RISKINSIGHT

Materials, Resources and Sustainability series

Reading time: ~20 minutes

Steel – fundamental to the global economy, critical to global sustainability targets

Introduction

This paper is part of a series on **materials and resources**. In this series we ask how we can use risk management approaches, techniques and tools to improve the way we source, develop, use and dispose of the materials, resources and products that power our modern economy, and to support everyone involved in their value chains. The series uses the United Nations Sustainable Development Goals (the SDGs) as a common thread to discuss diverse sustainability and risk aspects and elements to each subject.

Steel – an essential product in our economy

Steel is one the world's most widely used and important engineering, manufacturing and construction materials. [1] It is used in almost every aspect of our lives – from the vehicles we drive, to the buildings we inhabit and work in, the household goods we rely upon for everyday living, and so much more.

Steel is an alloy of iron containing a small percentage (less than 2%) of carbon. Many other elements may be present or added to this base make-up of steel, such as manganese, silicon, phosphorus, sulphur and oxygen. Stainless steel, for example, is an alloy containing a minimum 10.5% chromium content by mass.

Today, more than 3,500 different grades of steel exist, each with different physical, chemical, and environmental properties. [1] The rate of technological advancement in steelmaking in recent years has been rapid: approximately 75% of modern steels have been developed in just the last 20 years. Significant advances have been made in recent decades to make steel stronger, more malleable and lighter. If the Eiffel Tower were rebuilt today, engineers would only need one third of the steel that was used to build it (between 1887 and 1889).

The origins of steelmaking lie in ironmaking, which dates back to about 4,000 BC for weapons and other wares. People in China were using blast furnaces for iron production in the 6th century BC, as were people in India in the 3rd century BC. Ironmaking continued to be the main output of iron ore up to the Industrial Revolution, when improvements were made in steelmaking. [2]

When iron is directly smelted from its ore using heat, it is tricky to work with. Dense and heavy, it is brittle due to the inherent carbon content, which is above 2%. Reducing the carbon content leads to steel, which is more malleable, stronger and lighter. As well as reducing the carbon content to the desired amount, other elements can be added to introduce particular properties (as noted above).

The growth of railroads and industry during the 19th century across Europe and America, and the desire to construct new buildings that reach into the sky, put the iron industry under pressure to provide solutions. In the 1850s a British inventor, Henry Bessemer, came up with a technique to mass produce steel in a cost-effective way. Steel was unproven as a structural metal until Bessemer came up with what is today known as *the Bessemer Process*. [3] Prior to this process being introduced, other techniques such as Blister Steel and Cast Steel were adopted but were labour-intensive and costly. Bessemer designed a pear-shaped receptacle – called a converter – in which iron was heated while oxygen was blown through the molten metal. As oxygen passes through, it reacts with the carbon, releasing carbon dioxide and producing a purer metal.

The process proved to be fast and inexpensive, removing carbon and silicon from iron in a matter of minutes. However, too much carbon was removed and too much oxygen remained in the final product. Bessemer ultimately had to repay his investors until he could find a method to increase the carbon content and remove the unwanted oxygen.

Concurrent to Bessemer's efforts, the British metallurgist Robert Mushet began testing the addition of manganese to the compound of iron and carbon – known as *spiegeleisen*. Manganese had been found to remove oxygen from molten iron, and the carbon content in the spiegeleisen, if added in the right quantities, would provide the solution to Bessemer's problems. Bessemer began adding it to his conversion process with great success.

An additional challenge remained. Bessemer had not managed to work out how to remove phosphorus – an impurity that makes steel brittle – from the end product. As a result, at the time phosphorus-free ores from Sweden and Wales were preferred.

In 1876, Welshman Sidney Gilchrist Thomas came up with a solution by adding a chemically basic flux – limestone – to the Bessemer process. The limestone drew phosphorus from the pig iron into the slag, allowing this unwanted element to be removed from the steel. This innovation meant that iron ore from anywhere in the world could be used to make steel. The costs to produce steel began to decrease significantly. Prices for steel rail dropped more than 80% between 1867 and 1884, initiating growth of the world steel industry.

A large amount of steelmaking today is still produced with technology that is based on the Bessemer Process.

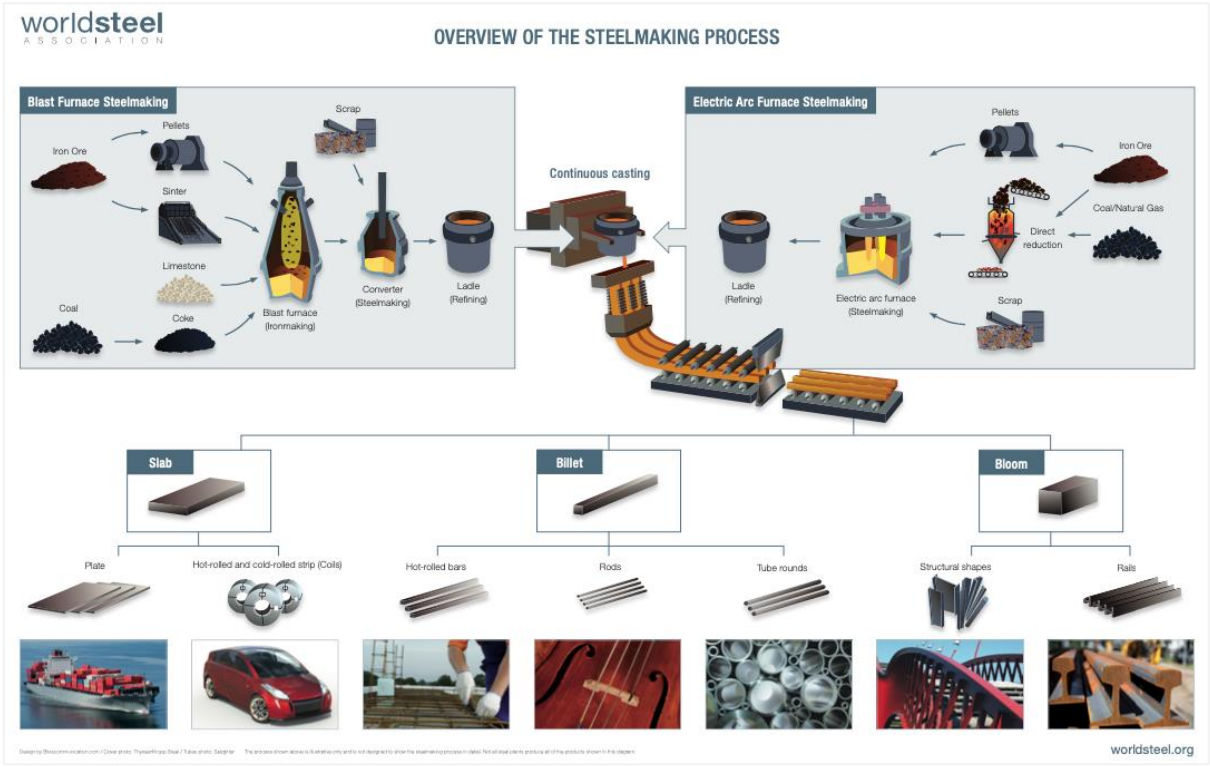
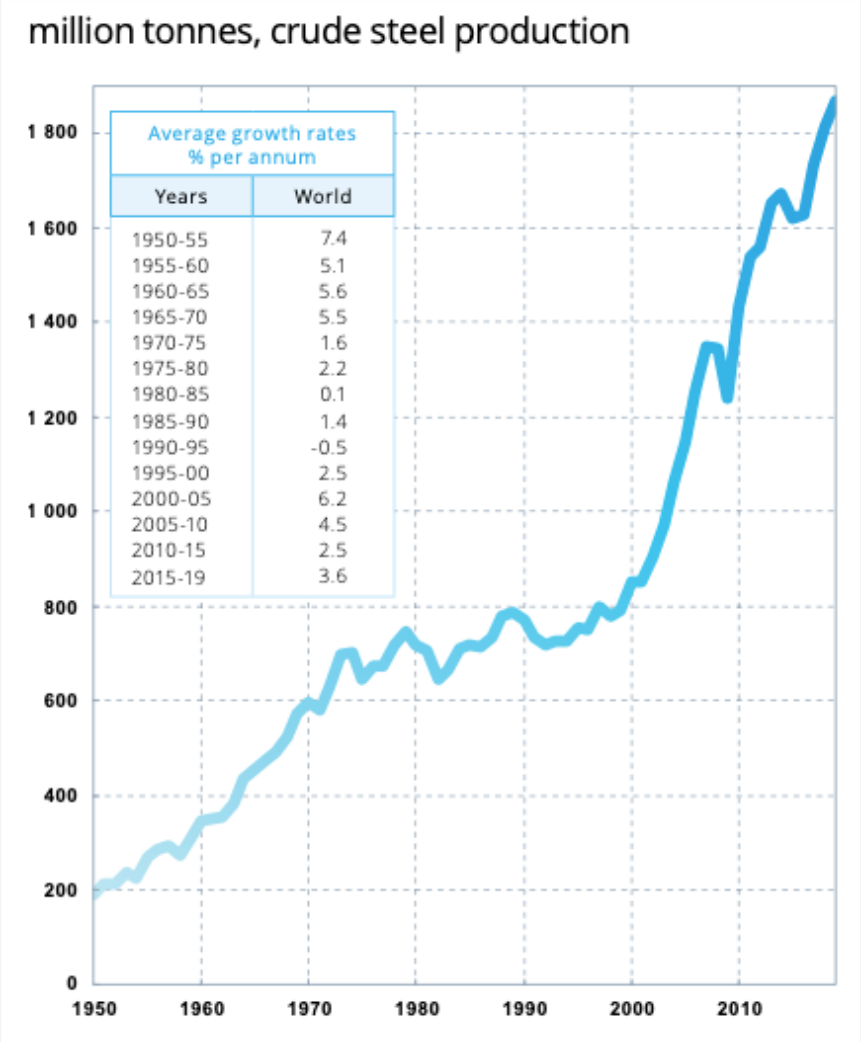


Image: the steelmaking process. Credit: World Steel Association

How are we currently using steel around the world today?

Steel production

According to the World Steel Association, crude steel production in 2019 reached 1,869 million tonnes. Whilst annual Growth in 2019 compared to 2018 was only 3%, as manufacturing demand remained low, the increase since 2000 is notable. [4]



Source: World Steel Association World Steel in Figures 2020

World crude production in 2020 is shaping up to be steady compared to 2019, despite the global economic challenges posed by COVID-19, largely due to demand in China holding up. [8]

For further context, the production of steel (and also iron) dwarfs the production of all other metals combined. It is by far the biggest metal production around the world. The next largest, aluminium, is about 66 million tonnes a year.

Major steel-producing countries 2018 and 2019

million tonnes, crude steel production

Country	2019		2018	
	Rank	Tonnage	Rank	Tonnage
China	1	996.3	1	920.0
India	2	111.2	2	109.3
Japan	3	99.3	3	104.3
United States	4	87.8	4	86.6
Russia	5	71.9	6	72.1
South Korea	6	71.4	5	72.5
Germany	7	39.7	7	42.4
Turkey	8	33.7	8	37.3
Brazil	9	32.2	9	35.4
Iran	10	25.6	10	24.5
Italy	11	23.2	11	24.5
Taiwan, China	12	22.0	12	23.2
Ukraine	13	20.8	13	21.1
Vietnam	14	20.1	15	15.5
Mexico	15	18.5	14	20.2
France	16	14.4	16	15.4
Spain	17	13.6	17	14.3
Canada	18	12.9	18	13.4
Poland	19	9.0	19	10.2
Saudi Arabia	20	8.2	20	8.2
Belgium	21	7.8	21	8.0
Austria	22	7.4	24	6.9
Egypt	23	7.3	22	7.8
United Kingdom	24	7.2	23	7.3
Netherlands	25	6.7	25	6.8
Indonesia[e]	26	6.4	28	6.2
South Africa	27	5.7	27	6.3
Australia	28	5.5	29	5.7
Slovak Republic[e]	29	5.3	30	5.2
Sweden	30	4.7	34	4.7

Source: World Steel Association World Steel in Figures 2020

Top steel-producing companies 2019

million tonnes, crude steel production

Rank	Company	Tonnage
1	ArcelorMittal[1]	97.31
2	China Baowu Group[2]	95.47
3	Nippon Steel Corporation[3]	51.68
4	HBIS Group[4]	46.56
5	POSCO	43.12
6	Shagang Group	41.10
7	Ansteel Group	39.20
8	Jianlong Group	31.19
9	Tata Steel Group	30.15
10	Shougang Group	29.34
11	Shandong Steel Group	27.58
12	JFE Steel	27.35
13	Valin Group	24.31
14	Nucor Corporation	23.09
15	Hyundai Steel	21.56
16	IMIDRO[5]	16.79
17	JSW Steel	16.26
18	SAIL	16.18
19	Benxi Steel	16.18
20	Fangda Steel	15.66
21	NLMK	15.61
22	Baotou Steel	15.46
23	China Steel Corporation	15.23
24	Techint Group	14.44
25	Liuzhou Steel	14.40

Rank	Company	Tonnage
26	Rizhao Steel	14.20
27	U. S. Steel Corporation	13.89
28	EVRAZ	13.81
29	CITIC Pacific	13.55
30	Gerdau	13.13
31	Jingye Steel	12.58
32	MMK	12.46
33	Shaanxi Steel	12.45
34	Sanming Steel	12.40
35	thyssenkrupp	12.25
36	Zenith Steel	11.93
37	Severstal	11.85
38	Tsingshan Stainless[6]	11.40
39	Nanjing Steel	10.97
40	Taiyuan Steel	10.86
41	Anyang Steel	10.54
42	Metinvest Holding	9.58
43	Xinyu Steel	9.47
44	Donghai Special Steel	8.90
45	Jinxi Steel	8.73
46	Erdemir Group	8.61
47	Steel Dynamics, Inc.	8.59
48	Kunming Steel	7.73
49	SSAB	7.62
50	Jiuquan Steel	7.48

[e] = estimate

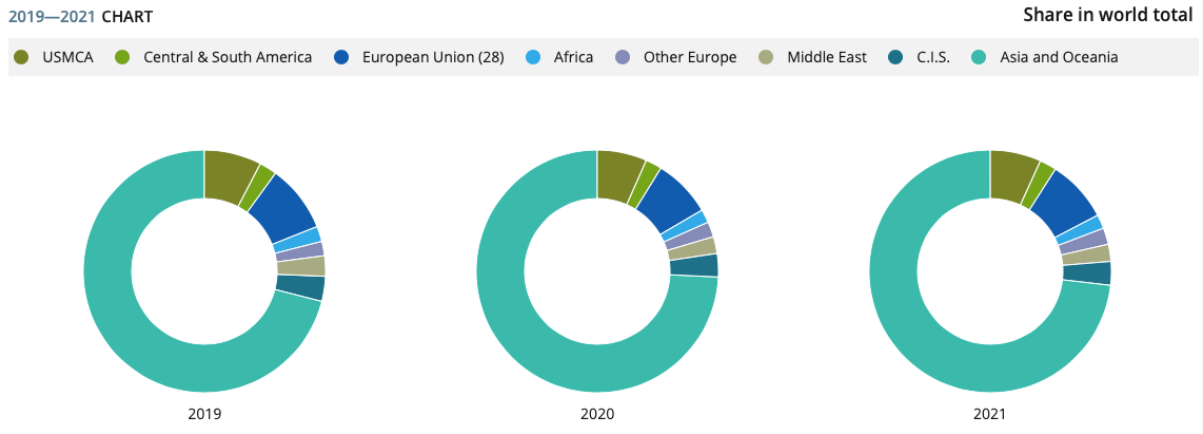
[1] Includes shares in AM/NS India and China Oriental
[2] Includes tonnage of Maanshan Steel and Chongqing Steel
[3] Includes tonnage of Nippon Steel Stainless Steel Corporation, Sanyo Special Steel, Ovako AB, and shares in AM/NS India and USIMINAS
[4] Includes tonnage of Serbia Iron & Steel d.o.o. Beograd and MAKSTIL A.D. in Macedonia
[5] Combined tonnage of Mobarrakeh Steel, Esfahan Steel, Khuzestan Steel and NISCO

Notes on company ownership and tonnage calculations:
For worldsteel members, the data was sourced from their official tonnage declarations. For Chinese companies, the official CISA tonnage publication was used, unless especially noted. Figures represent consolidated tonnage ending 31 December 2019, including interests in subsidiaries and joint ventures.

For an extended company listing go to worldsteel.org/steel-by-topic/statistics/top-producers.

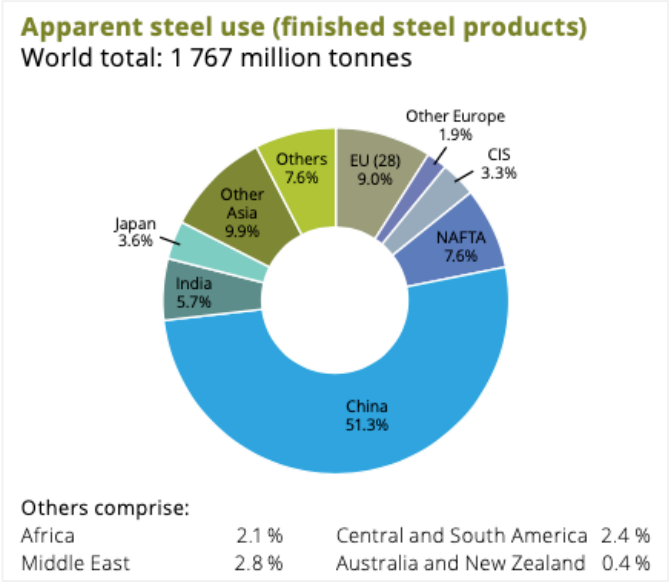
What about the global demand for steel?

The year 2019 saw global steel use at 1,767 million tonnes. Projections for 2020 demand, made by the World Steel Association, indicate a forecast 2.4% drop in demand for 2020, down by about 42 million tonnes to 1,725 million tonnes, caused by a drop in demand everywhere around the world except the “biggest engine”, China, plus Turkey (a much smaller player). A rebound in demand for steel of 4.1% is forecast for 2021, up to 1,795 million tonnes, principally driven by an increase in China’s appetite. [5]



Source: World Steel Association: Short-range Outlook October 2020

China is clearly the dominant user of steel today, accounting for over half of all use globally. It is forecast to have increased steel use by 8% in 2020, compared to other major users that are likely to see contractions in use. Whilst its growth in 2021 is forecast to be negligible, it will remain the dominant geographic user of steel. Most other steel-using countries are forecast to increase their use in 2021. [6] Developing countries may well be a major factor in future steel production and use.



2019—2021 TABLE

Steel Demand Forecasts

y-o-y growth rates (%) million tonnes

Regions	2019	2020 (f)	2021 (f)
European Union (28)	158.3	134.3	149.0
Other Europe	33.8	35.2	39.3
C.I.S.	58.9	53.6	56.5
USMCA	135.3	114.6	122.2
Central & South America	41.6	37.4	40.5
Africa	36.4	30.6	33.4
Middle East	47.9	38.5	40.9
Asia and Oceania	1 254.5	1 280.9	1 313.1
World	**1 766.7**	**1 725.1**	**1 795.1**

2019—2021 TABLE

Top 10 Steel Using Countries

y-o-y growth rates (%) million tonnes

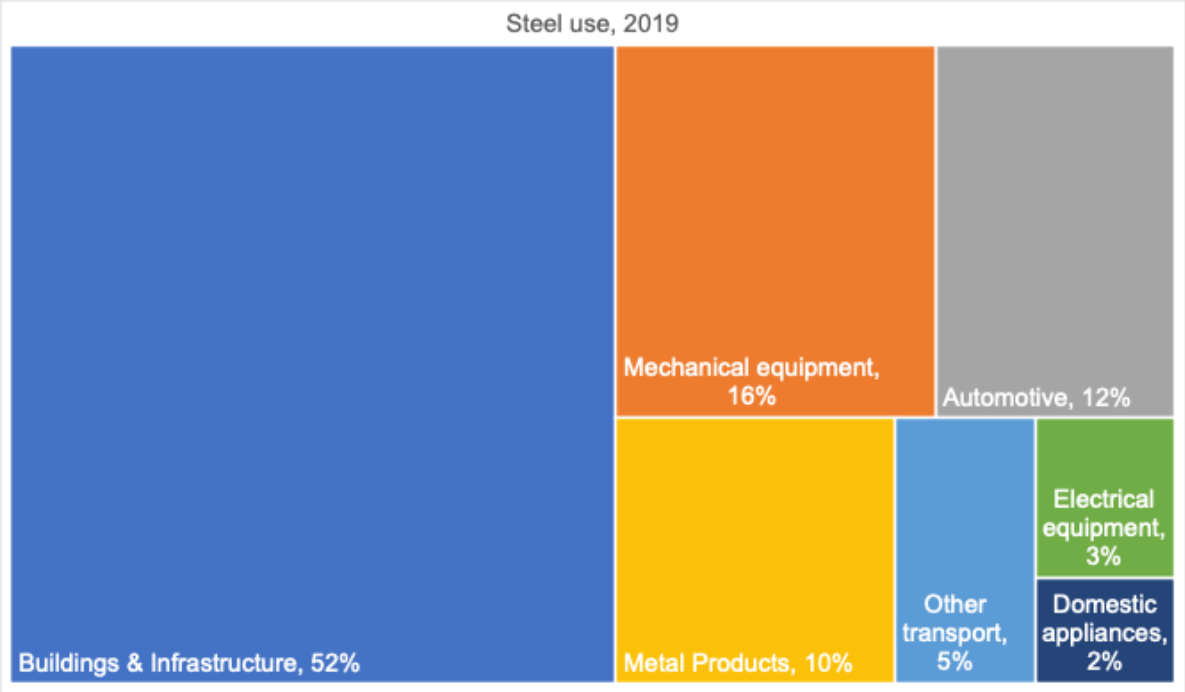
Countries	2019	2020 (f)	2021 (f)
China	907.5	980.1	980.1
India	102.6	81.9	100.4
United States	97.7	82.3	87.6
Japan	63.2	50.8	54.9
South Korea	53.2	48.9	50.8
Russia	43.7	40.0	42.0
Germany	35.0	29.7	33.7
Turkey	26.0	28.6	32.0
Italy	25.0	19.6	22.7
Mexico	24.6	21.3	22.9

f = forecast

Source: World Steel Association: Short-range Outlook October 2020

The industry sectors that use steel today

The biggest industry user of steel continues to be buildings and infrastructure, which accounts for over half of its use worldwide. This industry's use of steel in 2020 is forecast to have held up reasonably well, as governments around the world stimulate their economies with construction and infrastructure projects. Other industries such as automotive and mechanical equipment have been sluggish in 2020. [6]



Source: World Steel Association: The uses of steel

How *profitable* is steel production?

Profitability in the industry was already challenging before COVID-19 hit. In 2020 the problem has worsened, with the current weakness of major end-markets like the automotive industry and mechanical equipment leading many steelmakers in Europe to warn of a detrimental impact to their financial position. [7] Steel prices have at least picked up during 2020, which is some relief for troubled businesses in the sector.

Source: Financial Times

In some parts of the world, for example in Europe, observers note there is excess steelmaking capacity. They believe that the events of 2020, with COVID-19 having had such a major impact on the global economy, is a chance to reset things. [7]

Global overcapacity is an important matter to be addressed by the industry. Overcapacity is estimated to be approximately 500 million tonnes, compared with the total production as stated earlier of 1,869 million tonnes in 2019. China is key to this debate. Despite the closing of many old and inefficient steel mills in China, concerns remain about there being too much supply from the world's biggest steel producer. How can the problem be tackled? Whilst there are examples of consolidation in the industry, the key issue is excess capacity, which means facing tough decisions to close plants that are no longer required.

It is not just steelmaking companies that need to be convinced of the merits of rationalising production. The steel industry is still regarded by many governments as a symbol of national economic strength. In such places, politicians resist calls to close steelmaking plants (as has been seen in the UK and elsewhere in 2020).

The extractive industry that feeds steel production

The global geographical split of countries that extract iron ore, the chief product for steelmaking, is quite different to the geographical split of steel production – an indication of the disperse value chain of the industry. Australia dominates iron ore extraction in volume, followed by Brazil, India and China. In 2020, iron ore prices have risen sharply primarily due to demand from China.

Iron ore
2018

million tonnes, actual weight

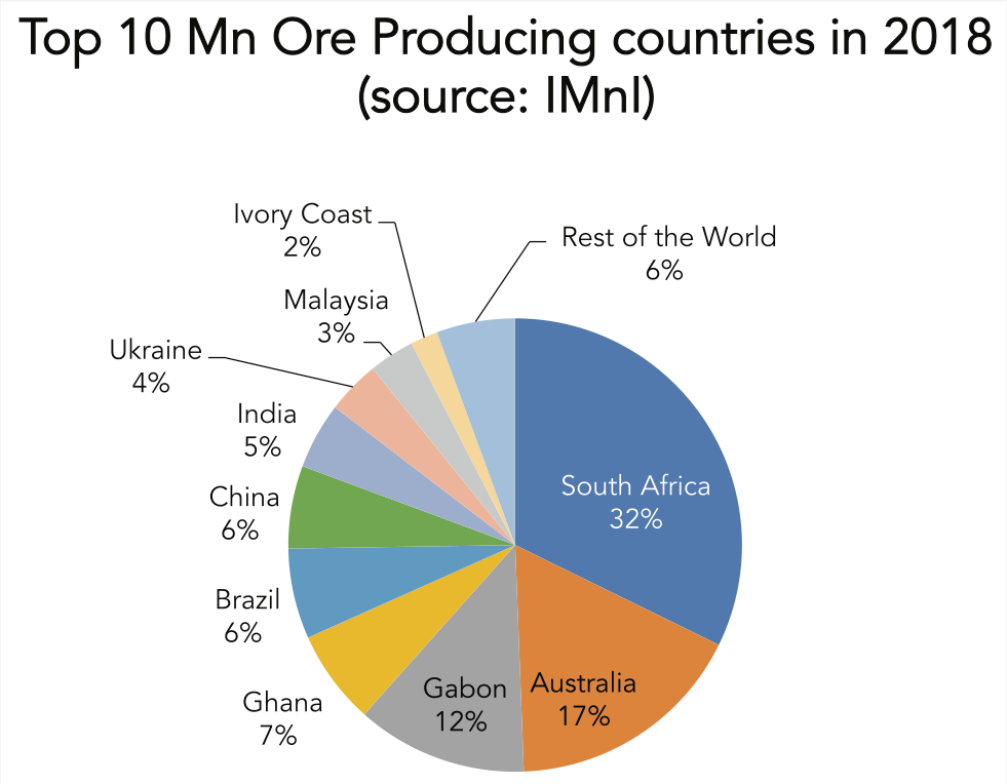
	Production	- Exports	+ Imports	= Apparent consumption
Austria	4.8	0.0	5.5	10.3
Belgium-Luxembourg	-	0.0	7.2	7.1
Czech Republic	-	0.0	5.3	5.3
France	-	0.1	16.1	16.0
Germany	2.0	0.0	39.6	41.5
Italy	-	0.0	7.7	7.7
Netherlands	-	22.6	27.0	4.4
Poland	-	0.0	7.7	7.7
Romania	-	0.0	3.0	2.9
Slovakia	-	0.0	6.3	6.3
Spain	-	0.2	6.6	6.4
Sweden	27.5	22.2	0.2	5.5
United Kingdom	-	0.0	8.9	8.9
Other EU	-	0.4	5.6	5.2
European Union (28)	34.4	45.6	146.7	135.4
Bosnia-Herzegovina	1.4	0.0	0.0	1.4
Norway	2.0	1.7	0.0	0.3
Turkey	6.1	0.8	10.7	16.1
Other Europe	-	0.0	2.2	2.2
Europe	43.9	48.2	159.7	155.4
CIS	180.4	67.5	8.3	121.2
Canada	52.4	47.7	10.1	14.8
Mexico	13.6	0.4	3.3	16.5
United States	49.0	13.0	5.7	41.7
NAFTA	115.0	61.1	19.1	73.0
Brazil	448.0	394.2	0.0	53.8
Chile	14.5	13.9	-	0.5
Peru	10.6	11.9	-	-1.3
Venezuela	4.0	2.5	-	1.5
Other America	0.3	0.4	5.4	5.4
Central and South America	477.4	423.0	5.4	59.9
Liberia	4.6	3.6	-	1.0
Mauritania	10.8	11.9	-	-1.1
South Africa	61.7	63.4	0.5	-1.3
Other Africa	5.6	1.1	7.2	11.6
Africa	82.6	80.1	7.7	10.2
Middle East	55.0	32.0	35.6	58.6
China [1]	145.8	11.1	1 064.6	1 199.3
India	204.7	17.9	15.9	202.7
Japan	-	0.0	123.9	123.9
South Korea	-	0.0	73.2	73.2
Other Asia	18.6	37.5	72.3	53.4
Asia	369.1	66.4	1 349.8	1 652.4
Australia	901.1	887.4	0.8	14.4
New Zealand and Other Oceania	3.5	2.5	0.0	1.1
World	2 228.0	1 668.1	1 586.3	2 146.2

[1] production adjusted so that Fe content is similar to world average.
Source: RMG.

Source: World Steel Association World Steel in Figures 2020

Important additional elements that are used in the steelmaking process are extracted in various parts of the world.

Manganese ore, a key ingredient for steel, is found in diverse places, with South Africa and Australia making up approximately half of all the ore extracted.



Source: International Manganese Institute, IMnI Statistics 2019

Manganese is used in different ways as part of steelmaking, depending on the technical requirement.

Water is an important part of steelmaking, for various processes. For cooling purposes, sea water is typically used, and most of it is returned.

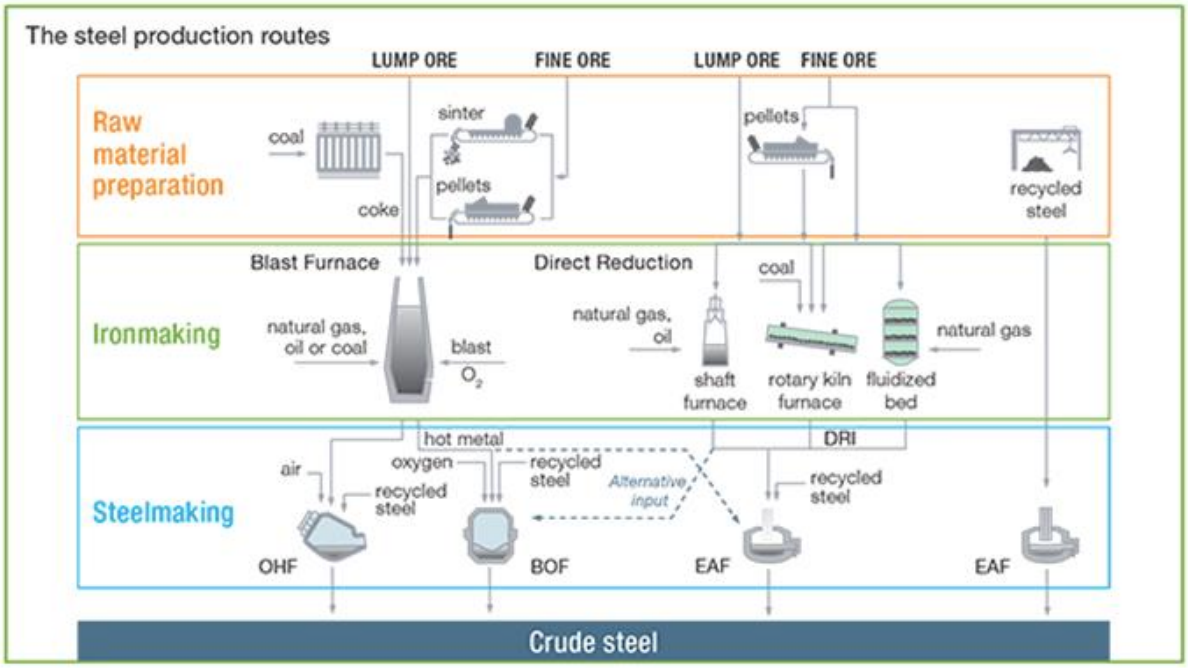
What is abundantly clear about the steelmaking industry is that a combination of resources are extracted from various parts of the world, to be used in different ways to make different types of steel.

The steelmaking process

In the steelmaking process, impurities of excess carbon (the most important impurity to tackle), nitrogen, silicon, phosphorous and sulphur are removed from iron, and alloying elements such as manganese, nickel, chromium, carbon and vanadium are added to produce a specified grade of steel. It is important to regulate dissolved gases such as nitrogen and oxygen and entrained impurities (termed "inclusions") in the steel to ensure the quality of the products cast from the liquid steel.

There are two main ways in which steel is made today:

1. Basic oxygen steelmaking (an improved version of the Bessemer process)
2. Direct reduced iron (DRI) steelmaking



Source: World Steel Association: steel markets

1. Basic oxygen steelmaking uses liquid pig-iron from the blast furnace and scrap steel as the main feed materials. Oxygen steelmaking is fuelled mostly by the exothermic nature of the reactions inside the vessel. Blowing oxygen through molten pig iron lowers the carbon content of the alloy and changes it into low-carbon steel. Fluxes of burnt lime or dolomite, as chemical bases, are added to promote the removal of impurities and protect the lining of the converter.

The basic oxygen process was developed in 1948 by Swiss engineer Robert Durrer and commercialised in 1952–1953 by the Austrian steelmaking company VOEST and ÖAMG. The LD converter, named after the Austrian towns Linz and Donawitz (a district of Leoben) is a refined version of the Bessemer process, in which the blowing of air is replaced with blowing oxygen. This technique reduced the capital cost of plants and time of smelting, plus it increased labour productivity. The majority of steel manufactured in the world is currently produced using the basic oxygen furnace.

2. Direct reduced iron (DRI) steelmaking can traditionally be divided into two main categories: gas-based and coal-based. In both cases, the objective is to remove the oxygen contained in the iron ore and to convert the ore to metallic iron, without melting it (below 1,200°C).

The direct reduction process is comparatively energy efficient. Steel made using DRI requires significantly less fuel because a blast furnace is not required.

When an electric arc furnace (EAF) is used, electrical energy is used to melt the solid scrap and/or DRI materials.

Direct reduction processes were developed to overcome the difficulties of conventional blast furnaces. DRI plants need not be part of an integrated steel plant, as is typical of blast furnaces. The initial capital investment and operating costs of direct reduction plants are lower than integrated steel plants and have been seen as more suitable for developing countries, where supplies of high grade coking coal are limited, but steel scrap is generally available for recycling. India is the world's largest producer of direct-reduced iron. Many other countries use variants of the process. Direct reduced iron is highly susceptible to oxidation and rusting if left unprotected.

Recently, DRI EAF steelmaking technology has evolved closer to oxygen steelmaking as more chemical energy is introduced into the process. An important emerging development with DRI is that it is possible to use hydrogen as an energy carrier to help with the process, which can make it much more environmentally friendly.

Looking at steel with the SDGs

The production, use and recycling of steel can be examined through the lenses of the SDGs. Looking at steel production, responsible use, disposal and recycling through the SDGs helps to give a balanced view of benefits and drawbacks, and challenges.

The linkage of SDGs to steelmaking in the SDG wheel above is more extensive than the stated SDG focus of some of the world's major steelmakers. This is not to say that steelmakers do not focus on some SDGs, rather, that they particularly focus on key ones such as a "top 3" or "top 5". [9, 10]

1. No poverty

China is by far the world's largest producer of crude steel. India, Brazil, Vietnam, Mexico, Egypt and Indonesia all produce crude steel (India being the world's second-largest producer, after China), and steelmaking in these countries helps to maintain employment for any people (and training) in parts of the world where wages are low.

In 2018, 71 members of worldsteel signed a charter committing them to improve social, economic and environmental performance. [11]

3. Good Health & Wellbeing

The manufacture of steel is hard work that takes place in tough physical conditions. worldsteel includes statistics on industry lost time injuries – but Health & Wellbeing requires a broader than this "lag indicator" metric.

Health & Safety standards in the industry are generally high. What about Wellbeing? Do steelmakers of all sizes (not just the largest ones) have proactive and thorough Wellbeing initiatives in place, similar to those that are seen in other industries around the world?

For example, in addition to typical Wellbeing services provided by Employee Assistance Programs (EAPs), there are a variety of services that can be made available to employees to help them with mental health and financial support (the two often being linked together). Such services can also be made available to the broader community, through family support and assistance to suppliers.

7. Affordable and Clean Energy

Steel is a key material used in producing the machinery and equipment that provides the world with renewable energy. From solar farms to tidal systems, geothermal and wind energy, steel is used in them all.

worldsteel claim that the energy used to produce a tonne of steel has fallen by 61% in the last 50 years. [11] Whilst this is an achievement, there is more to do.

The most common form of steelmaking – the basic oxygen process (described above) – is energy-intensive and typically uses coking coal to heat a blast furnace. Whilst coking coal is the "cleanest form of coal" (refer to an associated paper about coal for details), it is a fossil fuel and is not a clean source of energy. As the industry seeks to improve its carbon emissions (as detailed below), this needs to change.

Trials are underway to lower carbon emissions in the production of steel, using new technology for the direct reduced iron (DRI) process which involves hydrogen.

As an associated paper on hydrogen outlines, this DRI method of producing steel is much cleaner and could prove to be pivotal in how the industry moves forward through to 2050 as part of lowering it greenhouse gas emissions.

It is also worth noting that approximately 90% of water used in the steel industry is claimed to be cleaned, cooled and returned to source, and that most of the loss is a result of evaporation. [11, 12]

8. Decent Work & Economic Growth

Globally, approximately 6 million people work in the steel industry – making it a major global employer. [11] It is an important industry in many parts of the world.

When a steel plant is built and established it operates for many years, and in doing so provides stable employment for the area, community benefits and economic growth in related and connected industries (be they suppliers of raw materials, manufacturing plants or ports for shipping).

9. Industry Innovation & Infrastructure

Smart steel production and manufacturing does not just mean having a steel-producing smart factory. It means a transformation in the way the industry sources the raw materials and then manufactures and markets the products.

A major focus in innovation at the moment lies in pilot plants for using hydrogen in the steelmaking process, to make it more sustainable. Together with public funding for low-carbon projects, the hope is that European steelmakers can emerge as leaders in producing the metal more cleanly. However, many observers believe this will remain elusive unless difficult decisions are taken to shrink to a healthier size.

11. Sustainable Cities and Communities

It was outlined earlier that the building and infrastructure industry accounts for over half of all steel use globally.

There is a great deal of focus in how to make cities and other urban environments, and communities, more sustainable. SDG #11 is closely linked to SDG #12 for the steel industry.

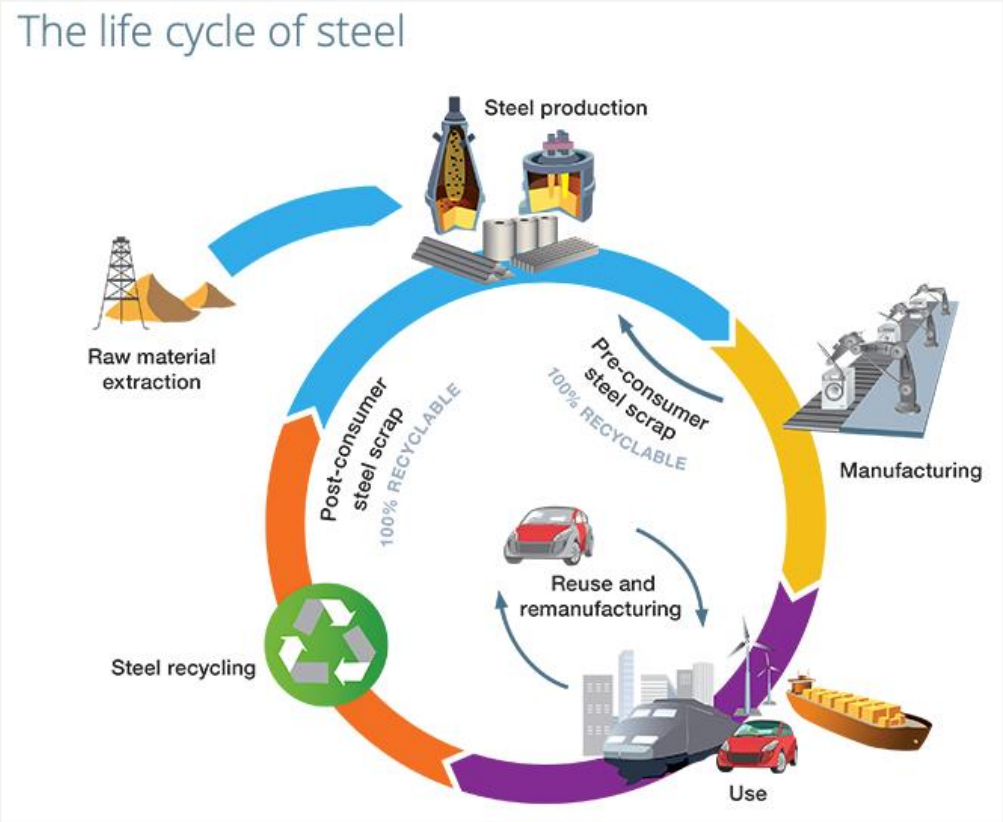
12. Responsible Consumption & Production

Steel is prevalent in our lives. The responsible production and use of steel, which includes recycling as part of the circular economy, is key to how we use it.

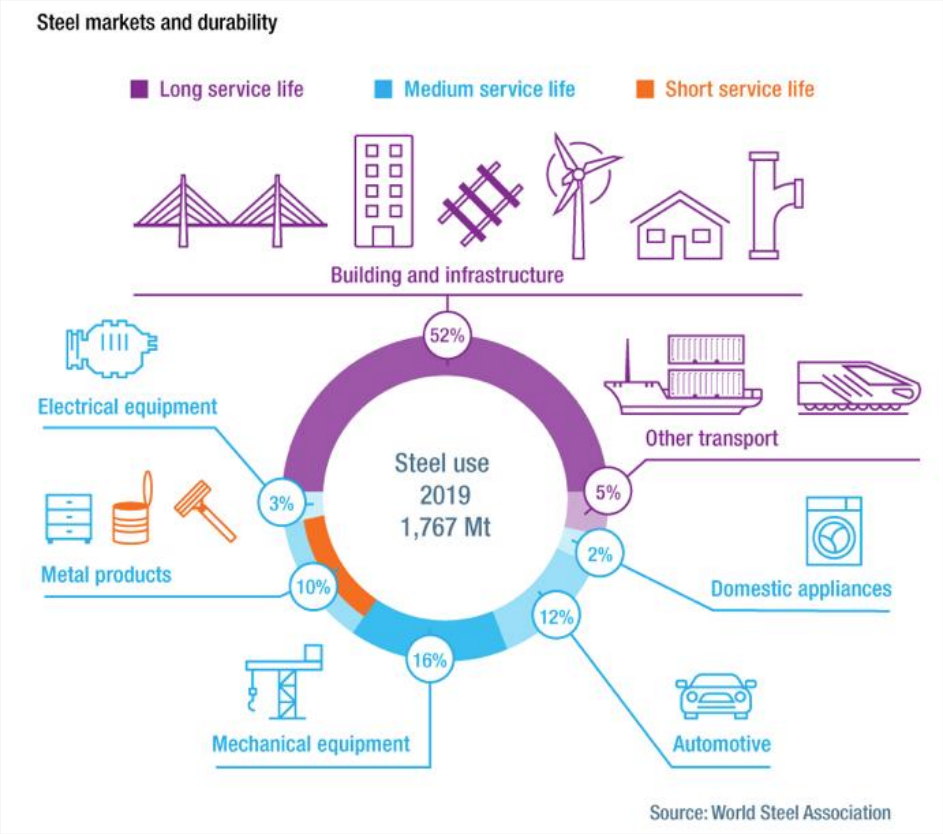
To understand the environmental performance of a product, its lifecycle needs to be mapped out. As described by the World Steel Association, a lifecycle assessment (LCA) of a steel product looks at resources, energy and emissions, from the steel production stage to its end-of-life stage, including recycling.

Steel is a widely recycled material. The Bureau of International Recycling (BIR) calculates that approximately 630 million tonnes of steel scrap is recycled every year, saving around 950 million tonnes of CO_2 emissions annually – which, to give context, is greater than the CO_2 emissions of the entire EU transportation sector. [13] As well as the saving in greenhouse gas emissions, steel recycling saves energy and conserves natural resources.

A not-for-profit organisation, Responsible Steel, manages a standards and certification process for sustainable and responsible steel across the value chain. [14]



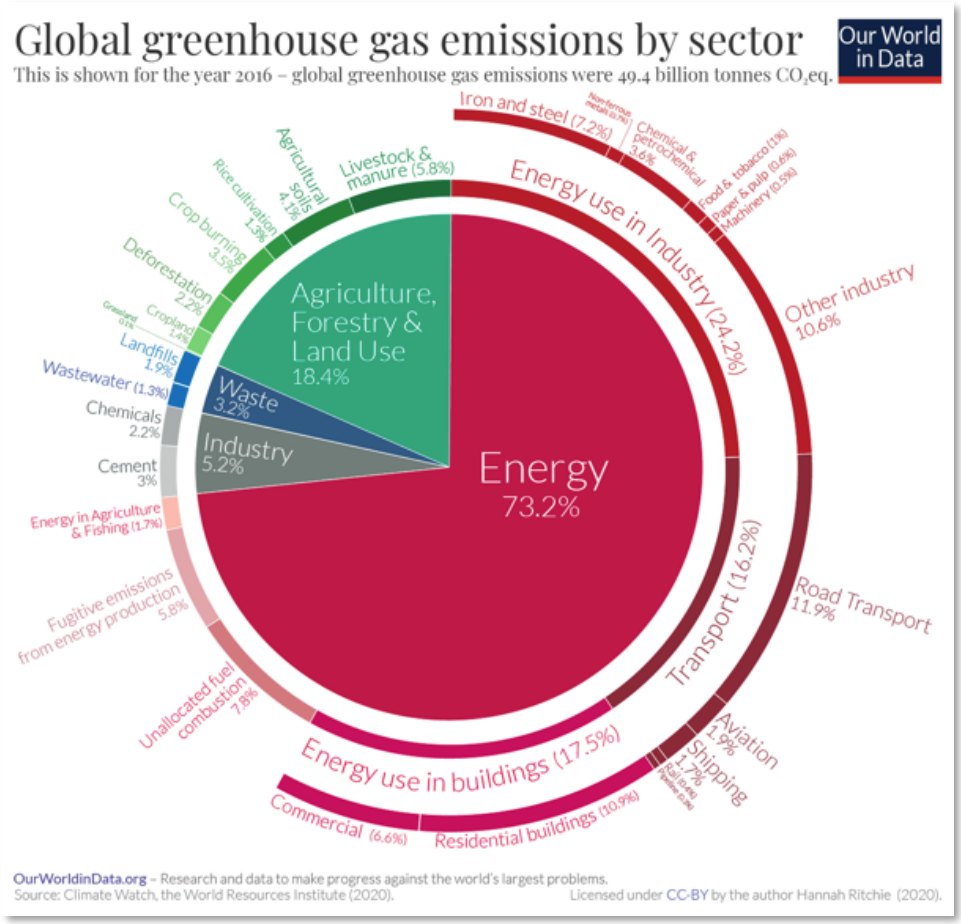
Source: World Steel Association: lifecycle thinking



Source: World Steel Association: steel markets

13. Climate Action

Decarbonising the steel industry presents one of the biggest challenges in tackling climate change. More than 70% of the world's steel is still made in blast furnaces where coking coal is used. The focus on SDG #13 is closely linked to SDGs #7, 11 and 12. Iron and steelmaking represents between 7 and 9% of total emissions.



Source: Visual Capitalist

It starts with the extractive industry that supports steelmaking. Mining groups that extract iron ore and other elements used for steelmaking such as manganese can look at ways to replace fossil fuels with bio-oil or electricity and hydrogen in the production of ore pellets. Transport of the ore (by rail and sea) can be improved.

As outlined with SDG #9, the DRI steelmaking process can be reengineered to be much greener by using hydrogen in the process. With a hydrogen-based direct reduction process the CO_2 emissions from iron and steel production can be much lower. The key question for the industry is: *can it work economically?*

17. Partnerships for the SDGs

The focus on SDG #17 is about ensuring that businesses, the industry, governments and other organisations can work together to solve future needs.

How do different stakeholders view sustainable steelmaking?

Given the outline of steel and the SDGs, and the focus on sustainable production and use, what are the positions of different stakeholder groups?

The general public

We use steel for many uses, many of which we may not even realise. From the buildings we live and work in, to the household goods we use and the cars we drive, and the equipment we use in all sorts of professions, we cross paths with steel all the time.

Our collective appreciation of the full lifecycle in the way steel is produced and used may improve in the coming years, as we all pay more attention to all aspects of sustainability, including our need to limit global temperature rises.

One aspect that the public is much more aware of today is the importance of recycling, and the circular economy. Whilst much attention is given to plastics recycling from a general household perspective, knowing that a great deal of steel is recycled (from the household goods we own, to our cars when they are sold for scrap) is surely a positive message. Many people probably do not realise just how much CO2 emissions are caused by iron and steelmaking, though this is changing.

Governments and international public policy

Some governments around the world are very proactive in pursuing strategies and policies to improve the sustainability of the steelmaking industry. Government actions are an important part of how steelmaking will evolve in future. It is all the more important, given the need to change many ways of society to be more sustainable and to reach the targets of the SDGs by 2030.

Good policy-making should play an important part in how steelmakers set out to achieve sustainability targets. Governments should focus on ensuring an overall regulatory framework is in place, which includes appropriate permitting rules to agree to new technology being used, and also the right price to pay for carbon emissions. Careful and appropriate use and management of subsidies is an important part of policy control as well.

One notable point with international public policy is that raw materials for steelmaking, particularly iron ore, can change rapidly in price. The issue is a complex one, in which the price of raw materials, when high, encourages greater extraction, though this has to be done in a sustainable way – which includes being responsible towards SDG #13, climate change, but also other SDGs, such as SDG #12, responsible consumption and production.

A few examples of activity around the world are as follows:

China

China is the world's largest producer of steel and its world's largest consumer, with large amounts of steel used across many sectors of its economy.

Although China has attempted to mitigate pollution, its continued increase in steel production poses a problem. China has influenced the demand for high-grade iron ore and has propped up prices for it. It has the ability to export surplus steel if it chooses to, which adds to its impact and influence on global steel prices.

From 1st January 2021 China is allowing imports of new-standard steel scrap – or recycled steel raw materials, the Ministry of Ecology and Environment has confirmed (the material is not be subject to a ban on solid waste imports).

India

The Indian Steel sector is in robust health and growing at a compound annual growth rate (CAGR) of about 5%-6% per year. Several infrastructure projects announced by the government across various sectors, including rail, road, aviation, gas pipeline, and housing, are expected to boost the steel demand in future. Investment in technological advancements in the industry to reduce the carbon loading attributable to steel continued to be a key focus area. [15]

A major internal driving force for domestic market expansion has been the country's vast population, low per capita consumption of iron and steel and its GDP growth. This implies that there is potential for rapid growth of the domestic market of Steel due to low-base effects. India's relatively young population and the trend of urbanisation both tend to boost demand for housing, transportation and public infrastructure, which translates into higher demand for steel.

The USA

The United States has recently experienced robust growth in steelmaking. The U.S. Steel Corporation has recently produced its first ton of steel at a brand-new facility in Fairfield, Alabama at a new plant that will produce 1.6 million tons of steel a year using electric arc furnace (EAF) technology.

Whilst some observers believe America's steel industry is in decline, others point to the fact that the US steel industry has recently modernised, and that it produces 70% of its steel via EAF, one of the highest figures of the major steel-producing nations. [16]

Partly due to the Trump administration's steel tariffs, which have brought steel imports down, US steelmakers are investing. Nucor, US Steel and other companies including Cleveland-Cliffs, Steel Dynamics, CMC, and AK Steel have invested in at least 16 major new projects. The top five US steel companies more than doubled their annual investments between 2017 to 2019, from US$1.5 billion to US$4.2 billion. These new steelmaking plants, steel mills, and ore processing facilities are using modern technology including EAF steelmaking.

Europe (various countries)

Europe is the second-largest producer of steel in the world, after China (with major producers including Germany, Italy, France and the UK). With an output of over 177 million tonnes of steel a year, it currently accounts for approx. 11% of global output.

The steel industry has held a strategic place in European economies for many years, and has been a key industry for employment, fostering innovation and economic growth. To face the downturn of steel demand after the challenges of 2020 and to ensure a promising future for the sector, the European Commission is working on measures to boost the industry. Steel is closely linked to many industrial sectors in Europe such as automotive, construction, electronics and renewable industries. [17]

Key ongoing challenges for the European steel industry are related to the cost and availability of raw materials and energy, environmental and climate change regulation, and competition from non- European producers.

South Korea

The steel industry in South Korea is an important part of its economy, with high impact on related industries. It has played a key role in the economic growth of South Korea by providing materials to industries such as automobile, shipbuilding and construction. [18]

The Korean steel industry used to focus on the mass production of crude steel. Since the year 2000, it has focused more on high-end production.

Australia

Australia is a small steel producer. The Australian steel industry consists of only a handful of steel producers, supported by over 300 distribution outlets throughout the country and numerous manufacturing, fabrication and engineering companies. [19]

Whilst it is a small steel producer, Australia is the largest exporter in the world (by far) of iron ore to other countries, which they use for steel production. It therefore has a major role to play in the steel industry overall.

NGOs, Environmental campaigners and Not for Profit Foundations

NGOs have had an important role around the world in steelmaking. ResponsibleSteel, a Not For Profit organisation, is the industry's first global multi-stakeholder standard and certification initiative. [25]

Academic Research and Scientists

The global academic and scientific community is working closely with governments and businesses to review the technological options for improving the sustainability of steelmaking. They are often supported by grants by governments and public bodies.

Financiers and Investors

From an investor standpoint, there is increasing evidence that investors want to see evidence of well-thought-out plans to reduce carbon emissions, and to tackle all other aspects of sustainability in steelmaking. Major investors have shareholdings in large steel producers, and there is a clear linkage with the need to reduce greenhouse gas emissions.

Importantly, momentum is growing to get businesses to embed climate risk into their financial decision-making – and investors play a key role in this. The aim is to make it mandatory for businesses and investors to demonstrate that their activities and investments are implementing steps to transition to a net zero emissions world. Seventy central banks are working to make this happen. How these requirements are stitched into the world's financial architecture will be a key focus for the 26th UN Climate Change Conference (UN COP 26) in Glasgow in November 2021.

Steel industry associations and producers

The World Steel Association members represent around 85% of global steel production. Steel companies around the world have been reporting to worldsteel on sustainability indicators since 2004. [20] These indicators provide a systematic way of measuring key aspects of our economic, environmental and social performance on a yearly basis.

Other associations such as Responsible Steel support the industry in its sustainability efforts and activities.

Businesses

Businesses in the global steel industry are looking at ways to improve their sustainability, whilst also having to navigate commercial challenges. As mentioned earlier, they are starting to research and invest in hydrogen technology for the DRI production process, although this method is not expected to become commercially viable for a number of years. However, examples of such efforts are provided below.

The efforts of ArcelorMittal, Thyssenkrupp, SSAB and Baowu to reduce carbon emissions from the steelmaking process

In the traditional process of making steel, iron is first extracted from its ore in blast furnaces at temperatures of up to 1,200 degrees Celsius using coke, a carbon-rich form of coal. One of the by-products of this process is CO_2. By replacing coke with hydrogen, the main by-product of steelmaking is water rather than CO_2. This could have a significant impact on carbon emissions for the steel industry. Yet so far, the percentage of steelmaking using this method is very small.

ArcelorMittal, a major force in the global steel industry, is working on a demonstration plant in Hamburg with Midrex Technologies for the large-scale production and use of Direct Reduced Iron (DRI) made with 100% hydrogen as the reductant, in place of coking coal. [21]

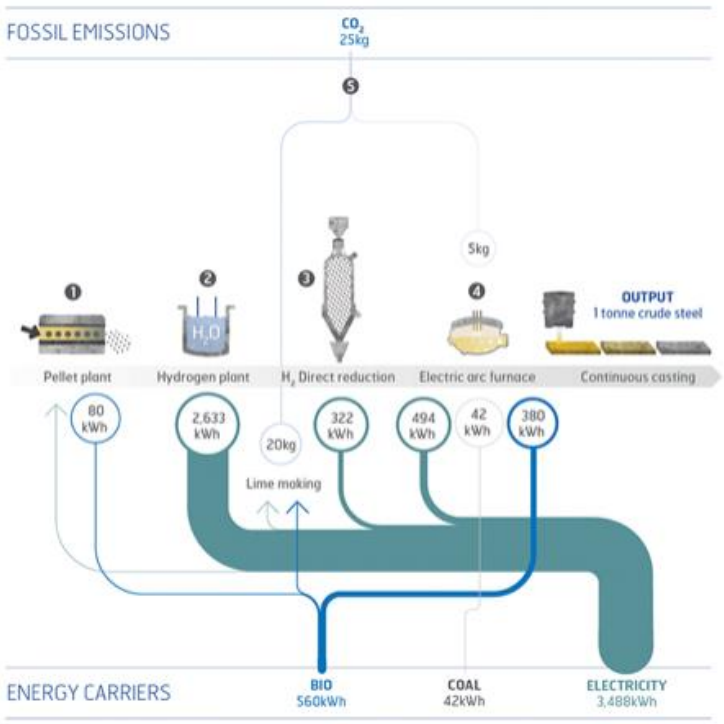
In the coming years, it is expected that the demonstration plant will produce about 100,000 tons of Direct Reduced Iron per year - initially with *grey hydrogen* sourced from natural gas. ArcelorMittal state that the intended conversion to green hydrogen

(i.e. coming from renewable energy sources) should take place once it is available in sufficient quantities and at an economical cost. The economics could take some time to come to fruition. Energy for hydrogen production for the demonstration plant, for example, could come from wind farms off the coast of Northern Germany. [21]

In Germany, in November 2019 Thyssenkrupp completed a successful, first-of-its-kind demonstration of running a steel furnace completely on hydrogen. [23]

Similarly, Svenskt Stål AB (Swedish Steel, or SSAB), which is headquartered in Sweden and is partly owned by the government of Finland, announced in January 2020 that it would be making substantial investments to accelerate the transition of its steel furnaces to use emissions-free, renewable hydrogen. [22.] The efforts to move to using renewable hydrogen in steelmaking will have a significant impact on the emissions of the two Nordic countries with major SSAB operations. It is anticipated that there could be a reduction of 7 per cent of Finland's greenhouse gas emissions and up to 10 per cent of Sweden's emissions. [22]

China's biggest steelmaker, Baowu, is also investigating the DRI hydrogen process and investing in research and development towards it. [24]



Breakdown of the steel production process using hydrogen. Credit: Hybrit

Linked to this, the mining firm BHP Group is making an investment from its US$400m climate investment fund through an agreement with Baowu. Under a five-year partnership agreed in November 2020, BHP will invest US$35 million in low-carbon steelmaking technologies and share technical knowledge with Baowu, one of its biggest customers. This includes a potential carbon capture and storage (CCS) project at one of Baowu's production sites in China and the utilisation of low carbon fuel sources such as hydrogen. [26]

A big question is – are businesses in the steel industry doing enough to invest in new processes such as the use of hydrogen in place of coal for the DRI process, and CCS initiatives?

As they seek to invest in various parts of the world such as Africa, Brazil, India and Mexico, can they do so with a commitment to environmentally-friendly production methods, as fundamentals of the steel market improve?

What can Risk and Operations teams in various industries do?

Risk Managers and Risk Advisors in all organisations can play a valuable role in working out how they can achieve their sustainability objectives, and how to take and manage risks to do so. Sustainability is business-critical today – from investors that are demanding to see strategies are in place, to employees who want to work for a business that demonstrates purpose. Risk professionals can be trusted advisors who can help people to achieve objectives, using risk-informed decision-making and risk tools and techniques to work out which risks (opportunities) to take and which risks (threats) need to be managed.

With regard to an organisation's use of steel, Risk Managers and Risk teams can work with their colleagues in Sustainability and Operations to think through how, for their organisation's particular circumstances, they should approach their situation. If an organisation procures products that use steel (as they most likely do), how can they ensure that it is procured responsibly? Using good Risk tools and thinking carefully through your options can help you to work out what is most feasible and impactful to you, now and in future.

Consideration	Ideas and thoughts for consideration
1. What exactly do you do, and how do you use steel?	• What do you design and / or produce, and how much steel is in them now / will be in future? • For the products that you use and / or procure, do you know how much steel is used to make them? • Will the price of steel have an impact on your future use / pricing of your own activities / products? • What can you do to ensure your consumption of steel is from responsible sources? • Do you know how much of the steel you use is from responsible recycling? • In your use of steel, are you asking your suppliers about their use of this element, and what they are doing to ensure it is responsibly sourced (including where it actually comes from)? • Are you able to set expectations on responsible and sustainable steel use into any contractual agreements with your suppliers? • When it comes to shipping of steel for your needs, either directly or indirectly, are you asking about the CO_2 emissions involved in shipping and ways to reduce them (e.g. refer to an associated paper on the shipping industry).
2. Do you have the opportunity to be involved in any research (are you already)?	• Are there opportunities for you to be involved in industry-specific or cross-industry / academic research into responsible sourcing of steel?

Consideration	Ideas and thoughts for consideration
3. Do you know your investor expectations, for sustainability of businesses they invest in?	• Do your investors have expectations about your carbon footprint, and the part that responsible use of steel can have on this? • Are any of them talking about the responsible use of steel (perhaps partly driven by targets being set in the global finance community)? • Are you engaging with them in how your green energy solutions could benefit their investment funds?
4. Do you know how government policy is changing, and how it could affect what you do?	• Government policies around the world towards the use of energy are changing. Are you aware of the regulations that currently exist for the potential to use hydrogen as part of steel production changes and how they could change? What risks – threats and opportunities – does this present for your organisation?
5. Sustainability reporting	• Have you thought about how your use of steel can help you with your sustainability reporting and your sustainability commitments?

Conclusion

This paper has discussed the importance of steel, and steelmaking, to the global economy. It is a major industry worldwide – and it is responsible for some 7-9% of global greenhouse gas emissions.

The steelmaking industry is under pressure financially to make stronger returns for investors, and investment into greener production techniques is critical to reduce the greenhouse gas emissions that it is responsible for. Such technology exists, and new production techniques are being trialed, but commercial challenges exist to ensure these hydrogen-fuelled DRI production processes will be cost-effective and therefore sustainable.

There is also great potential also to leverage the amount of steel recycling that already takes place and drive it even higher.

Governments around the world play an important role in helping steelmakers to improve production processes through policy-making to encourage the right type of investments in technology to ensure sustainable steelmaking is cost-effective. Investors and the finance community is also an important driver to this, to support steelmakers in the right way to drive improved production methods. The extraction of the ores used in the production process also needs to be done in the most sustainable and responsible way possible.

All businesses that use steel should be working with their steel suppliers to agree how sustainability measures can be put in place to ensure greenhouse gas emissions are being tangibly lowered. This is a critical factor in the world being able to achieve its climate change targets and to achieve the SDGs by 2030. The steelmaking industry really does have a critical role to play in achieving a sustainable future.

Further suggested reading

The World Steel Association has some interesting and useful information about steel, for example:

- The Steel Story
- Steel facts
- 2020 World Steel in Figures

ResponsibleSteel is a Not For Profit organisation that promotes sustainability in the steel industry.

The International Energy Agency (IEA) has published an Iron and Steel Technology Roadmap.

About the author

Gareth Byatt is Principal Consultant of Risk Insight Consulting. He works around the world with clients in various industries and sectors, including the mining industry which extracts the minerals used for steel, and the construction and infrastructure industry which is the world's largest user of steel.

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