CARBON TRANSITION INITIATIVE

Emerging Markets Investors Alliance

INDUSTRY BRIEF

DECARBONIZATION IN STEEL AND CEMENT PRODUCTION

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Executive Summary

Production of steel and cement are two industries that are especially difficult to decarbonize as both of the technological processes are highly energy intensive. Furthermore, the nature of these processes leads to carbon emissions that are hard to avoid at scale using currently available technologies. On top of that, demand for these materials is expected to grow, particularly in emerging markets.

Key strategies to reduce GHG emissions from steelmaking include:

- Carbon capture retrofits of blast furnaces to capture, store, and transport CO2 (CCUS);
- Transition from blast furnaces to electric arc furnaces, which produce fewer emissions;
- Use of electricity generated from renewable energy sources;
- Usage of renewable hydrogen (vs. fossil fuels) in steelmaking (steel can be produced from direct-reduced iron (DRI), which in turn can be produced from iron ore as it undergoes chemical reduction with hydrogen (electrolysis));
- Implementation of efficiencies in steelmaking processes (e.g., waste heat optimization, maximizing scrap recycling).

Approaches to cutting GHG emissions from the energy used in the cement production process include:

- Energy efficiency improvements;
- Switching to renewable sources of energy.

Eliminating carbon emissions from limestone calcination during clinker production is more complicated. Currently used approaches include:

- Reduction of clinker content in cement (including clinker substitution);
- Reduction of cement content in concrete.

Based on the currently available and economically feasible technologies, carbon emissions from cement production cannot be eliminated completely. The second group of factors, linked to the chemical processes of clinker production, is especially difficult to tackle. Carbon capture and storage seems to be the most obvious option, yet these technologies are very expensive at the moment. They are likely to be used in the future as the last resort after all other approaches to decarbonization of cement production will have been utilized.

Investors should use their advocacy and engagement capabilities along the following lines:

- Advocate with governments to create a supportive regulatory environment;
- Advocate with governments to reduce embodied carbon emissions in projects financed from public budgets;
- When talking to companies, investors would be wise to focus on the management's policies and approaches addressing transition risks and the inevitable strengthening of restrictions on carbon emissions, as well as growing carbon taxes or prices. Companies should also be prepared to demand for limestone-based cement weakening at some point in the future as customers will be looking for alternative low-carbon materials;
- CBI's sector criteria provide a set of specific science-based intensity targets;
- Investors should reinforce the need to decarbonize the production of steel and cement, focusing especially on their investment plans.

"Based on the currently available and economically feasible technologies, carbon emissions from cement production cannot be eliminated completely."

Key Terms

Calcination – a thermal treatment of solid materials (limestone, clay) without melting in order to remove carbon. As a result of the calcination reaction, carbon is removed from limestone and is ejected in the form of CO_2. The remaining calcium oxide (also called quick lime) is the core component of cement.

Cement recarbonation – a process by which concrete absorbs CO_2 through contact with air. It happens as lime (part of cement) reacts with carbon dioxide from the air and forms calcium carbonate.

Clinker – an intermediary product in making cement. It looks like lumps of 3-25 mm in size. Clinker is made by fusing together at very high temperatures limestone and clay or other aluminosilicate materials (calcination).

Coke – a high-carbon-content fuel produced by heating coking coal at a high (1,000 – 2,000 degrees Celsius) temperature with no air. This process is called **coking**. Coking coal differs from thermal coal by its structure.

Direct Reduced Iron (DRI) is produced from iron ore by reducing the oxygen content of the ore. This is done without melting the ore and is relatively energy efficient. DRI can be produced using "green" hydrogen instead of coal. It is mainly used in electric arc furnaces. DRI is susceptible to oxidation and contains some impurities that need to be removed before steel-making can begin.

Limestone – a sedimentary rock consisting mainly of calcium carbonate ($CaCO_3$). At very high temperatures, it dissociates into carbon dioxide and lime. If lime is exposed to CO_2, the process may reverse and the material will slowly recarbonate into limestone and water.

Slag – a byproduct of steel production generated when limestone is added to iron ore to separate its non-ferrous components. The separated substance is called slag.

Introduction

There are a number of similarities between the steel and cement industries. Both have construction as a major client, which underlines strong projected future demand for steel and cement for many years and decades to come, especially in developing countries. Both industries are highly energy intensive. Furthermore, they are based on technological processes that are fundamentally difficult to decarbonize.

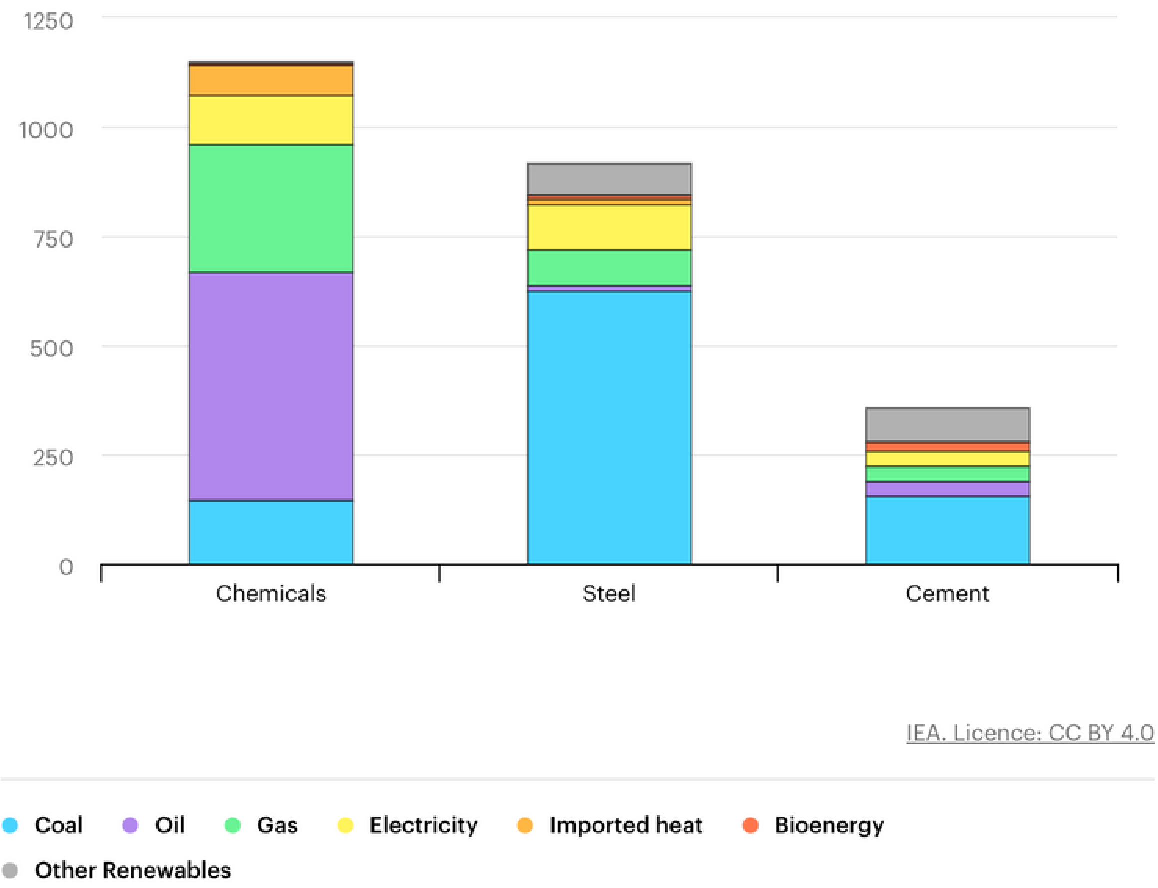
Steel and cement are also different. Production of steel is more advanced in terms of availability of decarbonization options. This is important because steel, used in wind turbines and electric vehicles, is an enabler of the accelerating energy transition. Cement, on the other hand, may be impossible to decarbonize completely, and the utilization of carbon capture technologies appears inevitable at this stage.

China and other emerging markets are large and growing producers and consumers of steel and cement. These trends are supported by their growing economies and increasing urbanization leading to investments in infrastructure and housing. Therefore, decarbonization of these industries is particularly relevant for investors in emerging markets.

Contribution of Steel and Cement to Global Warming

The iron and steel sector accounts for approximately 8% of global final energy demand and 7% of energy sector carbon dioxide (CO2) emissions (including process emissions) or 2.6 gigatonnes (Gt CO2) annually, according to the International Energy Agency (IEA).**[1]** The agency noted that the steel sector is the largest industrial consumer of coal, which is the primary energy source used (~75%). Coal is used to generate heat and to make coke, which is key in the production of steel from iron ore.

Fig. 1: Final energy demand of selected heavy industry sectors by fuel, 2019



Source: IEA, Final energy demand of selected heavy industry sectors by fuel, 2019, IEA, Paris https://www.iea.org/data-and-statistics/charts/final-energy-demand-of-selected-heavy-industry-sectors-by-fuel-2019, IEA. License: CC BY 4.0

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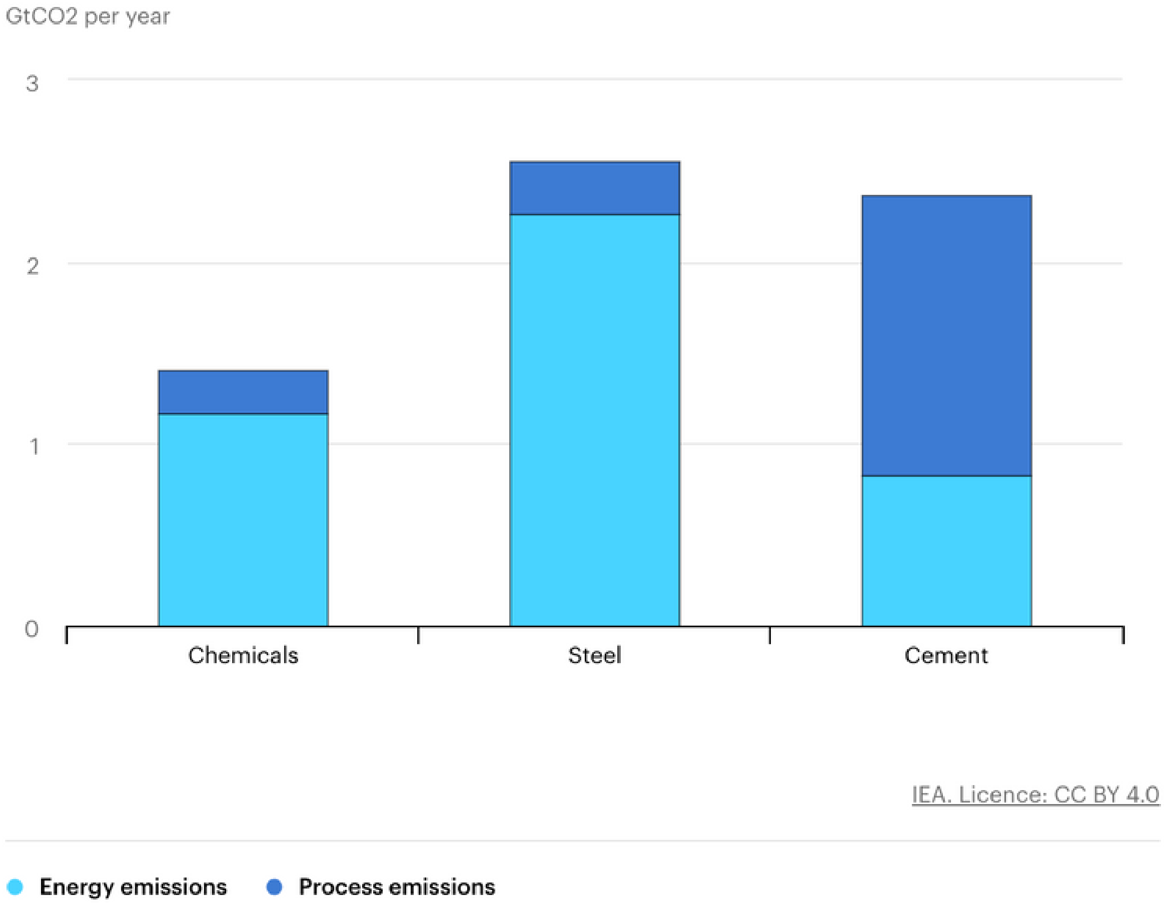
[1] IEA (2020), Iron and Steel Technology Roadmap, IEA, Paris https://www.iea.org/reports/iron-and-steel-technology-roadmap, License: CC BY 4.0

Fig. 2: Direct CO2 emissions from selected heavy industry sectors, 2019



Source: IEA, Direct CO2 emissions from selected heavy industry sectors, 2019, IEA, Paris https://www.iea.org/data-and-statistics/charts/direct-co2-emissions-from-selected-heavy-industry-sectors-2019, IEA. License: CC BY 4.0

The Role of Steel and Cement Industries in EM

Steel

Total world crude steel production was 1,878.5 Mt in 2022, a 4.2% decline compared to 2021. As noted by the IEA, "Global crude steel production capacity has more than doubled over the past two decades; three-quarters of the growth took place in China and around 85% of total capacity today is located in emerging economies."**[2]**

By 2050, almost one-fifth of the steel produced globally is expected to come from India, compared to around 5% today. India is already the world's second-largest steel-producing country and is expected to increase its annual production volumes by 2050 by an amount equivalent to twice that of the European Union's total production in 2019.

[2] IEA (2020), Iron and Steel Technology Roadmap, IEA, Paris https://www.iea.org/reports/iron-and-steel-technology-roadmap, License: CC BY 4.0

The largest steel-producing countries are primarily emerging markets, with China and India commanding the top two spots. In 2022, China and India produced 1,013.0 Mt (or ~54% of the 1,878.5 Mt global total) and 124.7 Mt (or ~7%) of crude steel, according to The World Steel Association.**[3]**

Fig. 3: Top 15 steel-producing countries

Rank		2022	2021	%2022/2021
1	China	1 013.0	1 034.7	-2.1
2	India	124.7	118.2	5.5
3	Japan	89.2	96.3	-7.4
4	United States	80.7	85.8	-5.9
5	Russia (e)	71.5	77.0	-7.2
6	South Korea	65.9	70.4	-6.5
7	Germany	36.8	40.2	-8.4
8	Turkey	35.1	40.4	-12.9
9	Brazil	34.0	36.1	-5.8
10	Iran	30.6	28.3	8.0
11	Italy	21.6	24.4	-11.6
12	Taiwan, China (e)	20.6	23.2	-11.2
13	Viet Nam (e)	20.0	23.0	-13.1
14	Mexico	18.2	18.5	-1.6
15	Indonesia (e)	15.6	14.8	5.2

e – annual figure estimated using partial data or non-worldsteel resources.
Source: World Steel, December 2022 crude steel production and 2022 global crude steel production totals https://worldsteel.org/media-centre/press-releases/2023/december-2022-crude-steel-production-and-2022-global-totals/

China is clearly the largest player in the steel sector. Of the top ten steel-producing companies (based on 2022 tonnage), six are headquartered in China. Specifically, China Baowu Steel Group Corporation Limited (China Baowu) is the largest steel company globally based on its 2021 crude steel production of 119.95 million metric tonnes (or ~6% of the global total). Notably, figures include tonnage of Taiyuan Steel and Kunming Steel. China Baowu is a state-owned enterprise, which has grown over the years primarily through M&A.

[3] World Steel, December 2022 crude steel production and 2022 global crude steel production totals https://worldsteel.org/media-centre/press-releases/2023/december-2022-crude-steel-production-and-2022-global-totals/

The company's goal is to achieve "carbon peak" in total carbon emissions by 2023, carbon reduction by 30% by 2035 and "carbon neutrality" by 2050, as stated in its 2020 Corporate Social Responsibility Report.**[4]**

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[4] Baowu Group 2020 Corporate Social Responsibility Report
https://res.baowugroup.com/attach/2021/10/29/1a2ad022172a46f6b2f31b5377a07ea5.pdf

Fig. 4: China Baowu's environmental performance metrics

Environmental Performance	Unit	2018	2019	2020
Total investment in environmental protection	RMB 100 million	40.43	64.76	127.35
Total investment in energy-saving technical reconstruction	RMB 100 million	5.38	6.22	16.2
Comprehensive energy consumption per RMB 10,000 of output value (comparable price)	Ton of standard coal	1.46	1.44	1.49
Reduction rate of comprehensive energy consumption per RMB 10,000 of output value[1]	%	-11.15	1.65	3.43
Comprehensive energy consumption per ton of steel	Kg standard coal	586	583	574
Reduction rate of comprehensive energy consumption per ton of steel	%	2.3	0.5	1.54
Sulfur dioxide emissions	Ton	29,889	23,667	20,697
Reduction rate of sulfur dioxide emissions	%	3.5	20.8	12.5
NOx emissions	Ton	63,894	55,881	49,802
Reduction rate of NOx emissions	%	10	12.5	10.9
COD emissions	Ton	2,051	1,504	1,396
Reduction rate of COD emissions	%	2.9	26.7	7.2
Freshwater consumption per year	Ton	--	24,512.59	24,067.23
Freshwater consumption per ton of steel[2]	10,000 tons	3.41	3.33	3.24
Reduction rate of freshwater consumption per ton of steel[2]	%	0	3.44	2.76
Utilization of byproducts (comprehensive utilization of industrial solid waste)	%	99.3	99.41	99.73
Return-to-production utilization	%	26.07	26.29	28.24
Utilization of social bulk waste (with disposal of urban hazardous waste)	Ton	8,811	10,713	14,093
Utilization of self-owned renewable energy (only including steel enterprises)	Ten thousand KWH	--	--	9,497
Sales of BETTER green products	10,000 tons	824.29	816.82	858.18
Sales of BEST green products	10,000 tons	218.83	224.34	269.49
Sales of BETTER + BEST green products	10,000 tons	1,043.12	1,041.16	1,127.67
Revenue of green industry	RMB 100 million	50.41	250.09	524.47
Number of suppliers with ISO14001 system certification on Ouyeel Procurement Platform	NOS	2,256	5,694	5,091
Proportion of green procurement for materials and spare parts in Baosteel[3]	%	8.3	6.2	24.6
Amount of green procurement for materials and spare parts in Baosteel[3]	RMB 100 million	14.1	9.6	50.4

[1]Note: In 2018, due to the transfer of the fine coal production line of Baowu Carbon Materials and the influence of the steel market, the output value of the Company decreased significantly, which increased the comprehensive energy consumption per RMB 10,000 of output value.

[2]Note: The data of 2019 is revised and renewed.

[3]Note: The data in 2018 and 2019 includes that of three steel bases of Baosteel, namely its subordinate factory, WISCO, and Meishan Iron and Steel, and the data in 2020 includes that of four steel bases of Baosteel and Baowu Aluminum.

Source: Baowu, China Baowu Corporate Social Responsibility Report
https://res.baowugroup.com/attach/2021/10/29/1a2ad022172a46f6b2f31b5377a07ea5.pdf
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In its sustainability report, ChinaBaowu highlighted the actions it is taking to promote sustainability, including:

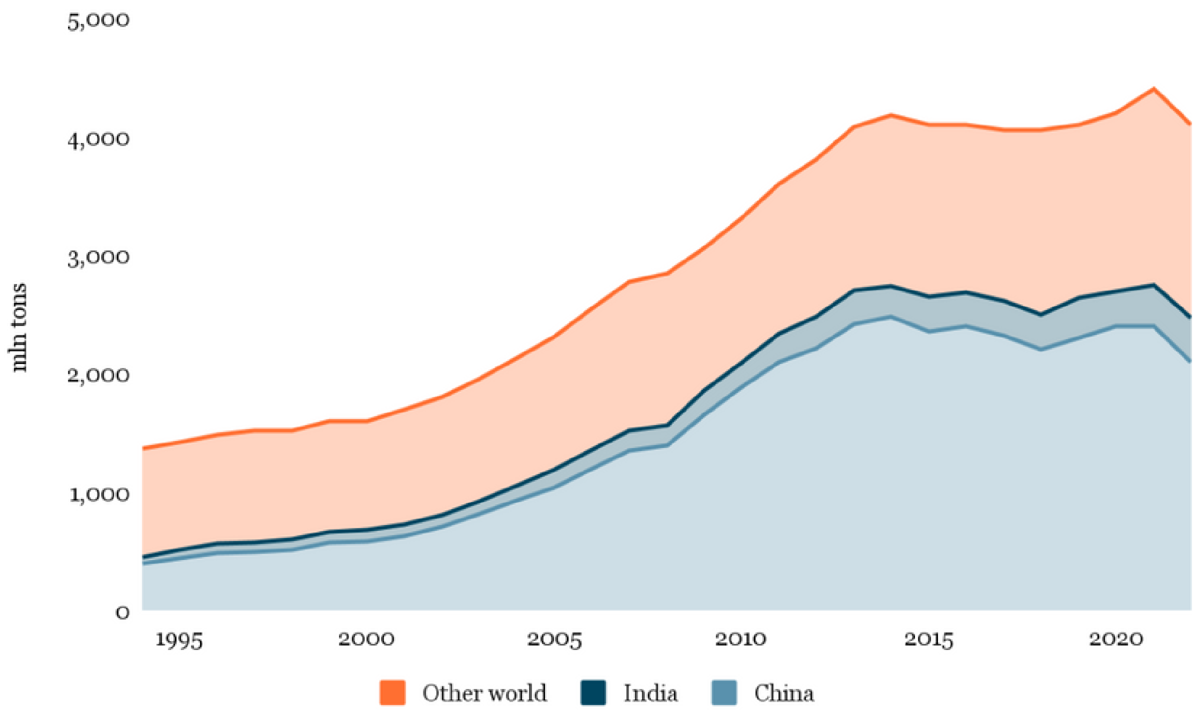
- Increase recycling of iron resources by reducing retained steel slag, which is a solid waste generated from the steel-making process output accounting for approximately 15% of the total steel output;
- Undertaking high-efficiency power generation and ultra-low emission transformation projects at its facilities;
- Pursue hydrometallurgy technology (i.e., replacing carbon with hydrogen) with the goal to reduce greenhouse gas emissions in the steel metallurgy process and achieve carbon neutrality in the steel metallurgy production process;
- Study high quality concentrate technology using complex mixed iron ore and practice of cascade recovery and utilization;
- Adopt energy-saving technical upgrading to reduce demand for coal;
- Increase use of clean energy.

Cement

Cement is ubiquitous globally, with three tonnes of the material being used per person every year.**[5]** China is by far the largest producer with a share of 55% in 2021, with the second largest player India at 8%.**[6]** Production of cement is the second largest industrial emitter of CO2, representing 7% of the total global emissions. Furthermore, with booming real estate and other sectors across developing countries, the IEA projects demand in 2050 to grow by 20% from today's levels in a business-as-usual scenario.**[7]** While it could be argued that production of cement in China is slowing down, industrialization in India, Africa, and other developing regions could offset the decline.

[5] Insights from the cement sector decarbonization roadmap workshop in India. LeadIT, 30 August 2022. https://www.industrytransition.org/insights/insights-from-the-cement-sector-decarbonization-roadmap-workshop-india/
[6] IEA 2022; Cement, https://www.iea.org/reports/cement, License: CC BY 4.0 https://www.google.com/url?q=https://www.iea.org/reports/cement&sa=D&source=docs&ust=1688145733959250&usg=AOvVaw3ZenbJwZIW78LwFBuRa7Gg
[7] Cement Science Based Target Setting Guidance. SBTi, September 2022. https://sciencebasedtargets.org/resources/files/SBTi-Cement-Guidance.pdf

Fig. 5: Global annual cement production

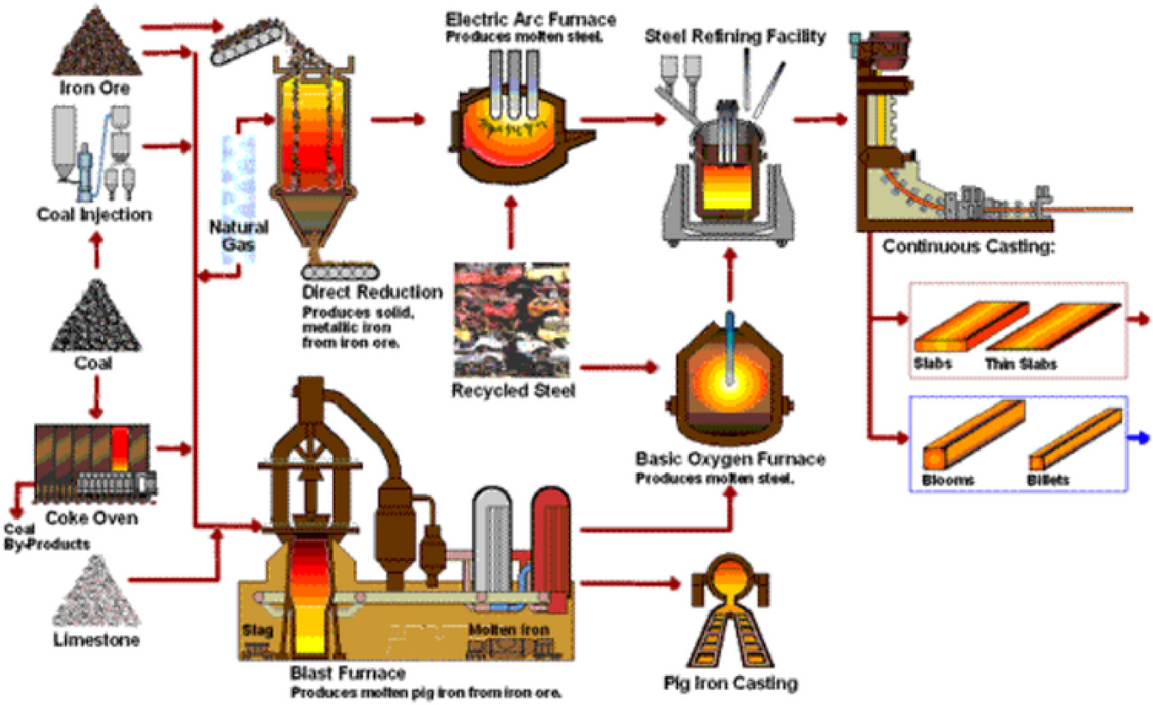


Source: [USGS National Minerals Information Center](https://www.usgs.gov/centers/national-minerals-information-center/cement-statistics-and-information) (https://www.usgs.gov/centers/national-minerals-information-center/cement-statistics-and-information)

Specific Challenges - Steel

Steel is produced from iron ore and/or scrap. In the steelmaking process, impurities (e.g., nitrogen, silicon, phosphorus, sulfur, and excess carbon) are removed from the sourced iron, and alloying elements (e.g., manganese, nickel, chromium, carbon, and vanadium) are added to produce different grades of steel. The process also entails reducing dissolved gasses (e.g., nitrogen and oxygen) and impurities or so called "inclusions" in the steel.

Fig. 6: Steel Flowtimes



Source: American Iron and Steel Institute, Steel Production https://www.steel.org/steel-technology/steel-production/

According to the American Iron and Steel Institute,**[8]** "Steel is primarily produced using one of two methods: Blast Furnace or Electric Arc Furnace.

The blast furnace is the first step in producing steel from iron oxides. The first blast furnaces appeared in the 14th Century and produced one ton per day. Even though equipment is improved and higher production rates can be achieved, the processes inside the blast furnace remain the same. The blast furnace uses coke, iron ore and limestone to produce pig iron.

Coal traditionally has been a key part of the coke-making process. The coal is crushed and ground into a powder and then charged into an oven where it is heated to approximately 1800°F in the absence of oxygen. As the oven is heated, the coal begins to melt so most of the volatile matter such as oil, tar, hydrogen, nitrogen, and sulfur are removed. The cooked coal, called coke, is removed from the oven after 18 to 24 hours of reaction time. The coke is cooled and screened into pieces ranging from one inch to four inches. The coke is a porous, hard black rock of concentrated carbon (contains 90 to 93 percent carbon), which has some ash and sulfur but compared to raw coal is very strong. The

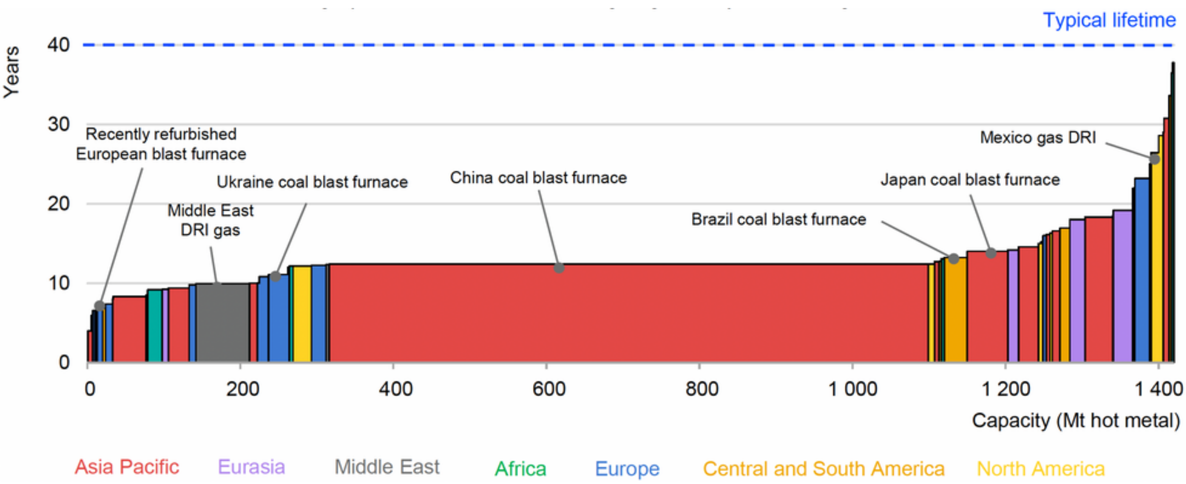
[8] American and Iron Steel Institute, Steel Production https://www.steel.org/steel-technology/steel-production/

strong pieces of coke with a high energy value provide permeability, heat and gases, which are required to reduce and melt the iron ore, pellets, and sinter. Today, natural gas is increasingly being added in place of coke to the same degree in the blast furnace to reduce carbon emissions.

The first electric arc furnaces (EAFs) appeared in the late 19th Century. The use of EAFs has expanded and now accounts for over 70 percent of steel production in the United States. The EAF is different from the blast furnace as it produces steel by using an electrical current to melt scrap steel, direct reduced iron, and/or pig iron, to produce molten steel."

In contrast to the U.S., EAFs' market share is much lower on a global scale. The blast furnace (BF)-basic oxygen furnace (BOF) route still accounted for approximately 70%-75% of the global steel output in 2021, according to Technavio.**[9]** These relatively new, long-lived, capital intensive investments have meaningful implications for the environment. According to the IEA, electric arc furnaces produce 85% less CO2 per ton of steel than blast furnaces on average.**[10]** However, the agency pointed out that the "current stock is quite young, with a global average age of 13 to 14 years for blast furnaces and DRI furnaces." This compares to a typical lifetime of 40 years, which makes a transition to EAFs more difficult.

Fig. 7: Geographic distribution and average age of key ironmaking assets



Source: IEA, Iron and Steel Technology Roadmap
https://iea.blob.core.windows.net/assets/35cef3fa-e77d-47c8-9ed3-e1ccd2c8b5f9/Iron-Steel-Roadmap-Presentation.pdf
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[9] https://www.yahoo.com/lifestyle/electric-arc-furnaces-market-size-233000345.html
[10] IEA, Iron and Steel Technology Roadmap, https://www.iea.org/reports/iron-and-steel-technology-roadmap

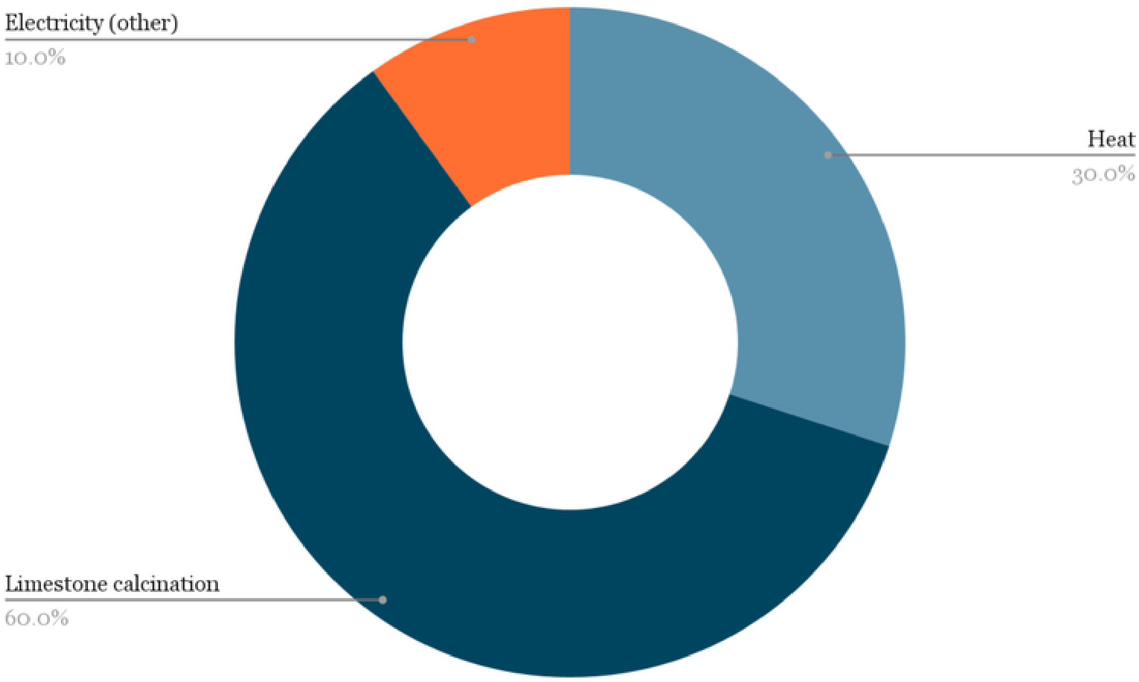
Specific Challenges - Cement

Production of cement includes several steps:[11]

1. Limestone and clay are mined in a quarry and then transported to a crushing plant by trucks or conveyor belts;
2. The rock is crushed to chunks of approximately 1.5 inches in size;
3. Limestone, clay, and other materials are mixed, milled, and then homogenized in a required proportion;
4. The mix is heated in kilns at a temperature of 1,400°C and transformed into clinker;
5. The clinker is then milled with gypsum added. The resulting cement can now be stored, packed, and shipped to customers.

Some characteristics of the cement production process make it particularly difficult to decarbonize. There are two main sources of GHG emissions in this process. The first one is a requirement for heat, which generates one-third of the total direct GHG emissions. The process is very energy intensive, and currently, coal or gas are used as its sources. The second source is a result of geogenic emissions from limestone calcination in clinker production, emitting the remaining two-thirds of the total GHG emissions. As a result, the industry is likely to lag in decarbonization, and may not be able to reach net zero emissions without some form of carbon capture and storage.

Fig. 8: GHG emissions from cement production in the EU



Source: European Commission, Joint Research Centre, (2023). "Decarbonisation Options for the Cement Industry" [Online]. Available: https://publications.jrc.ec.europa.eu/repository/bitstream/JRC131246/JRC131246_01.pdf [2023, April].

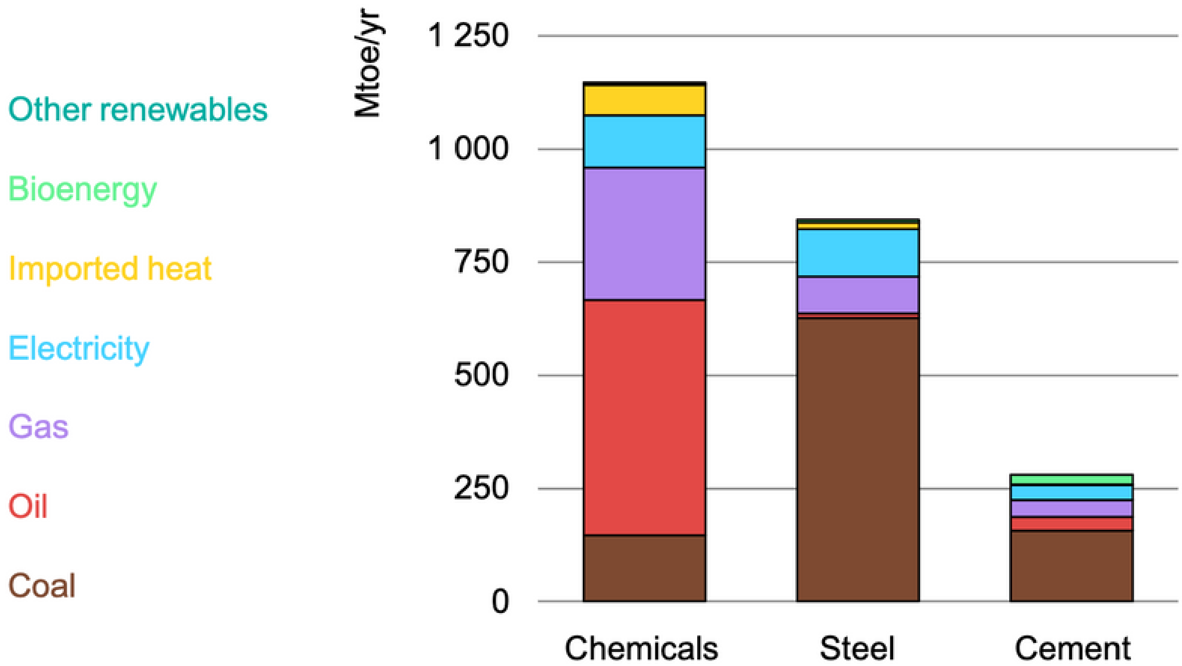
[11] CEMEX, How Cement is Made, https://www.cemex.co.uk/cement-production-process.aspx

Existing Solutions and New Technologies

Steel

The bulk of CO2 emissions from steelmaking come from the coal used in the production process. "Fossil fuels account for around 85% of the final energy used in heavy industries, which, combined, account for just under a fifth of total energy system CO2 emissions," according to the IEA.

Fig. 9: Heavy industry final energy demand and direct CO2 emissions, 2019



Source: IEA, Iron and Steel Technology Roadmap
https://iea.blob.core.windows.net/assets/35cef3fa-e77d-47c8-9ed3-e1ccd2c8b5f9/Iron-Steel-Roadmap-Presentation.pdf
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Under the IEA's Sustainable Development Scenario, "technology performance improvements and material efficiency deliver 90% of annual emission reductions in 2030. In the longer term, innovative technologies such as CCUS-equipped and hydrogen-based production are required."

Fig. 10: Cumulative direct CO2 emission reductions in iron and steel, Sustainable Development Scenario relative to baseline

Source: IEA, Iron and Steel Technology Roadmap
https://iea.blob.core.windows.net/assets/35cef3fa-e77d-47c8-9ed3-e1ccd2c8b5f9/Iron-Steel-Roadmap-Presentation.pdf
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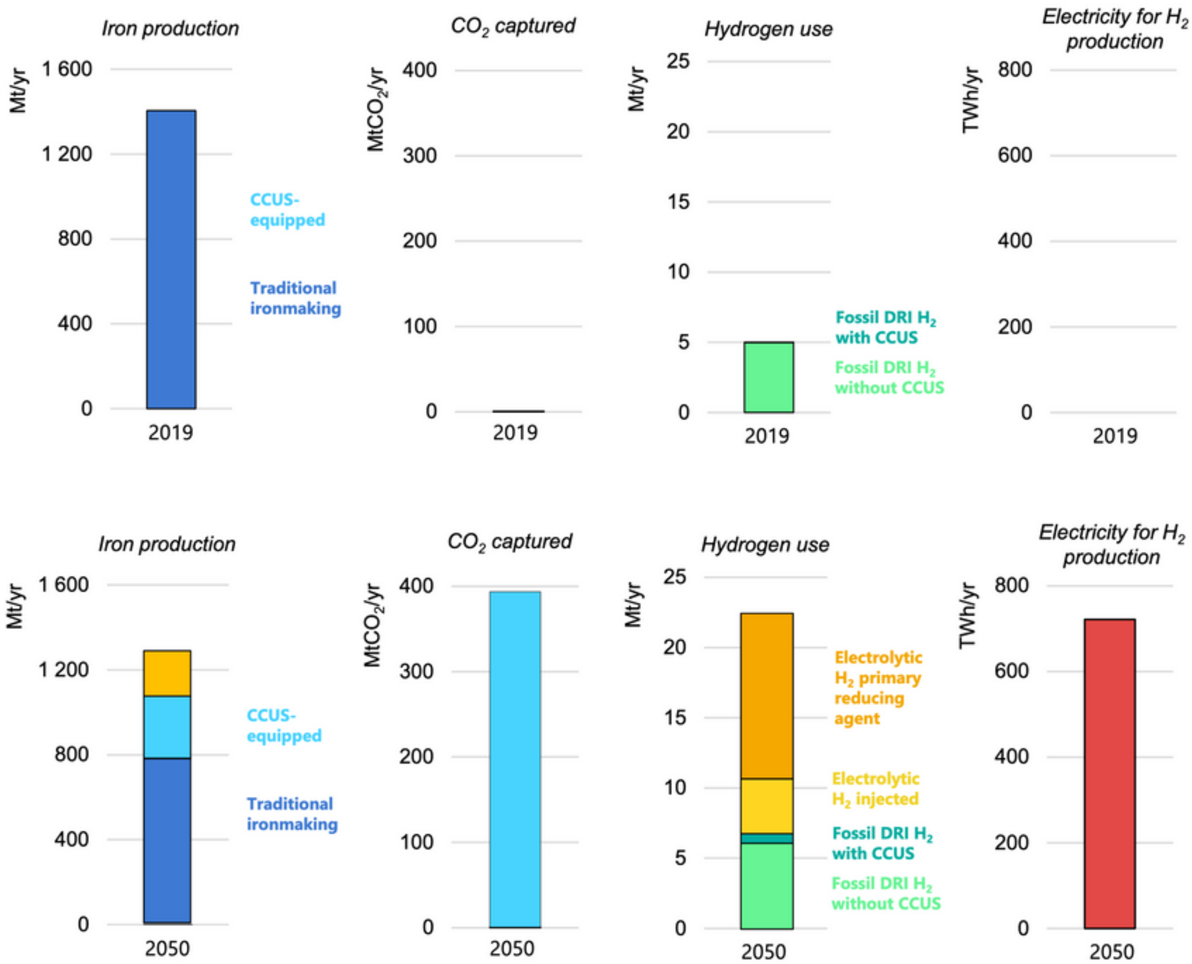
Key strategies to reduce GHG emissions from steelmaking include the following:

- Carbon capture retrofits of blast furnaces to capture, store, and transport CO2 (CCUS);
- Transition from blast furnaces to electric arc furnaces, which produce fewer emissions. Use of electricity generated from renewable energy sources;
- Usage of renewable hydrogen (vs. fossil fuels) in steelmaking. Steel can be produced from direct-reduced iron (DRI), which in turn can be produced from iron ore as it undergoes chemical reduction with hydrogen (electrolysis);
- Implementation of efficiencies in steelmaking processes (e.g., waste heat optimization, maximizing scrap recycling);
- Exploration of new technologies. For example, a recent study published by researchers at the University of Birmingham highlights how perovskites (a mineral) can reduce carbon emissions from blast furnaces. The study noted a potential "88% emissions reduction of the UK steel industry through £720 million investment."**[12]**

[12] Science Direct, Cost Effective Decarbonation of Blast Furnaces,
https://www.sciencedirect.com/science/article/pii/S095965262300121X?via%3Dihub=

Fig. 11: Sustainable Steel requires a major push for clean energy infrastructure, IEA''s Sustainable Development Scenario relative to baseline



Source: IEA, Iron and Steel Technology Roadmap
https://iea.blob.core.windows.net/assets/35cef3fa-e77d-47c8-9ed3-e1ccd2c8b5f9/Iron-Steel-Roadmap-Presentation.pdf
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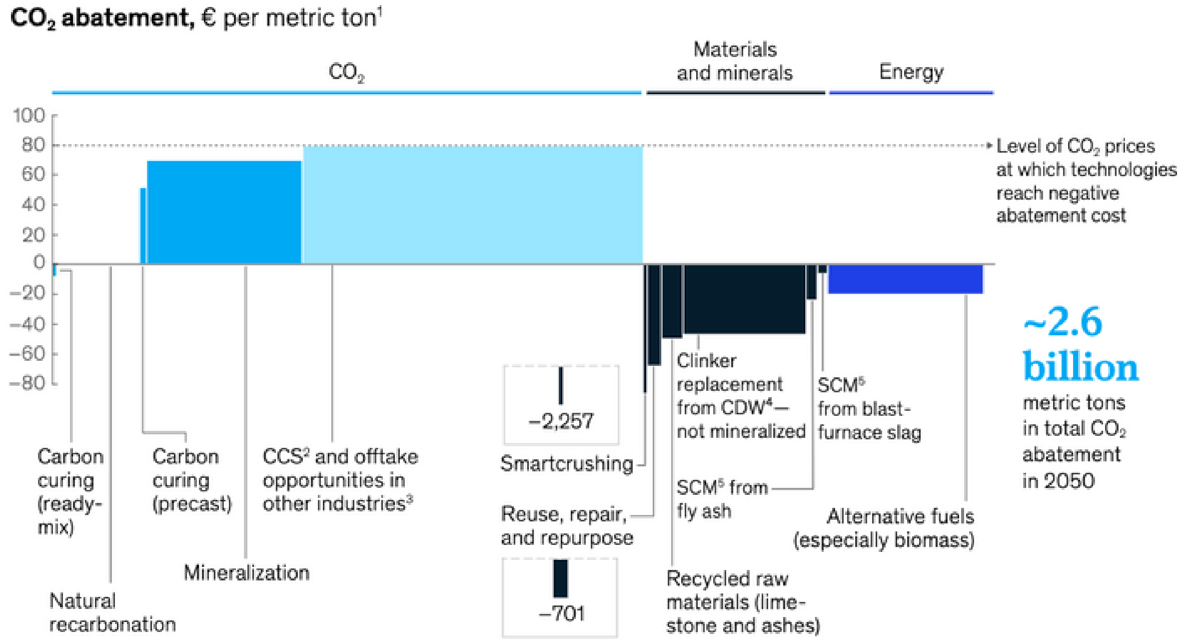
Cement

The first and most obvious step in reducing carbon emissions from cement production is to decrease its use and replace it with other substitutes. Utilization of alternative materials will require upfront changes in the design of buildings and infrastructure. There has been a great deal of innovation in this area. Interested readers may benefit from our earlier Real Estate Sector Investor Brief, which is available to EMIA members on our website.**[13]** However, it is unlikely that the need for cement can be eliminated completely.

[13] Pavel Laberko, CFA, Sharon Lui, "Real Estate and Carbon Transition", www.emia.org, July 4, 2022, https://www.emia.org/research/publications/issue-briefs-carbon-transition-initiative/carbon-transition-initiative-real

Fig. 12: CO2 abatement potential from recirculation of materials and minerals



Note: The CO_2 abatement cost curve displays the expectations on a global average. The width of the bars for mineralization and carbon reinsertion technologies is driven by regions with a high CO_2 price, such as Europe or North America.
[1]Based on 2022 price levels, free of inflation.
[2]Carbon capture and storage (CCS). Currently displays CCS and offtake opportunities in other industries (CCUS), yet only carbon capture and utilization (CCU) is considered circular. This split has not yet been assessed, but further circularity potential is expected.
[3]Split has not yet been assessed, but further circularity potential is expected.
[4]Construction and demolition waste.
[5]Supplementary cementitious materials.

Source: The circular cement value chain: Sustainable and profitable. McKinsey https://www.mckinsey.com/industries/engineering-construction-and-building-materials/our-insights/the-circular-cement-value-chain-sustainable-and-profitable#/

The major sources of GHG emissions in cement production mentioned earlier call for different decarbonization approaches.

Approaches to cutting GHG emissions from the energy used in the process:

- Energy efficiency improvements;
- Switching to renewable sources of energy.

One of the most tested and widely used ways to improve energy efficiency is to switch from the wet to the dry method of cement production. A less tried approach is to use electric kilns for clinker production.

Reduction of GHG emissions from generation of electricity used in the process is outside of the scope of this brief.

Eliminating carbon emissions from limestone calcination during clinker production is more complicated. Currently used approaches include:

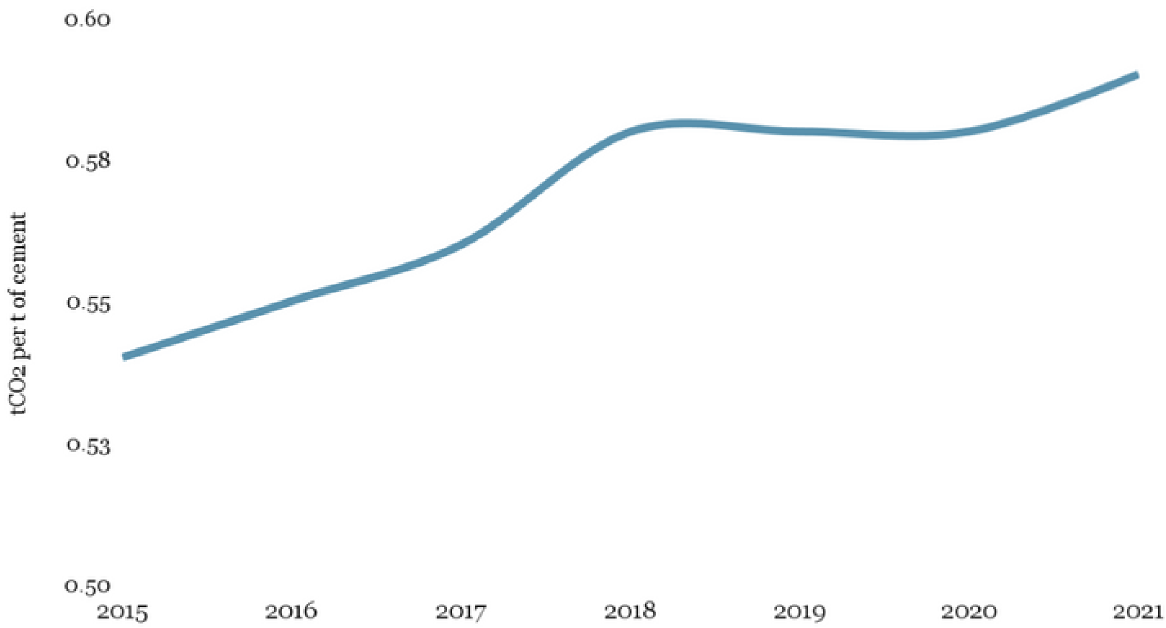
- Reduction of clinker content in cement (including clinker substitution);
- Reduction of cement content in concrete.

Various materials have been tested for substitution of clinker, but none have been used on an industrial scale. Examples include fly ash (a by-product of coal combustion), blast furnace slag (a by-product of steelmaking), volcanic rock and ash, calcined clays etc. Using construction and demolition waste (CDW) is another promising venue which, as an added bonus, cuts landfill costs. Yet, availability of these materials can be an obstacle, especially as the use of coal in energy and steelmaking inevitably shrinks. The quality of the resulting product is also a deterrent of consumer demand right now.**[14]**

There are pilot projects ongoing to fully replace limestone by other materials such as calcium silicate in clinker. This would eliminate emission of carbon during the calcination process. However, none of these projects have reached commercial scale and wide utilization so far.

Sadly, the share of clinker in cement has been creeping up lately. According to IEA, the average clinker-to-cement ratio has been growing at 1.6% per year in 2015-2020, reaching 0,72.**[15]** This has led to increasing emissions intensity of cement production.

Fig. 13: Direct emissions intensity of cement production



Source: IEA 2022; Cement, https://www.iea.org/reports/cement, License: CC BY 4.0

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[14] Making Concrete Change: Innovation in Low-Carbon Cement and Concrete. Chatham House. (https://www.chathamhouse.org/2018/06/making-concrete-change-innovation-low-carbon-cement-and-concrete)
[15] IEA 2022; Cement

Based on the currently available and economically feasible technologies, carbon emissions from cement production cannot be eliminated completely. The second group of factors, linked to the chemical processes of clinker production, is especially difficult to tackle. Carbon capture and storage seems to be the most obvious option, yet these technologies are very expensive at the moment. They are likely to be used in the future as the last resort after all other approaches to decarbonization of cement production will have been utilized.

Cement has an interesting feature that allows for partial recapture of CO2 emitted during the process of its production – **recarbonation**. When concrete is exposed to air for an extended period of time, it absorbs carbon dioxide. The larger the area of contact with air, the more CO2 is captured. With proper recycling approaches, up to 25% of the carbon emitted during cement's production can be reabsorbed.**[16]** Some research is even pointing at the possibility of carbon-negative cement, although these types of the material are too far from commercialization.

This feature of cement highlights the importance of buildings' end-of-life demolition approach. If the concrete resulting from the demolition is crushed and then left in open air for a few months, its absorption of CO2 is maximized.

[16] European Circular Economy Stakeholder Platform
(https://circulareconomy.europa.eu/platform/en/good-practices/cement-recarbonation)

How EM Regulators and Companies are Tackling the Problems

There are three approaches to decarbonization of the steel and cement industries, and each of them will need to be utilized as much as possible:

- Scope 1: Change production processes using existing and new technologies.
- Scope 2: Cut energy consumption by improving energy efficiency and using new technologies and shift to renewable energy sources.
- Scope 3: Reduce demand for these carbon-intensive materials (by using circular economy principles and by substitution as feasible).

All of these approaches will require significant investments. Both steel and cement industries are capital intensive, and their investment cycles are very long. This means that suitable moments to invest in new production processes and technologies do not happen frequently. Furthermore, many assets located in emerging markets are relatively young and thus still have a long life before replacement is needed. Replacing them early is not an easy decision. Given all these considerations, government support is likely to be needed.

The IEA specifically outlined recommendations governments undertake to help accelerate a sustainable transition for the iron and steel sector, which we believe is also be applicable to the cement industry:**[17]**

- Establish a long-term and increasing signal for CO2 emission reductions;
- Manage existing assets and near-term investment;
- Create a market for near-zero emissions steel;
- Support the demonstration of near-zero emission steelmaking technologies;
- Accelerate material efficiency;
- Increase international co-operation and ensure a level global playing field;
- Develop supporting infrastructure for near-zero emission technologies;
- Track progress and improve data collection.

[17] https://www.iea.org/reports/iron-and-steel-technology-roadmap

The IEA's Policies and Measures Database provides a list of existing or planned government policies and measures to reduce greenhouse gas emissions, improve energy efficiency and support the development and deployment of renewables and other clean energy technologies. The following are some country policies in place/pending to address the steel industry's carbon footprint:

Fig. 14: Examples of Country Policies

Policy	Country	Year	Status	Jurisdiction
"France 2030" Investment Plan - Heavy Industry decarbonisation investment	France	2022	In force	National
Green steel production support	Belgium	2022	Announced	National
Climate Innovation Research Opportunity investment program	United States	2021	In force	National
Japan-Australia partnership decarbonisation through technology	Japan	2021	In force	International
Federal Funding for Biocarbon Briquettes for Ferroalloy Production	Canada	2020	In force	National
Funding for Algoma Steel's climate action initiatives	Canada	2020	In force	National
Low-carbon and Zero -emissions Fuels Fund (including hydrogen)	Canada	2020	In force	National
Support package for UK Steel Company	United Kingdom	2020	In force	National
Guideline for Energy Efficiency Credit	People's Republic of China	2015	In force	National
Industrial Energy Management System ISO 50001	Philippines	2014	In force	National
Partial Risk Guarantee Fund for Energy Efficiency (PRGFEE)	India	2008	In force	National

Source: IEA, Policy database https://www.iea.org/policies?sector[]=Iron+and+steel

The Role of Investors

Sovereign debt investors should use their opportunities to **advocate with governments to create a supportive regulatory environment**. Implementation of standards for low-carbon steel and cement, standardized reporting for producers of these materials, and creation of incentives for businesses to find ways to reduce carbon emissions will go a long way to cut GHG emissions.

Investors should also advocate with governments to **reduce embodied carbon emissions in projects financed from public budgets**. According to UNIDO, buying by government agencies accounts for 40% of all cement and concrete and 25% of steel.**[18]** These agencies should spearhead decarbonization by setting limits on embodied carbon in projects under their control.

When talking to companies, investors would be wise to focus their queries on the **management's policies and approaches addressing transition risks** and the inevitable strengthening of restrictions on carbon emissions, as well as growing carbon taxes or prices. Companies should also be prepared to demand for limestone-based cement weakening at some point in the future as customers will be looking for alternative low-carbon materials.

As for the decarbonization targets, CBI's sector criteria provide a set of specific **science-based intensity targets**.**[19]** Investors can use them to benchmark a cement producer's announced decarbonization plans and pathways.

Investors should **engage with companies** to reinforce the need to decarbonize the production of steel and cement, focusing especially on their **investment plans.** The next several years will be a critical moment in time offering many opportunities to shift production of steel to a more sustainable path. More than 70% of currently operated coal-based blast furnaces will reach the end of their life.**[20]** After that, it is roughly one investment cycle until 2050. In other words, the period until 2030 is critical for the industry's contribution to global warming. Whether companies replace coal-based assets with the same technology or use new approaches and processes will make a difference for the following decades.

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[18] UNIDO Industrial Deep Decarbonization Initiative (https://www.unido.org/sites/default/files/files/2021-10/IDDI%20Infographic_14%20OCT.pdf)
[19] Climate Bonds Initiative. "Cement Criteria" [Online]. Available: https://www.climatebonds.net/files/files/standards/Cement/Sector%20Criteria%20-%20Cement%20Production%20%28April%202023%29.pdf. Accessed on June 9, 2023.
[20] Agora Industry, (2021). "Global Steel at a Crossroads" [Online]. Available: https://static.agora-energiewende.de/fileadmin/Projekte/2021/2021-06_IND_INT_GlobalSteel/A-EW_236_Global-Steel-at-a-Crossroads_WEB_V2.pdf [2023, April].

ESG ratings/evaluations completed by credit rating agencies are a useful resource for investors to assess environmental risk for the steel and cement industries and related companies. Investors can view performance indicators to see how companies compare on environmental factors (e.g., greenhouse gas emissions, waste pollution, water, land use and biodiversity). Figure 15 is from S&P Global's evaluation key sustainability factors report on metals and mining, which may be a good resource to help investors analyze steel companies.

Fig. 15: S&P Global Environmental Factors: weighting and KPIs for Metal Production and Processing

Metal Production and Processing

The industry is energy intensive with high related GHG emissions, particularly resulting from the consumption of fossil fuels to operate equipment. In addition, the smelting, refining, and processing of metals and minerals often requires chemicals that create substantial pollutant emissions and waste residue. As a result, we believe waste and pollution are almost as significant as carbon emissions, while water and land use are not as relevant.

Factor	Weight	Key performance indicators	Other performance indicators
Greenhouse gas emissions	40%	– Scope 1 and 2 emissions intensity (in tCo2e, per ton of output produced and/or US$ million of revenue).	– Energy use (in megawatt hour [MWh] per ton of output produced and/or US$ million of revenue). – Renewable energy in energy mix (% total electricity used). – Total fuel consumed (in gigajoules) – Fuel mix between coal, natural gas, renewable sources (%).
Waste and pollution	30%	– Total waste (slag, dusts, and sludges) per metric ton of output produced (in metric tons). – Waste recycled (% total).	– Hazardous waste per ton of output produced (in metric tons). – Air pollution per metric ton of output produced (NOx, SOx and particulate matter, all in metric tons). – Wastewater volumes (cubic meters [m3]) per ton of output produced and/or US$ million of revenue).
Water	20%	– Total fresh water withdrawn (in m3 per ton of output produced and/or US$ million of revenue). – Total fresh water consumed (in m3 per ton of output produced and/or US$ million of revenue).	– Water withdrawn from areas exposed to high and very high water stress (% water withdrawn). – Recycled water withdrawals (% total water withdrawal).
Land use and biodiversity	10%	– Operating assets in areas with protection or conservation status (% total assets).	– Operating assets in areas with threatened, vulnerable, endangered, and critically endangered species (% total assets).

Source: S&P Global, Metals and Mining
https://www.spglobal.com/_assets/documents/ratings/research/100049687.pdf

Conclusion

Steel and cement production processes generate significant amounts of GHGs due to their nature and due to high energy requirements. As demand for these materials is unlikely to drop while the world economy, particularly in emerging markets, keeps growing, and investments in infrastructure continue, decarbonization of steel and cement is essential for climate change mitigation.

There are several avenues to decarbonize the production of steel. They include energy efficiency, transition from blast to electric arc furnaces, use of "green" hydrogen, implementation of other new technologies, and carbon capture. Similarly, energy efficiency and use of its renewable sources are important in reducing GHG emissions in cement production. These emissions can also be cut by reducing the clinker content in cement and by reducing the amount of cement in concrete. Due to the nature of the production process based on the currently available technologies, some carbon capture is likely to be needed in the future.

Investors have an important role to play in decarbonizing these industries. They should advocate with governments for establishing a regulatory environment conducive to the shift to low-carbon materials. They should also nudge governments to clearly prefer low-embodied-carbon options for projects financed from public budgets. Naturally, investors should also engage with steel and cement producers to make sure their investment strategies and plans aim at science-based net zero targets.

Appendix: Additional Resources

Climate Bonds Initiative (CBI) Sector Criteria

CBI has developed specific sets of criteria that steel and cement producers must meet to be eligible for issuance of certified climate bonds. These criteria can be used to assess the credibility of companies' transition plans.

The Leadership Group for Industry Transition (LeadIT)

LeadIT was launched by the governments of Sweden and India at the UN Climate Action Summit in September 2019 and is supported by the World Economic Forum. The organization fosters collaboration between public and private policymakers to accelerate the energy transition of the hard-to-abate steel and cement production industries. Their website contains steel and cement trackers showing leading companies' progress towards decarbonization.

UNIDO Industrial Deep Decarbonization Initiative (IDDI)

The United Nations Industrial Development Organization's IDDI is a coalition of public and private organizations aiming to reduce carbon emissions from steel and cement industries. Their website contains recommendations to governments and policy makers that can be used by investors who advocate with public sector borrowers.

The Carbon Transition Initiative aims to study the impact of climate change in emerging markets and identify best practices available to the investment community to help assess and manage climate- and transition-related risks and opportunities. To achieve this objective, the initiative is organizing a series of webinars complemented by investor research briefs on macro issues and sectors that are material to carbon transition.
