.

A similar issue also arises with regard to downstream processing of steel products beyond the crude steel stage. After being cut into crude steel billets, the vast majority of products (over 90 percent) are typically hot rolled in a first step and cast via a continuous casting process into basic slabs, billets or blooms. These slabs, billets or blooms are then further processed via secondary forming processes, such as cold rolling, shaping, machining, jointing and coating. Hot rolling is estimated to add an additional 0.1 t CO_2eq/t hot rolled steel in the EU (Material Economics, 2019), where it is frequently natural gas-fired a process, although actual emissions will depend on the fuel source used and may be higher in coal-fired systems. Including hot rolling in addition to the crude steel stage does however appeal to recycled steel production routes, since this allows them to also capture more options to reduce emissions. In Germany and in the European context, for instance, this move beyond the IEA boundary appears to be a possible basis for compromise and significant – if not complete – consensus between integrated and non-integrated processes.

Typically, further downstream processes for hot-rolling add a similarly small amount of additional energy (heating)-related CO_2 emissions compared to the initial primary steelmaking. These processes can also include the addition of further chemical or alloying elements, such as galvanising and coating of steel, with some additional associated emissions.

Embodied carbon footprint of some of the main alloying inputs into steel products

→ Fig. 4



World Steel (2020) Life Cycle Inventory Study 2020 LCI data release, Annex 5. True numbers may vary depending on geography and site-specific energy and processes.

Figure 5 below shows data from World Steel on the average life cycle emissions of some of the most common long and flat steel products. These data do not include stainless or alloy steel products. The lower emissions outcomes for long products reflect the higher proportions of scrap used to make these products. However, the figures for the flat products indicate a very high degree of similarity between the total emissions of the basic hot rolled product (hot rolled coil) and the range of other processed products. In fact, it is noteworthy that the cold rolling and finishing steps each appear to add only approximately 0.1 t CO_2eq/t steel product. The products with high emissions increments are galvanised, tinplated and organic coated steel products. This reflects the additional emissions resulting from adding additional alloys, such as zinc, tin, and chemical/plastic treatments to the surface of the steel in each of these cases, rather than significant additional energy emissions.

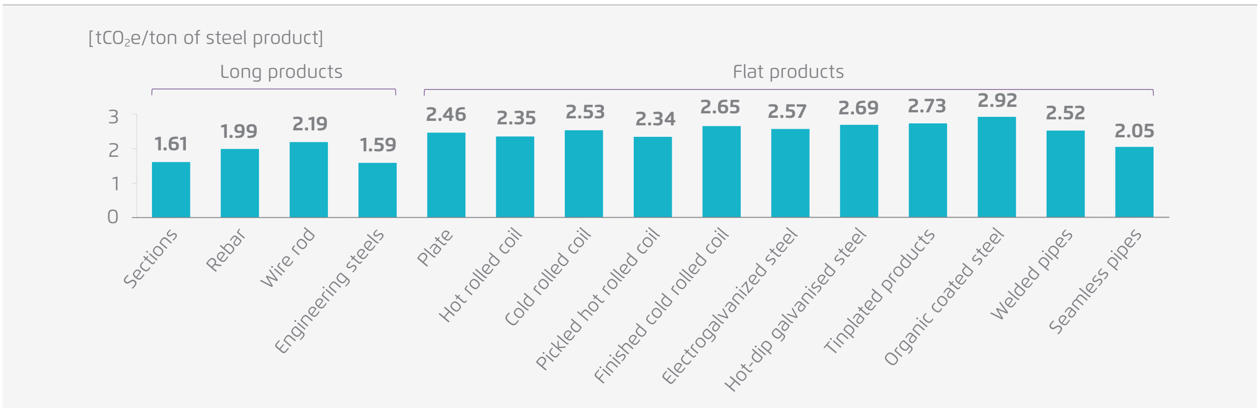
It is theoretically possible – although a very significant technical task – to identify additional ways of integrating some of these downstream processes into the emissions boundary. The main challenge is that there is a multitude of steel grades and steel products beyond the hot rolling stage of production, and these must also be cross-related with a very significant number of processing steps, many of which might be configured in unique or bespoke ways in different steel mills. While it may be possible for a given steel mill to allocate these emissions for its product range, defining globally accepted benchmarks for doing so would be a technically and politically challenging exercise. The main outcome of such an exercise might therefore be a rather unambitious and imprecise set of emissions benchmarks for these processes (if defined at the global or even national level in countries with a diverse set of steel activities).

Another important question is to what extent one should differentiate between *steel grades*. Even when one focuses on the crude steel stage of the process, different crude steel production routes may be more or less energy intensive depending on the purity of the steel needed to produce a certain grade. This is the logic behind WV Stahl's rulebook in the German and European context (discussed below) and is an important – albeit potentially complicating extension beyond the IEA's and ResponsibleSteel approaches.

In all of these aspects, a relevant consideration in defining the emissions boundary is therefore the trade-off between comprehensiveness and the materiality of additional emissions sources: what is the additional value gained by including downstream processing steps beyond hot rolling? As seen above, the additional emissions captured after the crude steel or the hot rolling boundary may be of limited global significance relative to the incentives created

Comparison of average LCA emissions of a range of basic flat and long steel products

→ Fig. 5



Agora Industry (2023) based on data from Global Steel Climate Council (2023) and World Steel Inventory Report (2020); nb. these data exclude high alloy and stainless steel products, for which the emissions levels would be significantly higher.

by labelling. More significant volumes of emissions may be captured by including additional non steel inputs into steel products, notably alloys.

The main criticism – or controversy – surrounding the IEA approach to steel stems from a general disapproval by steel recyclers of the scrap sliding scale adjustments for scrap. Their main concern is that the scrap sliding scale is unfair, in that it can sometimes attribute a higher labelling rating to primary steel that has higher emissions than to an equivalent quantity of secondary steel. For this reason, recyclers often favour an approach based on product types, such as flat and long products. However, approaches which put primary and secondary steel on a common scale would create another problem by rewarding recyclers for little to no abatement effort, while primary producers would need to make massive investments to achieve similar performance ratings. Thus, a common scale would simply drive demand for finite scrap and hand a large windfall profit to recyclers without creating appropriate incentives for investment into green processes for their production route.

In this context, another relevant initiative emerged from The Climate Group, which has partnered with ResponsibleSteel to create the global initiative SteelZero, with a current membership of 36 organisations. SteelZero has established globally applicable goals which require members to commit to procuring, specifying or stocking 100 percent net zero steel by 2050. In the interim, by 2030, members commit to procuring, specifying or stocking 50 percent of steel meeting one or a combination of the following requirements (SteelZero, 2020):

1. ReponsibleSteel certified steel, or steel meeting an equivalent international standard;
2. steel produced at a site where the owner has publicly defined "both a long-term emissions reduction pathway and a medium-term, quantitative science-based GHG emissions target for the corporation". A target approved by the Science-Based Targets Initiative or another scientifically credible target of comparable ambition, coverage and quality would meet the interim requirement;
3. "low-embodied carbon steel".

SteelZero defines net zero steel as steel that is "as close as operationally possible to 0 kg CO_2e/t crude steel" (SteelZero, 2020). Any remaining emissions should be offset using a recognised offsetting framework. Low-embodied carbon steel, according to SteelZero, is defined as less than or equal to 1400 kg CO_2e/t of crude steel where no steel scrap is used and 200 kg CO_2e/t crude steel where there is a 100 percent steel scrap share (SteelZero, 2020).[4] The initiative also uses CO_2e/t crude steel as a measurement unit and has adopted the scrap sliding scale approach used by RS and the IEA. SteelZero has not specified if their thresholds have been designed for all steel grades.

While the interim goals of SteelZero offer flexible options on the path to the ultimate goal, these options may also create some level of uncertainty, as it is not entirely clear if the same level of ambition and the same analytical boundary apply to the three different options. With regard to the net zero steel definition, the term "net zero" steel alludes to the fact that the production of steel does not lead to any CO_2 emissions anymore, which is not how the present authors define the term.

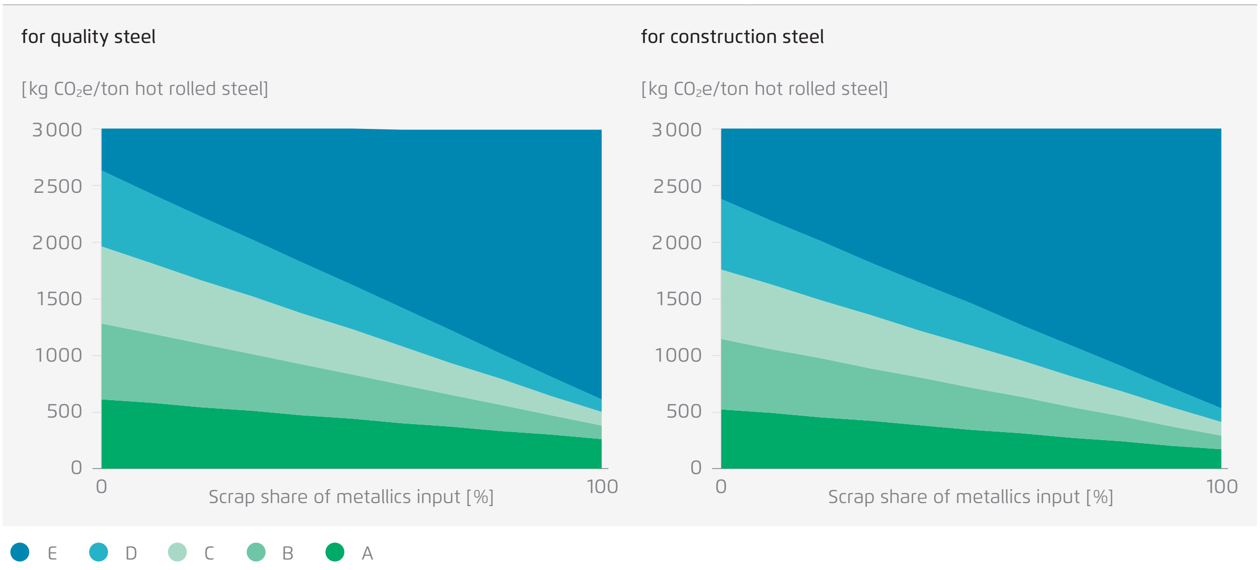
A fourth approach was put forward by the German steel association, Wirtschaftsvereinigung (WV) Stahl. It uses the same basic set-up as RS and IEA and aims to develop it further. As in those approaches, the classification system also uses a function of CO_2 emissions related to the proportion of scrap used in production. There are two main apparent differences, however, with respect to the analytical boundary and the calculation of thresholds.

First, the WV Stahl approach proposes to extend the analytical boundary to the hot rolling process step instead of setting the boundary at crude steel in order to show emissions reduction potentials linked to some of the early processing steps for steel. According to the WV Stahl, the emissions from hot rolling encompass both energy-related emissions as well as offcuts and other losses in the hot rolling mill. Conse-

4 The definition of low-embodied carbon steel is currently under review by the authors.

The WV Stahl steel classification system proposal

→ Fig. 6



WV Stahl (2023)

quently, the unit of measurement for the thresholds is kg CO_2e/t hot rolled steel. WV Stahl decided not to extend the boundary beyond the hot rolling step (at least for the time being) as final processing steps for different steel grades result in diverging levels of additional emissions, and efforts to agree on a common labelling approach should focus on the core emission-intensive steps of hot rolled steel production as a most important first step.

Second, WV argues that a classification system for steel needs to take into account the steel grade, and that a rulebook should consider grade-dependent adjustments. The classification put forward by WV Stahl specifically targets quality steel and construction steel, with calculations and thresholds based on specific steel grades C22 and C45 (WV Stahl, 2023). By distinguishing between quality and construction steel, the authors seek to account for the different levels in typical emission intensities across these steel classes in practice – high grade steels require greater energy and alloy inputs to achieve greater purity.

The analytical boundary encompasses not only the hot rolling process, but also alloys, the processing of scrap, the production of graphite electrodes and the emissions associated with the energy used upstream – all of which are not included in the IEA boundary. To be able to classify different steel grades in the label, the authors propose the use of emission factors for different alloy inputs using the ecoinvent database and formulas to adjust for the cumulative volume of different alloys in any given hot rolled steel. According to the authors, 100 percent of the emissions sources (including Scope 3 upstream) are covered by their proposed boundary, but a minimum of 90 percent of the emissions must be captured and verified (WV Stahl, 2023).

Third, the proposed thresholds derive from a technological perspective which aims to incentivise transformation processes for reaching each level. In contrast to the RS and IEA approach, the classifications are therefore defined on a bottom-up basis, based on different steel qualities. Especially for levels D and A, the values were derived bottom-up on the basis of virtual reference plants. These adaptations result in significantly higher thresholds for the secondary steel route, essentially because they include more processes and inputs within the boundary. They do this because they include those inputs and processes required to produce a specific steel grade - hence their emphasis on a steel grade approach. Under this approach, the thresholds would be adjusted upwards or downwards based on the steel grades used for a given product.

For quality steel, WV Stahl proposes four thresholds ranging from D to A. The E category represents all steel produced above the D threshold. The D threshold is set at 2 629 kg CO_2e/t hot rolled steel (0 percent scrap) and becomes progressively tighter until reaching 790 kg CO_2e/t hot rolled steel (100 percent scrap). The A threshold is set at 614 kg CO_2e/t hot rolled steel (0 percent scrap) and decreases to 264 kg CO_2e/t hot rolled steel (100 percent scrap). Equally spaced intermediate thresholds at B and C are proposed in this case as well (WV Stahl, 2023).

For construction steel, WV Stahl follows the same basic approach as for quality steel. Due to the smaller share of alloys in the steel, the thresholds for the construction steel label are comparatively lower. The D threshold is set at 2 370 kg CO_2e/t hot rolled steel (0 percent scrap) and decreases to 531 kg CO_2e/t hot rolled steel (100 percent scrap). The A threshold is set at 521 kg CO_2e/t hot rolled steel (0 percent scrap) and reaches 170 kg CO_2e/t hot rolled steel (100 percent scrap).[5] Construction steel typically entails a high level of steel scrap. Therefore, only a reference value for the 100 percent scrap level has been determined. The course of the thresholds results as a parallel shift to the thresholds of quality steel (WV Stahl, 2023).

According to the authors, regular reviews of the classification system – specifically the level A - are foreseen to ensure that the ambition of the labels mirrors potential future decreases in emission intensities of inputs such as alloys, lime or other factors such as the energy emission factor.

The WV Stahl approach is notable in its attempt to go beyond crude steel-based approaches and to try to address some of the competitiveness concerns expressed, especially by recyclers, over the scrap sliding scale and the narrower emissions boundaries proposed by the IEA and ResponsibleSteel. By including more parts of the production process, this approach captures more of the sources of emissions that recyclers or high-grade steel producers could change or amend in order to reduce their emissions relative to their competitors. The approach also seeks to enlarge the emissions scope to include alloy inputs into steelmaking and more of the downstream processing activities so that the labelling boundary corresponds more closely to existing protocols for reporting steel product emissions (as discussed above). Indeed, an approach based on steel grades seeks to achieve a label that is related more closely to final steel products rather than to production, as is the case with the IEA approach. The rationale for this approach is laudable and perhaps represents a model for the future.

WV Stahl inter alia uses emission factor data from the database ecoinvent to calculate its thresholds. The data-base is publicly accessible but offered at a fee. It is vitally important that consensus can be found among stakeholders within a reasonable timeframe on what these emission factor numbers should be. Lead markets are urgently needed for the transformation of the steel sector. If a sufficient degree of consensus on the data for benchmarking cannot be achieved in short order, then a less perfect but more practicable approach based on a more limited emissions scope may be preferable in the short run.

As with the ResponsibleSteel certification standard, the WV Stahl proposal also adopts a relatively small number of intermediate thresholds between A (near zero) and D (business as usual). For the reasons explained above, greater rewards for intermediate gains would be preferable.

Finally, a fifth proposal has been published in draft form by the Global Steel Climate Council (GSCC, 2023). The GSCC proposal is expected to depart from the scrap sliding scale approach and will not reflect the scrap share. Instead, the GSCC is exploring an approach based on differentiation between long and flat products, and in the future, alloy vs. non-alloy and stainless vs. non-stainless steels.

5 Since the exact values for both quality and construction steel were given only for 100 percent and 20 percent scrap, we have extrapolated from these to calculate the 0 percent scrap values here.

2.1.2 Conclusions and recommendations for a steel labelling approach

The existing approaches described above provide useful elements of a sound basis for a green steel definition that both incentivises transformation and reflects technical performance. Almost all of the steel label proposals discussed above feature a label based on a scrap sliding scale adjusting for the scrap share. The exception to this is the proposal – yet to be completed – from the GSCC.

In our view, an adjustment of the thresholds to reflect the scrap share seems sensible for three reasons. First, not adjusting for the scrap share may provide a large marketing windfall to scrap-based production, and simply lead to shifts in scrap flows while undercutting incentives to produce primary steel from vitally needed (but more costly) investments in breakthrough green technologies. Since scrap availability is limited, this would add too much demand for too little supply – at least initially – and send the wrong signal to steel investors regarding decarbonisation decisions from a global perspective. Second, at least in the short run, it must be accepted that recycled and primary steel are not yet perfect substitutes and therefore not perfectly interchangeable products. From this perspective, while acknowledging that scrap-based production is less emissions-intensive, it remains the case that scrap-based steel production has further scope for emissions reductions and should be incentivised to exploit this in order to gain classification as low emissions or near zero.

Thirdly, the potential competitive disadvantage for recyclers from a scrap sliding scale seems exaggerated if the boundary is based on crude steel production only. Even with the more ambitious thresholds of the IEA at the 100 percent scrap ratio, it can be argued that decarbonising scrap-based production in line with the low emissions A or near zero thresholds will be cheaper and technologically simpler than achieving the same label value of A or near zero for a primary steel production route in line with the same IEA label. At the crude steel emissions boundary, the vast majority of emissions derive from the use of fossil-based electricity inputs (80 percent of emissions according to IEA, 2022), something that can be changed with the signature of clean power purchase agreements from renewable energy providers. Some remaining sources of emissions, such as from upstream iron ore production (around 5 kg of CO_2/t crude steel), or the use of natural gas for pre-heating of scrap charge (around 30 kg CO_2/t crude steel), represent much smaller proportions of total emissions and can also be addressed via the electrification of the energy used in such processes (IEA, 2022). Finally, residual emissions from fossil fuels used as a carbon source (around 30 kg CO_2/t crude steel) and from lime fluxes used in the recycled steelmaking process (around 25 kg CO_2/t crude steel) would be harder – although not impossible[6] – to address, but represent only a marginal proportion of emissions. The competitiveness concerns of the recyclers over a scrap sliding scale based on crude steel may therefore be somewhat overplayed. Indeed, there are indeed already practical examples showcasing that achieving scrap-based steel production at below < 50 kg CO_2/tonne including scope 1 and 2 emissions of steel is possible[7] – thereby falling under the near zero IEA threshold already today.

Moreover, if the system boundary at crude steel were considered a temporary bridge until a shift to a broader emissions boundary, as in the WV Stahl proposal, then the long-term advantage given to primary steel routes would be unlikely to be economically very significant. Developing large-scale clean primary steel production will take at least a decade.

In terms of the analytical boundary to be used, we propose two plausible ways forward: The first, and simplest, option would be to take the IEA's emissions boundary but then to extend it, as in the WV Stahl proposal, to the hot rolling phase of production. Since more than 90 percent of steel is hot rolled, this would not be unduly restrictive. However, it would help to align reporting closer to existing reporting practices. It also would help to garner consensus with recyclers

6 For instance, bio-carbon based sources such as bio-methane could theoretically replace natural gas in some of these applications. The 25 kg related to limestone will need to find ways to reduce their CO_2 emissions. A potential solution could be Carbon Capture and Storage – for practical examples see previous laureates of the Innovation Fund.

7 See SSAB scrap steel: https://www.ssab.com/en

and give them additional abatement incentives. To do this, we would propose that the IEA's thresholds should be increased by + 0.1 t CO_2 on the upper emissions threshold (low emissions E), but that no emissions should be added to the lowest emissions threshold (near zero emissions), with the effect that the incremental labels in between would be shifted upwards by varying degrees (+20 kg for low emissions A, + 40 kg for low emissions B, etc.). The lowest emissions threshold should not be changed, since in a near zero steel making process, hot rolling should be possible using emissions-free fuels or electricity. This adjustment should also benefit recyclers, since it would recognise proportionately more of their emissions sources.

An additional possible extension to the IEA approach, building on WV Stahl's approach, could be to establish reference thresholds for the different dominant steel classes, including quality and construction steel. However, as proposed by WV Stahl, if undertaken, these should be based on representative examples of high and low grades, such as C45 and C22.

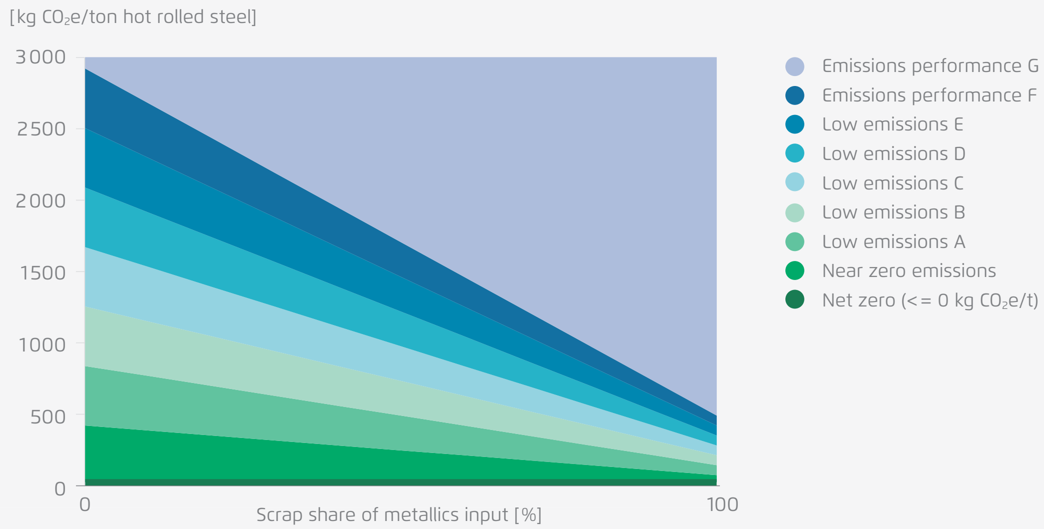
Focusing on the IEA boundaries (extended only to hot rolled steel) would have the benefit of relative simplicity and perhaps faster implementation and the use of the IEA's ready-made labelling system. One drawback of this approach is that it would result in different emissions boundaries from those of existing GHG reporting protocols and mechanisms. This would mean that for any company wishing to certify their steel products using the IEA labels, an additional subtotal of emissions in line with the IEA crude steel boundary would be required. This label would then need to be distinguished from the global warming potential of the final steel product. The label would refer to the GWP of the hot rolled steel used to make the steel product, but not to the final product itself. While this is not as neat as might be wished, it seems to be a relatively easy concept to communicate – especially in the context of a national government's lead market policy.

Should governments or lead market initiatives wish to extend the emissions boundary to align with the boundary of final products, then two further issues would need to be addressed. First and foremost, it should be noted that alloys and other chemical inputs are the main source of additional emissions, not downstream processing energy. In the case of alloys and other Scope 3 inputs, we would propose that steel product thresholds should not be adjusted by a fixed emissions factor, as this would make the labels too generous for some steel products. Rather, we would suggest that, when it comes to applying the label to a given steel product, case-specific modifications to the thresholds could be made for the proportion of alloys (by weight) in the product. This approach is in principle also suggested by WV Stahl's rulebook.

For instance, if a ton of stainless steel contained 10 percent chromium by weight, then 100 kg of ferrochromium x an emissions reference value for ferrochromium (say 6.60 t CO_2/t ferrochromium) would be deducted from the total life cycle emissions value for the purposes of assessing performance against the labelling thresholds. In this example therefore, 660 kg CO_2/t product would be added to the thresholds to take account of the 100 kg of ferrochromium in the steel product. The near zero emissions boundary would be increased in this case from 400 kg CO_2/t steel product to 90 percent * 400 kg CO_2 [carbon steel] + 10 percent * 6 600 kg CO_2 [ferrochromium] = 360 + 660 = 1 020 kg CO_2/t steel alloy product. The rationale for such an approach would be that it is simple enough to enable a quick implementation of the label. However, as part of future periodic revisions of the label, technological developments that enable a decarbonisation of alloy inputs need to be taken account of by e.g. ratcheting up the ambition of alloy reference values.

The main challenge with this approach would be finding agreement on the emissions reference values for the alloying elements. In the absence of other public data, we would propose using the values contained in Annex 5 of World Steel's 2020 Lifecycle Carbon Inventory report, referenced above. However, this list, while a useful starting point, is incomplete. Using the "IEA plus hot rolled steel" boundary and adjusting for alloys and other Scope 3 inputs would already encompass the vast majority of emissions of most steel products. Once again, however, the inclusion of alloys in this manner would not capture all product-level emissions that are typically report-

A (slightly) modified version of the IEA approach → Fig. 7



Agora Industry (2023) based on IEA (2022)

ed. Thus, a differentiated sub-total would be needed for certification using the standard underpinning the label. In order to incentivise marginal (but still costly) improvements, we would tend to support approaches with more intermediate thresholds rather than fewer. As an extension to the IEA approach, however, we tend to favour capturing those production shares in the label that do not qualify as low emissions via two further (F and G) emissions performance categories. We would also adopt the IEA's approach of equally-spaced intermediate bands between the first low emissions E and the near zero thresholds. However, we would depart from the IEA methodology to calculate the share of low emission production. In practice, that means that if a ton of production falls within a low emission C threshold, we would favor that not only a share of this ton qualifies as low emission, but rather all of it as low emission C. While other initiatives have proposed two intermediate thresholds, we propose four, in order to reward incremental CO_2 reductions, e. g. those resulting from a higher share of renewables in energy supply, partial replacement of fossil fuels with cleaner reductants, etc. In addition, for those producers that seek to reduce emissions even further to net zero or to achieve negative emissions and to be rewarded for these efforts, we propose to include a net zero threshold. As steel is a globally traded product, we do not propose a fallback option with a country-specific approach, but rather an international one.

2.2 Low emissions cement labelling

Cement is a mix of clinker, other main and minor constituents as well as small amounts of gypsum. Clinker production, which involves the crushing and calcination of limestone, accounts for around 90 percent of CO_2 emissions in the cement production process (see Figure 8; Material Economics, 2019). These emissions come mostly from the chemical transformation process of calcining limestone (around 60-65 percent) and to a lesser degree from the high temperature energy inputs into this process (around 35-40 percent). Because of this large share of process emissions, decarbonising clinker production is difficult without either carbon capture and storage or very innovative technologies using alternative binders or else advanced recycling technologies for recovered cement binder.

There are various cement types, which differ in terms of their clinker content. Ordinary Portland Cement (OPC) typically contains 95 percent clinker, while other novel CEM classes such as CEM II, CEM III and CEM VI have clinker shares ranging from around

35-80 percent, although exact numbers depend on specific geographies. Because of the challenges of reducing clinker process emissions, two of the key goals in decarbonising the cement sector are therefore to reduce the share of clinker in cement (Agora Industry, 2022) and to use less CEM I wherever possible.

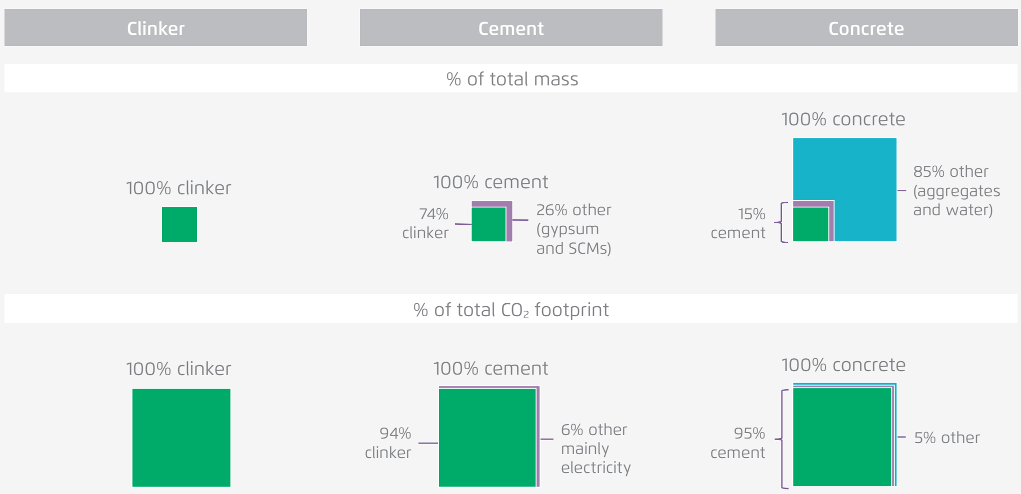
CEM I is often used by default in many construction applications because of its convenience: it can reach higher strengths quickly and is used to make self-compacting concretes, both of which can reduce construction time and thus save on project costs. CEM I based concretes can also be a default option to avoid having to develop different concrete mixes for multiple applications, which adds some degree of logistical complexity and requires more time than single generic approaches. However, while it has economic advantages, the extent to which CEM I is technically necessary in a net zero world of concrete-making is a matter of debate among experts.

Cement is not typically used directly on its own in construction, but in order to make concrete products, such as ready-mix concrete (RMC), pre-cast concrete (PCC) products, or mortars. Cement is a component of concrete and acts as a hydraulic binder to bind the aggregates together. Typically, concrete contains around 7-20 percent of cement by volume, but this share accounts for over 90 percent of concrete emissions (Agora Industry, 2022). Thus, in addition to reducing the clinker content of cement, another important goal of decarbonisation in the cement sector is to try to minimise the amount of cement "binder" used in the final concrete product.

The share of reactive cementitious binder per cubic meter of concrete can be reduced compared to existing practice in various ways, including by improving the grading of cementitious and aggregate granulates to improve the geometry of the concrete "packing", reducing the water content and adding superplasticisers or other chemical admixtures to maintain rheology (workability), and adding additional or substitute materials, such as ground limestone. A growing body of literature suggests that significant reductions in binder intensity per unit of concrete are technically possible. For instance, UNEP (2017) and Damineli et al. (2010) find that significant reductions of the ratio of cementitious binder to concrete are frequently possible compared to existing international practice (depending on location). According to UNEP (2017), different binder intensity ratios lead to CO_2 intensity differences of up to a factor of four

The carbon footprint of clinker, cement and concrete

→ Fig. 8



Material Economics (2019)

Note: „Other" CO_2 emissions from concrete include the manufacturing of concrete and emissions from materials other than cement. Transport emissions are excluded from these figures.

for concretes of the same strength class. However, in some regions, such as Europe, the potentials for cementitious binder reductions and thus also CO_2 reductions is currently limited either by cost concerns, by existing concrete product standards that effectively enforce higher cement content than is strictly necessary, or by existing practices which are not optimised to reduce CO_2 content. In Europe, the new version of the EUROCODE EC2 is intended to address some of these concerns based on an approach for the durability of concrete structures (exposure resistance classes) rather than their content.

2.2.1 Cement labelling vs. concrete labelling

While cement has received more attention than concrete in the labelling debate, concrete may often be a more suitable material to address by means of lead market and labelling policies. Because of the scope for reducing the share of reactive cementitious material, using innovative low clinker cement and concrete compositions, or using higher vs. lower emissions concretes more selectively at the construction site, more decarbonisation options are available for concrete than for cement. If lead market policies focus only on the clinker or cement stage of the value chain, these policies do not directly create incentives for such innovative products and practices at the concrete stage.

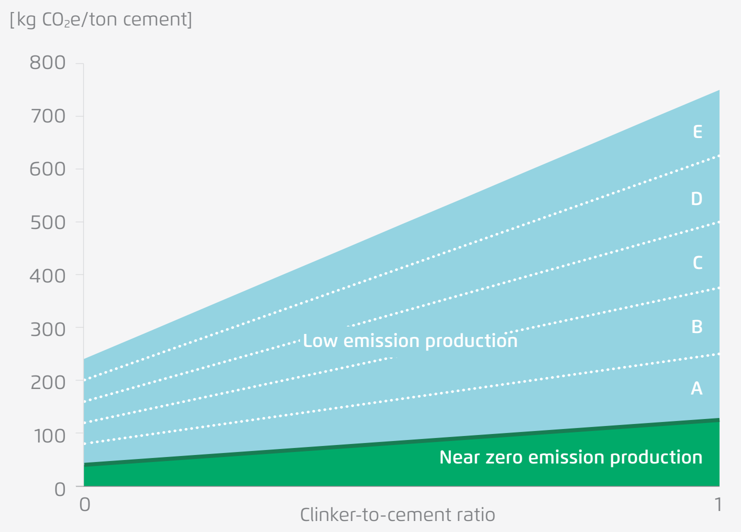
In many jurisdictions, concrete – rather than cement – is the product that is procured by the local government or construction project contractor. It therefore also makes sense from a practical point of view to focus lead market efforts on the main product procured by the client.

However, in some cases, labelling for cement can also make sense. First, for bagged cement that is sold retail, applying a label may be a good way to spur consumer demand for the lower-carbon product. Such retail cements often command a higher price premium. They can therefore be an economically more attractive initial option for cement companies to begin marketing more expensive low emissions cement products.

Second, in some jurisdictions (and typically in developing countries) cement, rather than concrete, is the product purchased by the project contractor and it is then mixed at the construction site itself into concrete. In such circumstances, labelling for cement might also be a useful way to steer demand towards

IEA proposal for near zero and low emissions cement labelling

→ Fig. 9



IEA (2022)

climate-friendly product alternatives to cement (although ideally a concrete labelling system applying at the level of the project contractor would be preferable).

2.2.2 Existing cement labelling approaches

As it has also done for steel, the IEA has proposed an approach for a globally applicable label for low emission and near zero cement in their G7 report (see Figure 7). It follows a similar design logic to that for the IEA's steel label - a "sliding scale" approach, in which thresholds for cement to obtain a given emissions performance label are defined as a function of the share of clinker in the cement product (a clinker-to-cement ratio). It follows the same methodology as the steel label. This means that for a given volume of total product with an emission intensity falling between the near zero and the low emission production thresholds, only a proportion would be deemed low emission production. This share is inversely proportional to the emission intensity of production (IEA, 2022, p. 128). There are six bands in total. However, governments can choose the final band range, which determines the amount of low emission cement produced. Like the steel label, the cement label follows a binary approach, meaning that cement production either qualifies as near zero or it does not (IEA, 2022).

For the near zero cement label, with a theoretical 100 percent clinker content, the IEA proposes a threshold of 125 CO_2 e/t cement. In the theoretical case of a clinker factor of zero, the near zero threshold falls to 40 CO_2 e/t cement. The formula is therefore y = 40 + 85c, where y is the emissions threshold in kg CO_2e/t cement and c is the clinker ratio. As an analytical basis for defining this near zero threshold, the IEA uses its own 1.5 °C scenario analysis for delivering a net zero economy in 2050, in particular the IEA Net Zero by 2050 Roadmap (IEA, 2021).

The E threshold - the maximum emissions intensity qualifying as low emissions cement – is set at 750 kg CO_2 e/t cement for a clinker factor of 100 percent and declines to 240 kg CO_2e/t cement for a theoretical clinker factor of 0. This threshold is approximately 100 kg CO_2 (-12 percent) below the IEA's CEM I 100 percent clinker cement best available technology reference value of 850 kg CO_2/t cement. The intermediate thresholds A-D de-marcate equal intermediate steps between the near zero and E thresholds (IEA, 2022).

The emissions system boundary is significant in that it differs from the relevant Product Category Rules typically used in certain parts of the world. The boundary chosen by the IEA focuses mainly on life cycle stages A1-A3 of cement production (i.e. those stages that mostly take place at the cement plant), but with some notable exceptions. It encompasses the mining and transport of limestone, the production of alternative cement constituents, the production of clinker and the grinding processes (see Figure 8).

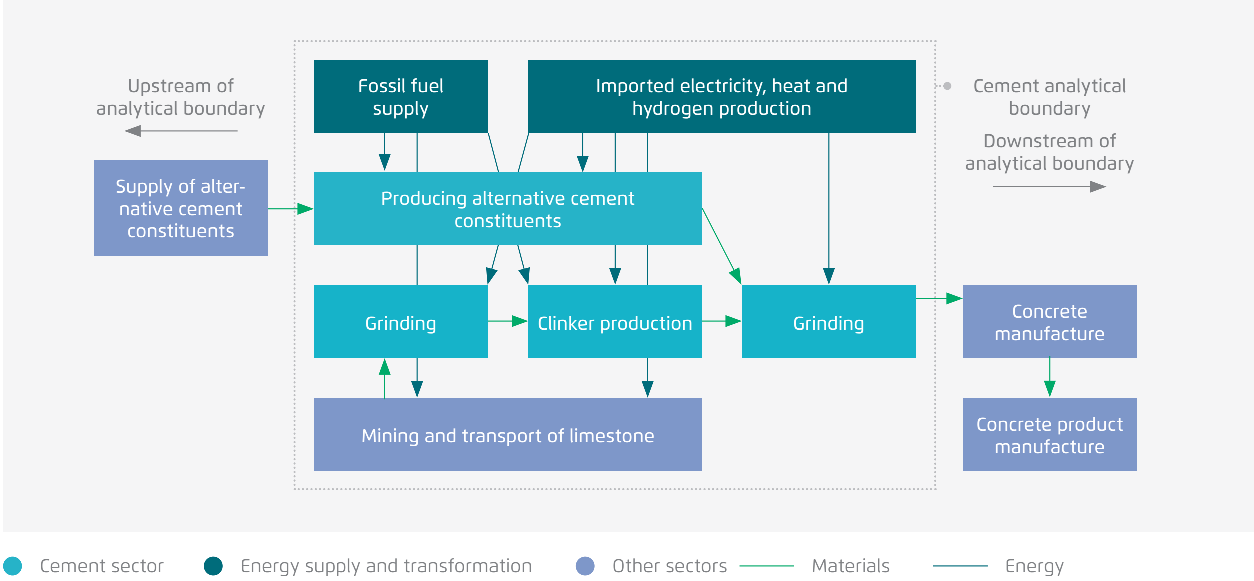
However, it excludes some elements commonly included in, for instance, European reporting standards. Notably, under EN 15804 and EN 16908, alternative cement constituents are included based on the economic method of allocation. In practice, this means that a small share of emissions from blast furnace slag or fly ash is attributed to cement when these co-products of steel or power production are used as a clinker substitute. Under North American PCRs, however, these items are considered co-products and are not included in the calculation of cement emissions.

The IEA method also excludes life cycle stages beyond the cement production phase, such as concrete manufacture (since it only focuses on the A1-A3 cement production phase of the life cycle). Thus, some downstream sources of emissions, such as transport of concrete to the production site, or recarbonation of cement during its lifetime (i.e. reabsorption of a share of emitted CO_2 over the lifetime of the final building), are excluded. This is justified by the IEA's aim of focusing the label on factors that can be influenced during the manufacturing (and highest emitting) phase of cement production.

Finally, an important emissions source that is included within the IEA's emissions boundary is the use of alternative fuels. Alternative fuels include the combustion of recovered mixed municipal or industrial fossil waste to heat the cement kiln. Biogenic waste is considered carbon neutral and therefore not

IEA cement emissions analytical boundary for defining near zero emissions cement production

→ Fig. 10



IEA (2022) nb. fossil fuel supply includes fossil-based waste used as fuel (e.g. mixed municipal waste)

included in the IEA boundary. Under existing ISO and EN standards for construction products, such as EN 15804, waste-based fuels are reported in the "gross" emissions but then deducted from the net emissions total because they are typically allocated to the sector that produced the waste (under the polluter pays principle).

Including alternative fuel emissions within the cement emissions boundary is a somewhat complex issue. On the one hand, it could be argued that the waste is a byproduct of other activities and would be combusted anyway (e.g. in waste incineration) if not "recovered" for cement production as a useful energy source. Including fossil waste emissions within the cement boundary would also be a deviation from current disclosure principles with regard to waste emissions. On the other hand, these emissions can represent large proportions of cement emissions in practice. Not including fossil waste fuels within the emissions boundary could theoretically result in perverse incentives: for instance, the zero rating on these emissions could dissuade cement producers from paying to capture these emissions as part of their CCS investments. Alternatively, cement producers might not have as much incentive to invest in genuinely climate neutral energy sources, such as (sustainable) biomass, hydrogen or electric kilns for clean energy supply.

One strength of the IEA's cement label is that its near zero threshold is based on an integrated assessment of what is required for a net zero compatible cement sector in 2050. The threshold – ranging from 40 to 125 kg CO_2/t cement – would imply a reduction of around 85 percent in emissions compared to the baseline for today's emissions, which is an ambitious level of reduction. In this respect, the IEA methodology is effectively underscoring the need for rapid deployment at scale of breakthrough technologies for this sector.

Another potential strength of the IEA approach is that it only defines low emissions cement from a level that is well below existing business as usual (around 100 kg CO_2/t cement, or 12 percent below their reference of 850 kg CO_2/t cement). It also includes several thresholds (6 in total) from the low emissions E level to the near zero emissions category, thus rewarding marginal (but very significant) reductions in emissions between the upper and near zero levels.

However, the IEA's proposal also contains some aspects that could arguably be improved upon. Firstly, the decision to adjust the cement labelling thresholds as a function of the clinker to cement ratio can be questioned. A practical effect of this part of the proposal is that incentives to abate cement emissions by decreasing the clinker content are significantly reduced.

The intention behind the sliding clinker scale seems to channel policy attention directly to clinker, the emissions-intensive portion of cement. While this makes sense in principle, the sliding clinker scale arguably does not provide the optimal incentive to reduce the clinker content in cements. As thresholds become progressively tighter with lower amounts of clinker, producers would not necessarily be rewarded for reducing the clinker factor in their cements through moving into a better label category. One of the main ways to reduce cement emissions is to reduce the clinker content of cement. However, the sliding clinker scale approach would likely be a major disincentive against using innovative cement and concrete types – such as LC3 cements – which aim to use radically lower clinker factors and alternative clinker substitute materials. Unlike in the case of steel, where there are strict physical limits on the substitutability of recycled and primary steel, there is no compelling technical reason why – as a rule – cements with significantly different clinker contents cannot be substituted for each other. (For instance, for the vast majority of applications, it is not clear that CEM I cements with 95 percent clinker content necessarily perform better than cements with 50-65 percent clinker content.)

A second question that could be raised about the IEA's cement labelling methodology is whether the upper label thresholds are sufficiently inclusive of the bulk of today's cement production globally. It is no doubt reasonable to insist that cement emissions must be a meaningful margin (e.g. 10-15 percent) below the reference technology today to be labelled low emissions cement. In this context, public procurement is a useful lever to incentivise difficult emissions reductions and governments should use the lowest emission cement available to them. However, including more label categories beyond those defined as low emissions could achieve more inclusivity of the label.

One organisation that aims to address these concerns regarding the IEA's cement labelling method is the German cement association Verein Deutscher Zementwerke (VDZ). It must be noted that the VDZ has not yet published a labelling proposal. However, the association has been involved in discussions around labelling of cement in the German context, and some of the ideas emerging in these discussions are worth discussing here. The "IEA modified proposal", if the VDZ initiative may be described in this way, essentially involves keeping the best parts of the IEA's cement labelling framework but then adding one additional component.

Specifically, the suggestion is to use the IEA's sliding scale in order to allow countries to fix the thresholds at a specific clinker ratio in the IEA cement labelling system. For instance, in Germany, where the average clinker ratio is roughly 0.7, it is suggested that all of the IEA thresholds should be defined using that number: e.g. 40 + 85 * 0.7 = 99.5 kg CO_2/t cement for the near zero threshold (and rounding up to 100 kg for reasons of simplicity and ease of communication), 240 + 0.7 * (750–240) = 597 kg CO_2/t cement (here again rounding up to 600 kg) for the upper boundary of the low emissions E threshold, and then equidistant thresholds in between. The x axis is thus effectively eliminated from the equation by using a specific national clinker ratio to define, for any given country, absolute (rather than sliding) emissions thresholds for each of the IEA's labels. Notably, the concept of fixed thresholds is also being discussed in the context of the IDDI initiative.

This approach also has the advantage that it can be used to adjust the thresholds to a slightly higher level based on the current average clinker factors of any country. For instance, in a country like India, where large amounts of CEM I are used, the thresholds could be adjusted to a 95 percent clinker level. Although doing so reduces the environmental ambition to some extent, it has potential practical advantages in terms of global inclusiveness.

One potential downside of the option for countries to pick their own clinker factor is that thresholds then will not be perfectly uniform across countries. This is perhaps less of a problem at the upper end of the labelling scale, as these thresholds are in part the starting point for setting subsequent more ambitious policy targets based on lower thresholds. Cement is not a heavily traded product, and the label could apply based on the thresholds of the destination market, i.e. where the cement product is sold rather than where it is produced. Moreover, the trade-off between inclusiveness and initial ambition might tend to argue for some flexibility initially in order to include large developing countries in a common approach.

Nonetheless, the decision to have different near zero thresholds for each country or jurisdiction can be questioned. An advantage of the near zero threshold is that it provides a common landing point for where countries' cement production should ultimately converge in the long run and for the level of ambition of near zero technology investments. Seen in this light, a difference of, say, 50 kg CO_2/t cement across different jurisdictions is arguably a weakness, as it could imply very significant differences in production costs and emissions per unit of product for two cement products that are both labelled near zero emissions. Indeed, different definitions of near zero emissions cement in 2050 would seem to be a structural problem best avoided.

Table 1 below illustrates the potential outcomes of the approach, which is reflected in the current IDDI approach and has bees been taken on board in the German discussion. The second column shows what the labelling thresholds would be in kg CO_2 e/t cement for a hypothetical Country A, which transposed the IEA approach using a 70 percent clinker ratio. The third column shows the same thresholds for a hypothetical Country B which transposed the IEA approach using a 100 percent clinker ratio. The fourth column then shows the effect of maintaining the same approach, but making sure that Country B and Country A adopted the same near zero emissions threshold, based on the global average 70 percent clinker ratio. A key result is that imposing the same near zero threshold on all countries allows for significant divergence in thresholds at the upper end of the labelling scale, but these divergences are gradually reduced in magnitude as countries move towards the upper end of the scale and align at the near zero threshold. Arguably, a general clinker factor of 70 percent would mean that some countries with an already comparatively low clinker factor of below 70 percent would start marginally better off. However, we deem this to be acceptable in light of a label

Climate-friendly cement labelling thresholds (in kg CO_2e/t cement) based on applying a fixed clinker factor to the IEA thresholds

→ Table 1

Rating	Thresholds for Country A (70% clinker factor*IEA approach)	Thresholds for Country B (100% clinker factor*IEA approach) (Option 1)	Thresholds for Country B (using same NZE definition) (Option 2)
Near zero emissions	99.5	125	99.5
Low emissions A	199	250	229.6
Low emissions B	298.5	375	359.7
Low emissions C	398	500	489.8
Low emissions D	497.5	625	619.9
Low emissions E	597	750	750

Agora Industry, based on IEA (2022) and adapting ideas from VDZ that needs to be ambitious and yet inclusive for many countries with diverging starting points.

Launched at COP26, with the United States and the World Economic Forum as its co-chairs, the First Movers Coalition (FMC) is a public-private partnership that encompasses a growing number of mainly multinational companies and several government partners[8] (US Department of State, 2022). The FMC's goal is to purchase near zero cement: FMC members in construction and engineering commit to purchasing, and other members in real estate, property development and government advisory bodies commit to specifying, at least 10 percent near zero cement by 2030 – inclusive of any Supplementary Cementitious Materials (SCMs) by 2030 and excluding fossil-based SCMs by 2035 (FMC, 2023). The FMC defines near zero cement as cement with an embodied carbon limit of 184 kg CO_2 e/t cement. This includes A1-A3 emissions as per EPD standards for Portland cement (FMC, 2023). The targets were calculated based on industry EPDs developed on the basis of the standards ISO 14025 and ISO 21930 – specifically, PCA EPD 195 and concrete EPD 10294.[9]

The FMC focuses on the upstream part of the cement value chain (A1-A3), where the bulk of emissions is located in cement production, and does not explicitly include recarbonation. The FMC approach does not set any intermediate thresholds for low emissions cement, unlike the IEA or the VDZ. It is therefore a binary "in or out" evaluation. While such an approach could be useful for certain objectives – including those of the FMC (such as setting a clear benchmark for a very small set of first movers to start purchasing their cement from very specific suppliers) – it creates hurdles for the formation of lead markets for public procurement or for much larger scale markets.

Failing to provide more intermediate categories precludes procurement agencies, and many private companies, from starting to buy low emissions cement in the years to come and thereby spurring the development of a market for low-CO_2 cements. Acknowledging that the initiative seeks to surface supply of near zero materials through signalling demand from its members, it effectively means waiting many years for the ultra-low emissions options to become available, and then only in specific locations. So this approach risks being much more exclusive and does not cultivate wide-scale markets in the same way.

Moreover, the near zero threshold of 184 kg CO_2 e/t cement proposed here is less ambitious in comparison to the proposals made by the IEA (40-125 kg CO_2e/t cement depending on clinker factor) and the options discussed in the German context described above (= < 125 kg CO_2e/t, fixing the IEA thresholds at a certain clinker factor).

2.2.3 Conclusions and recommendations for a cement labelling approach

As in the steel and concrete sectors, establishing a labelling approach for cement should aim for high climate ambition and set a future vision for sector transformation. In this respect, the thresholds adopted by the IEA and further developed in the German context appear to be good starting points for the near zero emissions threshold. However, these approaches and ideas arguably require some further development.

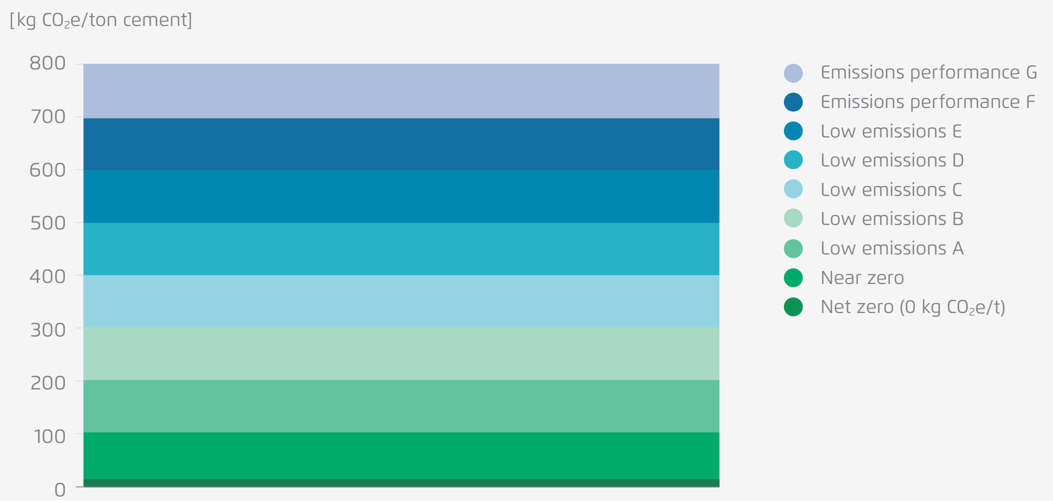
Specifically, Agora would suggest retaining the basic calculations of the IEA for defining the thresholds but not the adjustment based on the percentage of clinker along the x-axis (sliding scale). Instead, Agora proposes several adaptations.

Firstly, we propose using the IEA calculation for the near zero threshold to adopt a universal near zero emissions threshold. For this, we propose a 70 percent clinker factor (the current global average clinker content according to the IEA). Using the IEA formula of 40 + 85*0.7, this results in a near zero threshold of 99.5 kg CO_2/t cement as a general proposal. This could either be rounded to 100 or not (as in the discussion on this in the German context) – its practical effect is negligible.

8 Government partners include Canada, Denmark, Germany, India, Italy, Japan, Norway, Singapore, Sweden, United Arab Emirates, United Kingdom, United States of America, and Australia (FMC, 2023).
9 Information obtained via email.

Agora's default cement label: adaptation of the IEA approach with 70 percent clinker factor

→ Fig. 11



Agora Industry (2023) based on IEA (2022)

Secondly, to define the low emissions E threshold following the IEA terminology, we would suggest a default option based on a fixed 70 percent clinker factor (see Figure 11 above). However, if any country were to find this approach too arduous initially because its average clinker share was currently significantly higher, we would propose the option of using an alternative clinker factor based on the national average as a fallback approach. This would again be done by using the IEA scale and picking a fixed clinker factor appropriate to the specific national context (not higher than the national average for the relevant products). We would depart from the IEA methodology to calculate the share of low emission production described in chapter 2.11.

Countries would thus be able to choose their clinker factor to define their own low emissions E threshold and then, by extension, those thresholds between near zero and low emissions E. For instance, a given country A and another country B where the average clinker contents of cement are 70 percent and 85 percent respectively could each choose to pick the corresponding low emissions E thresholds of 597 and 673,5 kg CO_2/t cement. These countries would then define four equidistant intermediate thresholds between the 99.5 kg CO_2/t cement near zero value and these low emissions E values. Thus, their low emissions D, C, B, A would be different from each other, but increasingly close as they approached the common near zero threshold.

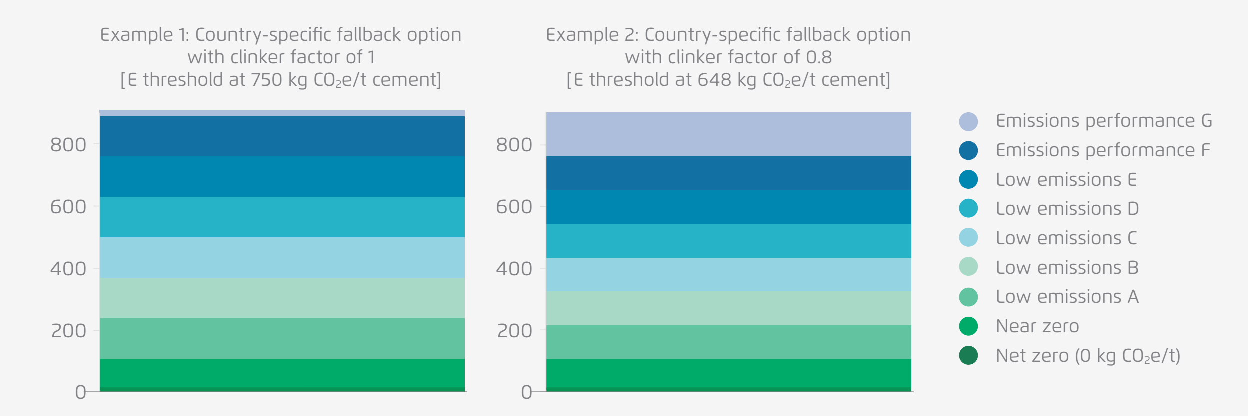
For producers wishing to reduce emissions even further, to zero or below zero, our proposed net zero threshold rewards these additional efforts with a specific net zero label category. This is important in our view because cement plants using CCS will have the possibility, when (sustainable) biomass is available, of adding negative emissions in order to achieve full emissions neutrality and providing technical sinks.

Finally, we also suggest including the whole range of cements being produced today in the label. For this purpose, we have added emissions performance categories F and G. The performance class F label threshold would be determined based on the addition of the same increment as between the preceding label thresholds: thus, it would depend on which clinker factor each country had used. The performance class label G would capture any cements beyond class F. The result of these suggested changes is shown in Figures 11 and 12.

The Agora proposal thus tries to strike a balance. On the one hand, the thresholds near zero through low

Agora Industry country-specific fallback cement label

→ Fig. 12



Agora Industry (2023) based on IEA (2022)

emissions E are simple extensions of the IEA approach, departing from the IEA's clinker factor-based sliding scale. On the other hand, CEM I or high clinker cements can be counted as low emissions if they reduce their emissions to the appropriate degree. Moreover, by adding additional categories above the level of low emissions E, this approach creates a wider range of label categories to enable the inclusion of all countries or jurisdictions, regardless of their starting points.

The use of many (small interval) label categories between G and A or near zero enables adaptability in differing contexts where governments may wish to set different levels of ambition. The use of various lower emissions cement types, from CEM II to CEM IV, could be incentivised by a policy of target setting using appropriate thresholds for procurement.

Regarding the analytical boundary to be used for the cement threshold, Agora would recommend an approach similar to that of the IEA. Specifically, we propose using only the A1-A3 modules of the relevant life cycle standards. We would therefore ignore the recarbonation aspect, as it does not support the specific policy aim of labelling in order to underpin investments in low emissions production, and at the same time complicates harmonisation between the EU and other jurisdictions such as North America.

With regard to the supply of alternative cement materials, such as co-products like slag and fly ash used as clinker substitute materials, we propose excluding those raw materials that are by-products from other production processes and are therefore not produced primarily for cement production in line with the IEA approach. Thus, steel slag and fly ash would not be included in the calculation. By limiting the exemption only to co-products, it would also ensure that potential new alternative materials (such as calcined clay) could be included in the calculation where they would have a material impact on emissions (thus avoiding distortions).

However, Agora would propose that excluding alternative fuels from the production boundary should be rejected by policymakers, as this could lead to significant perverse incentives to burn fossil waste, and it could fail to capture a potentially very significant fraction of fossil emissions arising from cement production. Including this additional emissions source in the boundary would not be difficult, as it is already reported today but simply not included in the total life cycle GWP.

2.3 Low emissions concrete labelling

Concrete is a mixture of cement, additions, coarse and fine aggregates as well as water. It also contains small amounts of chemical admixtures. As outlined in chapter 2.2, the emissions-intensive component in concrete is the clinker (due to its process emissions), and by extension, the cement, which is composed of clinker and other main and minor constituents as well as gypsum. Thus, while cement only constitutes around 7-20 percent of concrete by mass, it is responsible for around 95 percent of the overall emissions from concrete production (Agora Industry, 2022).

A multitude of different concrete types is available on the market. They can be differentiated based on several classification methods: their properties (e.g. bulk density, hardening state); the conveying method (e.g. pump concrete, spun concrete); the processing methods (rolled concrete, vacuum concrete); to the place of manufacture (e. g. ready-mix concrete, precast concrete); or the field of application (e.g. structural concrete, bulk concrete). Concrete is often reinforced with steel to enhance its structural performance, including to add overall strength. Ready-mix concrete is the main kind of concrete used in most developed markets for building, construction and industrial projects. While exact numbers are difficult to obtain, conversations with industry experts suggest that it represents about 70 percent of the total market share for concrete applications, with bagged cement (site-mixed concrete) and precast concrete sharing the remaining 30 percent.

Given its large market share, some have suggested that labelling should begin with ready-mix concrete. However, more differentiated product labelling to include products such as precast, bagged concrete and mortar is arguably also justified.

Concrete is subject to a number of performance requirements. These include compressive strength, durability, bulk density and deformation behavior. Usually, concrete is classified according to its strength class, i. e. the resistance of the material to pressure acting on it from one or several sides. For example, most Environmental Performance Declarations report the environmental performance of concrete relative to its compressive strength.

Compared to cement, a wider range of decarbonisation options is available in the concrete sector, and governments typically procure concrete. Companies can, for example, reduce emissions through reducing either the clinker factor in the cement or the cement share in the concrete, by means of cement and concrete recycling solutions or by minimising the energy-related emissions (Cembureau, 2023).

Concrete labelling has initially received little attention in the labelling debate. The IEA has not proposed their own approach to concrete labelling, and it was not within the scope of work of the Industrial Deep Decarbonisation Initiative (IDDI) at first. However, many stakeholders have pushed for a label for concrete, since the material is essential in public procurement and a label could therefore have a large steering effect. Consequently, IDDI has enlarged its materials scope to include concrete, and will come up with a proposal in 2024. A number of other actors have proposed their own labelling approach and thresholds, including LCCG, ConcreteZero and the First Movers Coalition. A widely endorsed approach is to label the CO_2 intensity of concrete differentiated by strength class. However, here too critical questions remain to be resolved, such as the accounting of co-products such as slag or fly ash.

2.3.1 Overview of existing labelling proposals

The Low Carbon Concrete Group (LCCG) is a UK group of professionals from the concrete and cement industry, academics and other stakeholders. LCCG published a low-carbon concrete routemap in April 2022. In the routemap, the LCCG proposes a concrete label based on kg CO_2e/m^3 by strength class. According to the group, this approach is sensible since it enables a comparison of different concretes in practice. The approach includes the strength classes C8/10 to C50/60. A cut-off was made at C50/60 as beyond this data available were insufficient (LCCG, 2022).Data for the LCCG label were provided by several companies that produce concrete in the UK. Most of the data provided was on ready-mix concrete, but some was included on precast concrete . The analytical boundary used includes A1-A3 cradle-to-batching-gate for ready-mix concrete and cradle-to-mould for precast. This means that the focus lies on the concrete production as the stage in the concrete value chain where most emissions originate. It also means that further life cycle stages - notably including recarbonation – are excluded. The authors propose nine thresholds in total: A++, A+ and A to G. The A+ and the F thresholds represent the lower (0–5 percent) and the upper (95–100 percent) bounds of the benchmarked concrete data[10]. The G threshold represents all production beyond the F threshold. Conversely, concrete with lower emissions than those of the bench-marked data is given an A++ rating. In theory, the A++ rating would therefore also capture concrete with negative emissions. The range for the intermediate thresholds is given in table 2. The A++ rating starts at around 30 kg CO_2e/m^3 for C8/10 and rises to around 150 kg CO_2e/m^3 for C50/60. The F rating starts at around 260 kg CO_2e/m^3 and ends at approximately 450 kg CO_2e/m^3 (LCCG, 2022).

Noteworthy about this approach is that it is an initiative targeted at the national level using UK-level data and not specifically intended for regional use. However, the basic approach of LCGG merits a closer look, as the principles behind the analytical boundaries for emissions associated with concrete could be translated to other regions using local data, although it is an open question how easy it is to do so. The measurement unit of kg CO_2e/m^3 per unit of compressive strength seems to be a sensible and practical approach given its widespread use by industry and reporting mechanisms such as EPDs alike. Also, the focus on life cycle stages A1-A3 is welcome in view of its focus on the emissions-intensive stage of the value chain. However, using percentage reductions to determine the thresholds involves a certain level of uncertainty and risk of miscommunication. The LCCG benchmarks are updated every 12 months. When updating the label using more current data, there is an additional risk that thresholds may become less ambitious if the emissions intensity of concrete production at that point in time increases. The use of precast and ready-mix concrete data to establish label thresholds is controversial with some in the industry. It remains a subject for further discussion whether ready-mix and precast should be subject to the same thresholds.

ConcreteZero, a global initiative led by The Climate Group together with the World Green Building Council (WGBC), aims to bring together a growing number of organisations (including public procurement bodies, architects and companies involved in the supply of concrete in the LCA stages beyond A1-A3) to use, procure and specify net zero concrete. Members commit to using 30 percent "low embodied carbon concrete" by 2025, 50 percent "low-embodied

10 The first yearly update of the LCCG Benchmarks and its threshold rankings is expected to be published in the fall of 2023.

LCCG concrete label rating categories

→ Table 2

Rating	kg CO_2e/m3 fractile range within the strength class
A++	kgCO_2e/m3 below those of benchmarked concretes
A+	0%–5%
A	5%–20%
B	20%–40%
C	40%–60%
D	60%–80%
E	80%–95%
F	95%–100%
G	kgCO_2e/m^3 above those of benchmarked concretes

LCGG (2022)

carbon concrete" by 2030 and 100 percent "net zero concrete" by 2050 (Climate Group, 2023).

ConcreteZero's "low-embodied carbon concrete" threshold is defined as concrete with "less than or equal to the LCCG benchmark rating A", thereby making use of the LCCG label. ConcreteZero defines "net zero concrete" as concrete whose GHG emissions are as close as possible to zero metric CO_2e/m^3 (at least 90 percent mitigation). Emissions offsets should be used only for residual emissions using a recognised offsetting framework. No definition for residual emissions is provided. According to the authors, this definition of net zero concrete is aligned with the Science Based Targets Initiative definition. While the ConcreteZero definition of low-embodied carbon concrete builds on the LCCG label from the UK, the initiative is global (ConceteZero, 2023), so their definition seems to be targeted at that level too.

The Science Based Targets Initiative (SBTi) targets the company and not the product level analysed here. However, given that ConcreteZero explicitly mentions that it aligns with the SBTi suggests that it merits a closer look. To meet the SBTi goal, companies must make an effort to halve their emissions by around 2030 and reduce them by at least 90 percent by 2050. According to the SBTi guidance, residual emissions must be counterbalanced through the permanent removal of CO_2. This could be achieved through Direct Air Capture and Storage, Bioenergy with Carbon Capture and Storage (BECCS), land restoration, and/or soil and forest management. Leading up to 2050, companies should actively pursue mitigation action beyond their own value chain, e. g. by purchasing REDD+ credits (SBTi, 2022).

Given the novelty of the subject, ConcreteZero's use of the LCGG label as a starting point at the time is understandable. However, as already mentioned, using national level thresholds for a globally applicable level is unlikely to be the most efficient and equitable way to reduce global emissions. Also, for concretes that can involve a certain level of residual emissions, the term "near zero concrete" may be more suitable than "net zero concrete". If the possibility of using offsets for residual emissions in the sector is being put forward, a definition of residual emissions may be necessary. SBTi defines residual emissions in their guidance document as "GHGs still being released into the atmosphere when the company has achieved its long-term science-based target" (SBTi, 2022, p. 9). While it is clear that this means that 90 percent or more of emissions reductions need to take place at the production site itself, the question still remains what the nature of these residual emissions is. In addition, the climate protection potential of projects typically used for offsets such as afforestation is uncertain due to the risk of natural disasters such as droughts or fires. An overreliance on offsets therefore carries th risk of failing to reach the global net zero target. Finally, it is difficult to define a high-certainty baseline for off-setting projects targeting, for example, afforestation.

The First Movers Coalition has formulated goals for both cement and concrete. Members of the First Movers Coalition commit to purchasing near zero concrete that meets the embodied carbon limits shown in Table 3. More specifically, FMC members in construction and engineering commit to purchasing, and other members in real estate, property development and government advisory bodies commit to specifying, at least 10 percent "near zero" concrete by 2030 – inclusive of any SCMs by 2030 and excluding fossil-based SCMs by 2035 (FMC, 2023).

The FMC approach also measures kg CO_2e/m^3 for different compressive strength classes but uses a different unit – pounds per square inch (psi) – from that used by other initiatives (see Table 3). In contrast to ConcreteZero, the commitments specified do not include carbon offsetting. The "near zero" concrete threshold put forward by FMC includes A1–A3 emissions (cradle-to-gate) according to EPD standards for ready-mix concrete (FMC, 2023). In contrast to ConcreteZero or the LCCG Initiative, no intermediate low emissions concrete thresholds, nor thresholds for net zero concrete, are proposed.

There are different ways of measuring compressive strength. From our research, megapascal (MPa) is the most commonly used. FMC uses psi here, which can be converted into MPa. A conversion of units may be needed to enable comparisons between different targets and emissions reduction achievements. FMC

FMC's near zero concrete thresholds → Table 3

Specified compressive strength (f´c in psi)	Conversion into MPa	Embodied carbon (kg CO_2e/m^3)
0–2500 psi	0–17	70
2501–3000	17–21	78
3001–4000	21–28	96
4001–5000	28–34	117
5001–6000	34–41	124
6001–8000	41–55	144

Agora Industry (2023) based on FMC (2023)

sets absolute targets and not percentage reductions, which is to be welcomed on account of the communicability and clarity of these targets. However, because it only formulates a near zero target, this approach does not reward incremental emissions cuts. Nor does it provide governments with product shares identified as low emissions, which would enable them to start procuring lower-CO_2 products. Also, compared to other proposals for near zero thresholds analysed here, the FMC proposal is less ambitious (e. g. LCGG A++ threshold for C12/15 proposes a CO_2 limit of around 30 kg, while FMC proposes 70 kg for the same strength class). The focus on A1-A3 and on ready-mix concrete seems reasonable for the reasons outlined at the beginning of this chapter.

The Global Cement and Concrete Association (GCCA) has also been involved in discussions around concrete labelling. GCCA has set out different options for the implementation of a concrete labelling system, while not proposing one themselves (yet). The association has voiced its support for a label that is based on Environmental Product Declarations (EPDs) for concrete with thresholds established at a country level. In cases where country specific data is unavailable to establish thresholds, GCCA has put forward the idea of a fall-back approach.

Finally, the Industrial Deep Decarbonisation Initiative (IDDI) was established at the Clean Energy Ministerial, and its secretariat is run by the United Nations Industrial Development Organization (UNIDO). Its membership include the national governments of the United States, Germany, Canada, the UK, India, Saudi Arabia, UAE, Brazil and Japan, so it has the potential for some of the largest economies in the world to pursue aligned strategies in a few key areas. For example, it aims to complement private sector demand creation initiatives like FMC by focusing on public procurement for steel, cement and concrete.

Four levels of public procurement pledges are defined by the IDDI (2023):

- → **Level 1** – Starting no later than 2025, requires disclosure of the embodied carbon in cement/concrete and steel procured for public construction projects.
- → **Level 2** – In addition to Level 1. Starting no later than 2030, requires whole project life cycle assessments for all public construction projects, and, by 2050, achieve net zero emissions in all public construction projects.
- → **Level 3** – In addition to Levels 1 and 2. Starting no later than 2030, requires procurement of low emission cement/concrete and steel in public construction projects, applying the highest ambition possible under national circumstances
- → **Level 4** – In addition to Levels 1, 2 and 3. Starting in 2030, requires procurement of a share of cement and/or crude steel from near zero emissions material production for signature projects.

Where IDDI goes further than other concrete initiatives mentioned above is that it aims also to address – via the development of guidance documents for procurement agencies – the underlying data transmission and reporting standards that are needed for a robust application of low emissions product labelling to procurement in practice. Currently, the IDDI assembles all the different initiatives and stakeholders working on labels in a joint forum. IDDI aims to come up with a proposal for low emissions and near zero concrete definitions in 2024.

2.3.2 Synthesis and recommendations for a concrete labelling approach

The different initiatives analysed above demonstrate a variety of possible approaches to CO_2 performance concrete labelling. In the following section, we synthesise the findings of our analysis of the different approaches and outline our own recommendations for a labelling approach based on ambition, (technical) feasibility, fairness, communicability and simplicity.

First and foremost, it is noteworthy that there is already a high degree of convergence on several relevant aspects. With regard to measurement units for the label, the different actors have in past discussions on the topic broadly agreed on several points.

Firstly, on the measurement of concrete emissions in kg CO_2e/m^3 per unit of compressive strength (MPa). This also conforms to current practice, as concrete is usually measured and sold by volume (m^3). Furthermore, compressive strength is the most widely used and arguably most useful way of measuring the functional performance of concrete. Furthermore, most Environmental Product Declarations (EPDs) – a globally used tool to report the environmental performance of concrete – measure the material's embodied emissions in CO_2e/m^3 per unit of compressive strength (MPa). Only a small number of EPDs analysed as part of this study adopt a different measurement unit (e.g. kg CO_2e/t per MPa or kg CO_2e/m^3 per Psi). Therefore, kg CO_2e/m^3 per MPa can be seen as a straightforward approach that mirrors technical practice.

Secondly, in terms of the analytical boundary, the majority of actors support an A1-A3 cradle-to-batching-gate approach for ready-mix concrete. There are several arguments for this approach. It is in the life cycle stages A1-A3 (i.e. from the extraction of raw materials to concrete production) that the bulk of emissions occur, thus meriting special focus. In addition, procuring agencies depend crucially on the decarbonisation of the A1-A3 stages to be able to procure low emissions and subsequently climate-neutral materials. Furthermore, the environmental impact of life cycle stages beyond A3 is project-dependent (e.g. how much recarbonation can occur varies by individual project) and thus difficult to measure by means of a single label. These subsequent life cycle stages also contribute only a minor share to the overall emissions generated over the life cycle of producing and using concrete. However, emissions from subsequent life cycle stages should be included in future regulations on embodied carbon in order to incentivise decarbonisation of these stages of the value chain as well. A focus on A1-A3 cradle-to-batching gate for ready-mix concrete is thus a logical approach.

A key issue in the debate over the appropriate analytical boundary for concrete is how to take account of co-products from other industries, notably fly ash from coal power production and granulated blast furnace slag from steel production. These by-products are often used as input materials for cement in concrete today. However, accounting methods differ. In the United States, these products are treated as waste products, and their emissions are therefore not attributed to the cement and concrete industry. In Europe, on the other hand, they are. This has consequences for the overall emissions of the concrete industry in a given country or region and therefore for potential label thresholds. While the long-term goal should be to harmonise accounting rules, they can nevertheless be used as a data basis for establishing the reference CO_2 emissions given the short timeframe remaining in which to implement solutions.

As with cement, the concrete labelling and thresholds should adequately reflect regional differences but apply a common landing point for 2050 (in terms of the near zero emissions threshold). Countries set out on their transition pathways towards climate neutrality with differing individual legacies, hurdles, and opportunities. These range from standards for producing concrete, to financial options for supporting new technologies, to the availability of Supplementary Cementitious Materials (SCMs).

For this reason, and as in the case of cement, we propose applying a primary or "default" option based on a theoretical calculation, but also a fallback option in cases where countries want to opt out and establish country-specific starting points for the labels. Once again, we suggest building on the solid basis of the proposals from the IEA and VDZ.

Our near zero threshold is therefore based on a theoretical calculation for 2050. It adopts the IEA calculation for near zero cement for an average clinker ratio of 0.7 and converts it into an equivalent amount of emissions per m^3 of concrete. This calculation is performed assuming a reactive binder intensity of 230 kg cement per m^3 of concrete for C16 and 264 kg cement/m^3 concrete for C50. These figures are based on analysis of world-best binder ratio using technically feasible levels of cementitious powder according to experts (see Damelli et al., 2010; UNEP, 2017). We then add an amount of 10 kg CO_2e/m^3 for additions across strength classes. Further emissions are not added for other common emissions sources today, such as aggregates or energy inputs into concrete mixing, since it is assumed that in a near zero concrete plant, these emissions have been eliminated, inter alia via decarbonised electrification of the relevant processes. Using this approach, we arrive at a near zero threshold of 33 kg CO_2e/m^3 for C16 concrete and 36 kg CO_2e/m^3 for C50.

Since beyond C16 and C50 the correlation between added or reduced strength of concrete and binder intensity tends to break down, we do not include calculations of thresholds beyond these points on the x axis. In principle, we think policymakers could probably simply extend the same thresholds for C16 and C50 out to additional strength classes in a linear manner if they so wish. In any event, these extended thresholds would probably only apply to a small fraction of the total concrete on the market, since over 80-90 percent are clustered between these classes.

Next, we define the highest category of low emissions concrete, following the IEA logic as applied to cement. For this calculation, we adopt the IEA's low emissions threshold for a clinker factor of 0.7 (current global average) and convert it into m^3 of concrete by assuming a less ambitious binder intensity than in the case of near zero cement. This binder intensity once again rises for higher strength classes - from 250 kg cem/m^3 (C16) to 380 kg cem/m^3 (C50). These figures are closer to the global average binder intensity, according to the literature (see Daminelli 2010; UNEP, 2017). Furthermore, we add a sum of not just 10 kg CO_2e/m^3 as in the near zero case, but rather of 40 kg CO_2e/m^3 concrete in order to cover emissions from superplasticisers (10 kg CO_2e/m^3 concrete) and aggregates (10 kg CO_2e/m^3 concrete) as well as from energy inputs to concrete mixing (20 kg CO_2e/m^3 concrete). Unlike with the near zero threshold, in this case more of today's actual emissions are included.

To arrive at the intermediate thresholds, we calculate equal intermediate steps from E to near zero. The differentiation into five evenly-spaced thresholds enables concrete producers to be rewarded for incremental improvements in their production processes. The distance between each threshold is therefore 46.2 kg CO_2e/m^3 concrete at the high strength end and 31.25 kg CO_2e/m^3 at the low strength end. As in the case of cement, as described above, two further thresholds are added beyond the low emissions E threshold. These are performance class F (an additional 31.25-46.2 kg CO_2 above the E threshold) and a catch-all performance class G, which is designed simply to catch every concrete that has a higher emission intensity than this. This means that all concretes receive a label, no matter what their emissions level.

In addition, we also propose a net zero concrete treshhold (set at 0 kg CO_2e/m^3 concrete) for companies that seek to reduce emissions to zero or even to achieve negative emissions and thereby reach an even better label rating. This level of ambition can be achieved via the capture of residual emissions and the use of bioenergy to generate negative emissions. BECCS-based cement and concrete production is a potentially important option for the use of CCS, which is why we include this level of performance as a goal deserving additional credit beyond the near zero level.

We do not recommend including offsetting as a way of reaching the targets because the objective of labels should be to incentivise the transformation of the core processes to which the labels apply.

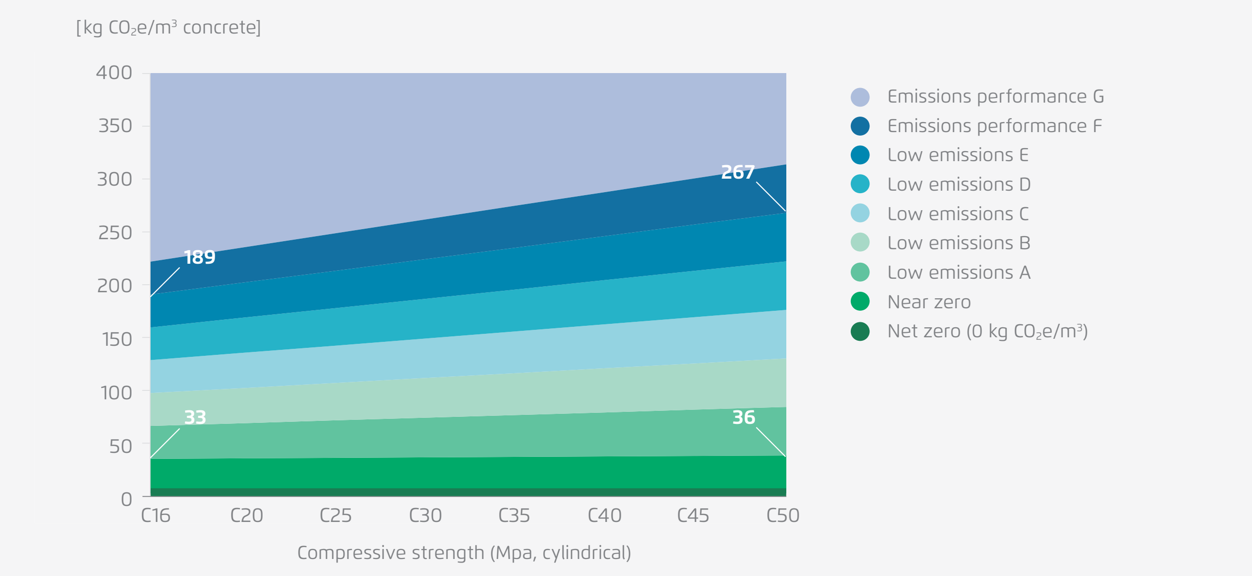
It should be borne in mind that any threshold can in principle be reached through multiple routes, including but not limited to CCS (see Figure 14). This encourages flexibility and offers room for innovation on the part of companies. For example, among possible routes to reach the "low emissions A" concrete threshold without CCS, companies can reduce the clinker-to-cement ratio (e.g. by using increasing shares of SCMs or innovative mix designs) or the cement-to-concrete ratio (using superplasticisers, optimised grading of particles, dispersants and other admixtures), reduce their energy emissions (e.g. via kiln and calciner electrification, or using biomass or other decarbonised fuels), and/or recycle cement and concrete at the end of its life. However, it is fair to say that in many cases, near zero emissions thresholds would require CCS, at least based on today's technological knowledge. So the most ambitious threshold under the labelling system is reserved for the most innovative and costly decarbonisation options – at least from today's technological standpoint.

For concrete, as for cement, we also propose to allow for an adjustment by individual countries to the upper thresholds when the initial cement or clinker content is significantly higher than the levels assumed. This is in order to ensure the inclusiveness of the labelling system.

The approach adopted is similar to that described in the preceding section on cement. Once again, to allow for the different clinker factors used in different regions of the world, we propose that the methodology described above for defining concrete thresholds may be adjusted for different clinker factors, but only for thresholds above the net zero emissions and near zero emissions levels.

The zero emissions and near zero emissions thresholds are defined as described above in the default case and using the 70 percent clinker factor assumption. However, to allow for regional differentiation, the other thresholds can be defined based on alternative clinker ratios as appropriate to the country in question. For instance, for a country with a national average of 90 percent clinker content in cement, we propose that the low emissions E threshold is recalculated based on the IEA formula and then fol-

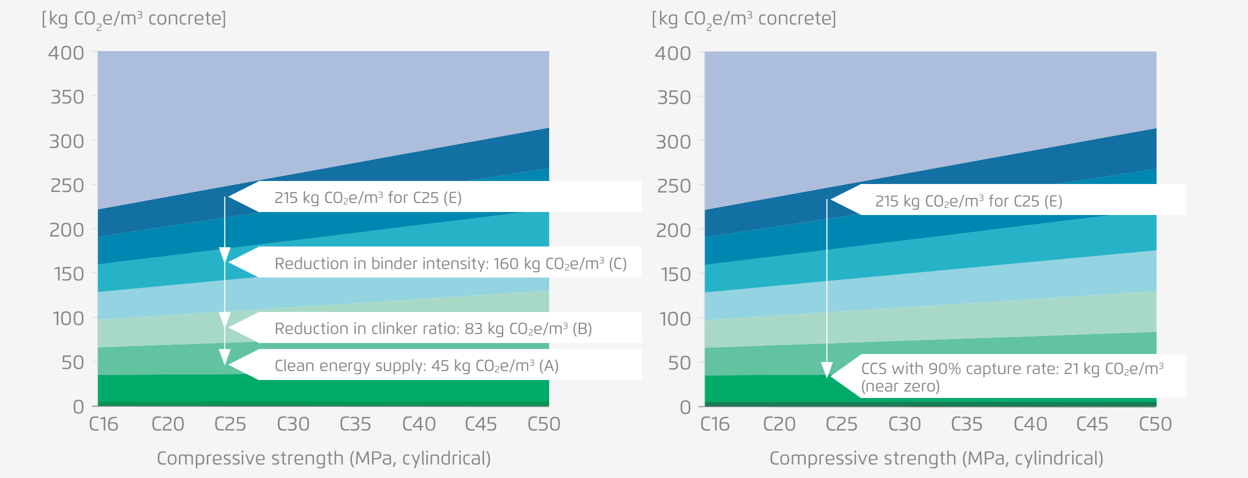
Agora Industry default concrete label (70 percent clinker content assumed) →Fig. 13



Agora Industry (2023) based on IEA (2022)

Illustration of different ways to achieve a more ambitious Agora Industry concrete label rating

→ Fig. 14

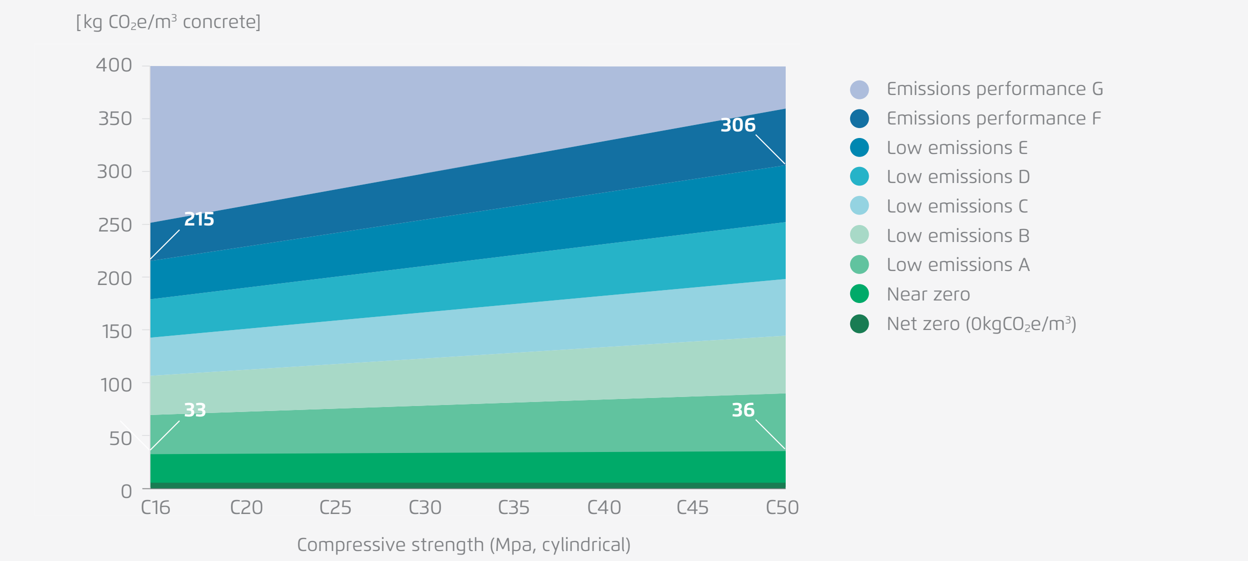


Agora Industry (2023) based on IEA (2022)

lowing our concrete conversion formula, using the 90 percent clinker factor as an input. This would be 240 + 0.90 * (750-240) = 699 kg CO_2/t cement, which is then converted into thresholds per m^3 of concrete and by strength class by assuming a rising binder intensity of 250 kg cem/m^3 (C16) to 380 kg cem/m^3 (C50) and by adding 40 kg CO_2e/m^3 concrete for non-cement related emissions in concrete as described above.

Agora Industry fallback country-specific concrete label based on country-specific average clinker factor (example here shown for 90 percent clinker factor assumption)

→ Fig. 15



Agora Industry (2023) based on IEA (2022)

In this case, the calculation using a 90 percent clinker factor for a hypothetical country would result in a low emissions E threshold of between 215 kg CO_2e/m^3 (C16) and 306 kg CO_2e/m^3 (C50). Intermediate thresholds A through D could then be defined based on equidistant steps between this level and the near zero emissions threshold. Thresholds above the E level, for F and G, could be defined following the logic described above for the default method, i.e. performance level F would add an additional interval of the same distance as D-E, while G would cover all concretes with performance levels above F.

An example of this calculation is given in Figure 15.

3 Recommendations for next steps

Labelling will be a fundamental component of demand-side policies for climate-friendly materials and should be implemented quickly to help the rapid development of market signals for investment in cleaner production processes. The proposals described above provide suggestions on how this rapid implementation might be carried out.

In any event, however, some important questions will need to be resolved in the near future. These are not necessarily barriers to moving forward with lead market initiatives as described above, but they do represent areas where further actions might still be required, suggesting the following medium- and longer-term objectives:

- → **Enhanced data availability, quality, and harmonisation:** In order to enable reliable comparison of the environmental performance of materials and final products across regions, high-quality and comparable primary data on the climate impact of each specific material or final product will need to be collected. This also means to move away from the use of generic data over time towards a product and plant-specific data collection, and a maximisation of the data coverage to the extent possible.
- → **The harmonisation of national or regional accounting rules at the global level and their revision in the light of future technological developments:** In the cement and concrete industries, the way in which co-products are dealt with differs from region to region. In North America, for example, the emissions from fly ash from the coal industry and slag from the steel industry are allocated to these industries. In Europe on the other hand, they are economically allocated to the cement industry because these products are used as SCMs in the production of cement and concrete. In the short run, these different accounting rules need to be considered when designing labels, as shown above. However, in the long run, the goal should be to harmonise these rules in order to enhance comparability. At the same time, new technological developments, e.g. in carbon capture and storage (CCS), will make a revision of standards underpinning cement and concrete production necessary in order to also encompass rules for the associated accounting of emissions.
- → **A dynamic revision of the labels:** A balance must be struck between stability and reliability to enable both investment and the ability to adapt to changed technological, scientific and market circumstances. Technological innovation in all areas will most likely make a revision of the labels necessary in the next few years. Once new climate-friendly technologies have been developed or existing technologies have been further improved, increased CO_2 reductions in all sectors may be possible. As a result, label thresholds could become even more ambitious. Regular reviews of the labels could be mandated to check whether adjustments are necessary. The key is to ratchet up ambition in line with what has become technologically possible. For example, a key question regarding labels for the cement and concrete sector that will need to be dealt with is where the analytical boundary will need to be drawn once CO_2 is captured, transported and stored. Another question is how to deal with negative emissions from bioenergy carbon capture and storage (BECCS) and any possible extension of the analytical boundary used.
- → **Expanding product coverage over time where necessary:** In some cases, the full output of a given CO_2-intensive material might not be covered by a label at the beginning of the relevant initiatives. For instance, it was discussed in this paper that only ready-mix and not precast concrete might be covered due to concerns from industry players about cross-product competition. This could be addressed in subsequent iterations. In addition, the set of products covered might also be expanded. The exclusion of aluminium from the current discussion on labelling and lead markets is notable, as are those of plastics and certain basic chemicals.
- → **Creating links between labelling and other demand-side policies:** Labels are just one – albeit a critical – part of a demand-side related policy package. The design and ambition of labels has

implications for other demand-side policies such as public procurement and embodied carbon limits on final products like cars or buildings. For example, public procurement bodies could use labels as a basis for the formulation and implementation of (interim) targets. Understanding and leveraging the potential synergies between these different policies is key.

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Agora Industry

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About Agora Industry
Agora Industry develops scientifically sound and politically feasible concepts for successful pathways to a climate-neutral industry – in Germany, Europe and internationally. The organization which is part of the Agora Think Tanks works independently of economic and partisan interests. Its only commitment is to climate action.

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Proofreading: Ray Cunningham
Typesetting: Sabine Zentek
Title picture: 1971yes | iStock

313/06-A-2023/EN
Version 1.0, December 2023

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