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THE STEEL INDUSTRY IN POLAND

Sector Analysis, Challenges, Future Vision

Maciej Bukowski, Krzysztof Bocian

Economics and Economic Policy

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Economics and Economic Policy

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Key conclusions

- The **steel industry is a staple of the global economy** since the beginning of the Industrial Revolution in the 18th century. The particularly rapid development of this industry began in the mid-19th century with the invention of industrial steelmaking processes by Bessemer, Gilchrist, Siemens and Martin. The systematic increase in the production capacity in the steel industry continues to this day, as more countries become industrialised. The last few decades have been a steel boom period, especially in East and South Asia, boosted by the increase in production and use in countries such as China, India, Turkey, Brazil, Indonesia, Vietnam and Thailand.

- After the crisis of the 1980s, the **steel consumption in Poland has been continuously growing** for three decades, in line with the increasing demand for raw materials in the economy. This growth is related to the rapid development of processing industries, such as automotive, production of electrical machines and devices, as well as electrotechnical equipment, including domestic appliances. The development of the construction sector driven by infrastructure investments and, in the last twenty years, also by residential construction, is also important. For the years ahead, a further increase in steel consumption can be expected due to electrification and economic development, as well as further infrastructure investments, mainly in railways and roads. The rapid growth of industrial production and the development of residential construction are also expected to continue over the next ten to twenty years.

- **Poland has one of the highest steel trade deficits in the world.** It is the twenty-first economy in the world, and at the same time, the tenth importer of steel, as well as – taking into account exports – even the fifth net importer of steel. Such a large negative steel trade balance has its roots in the transformation of the steel sector in the years 1980-2000, which resulted in shutting down obsolete steel plants, while employment and steel production dropped, but the efficiency of steel production improved many times. This enabled the sector to remain competitive in a market economy, but also resulted in a trade deficit. At present, Poland consumes twice as much steel as it produces, and its needs are met by imports.

- In the coming decades, **greater emphasis on satisfying internal demand with domestic production** by the development of stable and independent industrial base in the steel industry should be a priority of the industrial strategy for the steel sector. The growth in domestic production will contribute to an increase in the number of well-paid jobs, stimulating the development of other industry sectors and strengthening resilience of the Polish economy to external risks. However, for this to happen, the low-emission transformation of the industry is of key importance.

- **Poland stands out not only globally, but also in the European Union, due to its relatively high (53%) share of secondary smelting using electric arc furnaces**, which also results in average lower emissions of the domestic steelmaking sector that, while producing 5.4% of steel in the EU, is responsible for just 2.4% of emissions of the sector in the EU. At the same time, globally, the main steelmaking technology is blast-furnace (BOF) technology. In global terms, it accounts for about 72%, and at the European level, for 66% of steel production. It is also the main source of carbon dioxide emissions in the global steel industry, producing as much as 93% its emissions.

- **Higher electrification of the steel industry is recommended, inter alia, by the International Energy Agency**, as the most promising path towards the decarbonisation of this sector, especially in the medium term. In Poland, the availability of scrap as a critical or strategic raw material may prove to be a crucial aspect of this process. Currently, Poland is a net exporter of scrap, which sets limits on the further expansion of electric arc furnace (EAF) production capacity in the country. Consequently, in order to continue the decarbonisation of the sector, regulations limiting the export of scrap from Poland together with an industrial policy encouraging producers to increase domestic production of steel in arc furnaces will be required.

- **In case of blast-furnace steel plants, the application of the carbon capture and storage (CCS) technology may be a chance.** Pilot systems have shown that this technology has the emission reduction potential reaching approximately 70%-80% of the original emission level. With its favourable geological conditions for carbon storage, Poland should take into account this option as a base option for existing steel plants producing primary steel. This would potentially enable it to benefit from economies of scale as a result of joining efforts with other industries, especially the cement industry, which has already started investing in CCS facilities, as well as with the chemical and petrochemical industries.

- **Direct reduction of iron (DRI) technology, which is still in its infancy, is especially promising, in particular, for newly erected steel plants.** This technology uses a different reducing agent for the oxidation of iron (natural gas, synthesis gas or hydrogen). The technology can be successfully used in electric arc furnaces, where produced pig iron would be processed into steel with required material properties. Taking into account decarbonisation, projects using hydrogen as a reducing agent (DRI-H2) will be of key importance, but they require the development of infrastructure for the production and transport of pure hydrogen.

- **Technology changes in the steel sector will last for decades and will require significant investment outlays.** The concentration of these activities should support the development of various steel making paths and ensure the low-emission status of the sector by 2050, which will require concurrent development of the infrastructure auxiliary to and supporting emission reduction technologies in steel plants. In the case of EAF, access to green energy is crucial, which means the transformation of the energy sector with a much greater use of RES, and in the case of BOF furnaces – investments in CCS, including systems for carbon capture, transport and injection into underground storage sites, or its utilisation in other industries. For the purposes of DRI technology and the use of hydrogen as a reducing agent, investments in hydrogen infrastructure (production and transmission) and a higher number of DRI projects will be required.

- **The steel sector will contribute to the low-emission development of the global and Polish** economy both directly, by providing green steel for the construction, industrial and energy sectors, and indirectly – by multiplier effects resulting from investments in the steel industry.

1. REVIEW OF THE STEEL SECTOR

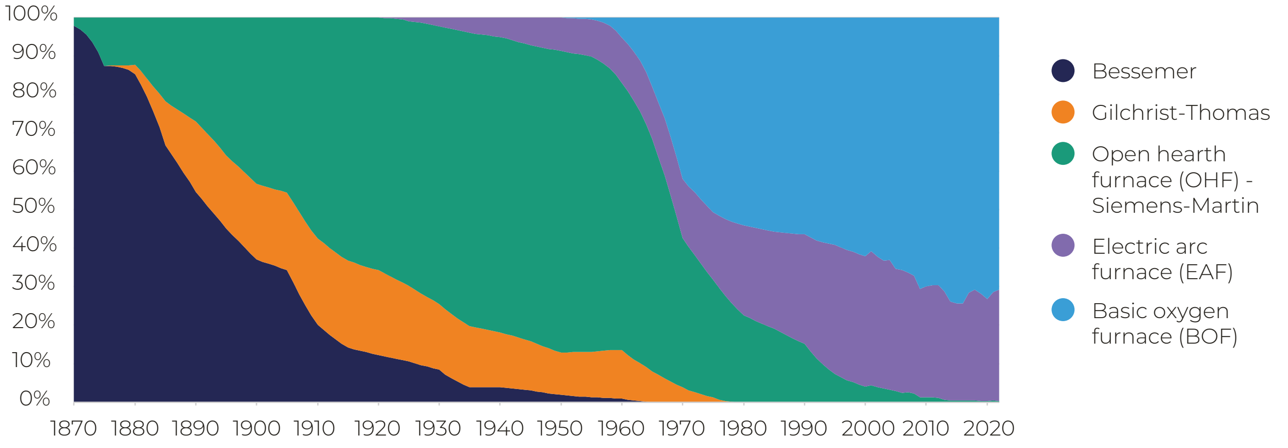
1.1. Production technologies

Steel is an alloy of iron mixed with a small amount (0.2-2.0%) of carbon and, depending on the purpose, with only trace amounts of other elements. From mastering the process of iron smelting about 3,000 years ago until the end of the 18th century, steel was made from ore in furnaces of simple construction and very low efficiency, fired with wood and, at a later stage, with charcoal, which involved extensive forest exploitation.

As a result, both iron and steel were relatively expensive, and were made in limited quantities, primarily for the purposes of making weapons or relatively small objects, such as farming tools or cutlery. Singular larger metal structures were made of wrought iron only in exceptional cases. The stalemate was broken not before the development of modern steelmaking methods in Europe, at the turn of the 18th and 19th centuries. It was possible as a result of some technological breakthroughs allowing producing much larger quantities of steel at significantly lower unit costs.

The first step towards mass production of steel was the development, in the early 19th century, of the open smelting process, which involved melting iron in large furnaces with flat, wide bottoms, and with fuel combustion chambers. However, the real breakthrough took place in the mid-19th century, when Henry Bessemer developed a process that allowed steel to be made much more effectively and quickly, based on molten pig iron. This allowed for a significant reduction of production time and unit costs, thus considerably improving the availability of steel, which became a strategic material in the 19th century, especially after Sidney Gilchrist Thomas and Percy Gilchrist modified the Bessemer process to reduce the phosphorus content in steel, improving its strength and, in particular, resistance to cracking. Additionally, the first artificial fertilizers in history were produced based on recovered phosphorus.

Figure 1. Global steelmaking processes 1870-2022.



Source: WiseEuropa based on data of the World Steel Association and Lund University, Hydrogen steelmaking for a low-carbon economy.

The second half of the nineteenth century was a period of very rapid technological progress in steel production. The improvement of open hearth furnace (OHF) technology by Siemens and the Martin brothers was a principal innovation. Open hearth furnaces, allowing control over the chemical composition of steel and, as a result, the production of various types of steel, became the global steel industry standard at the beginning of the 20th century, despite the fact that the process was relatively time-consuming and required a large amount of thermal energy, which became an issue, especially during energy crises of the 1970s. The steel sector's technological response was the improvement of the converter process by using a stream (blast) of pure oxygen in the furnace to remove impurities from molten iron by oxidation. This technology (BOF – Basic Oxygen Furnace) allowed producing high purity steel, while energy consumption was much lower than before, which enabled the BOF technology to gradually replace the open hearth process in the global steel industry, reaching a share of about 70% in the total global steel production after 2010.

At present, it is complemented by the electric arc furnace (EAF) technology that was developing in parallel. This process allows for quick and flexible processing of steel raw materials – mainly scrap, and thus the production of various types of steel based on iron obtained from scrap. The process is much less energy-intensive than other technologies discussed above, but it requires significant quantities of previously manufactured steel products – scrap used as a source of iron. This is possible primarily in countries that have a long history of industrialisation, where significant quantities of recycled materials are available and the energy system has surplus of cheap electricity allowing installing arc furnaces. Currently, EAF output accounts for about one-third of global steel production, and in OECD countries, it is even 55%.

The most important conclusion based on the history of technological changes in the steel sector is the very slow pace of replacement of main technical solutions with new ones. It took about 50-60 years to replace the Bessemer-Glichrist-Thomas process with the Simens-Martin process. Next, about four decades were need to replace open hearth furnaces with a combination of the BOF process and arc furnaces. This is due to the fact that the steel industry is a capital-intensive industry, and a newly built steel plant is expected to operate for at least a few decades to generate the expected return on the capital invested. Consequently, the technological transformation of the global steel industry in the future will require several decades to be fully completed on a global scale.

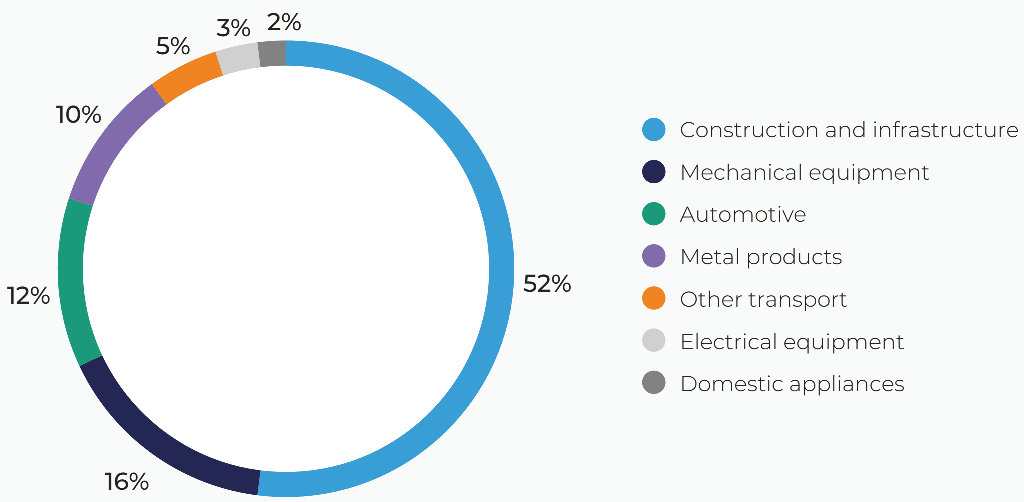
From the point of view of the environment, this means, in particular, that effective decarbonisation of steel production (see: chapter 2) by 2050 will be possible only if both the countries with highly depreciated steelmaking assets and the countries, where production capacities are being developed, are involved. If not, the "technology ratchet" may cause that the development of a zero-emission global steel sector will require investments for even 100 years rather than for 40-50 years.

Further in the report, we discuss this issue in more detail, also assessing the chances of such transformation at a regional (EU) and Polish level.

Box 1. What is steel used for?

- **Construction and infrastructure:** this sector uses 52% of global steel production. Steel is necessary in the construction of houses, bridges, roads, tunnels, railways and other infrastructure facilities. It is used, inter alia, for construction profiles and sections supporting and strengthening building structures.
- **Mechanical equipment:** accounts for 16% of global steel consumption. Steel is used to manufacture industrial equipment, agricultural machinery, and in the energy sector (e.g. wind turbines), both in structural elements and mechanical parts.
- **Automotive:** the automotive industry uses 12% of the world's steel to manufacture car bodies, wheel-axle assemblies, axle suspensions, engine elements and various other vehicle parts.
- **Metal products:** the sector is responsible for 10% of global steel consumption. Steel is used, inter alia, to manufacture pipes, steel sheet, bars, structural elements, as well as various other tools. It is also used in components of military equipment (ammunition, barrels, steel plates, etc.).
- **Other transport:** including ships, trains and other non-motor means of transport. It uses 5% of the world's steel. Steel is a key material in the construction of ship hulls, railway wagons and other specialised vehicles.
- **Electrical equipment:** 3% of the world's steel is used to manufacture transformers, electronic equipment housings and other structural elements and equipment in the electrical machinery industry.
- **Domestic appliances:** steel is used to make kitchen appliances, washing machines, refrigerators and other appliances, both structural elements, such as housings of domestic appliances, and mechanical elements (e.g. washing machine drums). The sector is responsible for 2% of global steel consumption.

Figure 2. The uses of steel (2022).



Source: WiseEuropa based on data of the World Steel Association.

Steel production technologies part 1

Bessemer and Gilchrist-Thomas

Essence: Quick and economical process, excellent for making large quantities of steel. The Bessemer process was focused on reducing carbon content, as a result of which it was suitable mainly for the production of structural steel.

Differences: Compared to other existing methods, the Bessemer process was fast and efficient, but was subject to limitations related to removal of phosphorus, which made the steel processing difficult. The removal of excess phosphorus by Gilchrist-Thomas improved the quality of steel and ensured its better mechanical properties.

Description: The process involved blowing compressed air directly through molten iron, which allowed oxidising impurities and reducing the carbon content. As a result, the steel production time and costs were lower. The Bessemer process was initially focused on the production of structural steel, but after Gilchrist-Thomas improvements allowing removing excess phosphorus, it could have been used for various purposes, including the production of specialised steel with better mechanical properties.

Future: They are the technologies of the past – they are no longer used in modern steelmaking, as they were replaced by open hearth furnaces and then by oxygen blast furnace technologies.

Advantages	Disadvantages
• Fast production process allowing for mass production of steel • Reduced production costs compared to previous technologies due to less production time and higher efficiency • Gilchrist-Thomas improvements allowed for better control over the chemical composition and, therefore, the properties of steel • Initially used for the production of structural steel, and after improvements also for other purposes	• Initially, limitations in the removal of phosphorus affected the quality of steel • Due to steel processing difficulties, it was suitable mainly for the production of structural steel • It resulted in the loss of certain valuable alloys • In order to improve quality, low-phosphorus ores were required, which increased production costs • Relatively high iron losses in the production process

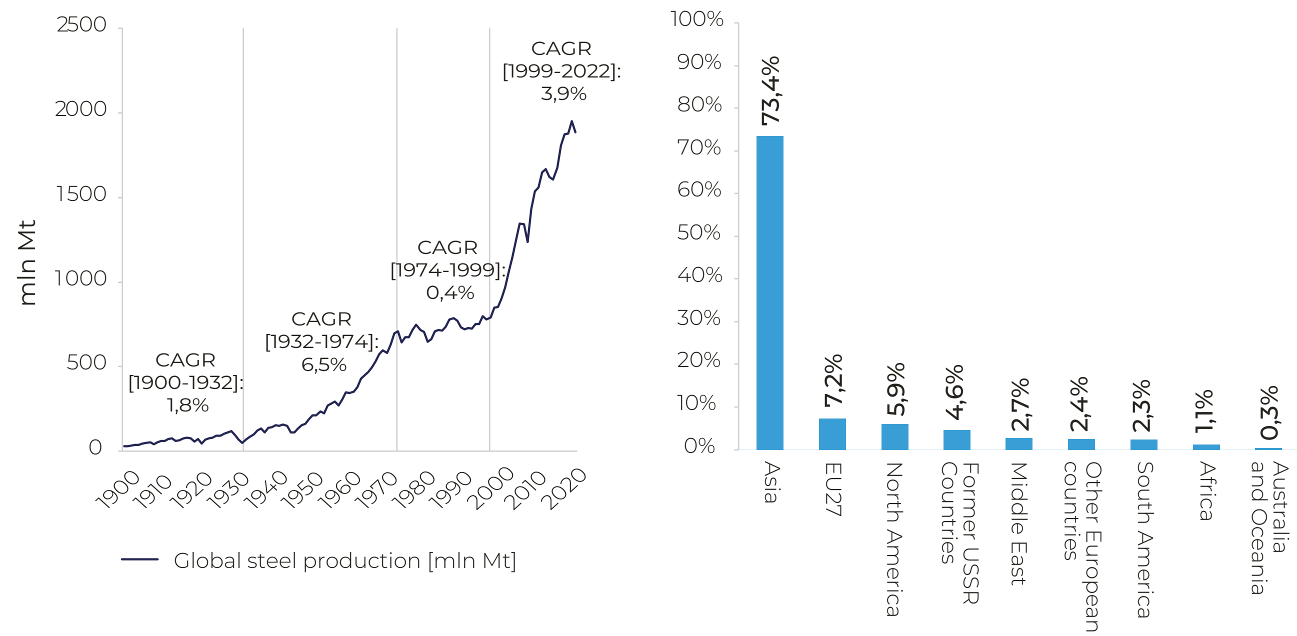
1.2. Role of steel in the global economy

The steel production technology changes described above had a significant impact on the development of the global economy over the last 200 years. This was due to the fact that the market was provided with material, the properties of which satisfied the needs of various sectors. – steel is one of the most versatile materials used in almost all branches of the economy. Its universal nature results from its unique properties. One of them is strength, including tensile strength, compression strength and bending strength, which makes it a perfect structural material commonly used for the construction of buildings, bridges, towers, poles and other infrastructure objects. Other key characteristics of steel include its flexibility and plasticity – steel can be easily formed and shaped into various configurations, which makes it a material useful for the production of various products, including machines, tools and end products such as cars. Another useful property of steel is that, thanks to additional elements, it is very resistant to corrosion and mechanical damage, as a result of which steel products have a long useful life and require minimal maintenance, so steel has very high economic effectiveness.

Consequently, it is not a surprise that mass production of steel is closely associated with industrialisation and economic growth. Steel allows for the development of the processing industry – primarily, by providing material for the construction of machines equipped with standard replaceable elements that are easily repaired and maintained. Then, these machines allow for the mass production of uniform products, which translates into a drop in their unit cost and an increase in overall manufacturing productivity.

At the same time, cheap steel offers an opportunity to build large-scale infrastructure, such as railway tracks, bridges, sea ports and airports, or power pylons. Also, the construction of vehicles that use this infrastructure – cars, trains, planes and ships – would be impossible without steel. Consequently, the development of steel production is a necessary condition for industrialisation not only through the development of mass production, but also by creating a market for this mass production by the expansion of transport systems and an unprecedented drop in the costs of long-distance transport of goods.

Figure 3. Global steel production 1900-2022 (left) and geographical distribution of steel production in 2022 (right).

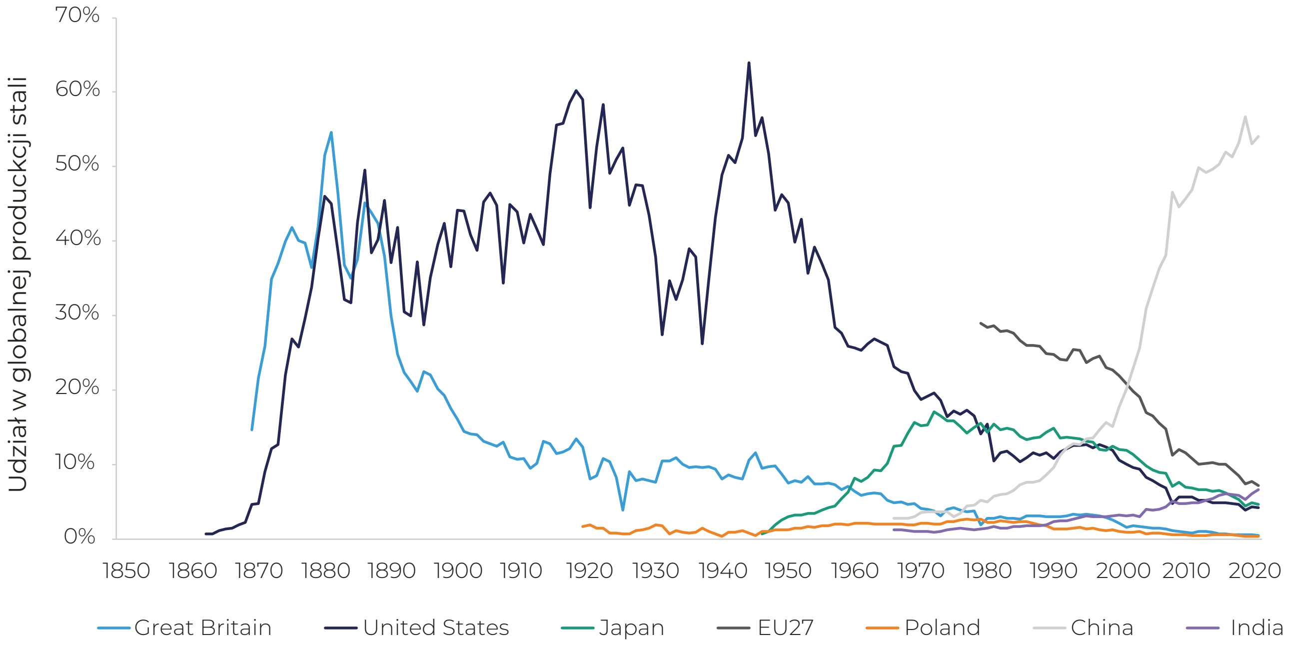


Source: WiseEuropa based on data of the World Steel Association.

Consequently, it is not a surprise that the systematic growth of the global steel production and use follows the process of subsequent countries entering the path of industrialisation. At a given time point, steel plants are concentrated in the part of the world having the highest development pace. In the first half of the 19th century, it was Great Britain, which was responsible for as much as half of the global steel production. However, the role of the United Kingdom gradually diminished, as Western Europe, the United States and subsequently also the USSR and Eastern Europe experienced industrialisation. This is because the export of British technologies allowed the rapid industrialisation of other economies and then the emergence of new regions dominating the global steel market: the United States and Western Europe. This was the result of the industrial boom in these regions, first during the so-called the second Industrial Revolution (1870-1914), and then during the boom period after World War II (1945-1975), which in both instances involved large infrastructure investments and contracts for the civil and defence industries. This provided space for the development of existing and the establishment of new steel giants such as U.S. Steel, Cleveland-Cliffs, Nucor and Pennsylvania Steel in the United States and ArcelorMittal and ThyssenKrupp in Europe. In the second half of the 20th century, the steel industry started its rapid growth in industrialising Asia, primarily in Japan and South Korea, and then in China.

At present, the Middle Kingdom – like Great Britian 200 years ago – is responsible for about half of the global steel production. South Asia, where the industrialisation process is especially fast today, gradually moves to the second position. This applies especially to India, ranking the second globally (6.6% of steel production), but also the countries such as Indonesia, Vietnam, Malesia and Turkey. Taking into account steel production, Poland is ranked 23rd globally (0.4% share), and in terms of steel consumption – 18th (0.8% share).

Figure 4. Share in the global steel production, 1850-2022.



Source: WiseEuropa based on data of the World Steel Association, World Bank, Japan Iron and Steel Federation, Federal Bank of St. Louis, AGH University.

At present, the centre of gravity of steel production and use has moved towards rapidly developing Asia, in particular China and India, but also Vietnam, Taiwan, Indonesia and Turkey.

In the last two decades, developing countries recorded significant increase in steel production capacity – almost 4-fold, from 462 million Mt to 1,800 million Mt in the years 2000-2022. During the same period, steel production capacity in developed OECD economies remained almost unchanged (increase by just 8%, from 607 million Mt to 658 million Mt).

The centre of this growth was China, where the economy, since the beginning of reforms and the opening to the outside world at the turn of the 1970s and 1980s, recorded growth higher than that of Japan and South Korea in the years 1950-1990. Economic reforms in China included, inter alia, the establishment of a number of special economic zones on the eastern coast of the Middle Kingdom (such as Zhuhai, Shenzhen, Shantou, Xiamen, Shanghai). These zones became centres of industrial activity, attracting investors from around the world and stimulating internal economic growth for almost 40 years. Since 1990, intensive investments in transport infrastructure (ports, roads, railways) accompanied the rapid growth in production, as without them significant increase in exports and, in the longer term, also in internal consumption would be impossible. At the same time, China was developing its energy infrastructure to meet the energy needs of its rapidly growing economy, while very large migrations from rural areas to cities, stimulated by the demand for labour in the western provinces, resulted in an unprecedented real estate boom, as a consequence of which millions of apartments were built. All this together meant a steep increase in demand for construction materials, especially steel, transforming the Middle Kingdom into the largest producer of steel in the world.

Table 1. **Major steel producers and users in 2022.**

Production				Consumption			
Rank	**Country**	**Production (million Mt)**	**Share in global production**	**Rank**	**Country**	**Consumption (million Mt)**	**Share in global consumption**
1	China	1018,0	54,0%	1	China	920,9	52,1%
2	India	125,3	6,6%	2	India	114,9	6,5%
3	Japan	89,2	4,7%	3	USA	94,5	5,3%
4	United States	80,5	4,3%	4	Japan	55,0	3,1%
5	Russia	71,5	3,8%	5	South Korea	51,2	2,9%
6	South Korea	65,8	3,5%	6	Russia	41,7	2,4%
7	Germany	36,8	2,0%	7	Germany	31,6	1,8%
8	Turkey	35,1	1,9%	8	Turkey	30,7	1,7%
9	Brazil	34,1	1,8%	9	Italy	24,9	1,4%
10	Iran	30,6	1,6%	10	Mexico	24,8	1,4%
11	Italy	21,6	1,1%	11	Brazil	23,5	1,3%
12	Taiwan	20,8	1,1%	12	Vietnam	22,2	1,3%
13	Vietnam	20,0	1,1%	13	Iran	19,1	1,1%
14	Mexico	18,1	1,0%	14	Taiwan	17,4	1,0%
15	Indonesia	15,6	0,8%	15	Indonesia	16,5	0,9%
16	France	12,1	0,6%	16	Thailand	16,4	0,9%
17	Canada	12,1	0,6%	17	Canada	13,5	0,8%
18	Spain	11,5	0,6%	18	**Poland**	**13,3**	**0,8%**
19	Malaysia	10,0	0,5%	19	Spain	12,4	0,7%
20	Egypt	9,8	0,5%	20	Egypt	11,1	0,6%
21	Saudi Arabia	9,1	0,5%	21	Saudi Arabia	10,7	0,6%
22	Austria	7,5	0,4%	22	France	10,1	0,6%
23	**Poland**	**7,4**	**0,4%**	23	Philippines	10,1	0,6%
24	Belgium	7,0	0,4%	24	Malaysia	7,8	0,4%
25	Ukraine	6,3	0,3%	25	Australia	7,3	0,4%
	Pozostałe	109,5	5,8%		Others	166,6	9,4%
	World	**1885,4**	**100,0%**		**World**	**1768,2**	**100,0%**

Source: World Steel Association.

Steel production technologies part 2

Open Hearth Furnace (OHF) – Siemens-Martin

Essence: In this open hearth technology, raw materials such as iron ore, coal and scrap were melted in an open furnace. This process allowed control over elements added and the chemical composition of steel and, as a result, the production of various types of steel.

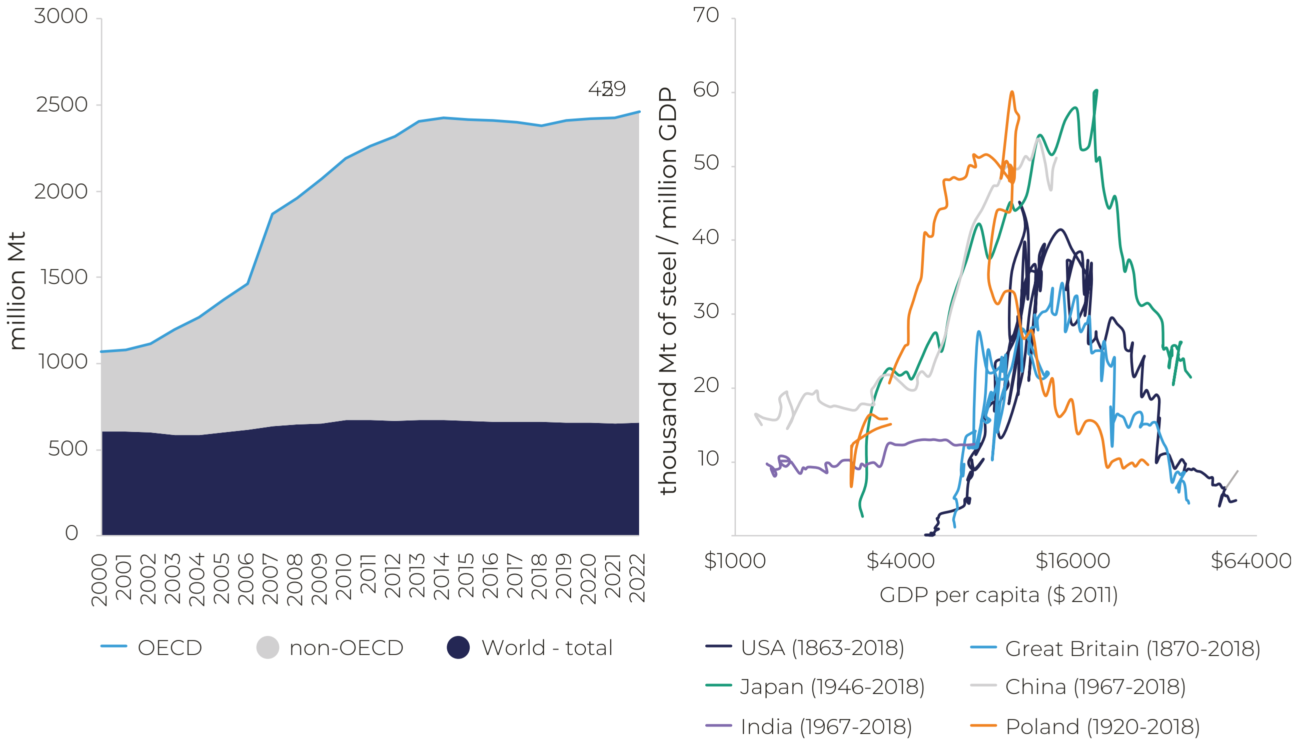
Differences: In comparison to the Bessemer process, OHF was more flexible, allowing the production of various types of steel depending on raw materials and alloy additions. For that reason, it dominated steel production already at the beginning of the 20th century.

Description: Flexible process allowing the production of various types of steel depending on available raw materials. Its typical features included a long melting time, but the process allowed flexible control over the chemical composition of steel. OHF was widely used in steel-making for all types of applications until the 1970s. It was very energy-consuming.

Future: Even though the open hearth technology was used until the beginning of the 21st century, it is no longer used in steelmaking globally, and was replaced by the oxygen blast furnace technology and the electric arc furnace technology.

Advantages	Disadvantages
• Allowed the production of various types of steel • Various raw materials could be used, including steel scrap • Ability to control the chemical composition of steel during the process	• Long melting time resulting in lower efficiency compared to current EAF and BOF technologies • Large amount of thermal energy required

Figure 5. Global crude steel production capacity, 1900-2022 (left) and intensity of steel production (right).



Source: WiseEuropa based on data of the World Steel Association, Madison, World Bank, Japan Iron and Steel Federation, Federal Bank of St. Louis, AGH University.

In the last decade, China has reached a level of GDP per capita, above which the demand for steel can be expected to decline, and the global steelmaking centre is likely to move to other regions of the world. This has been proven by the history of Japan, where industrialisation in the past followed a similar pattern to that of China, when from the 1940s to the end of the 1980s, the Land of the Rising Sun was undergoing a transformation after the war's devastation, reaching the position of a leading industrial nation. Steel corporations, such as Nippon Steel, Kobe Steel and Sumitomo, developed during that period. At its peak, Japan was responsible for 17% of global steel production, but after becoming a developed country, the economy started to shift resources to the much less material-intensive service sector and the intensity of steel consumption started to decrease, as it happened previously in other OECD countries after attaining a similar level of wealth.

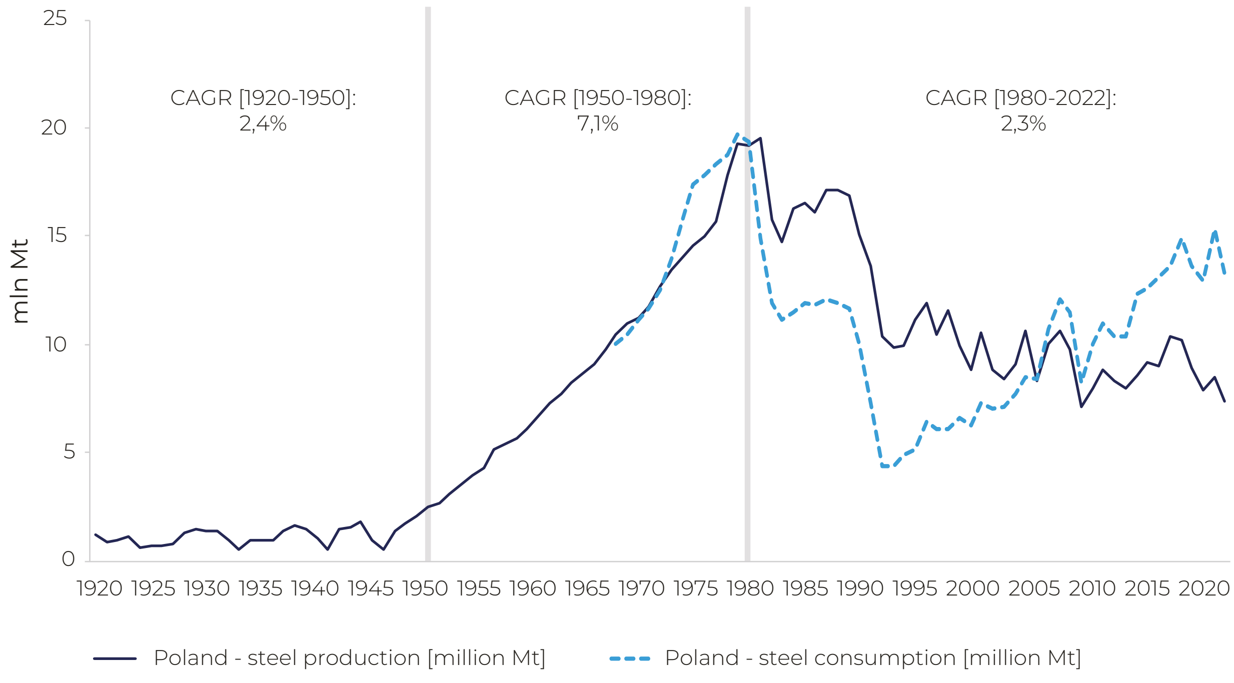
1.3. Steel industry in Poland

Throughout history, the role of the metallurgical industry in Poland was similar as in other European countries. Consequently, until the mid-19th century, it was a relatively undeveloped cottage industry. Ore mining and iron production were geographically dispersed in regions, such as the Świętokrzyskie Mountains, western Masovia and the Upper Silesia. The development of the steelmaking sector accelerated not before the second Industrial Revolution in the years 1850-1914, as a result of which about 100 small iron ore mines were established in Poland, and in 1920, production exceeded 1 million tons of crude steel. In the interwar period, the steel industry experienced downturns and upturns, primarily as a result of violent shocks such as the Polish-Soviet War, the boom in the 1920s, the Great Depression of the 1930s, and the expansion of the Central Industrial Region (COP) just before World War II.

After 1945, the command-and-quota system in the economy was introduced, and decisions on the expansion of any industry, including the steel industry, were made by a central authority in long-term plans. In accordance with the applicable theory, particularly large funds were allocated to heavy industry and investments in the infrastructure related to the reconstruction of the country after the war. Therefore, in the 1950s and 1960s, several geological surveys were carried out, which resulted in the discovery of new iron deposits and the construction of mines and steelworks. In consequence, 20 years after World War II, steel production was many times higher than before the war, reaching 9.1 million tons. The 1970s and 1980s witnessed further development of the steel industry – several steel plants were modernised and new ones were opened, which allowed for a significant increase in steel production in Poland. Main production centres included Nowa Huta in Kraków, developed since the 1950s, and Huta Katowice, erected 20 years later.

In 1980, the output of the domestic steel industry reached as much as 19.5 million tons of steel, which was not only the historical peak of production of this material in the country, but also ensured that Poland achieved a high share (about 2.7%) in the global production.

Figure 6. Production and use of steel in Poland, 1920-2022.

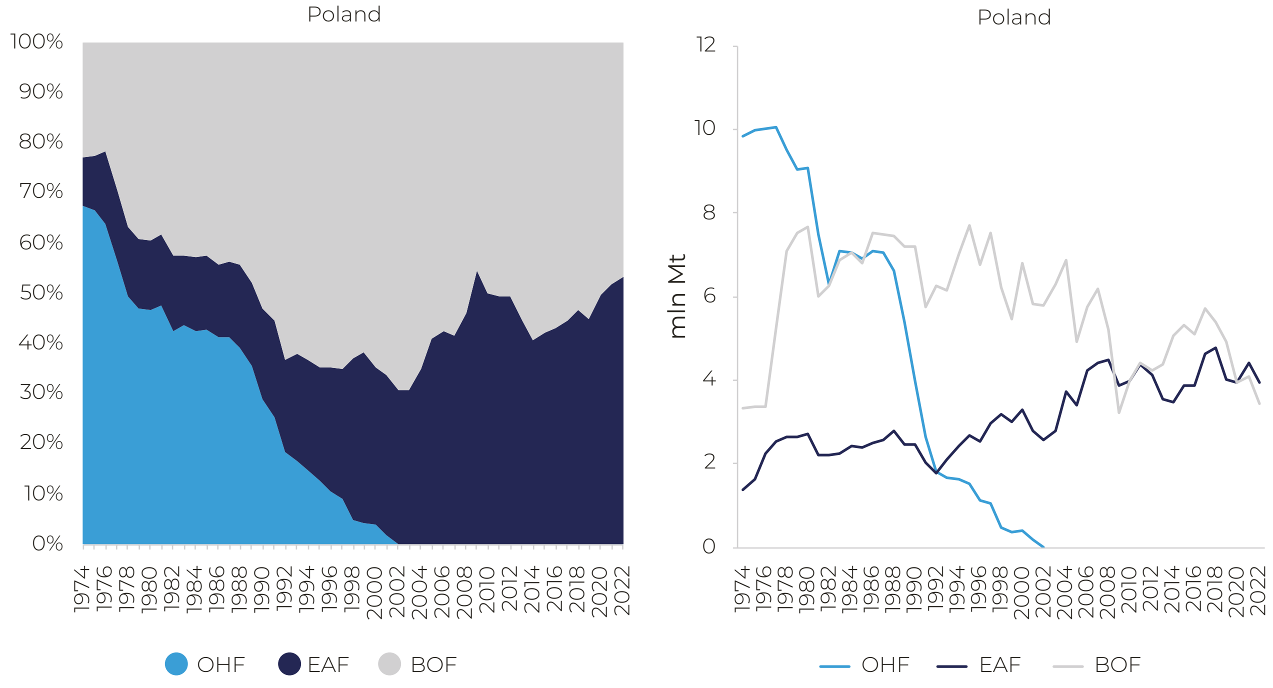


Source: WiseEuropa based on data of the World Steel Association and AGH University.

Despite significant investments in the heavy industry sector during the Polish People's Republic period, from the technical point of view, the sector was far behind OECD countries. The efficiency of the technologies used was low, and about 30% of steel produced in the 1980s remained in steel plants as technological waste. During this period, the least efficient installations, including open hearth furnaces posing a significant risk to the environment, started to be shut down for economic reasons, but the technological change process in the domestic steel industry was delayed compared to leading countries, and the last Siemens-Martin (OHF) installations were decommissioned not before 2002.

After 1989, with the introduction of market economy rules, the demand for steel dropped dramatically. The reason was, on the one hand, much greater focus on costs in industrial companies, and on the other hand, decommissioning or significant limitation of the activities of those of them that did not meet the market economy conditions. This included, inter alia, industries that until that moment needed large quantities of steel, such as pre-fabricated construction sector and the defence industry. The fast-growing new type of industry often preferred to import steel components rather than purchase them from domestic steel plants that were often unable to meet higher quality requirements and a different demand profile from processing companies. As a result, the steel sector required urgent restructuring. Many smaller, unprofitable plants were closed (e.g. the Ursus foundry in Lublin), others changed their business profile, and the rest – including the largest ones – were privatised with the participation of foreign investors.

Figure 7. Steel production in Poland by technology in the years 1974-2022 – structure (left) and nominal values (right).



Source: WiseEuropa based on data of the World Steel Association.

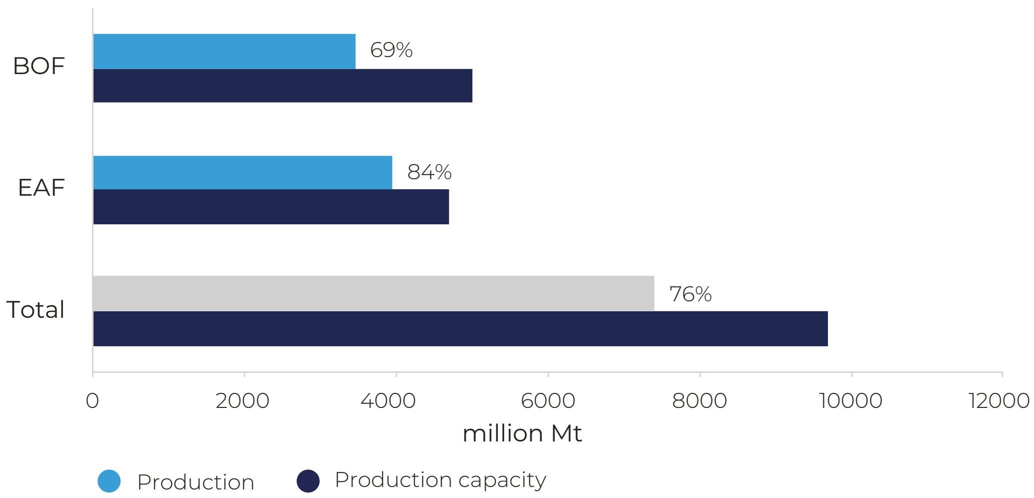
This process completely changed the face of the Polish steel industry, reducing both employment and production volume. Steel production technologies and the dominant production profile have also changed. While in 1989, in Poland there were twenty-six, largely obsolete steel plants with a total capacity of approximately 20 million tons of crude steel, currently there are eight modern plants with production capacities twice as small: Kraków, Dąbrowa Górnicza, Zawiercie, Ruda Śląska, Gliwice, Częstochowa, Ostrowiec, Warsaw. The closure of many smaller plants cased a significant decline in steel production, which dropped from approximately

17 million tons in 1988 to about 10 million tons in 1991-2001, and circa 7 million tons at present. Employment decreased even more: from approximately 130 thousand people in 1989, through about 30 thousand people in 2004 to circa 20 thousand people in 2023.

This means that the closure of unprofitable production capacities and modernisation of functioning steel plants allowed a more than three-fold increase in efficiency, which enabled domestic steel plants to effectively compete with the European steel sector. Unlike the hard coal mining industry, where the production drop and the closure of mines did not result in improved competitiveness, often causing reorganisation programmes and large public subsidies, the steel industry transformed into a sector able to function on commercial terms.

What made it possible where, inter alia, technical changes including a significant increase in the share of efficient secondary smelting in the electric arc furnace in total production (from about 20% in 1990 to more than 50% today).

Figure 8. Use of steelmaking production capacity in Poland, by technology (2022).*



* Production in 2022; production capacity – status as at March 2023.

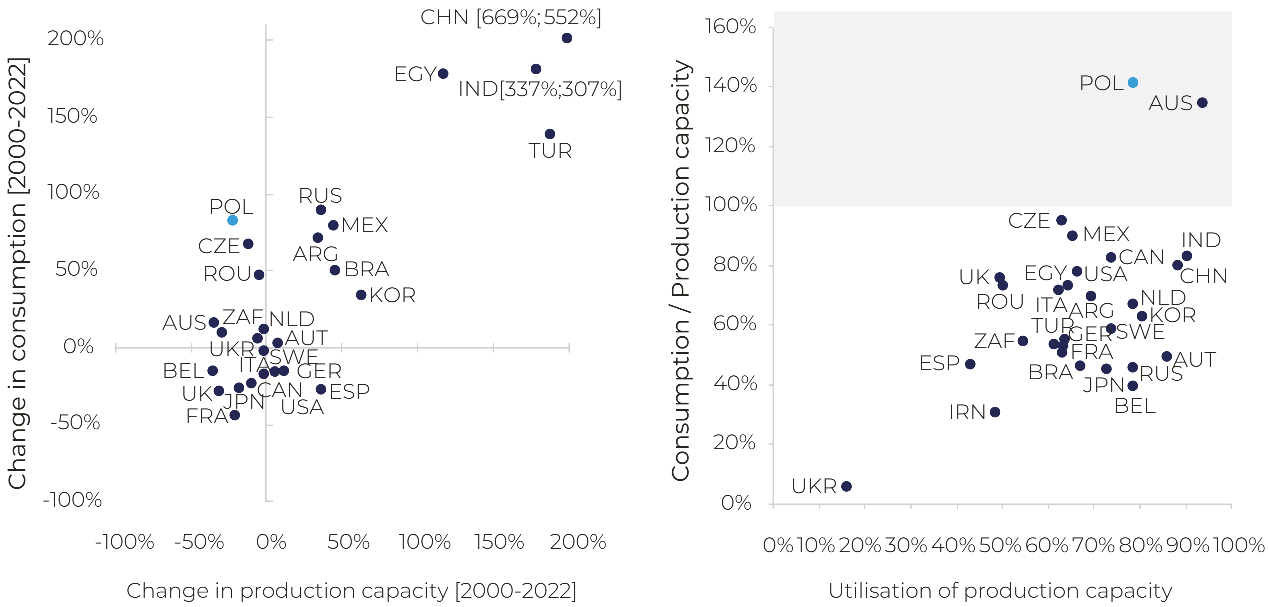
Source: WiseEuropa based on data of the World Steel Association and Global Efficiency Intelligence.

Despite the technological progress and good efficiency indicators, the Polish steel industry faces significant challenges. First of all, for 15 years the demand for steel has been higher than domestic production, and this gap is growing. Taking into account data for 2022, domestic steel production meets slightly more than half of the demand. Preliminary estimates for 2023 indicate that the downward trend continued (-13% y/y) and that the volume of steel produced in the country will shrink to 6.4 million Mt, i.e. to the level from 1960.

The demand and supply gap is so huge that Poland is the tenth largest importer of steel in the world – as well as the fifth largest net importer, i.e. the country importing many times more than it exports. Since 2000, steel consumption in Poland has increased by 82%, while production capacity has decreased by 22%. This is unusual because steel consumption in Poland in nominal terms has been growing continuously for over three decades thanks to the intensive industrialisation of the country, significant infrastructure investments, and a rapid increase in the number of houses and apartments erected.

Therefore, Poland is among a small group of industrialised countries that are unable to meet their own demand for steel with domestic production, even at the level of production capacity, which in 2022 was more than 40% lower than domestic demand. This distinguishes Poland from other economies with high dynamics of demand for steel, where the increase in demand is usually associated with an increase in production capacity and production itself.

Figure 9. Change in demand for steel and production capacity in the years 2000-2022 (left) and demand to production capacity and its utilisation (right).



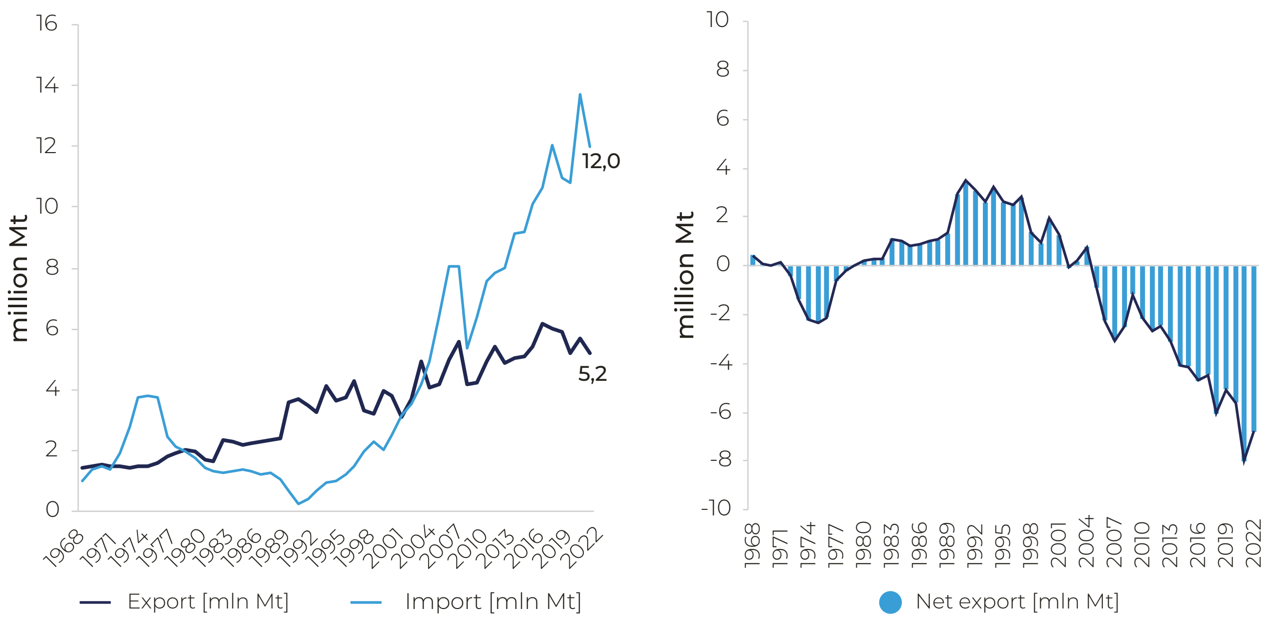
Source: WiseEuropa based on data of the World Steel Association and OECD.

The lack of expansion of production capacity in domestic steel plants after 2000 was probably caused by their surplus in other countries of the European Union.

Steel trade in Poland includes mainly intra-EU flows, i.e. flows from the European Union internal market, where Poland obtains and exports the highest quantities of steel. Main directions of imports are Germany (24%), Italy (9%), Czech Republic, Ukraine and Slovakia (8% each). In 2022, imports from China were only 0.13 million Mt, i.e. less than 1.1% of all steel imports to Poland. The structure of imports is, to a great extent, similar to the structure of exports – the major part of Polish steel is exported to Germany (24%), the Czech Republic (24%), Slovakia (8%), Italy (5%) and Hungary (5%).

This shows the network of connections in the processing industry within the EU, with Polish steel imports focusing mainly on flat products (as much as 60% of the import structure) and long structural elements used in construction and infrastructure (21%). Paradoxically, Polish exports also concern mainly long products (51%) and flat products (31%). Poland records the highest deficit in steel trade in steel plates used in construction or the shipbuilding industry, cold- or hot-rolled sheets, used, inter alia, in the automotive, machinery, agricultural and household appliances industries, as well as in other materials requiring high precision (see: Box 2).

Figure 10. Export and import of steel products in Poland (left) and net export (right).



Source: WiseEuropa based on data of the World Steel Association.

Box 2. Types of steel products traded globally and in Poland

Trade in steel products covers 5 main categories:

1. **Long products** – hot rolled bars, cold rolled or drawn bars, rebars, railway rails, wires, shapes (sections), used mainly in construction and infrastructure for structural purposes, e.g. rebars are used in construction to reinforce concrete; structural profiles, beams, columns, shapes are used for erecting huge structures, such as multi-storey buildings and bridges.
2. **Flat products** – hot and cold rolled coils, coated products, tinplate, plate, hot-dip galvanised products, enamelled and electrical steels (for transformers). They are used mainly in industrial machines and durable consumer goods. They are used, inter alia, for stairs, industrial floors, wall elements, metal roofings, vehicle parts. e.g. chassis or walls of trucks.
3. **Steel pipes and tubes** – they include mainly pipes for boilers, pipes for machinery industry, cylinder pipes, structural tubes, perforated pipes, special-shaped pipes and other. They are used in: pipelines, construction, bridges and cranes, metal and mechanical structures, machines, automotive, water, oil, natural gas and liquid transport.
4. **Semi-finished steel products** – semi-finished steel products are intermediate castings produced in a steel plant that need further processing before being finished goods. Semi-finished steel products are additionally divided into:

- **ingots** – metal cast into rectangular or square shape. Ingots are very large casting products, greater in size and shape than blooms, billets and slabs. Ingot generally has rectangular/square cross section, but it is not necessary that it should be uniform throughout its length;
- **blooms** – they have a rectangular/square cross section exceeding 36 square inches. They are mainly used in the manufacture of "long" products such as structural shapes, structural profiles, building beams, rails and columns;
- **billets** – they result from the second stage of the steel production process. They are hot-rolled or forged from an ingot or strand cast. Smaller and longer than a bloom, billets are usually a square cross section less than 36 square inches. They are also used for the manufacture of "long" steel products such as bars, pipes or wire, but of smaller size;
- **slabs** – they are wide and rectangular in shape. They are used for the manufacture of "flat" steel products such as sheets, coils, strips, plates.

5. **Stainless steel** – products made of stainless steel are popular due to their resistance to corrosion, oxidation and high temperatures. Other characteristics of stainless steel include low maintenance costs and cleanliness.

Table 2. Structure of steel trade by product type – Poland, 2022.

	Mt		% share	
	Import	Eksport	Import	Eksport
Flat products	7 188 645	1 544 406	60%	31%
Long products	2 457 197	2 524 875	21%	51%
Pipe and tube	821 979	485 136	7%	10%
Semi-finished	832 743	186 741	7%	4%
Stainless	635 205	163 250	5%	3%
Total	11 935 768	4 904 409	100%	100%

Source: WiseEuropa based on data of the International Trade Administration.

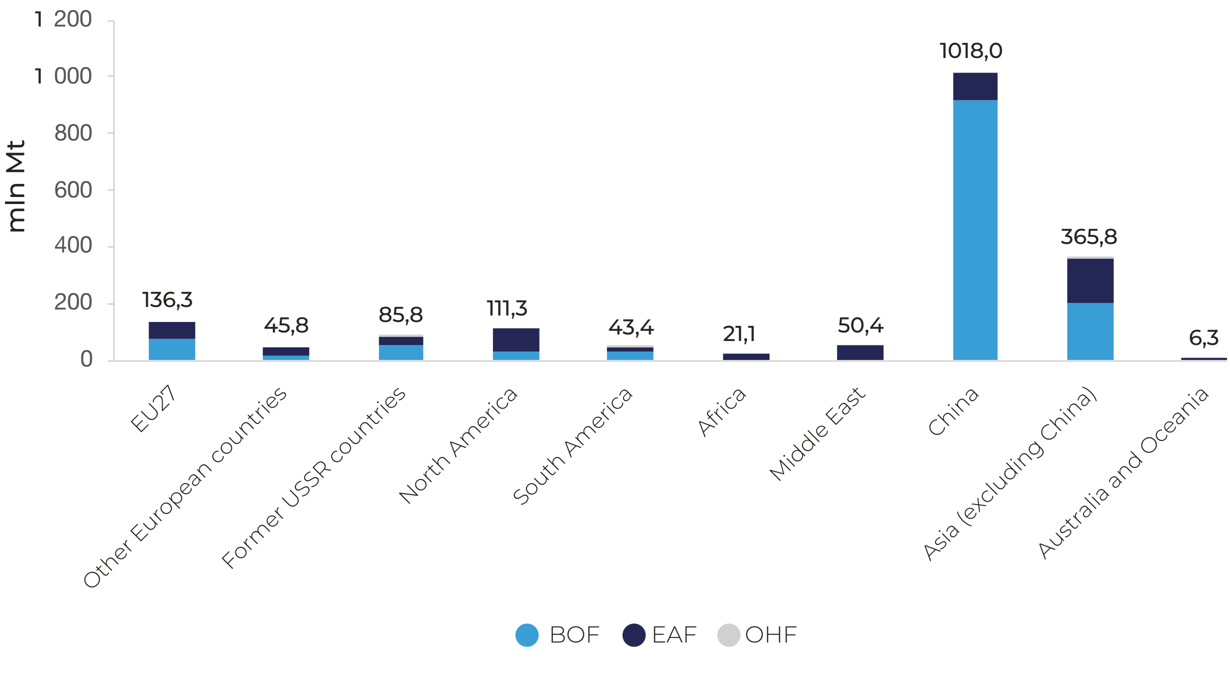
2. CHANGE DIRECTIONS

2.1. Steel production and the environment

The steel industry is responsible for around 2.5% of CO_2 emissions in Poland, 5% – in the European Union and about 7-8% worldwide. To stay on track with climate targets, over the next decades, a significant expansion of the scope of application of low-emission technologies in the sector will be necessary, including the development or creation of new solutions to be used not only in OECD countries, but also in emerging economies. CO_2 emissions and energy use in European steel production have already been halved since 1960, but the sector aims to achieve further cuts of 80-95% by 2050, compared to 1990 levels.

Since the conventional Blast Furnace – Basic Oxygen Furnace (BF-BOF) production route is highly CO_2-intensive, the sector is increasingly focusing on steelmaking based on the Electric Arc Furnace (EAF) and is searching for new solutions to decarbonise the part of production capacity that is still based on the iron ore smelting process. The European Union, including Poland, stands out against the global background, where steel is still produced mainly using the BF-BOF route. The dominance of this technology is especially visible in China (90%), which accounts for more than half of global steel production.

Figure 11. Production technologies by country group (2022).



Source: WiseEuropa based on data of the World Steel Association.

In most European countries – and more general in most OECD countries – the steel production structure is gradually being transformed to electric arc furnace plants. This is due to the fact that the EAF technology is based on steel scrap that is available in significant quantities not before a given economy transforms into a developed one, i.e. its demand for raw materials decreases as adequate infrastructure is available and industrial production is sufficient.

Regular modernisations of machines, industrial equipment and cars take place in 20-30 year cycles, while infrastructure elements are replaced in cycles of 40-60 years. Consequently, the period for steel recovery in the economy exceeds 50 years, so quantities of scrap sufficient for the EAF technology to develop are available only in countries where industrialisation began early enough. Countries, such as India, which import large quantities of scrap even before becoming a developed country, are an exception. But also, in case of these countries, infrastructure and industrial boom should result in a rapid growth of blast furnace technologies sufficient to reduce the relative role of arc furnaces in steel production. By using recycled materials, manufacturers reduce costs of steel production both as a result of using inexpensive raw material and lower energy costs. However, electricity must be cheap enough – for this reason EAF is much more used in EU countries that have low-cost hydropower than in Japan, where cheap electricity surplus is limited.

In this regard, it is worth noting that although all forms of steel are – in general – recyclable, the origin of scrap and the purpose of steel made from scrap also matter in the context of the profitability of the EAF routes.

There are three main sources of steel scrap: 1) home scrap – steel scrap generated within steel plants in the steel production process; it is usually redirected back into the furnace; 2) prompt (industrial) scrap that is a result of product manufacturing in other industries, e.g. automotive, household appliances, machines and devices; 3) obsolete scrap – it covers the rest of steel waste, stemming from areas such as individual household appliances, old cars that are sent to a junkyard, office, and household waste, as well as old junked buildings or structures that are sent to a junkyard and recovered for their steel elements. The chemical composition of steel made from scrap in EAF furnaces may vary, as scrap may contain traces of certain elements (e.g. copper, tin, nickel) that are difficult to remove and may affect the steel properties. The BOF method allows for more precise control over the steel's chemical composition because this process is based on iron ore, allowing controlled addition of carbon, manganese and other elements to obtain the desired steel properties. This is important for some industries, such as aerospace or automotive, as they need materials with a high strength-to-weight ratio and specific resistance to temperature and stress. For this reason, some countries – such as Japan – may prefer BOF technology over electric arc furnaces (EAF).

Table 3. Global steel production and CO2 emission by technology.

	Production		Emission		Emission intensity
	million Mt	%	CO_2 million Mt	%	CO_2 Mt/ steel Mt
Total	1 869	100%	3 170	100%	**1,6961**
EAF	523	28%	209	7%	**0,3996**
BF/BOF	1 346	72%	2 961	93%	**2,1999**

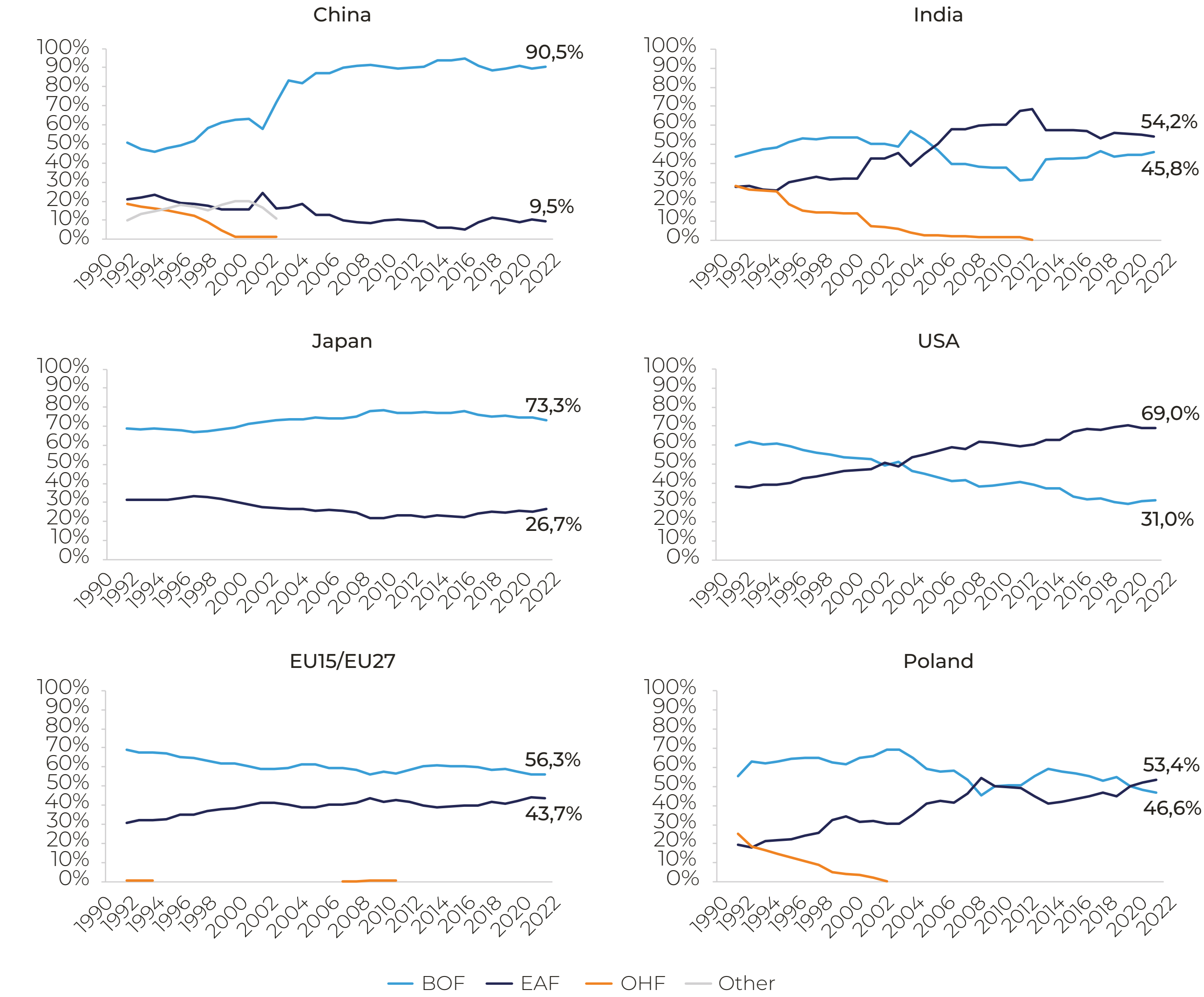
Source: WiseEuropa based on data of the World Steel Association and Global Efficiency Intelligence.

Much lower emission, reaching approximately 0.4 tons of CO_2 per ton of steel produced is an advantage of electric arc furnaces. For the purposes of comparison, the emission rate of the globally dominant BF-BOF technology is six times higher (2.2 tons of CO_2 per ton of steel). Consequently, it is not a surprise that although EAF steel plants make 28% of total steel produced globally, they are responsible for just 7% of CO_2 emission, with some regional differences. In addition to the share of EAF steel in total production, factors affecting the emission intensity of the steel sector also include: 1) fuel mix for power generation used in the steel industry; 2) emission intensity of the electricity sector; 3) type of raw materials used for the BOF and EAF routes; 4) range of steel products manufactured; 5) age of plants; 6) production capacity utilisation; 7) environmental regulations and, thus, penetration of energy-saving technologies in the industry.

At present, the steel industry is at the beginning of technological changes that will offer it a chance to significantly reduce its environmental impact. To achieve the climate objectives agreed under the Paris Agreement, the global steel industry will have to significantly increase production in electric arc furnaces, implement carbon capture and storage (CCS) technologies in converters, as well as search for and develop new technologies, in particular the direct reduction method using hydrogen as a reducing agent (see next section).

Unlike the energy sector, the Polish steel industry compares favourably with the EU27 countries in terms of emission intensity. Poland is responsible for just 2.4% of all emissions from the steel industry in Europe, while its share in production is two times higher (5.4%). This is due to a relatively large share of EAF in the steel industry (53%), placing Poland among the leading European countries that use this route for steel production. At the same time, every year, the nominal capacity utilisation rate of Polish BF-BOF plants is decreasing, which probably reflects their lower competitiveness compared to imported steel. Therefore, the technological future of steel production in Poland is uncertain. On the one hand, EAF steel plants continue to develop, but in terms of volume and production profile they are unable to fully replace steel produced using the BF-BOF route, which results in a deepening imbalance between the steel supply and demand in the domestic market. However, further development of converter technology in Poland is uncertain for regulatory reasons.

Figure 12. Production technologies in selected countries, 1990-2022.

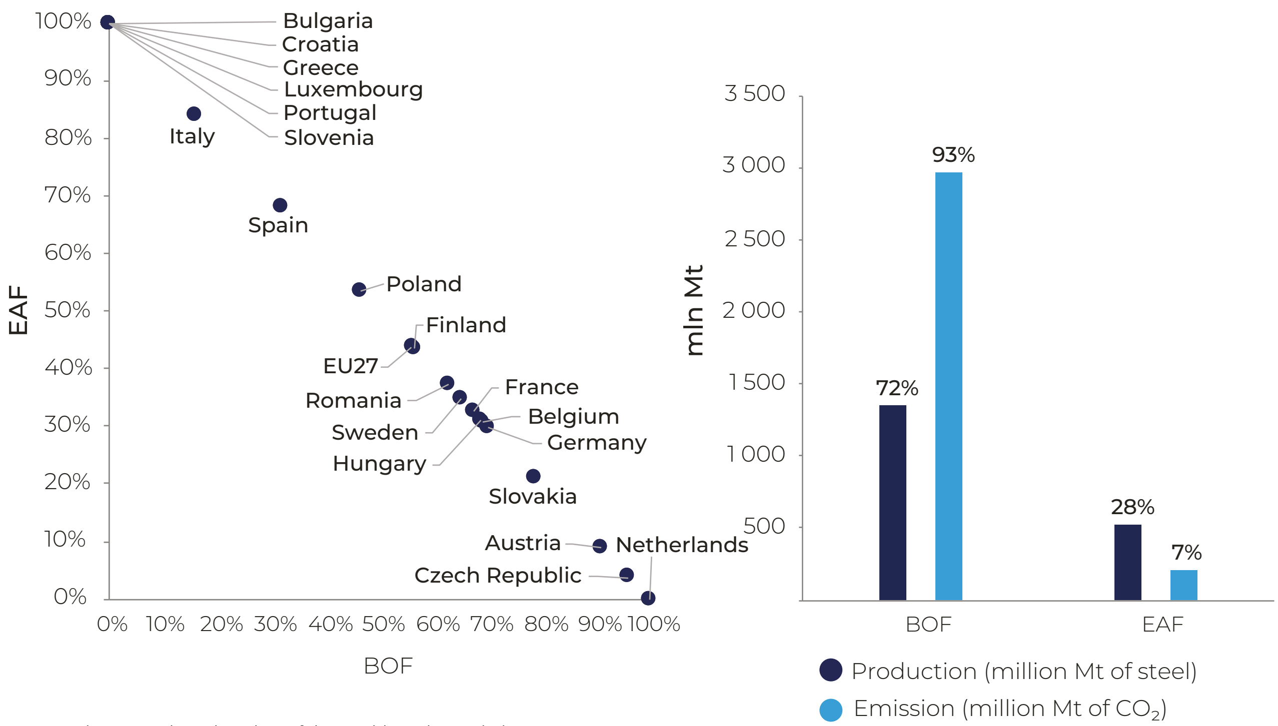


Source: WiseEuropa based on data of the World Steel Association.

The EU-ETS system, which requires manufacturers to buy CO_2 emission allowances if their production involves such emissions, is the main instrument for decarbonisation of the steel sector in countries of the European Union. Until now, Polish steel plants have enjoyed considerable protection against financial consequences of this system, as they benefited from the allocation of free carbon dioxide emission allowances.

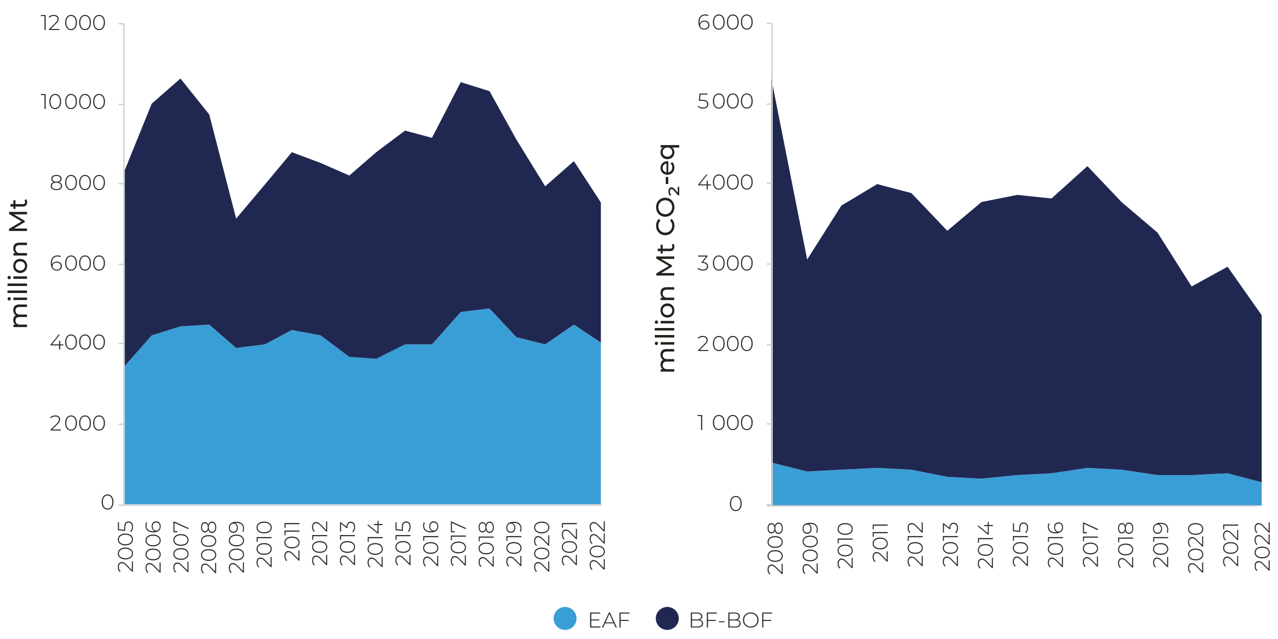
As a result, in the years 2005-2020, the Polish steel industry received support corresponding to emissions of almost 80 million tons of CO_2, which was more than enough to cover the actual emissions during this period, amounting to approximately 50 million tons of CO_2. The difference, close to 300 million tons of CO_2, was in fact a subsidy for the Polish steel sector that could generate additional profits by selling emission allowances to other industries in case of which no derogation could be used or was insufficient (e.g. energy sector). However, starting in 2026 and by 2034, free emission allowances for steel production in the European Union will be gradually phased out, which will increase costs for existing producers, especially these relying on the most emission-intensive production technology, promoting investments in low-carbon technologies.

Figure 13. Technology share in steel production in EU27 countries (right) and global steel production and CO2 emissions by technology (left).



Source: WiseEuropa based on data of the World Steel Association.

Figure 14. Production (left) and emissions (right) in the steel sector in Poland.



Source: WiseEuropa based on data of Statistic Poland and EU ETS.

Steel production technologies part 3

Basic Oxygen Furnace (BOF)

Essence: In the BOF process, a stream of pure oxygen is used to remove impurities from molten iron by oxidation. It is a fast and effective process, allowing producing large quantities of high purity steel.

Differences: BOF uses mainly molten iron obtained from the blast furnace steelmaking process. BOF is not as flexible as EAF taking into account the production of various types of steel. It is especially important for countries in the process of industrialisation.

Description: Fast and effective process of removing carbon and other impurities using oxygen. In the process, an oxygen converter is used, where a stream of pure oxygen allows removing impurities from molten iron by oxidation. It is very important in the production of electrical and stainless steel. It prevails in the modern steel industry.

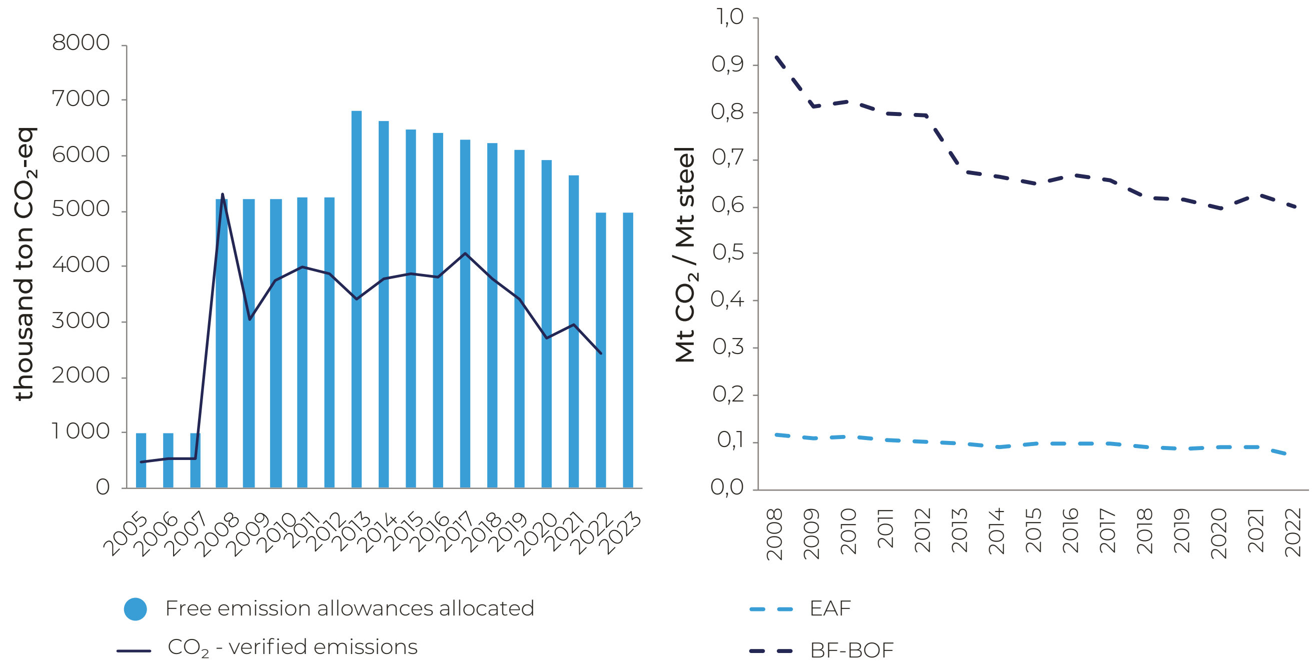
Future: In the 21st century, the key challenge for the BOF technology is the need to reduce the CO_2 emitted in producing steel from iron ore. To this end, steel plants need to be equipped with carbon capture and storage (CCS) systems or solutions for direct reduction of iron using green hydrogen (DRI – H2) must be integrated into the steel production lines.

Advantages	Disadvantages
• Uses oxygen to remove impurities from molten iron • Fast and effective process of removing carbon and other impurities • Can be used to make high purity steel	• Requires large amount of energy and raw materials • Produces a lot of gaseous waste products, which requires appropriate environmental monitoring

CBAM (Carbon Border Adjustment Mechanism), a carbon border tax, is intended to provide protection against a possible deterioration of price competitiveness of steel production in the EU27 after free emission allowances are phased out. Importers of goods covered by the tax will be required to purchase CBAM certificates in the amount corresponding to emissions released in the production process of a given product. Consequently, this mechanism is the tool to put a fair price on the carbon emitted during the production of goods that are entering the EU. It is to protect internal producers while encouraging cleaner production in non-EU countries. The scope of regulation covers some high-emission products: cement, electricity, artificial fertilizers, cast iron and steel, aluminium, and their derivative products.

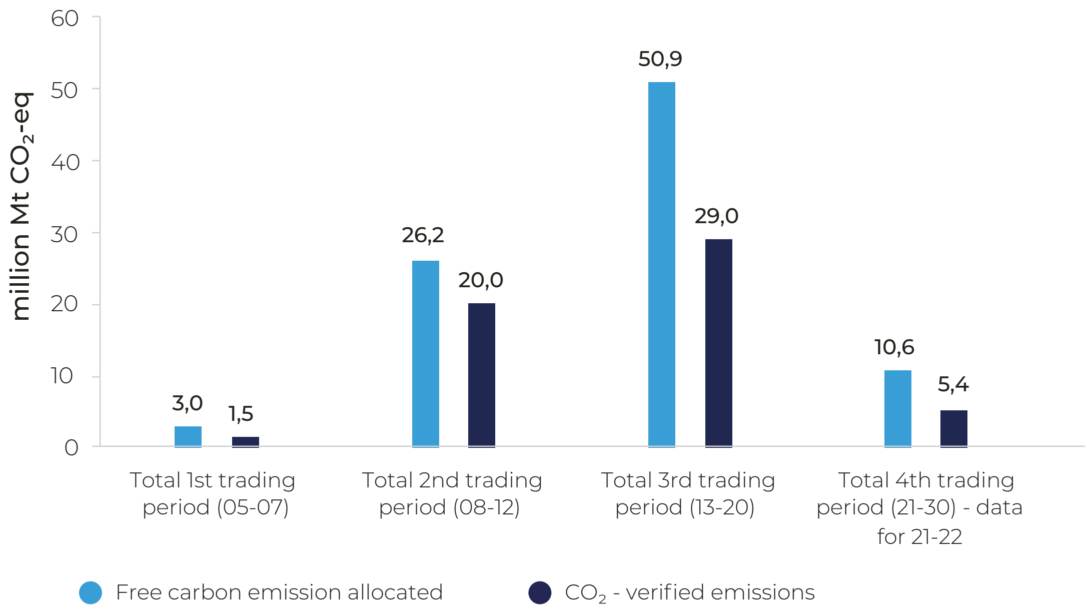
The aim of CBAM is to align carbon emission costs of goods imported with goods produced in the EU, thus supporting decarbonisation of the industry and increasing interest in low-carbon steel production – as in the case of EU-ETS that is to favour low-emission manufacturers.

Figure 15. Carbon emission allowances allocated to the steel sector in Poland and their utilisation (left) and emission intensity in Poland by technology (right).



Source: WiseEuropa based on data of Statistic Poland and EU ETS.

Figure 16. Carbon emission allowances allocated to the steel sector in Poland by period.



Source: WiseEuropa based on data of EU ETS.

2.2. Technology options for environmentally friendly steel production

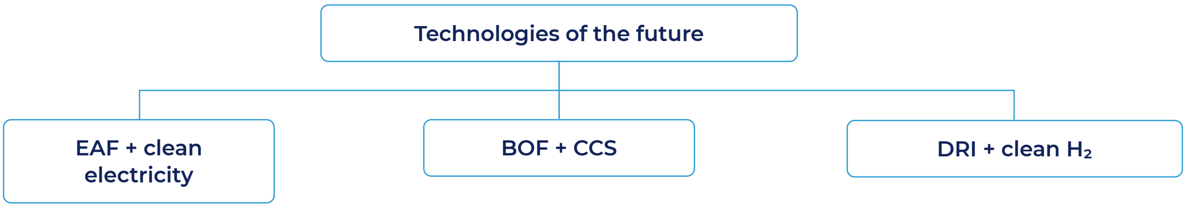
The steel industry is responsible for around 7-8% of CO_2 emissions globally – more than any other heavy industry. It is estimated that in order to comply with climate targets, the sector must reduce emissions by 75%, from the current 3,000 million Mt CO_2 to 780 million Mt CO_2 in 2050. Furthermore, this will have to happen while increasing production as the global demand for steel is growing. In OECD countries, including the EU, this pressure on growth will be much less than in developing countries.

In the short term, carbon emission reductions can be achieved, inter alia, by improving energy and material efficiency.

Energy efficiency includes activities related to increasing the electrification of the steelmaking process, while using electricity from renewable sources, and reducing coal consumption, which – at a global level – currently meets almost 75% of the energy demand of the sector – while electricity accounts for less than 10%. With these proportions, low-carbon electrification is one of the lowest-hanging fruits in the sector decarbonisation in a net-zero scenario. The IEA estimates suggest an increase in electricity consumption in the steel sector by about 5 percentage points every year until 2030, to unlock the fast-track to decarbonisation.

At the same time, material efficiency involves increasing steel and steel product manufacturing yields, introduction of light-weighting structures, extending building and infrastructure lifetimes and promotion of direct reuse of steel (without melting). However, the technical potential for material efficiency improvements is limited, and does not exceed a few or a dozen or so percent of the sector's total emissions.

To achieve long-term climate objectives, the implementation of technologies with significant reduction potential will be necessary, in particular: (1) further increase in production through the electric arc furnace (EAF) route with the possibility of broader use of iron ore in addition to scrap in this process; (2) adding CCS facilities to the BF-BOF process to significantly reduce carbon emissions; (3) development of the direct reduction process for producing steel using hydrogen as a reducing agent (DRI+H2 technology).



Electric Arc Furnace (EAF) using scrap and iron ore – secondary steel production in an electric arc furnace, where raw materials – mainly steel scrap – are melted by an electric arc, dates back to the 1920s. This process is much less emission-intensive than the BOF process, however, it requires large amounts of electricity and a significant supply of scrap that is not available in sufficient quantities everywhere. For this reason, there is growing interest in the use of direct reduced iron/sponge iron as an additive to scrap in electric furnaces, which, to some extent, will require reduction in an electric arc furnace, although within the scope less than in case of processes based on iron ore. Consequently, the use of hydrogen as a reducing agent in arc furnaces is being researched. For this process to be environmentally sustainable, hydrogen also needs to be obtained from zero-emission – renewable or nuclear – sources. In order for the entire production chain to contribute to a deep reduction in greenhouse gas emissions, electric arc furnaces should also have access to zero-emission electricity.

Basic Oxygen Furnace with the CCS technology (BOF + CCS) – primary steel production using a blast furnace and an oxygen converter is even older than electric furnaces, as it dates back to the 19th century. However, the carbon capture and storage technology – CCS – can be integrated into the modern BOF route. Although this technology does not eliminate CO_2 emissions in the technological process, it has significant reduction potential by capturing it at the source and preventing emissions into the atmosphere by injecting captured CO_2 into underground geological formations for permanent storage. Pilot plant results show that this technology allows to reduce CO_2 emissions from the BOF process into the atmosphere by 60% to even 98%, with the average in the range of 70-80%. It also creates potential economies of scale, as the same elements of CCS infrastructure (e.g. pipelines, injection stations) can be used by other industries, e.g. chemicals or cement. At the same time, many other industries use CO_2 as a raw material for their products, such as fuels, chemicals and construction materials. Consequently, some of the captured carbon dioxide from the steel production process could be used, and some of it stored in appropriate locations.

Direct Reduced Iron + Hydrogen (DRI+H2) – production of primary steel by direct reduction of iron using hydrogen as a reducing agent. The entire process begins with the preparation of iron ore, which can be supplied from various sources. The ore is crushed and processed to obtain appropriate particle sizes and remove unwanted substances. Then it is placed in furnaces where it undergoes a chemical reduction process: the oxygen contained in the ore reacts with a reducing agent, which may be natural gas, hydrogen or synthesis gas. As a result of this reaction, so-called reduced iron is obtained, which is then separated from the remaining ingredients, and the resulting product (pig iron) is used, for example, to melt steel in electric arc furnaces.

Unlike EAF and BOF with CCS facilities, DRI+H2 technology is a relatively new solution, which, however, uses ideas taken from existing solutions based on natural gas. The use of hydrogen as a reducing agent is especially important in the context of the net-zero scenario, because it would enable a significant reduction in emissions in the steel sector also in steel plants using iron ore as the basic raw material – however, on the condition that hydrogen is obtained from zero-emission sources.

Table 4. **Trends followed by global steel producers in relation to environmentally friendly steel production.**

Enterprise		Country	Activity
	Baowu	Chiny	Two largest steel companies in the world are testing both the CCS and hydrogen routes.
	ArcelorMittal	Luksemburg	
	ThyssenKrupp	Niemcy	Hydrogen-based steelmaking projects have been already started, and the enterprises plan to fully convert their fleets to hydrogen-based production. They are developing new equipment to accommodate lower-grade iron ore in hydrogen-based steelmaking.
	Posco	Korea Południowa	
	Tata Steel IJmuiden	Indie	
	SSAB	Szwecja	The leader in hydrogen-based steelmaking plans to primarily rely on purer forms of iron such as recycled steel.
	Nippon Steel	Japonia	They aim to reduce emissions by applying CCS to existing coal-based blast furnaces but have recently started to investigate hydrogen too.
	JFE	Japonia	
	US Steel	Stany Zjednoczone	Pilots are scheduled to be rolled out for both CCS and hydrogen on the back of increased policy support in the US for both hydrogen and CCS.
	Vulcan Green Steel	Oman	They plan to build hydrogen-based steel plants from scratch.

Source: WiseEuropa.

Investments in the steel industry needed to deploy low-CO_2 steel plants will need to go hand in hand with investments in the infrastructure required to enable these solutions. At the national level, they will include primarily the development of low-emission energy sector, both in terms of generation (renewable energy sources and/or nuclear energy) and transmission (transmission and distribution networks, transformers, storage infrastructure).

Hydrogen needed to develop the DRI+H2 technology in Poland would have to be produced locally, using low-emission energy sources, or obtained from specialised domestic or foreign producers, which would also require the construction of the necessary infrastructure to support transmission, as well as domestic and international trade. At the same time, in case of CCS as a technology complementary to the BF-BOF route, the necessary investments outside the steel industry would primarily include storage infrastructure and networks for injecting captured CO^2 to these storage facilities, as well as for transporting it to other end-use industrial uses of carbon dioxide.

At present, 123 projects and investments of iron and steel plants have been announced that will be based on or partially use direct reduction of iron (DRI) technology, of which 22 such projects have been announced in the European Union. Recommendations of the IEA on the support for the steel sector in decarbonisation call for a further increase in expenditure on zero-emission primary steel production and deployment of technologies at commercial scale before 2030. However, awareness of the need for decarbonisation in and around the steel sector may not be sufficient to achieve the objectives agreed under the Paris Agreement within the expected time. Therefore, in addition to the European Union, many other countries are implementing various policies encouraging the industry to quickly decarbonise, in particular, to ensure electrification of the steelmaking process. China, which produces 90% of its steel using the blast furnace route, plans to expand its ETS to cover heavy industry emissions, increase the use of steel scrap and reduce emissions of the sector by 2030. India, the second largest steel producer in the world, is focusing on the use of scrap to reduce CO_2 emissions in the steel industry and further development of EAF, which already accounts for 54% of production there. The country is also one of the world leaders in new projects based on DRI technology.

Table 5. Projects related to primary steel production based on the DRI technology in Europe.

#	Country	Plant name	Owner	Partner	Nominal iron capacity (thousand tonnes per annum)	Nominal crude steel capacity (thousand tonnes per annum)	Primary steelmaking process (integrated, electric, or oxygen)	Primary steel production equipment
1	Belgium	ArcelorMittal Gent steel plant transition (DRI-EAF addition)	ArcelorMittal SA	ArcelorMittal SA [100%]	2500	2500	Integrated (DRI)	DRI, EAF
2	Finland	Blastr Inkoo steel plant	Blastr Green Steel AS	Blastr Green Steel AS [100%]	> 0	2500	Integrated (DRI)	DRI, EAF
3	France	ArcelorMittal Dunkerque steel plant transition (DRI and EAF addition)	Arcelormittal Atlantique et Lorraine SASU	ArcelorMittal SA [100%]	2500	4500	Integrated (DRI)	DRI, EAF
4	Germany	ArcelorMittal Hamburg steel plant	ArcelorMittal Hamburg GmbH	ArcelorMittal SA [100%]	600	1100	Integrated (DRI)	DRI, EAF
5	Germany	ArcelorMittal Hamburg steel plant (DRI addition phase I)	ArcelorMittal Hamburg GmbH	ArcelorMittal SA [100%]	100	N/A	Ironmaking (DRI)	DRI
6	Germany	ArcelorMittal Hamburg steel plant (DRI addition phase II)	ArcelorMittal Hamburg GmbH	ArcelorMittal SA [100%]	600	N/A	Ironmaking (DRI)	DRI
7	Germany	ArcelorMittal Bremen steel plant transition (DRI-EAF addition)	ArcelorMittal Bremen GmbH	ArcelorMittal SA [100%]	2000	1750	Integrated (DRI)	DRI, EAF
8	Germany	Salzgitter Flachstahl steel plant transition (DRI-EAF addition)	Salzgitter Flachstahl GmbH	Salzgitter AG [100%]	2100	1900	Integrated (DRI)	DRI, EAF
9	Germany	ArcelorMittal Eisenhüttenstadt steel plant transition (DRI-EAF addition)	ArcelorMittal Eisenhuettenstadt GmbH	ArcelorMittal SA [100%]	> 0	1750	Integrated (DRI)	DRI, EAF
10	Germany	ThyssenKrupp Steel Duisburg steel plant transition (DRI-EAF addition)	Thyssenkrupp Steel Europe AG	Thyssenkrupp AG [100%]	2500	> 0	Integrated (DRI)	DRI, EAF
11	Germany	Hüttenwerke Krupp Mannesmann (HKM) steel plant transition (DRI addition phase I)	Huettenwerke Krupp Mannesmann GmbH	Thyssenkrupp AG [50%]; Salzgitter AG [30%]; Vallourec SA [20%]	> 0	3000	Integrated (DRI)	DRI, EAF
12	Germany	Hüttenwerke Krupp Mannesmann (HKM) steel plant transition (DRI addition phase II)	Huettenwerke Krupp Mannesmann GmbH	Thyssenkrupp AG [50%]; Salzgitter AG [30%]; Vallourec SA [20%]	> 0	3000	Integrated (DRI)	DRI, EAF
13	Germany	AG der Dillinger Hüttenwerke Dillingen steel plant transition (DRI-EAF addition)	Aktien Gesellschaft der Dillinger Huettenwerke Societe Anonyme des Forges et Acieries de Dilling	SHS Stahl Holding Saar GmbH & Co KgaA [57.2%]; ArcelorMittal SA [33.4%]; Saarstahl AG [9.4%]	2500	1750	Integrated (DRI)	DRI, EAF
14	Italy	DRI d'Italia Taranto plant	DRI d'Italia Spa	Invitalia Attivita Produttive SpA [100%]	2000	N/A	Ironmaking (DRI)	DRI
15	Netherlands	Tata Steel IJmuiden steel plant transition (HIsarna addition)	Tata Steel Ijmuiden BV	Tata Steel Ltd [100%]	3155	N/A	Integrated (DRI)	DRI, EAF
16	Netherlands	Tata Steel IJmuiden steel plant transition (DRI/EAF addition)	Tata Steel Ijmuiden BV	Tata Steel Ltd [100%]	3155	7500	Integrated (DRI)	DRI, EAF
17	Romania	GFG Liberty Galati steel plant transition (DRI and EAF addition)	Liberty Galati SA	Gfg Alliance Ltd [100%]	2500	1100	Integrated (DRI)	DRI, EAF
18	Spain	ArcelorMittal Asturias (Gijón) steel plant DRI and EAF expansion	Arcelormittal Espana SA	ArcelorMittal SA [100%]	2300	1100	Integrated (DRI)	DRI, EAF
19	Sweden	H2 Green Steel Boden steel plant	H2 Green Steel AB	H2 Green Steel AB [100%]	2100	2500	Integrated (DRI)	DRI, EAF
20	Sweden	H2 Green Steel Boden steel plant expansion	H2 Green Steel AB	H2 Green Steel AB [100%]	2100	2500	Integrated (DRI)	DRI, EAF
21	Sweden	HYBRIT Gallivare sponge iron plant	HYBRIT Development AB	SSAB AB [33.3%]; Luossavaara Kiirunavaara AB [33.3%]; Vattenfall AB [33.3%]	1300	N/A	Integrated (DRI)	DRI
22	Sweden	HYBRIT Gallivare sponge iron plant EAF expansion	HYBRIT Development AB	SSAB AB [33.3%]; Luossavaara Kiirunavaara AB [33.3%]; Vattenfall AB [33.3%]	N/A	2700	Integrated (DRI)	DRI, EAF

Source: Global Energy Monitor.

3. VISION OF THE FUTURE OF THE POLISH STEEL SECTOR

3.1. Green transformation challenges facing the steel sector in Poland

The expected technology shift in the Polish steel industry, which is to occur by 2050, will require significant financial outlays, while bringing significant economic, employment and social consequences. Among the technologies currently used, secondary steel melting in electric arc furnaces has the lowest emission intensity. Its share in Poland is higher than the European average and – as can be assumed in connection with the announced investments – it will also increase in the next decade, especially since Poland is also a net exporter of scrap, i.e. main raw material used in the EAF process. If the domestic production using this route is increased, value added generated in the whole steel value chain in Poland would be higher. This trend should be supported by the decarbonisation of the energy industry, where a significant increase in expenditure on renewable energy sources is planned and an increase in its share in electricity production from the current 30% to approximately 60%.

The key challenge will still be to reconcile decarbonisation with the imbalance between demand for steel and its domestic production. EAF technology alone will probably not be enough to meet the reduction assumptions implied by the European Green Deal and close a significant part of the gap in steel trade with other countries. For this to happen, it will be necessary to decarbonise the steel industry while expanding production capacity based on low-emission technologies. The main option for decarbonisation of existing BOF facilities in Poland will probably be CCS technologies (Capture, Utilisation, and Storage of Carbon Dioxide), in which the cement industry is already investing in the country, and the development of which in terms of infrastructure has been announced in government strategies. Their continuation is particularly important for social reasons (local labour market), especially since the currently operating steel plants are located in coal regions (Upper Silesia, Małopolska) that will be simultaneously affected by the transformation of the mining sector itself and the transformation of coal-based energy.

The implementation of CCS in Poland would allow not only to maintain production in existing blast furnaces, but also to build new plants with much lower emission rates. Due to the gradual reduction in coal production in the country, it cannot be ruled out that such new plants could be built in the north of Poland (coast) to shorten the distance of transport of captured carbon dioxide and coal itself as a reducing agent.

An alternative path may be the development of DRI-H2 technology. Its advance in the country will probably require support for pilot installations. There are currently 123 DRI projects in the world, of which 22 in Europe (mainly in Germany and the Scandinavian countries). The announcement of such a project in Poland in the coming years would give a clear signal that the Polish steel industry entered the path of green steel production. However, this will require the development of green hydrogen infrastructure, which may again favour locations closer to the coast.

3.2. Positive scenario – green transformation success

The potential benefits of a successful green transformation in Poland including the decarbonisation of existing production capacities and the development of new ones based on low-emission technologies are significant.

- **The development of the steel sector through the expansion of low-carbon production capacity** will contribute to reducing dependence on steel imports, not only improving the steel product trade balance, but also increasing the strategic security of the country. It is especially important taking into account serious disruptions in the flow of goods due to growing international tensions.
- **Decarbonisation of the Polish steel sector is an opportunity to increase the international competitiveness of the sector,** taking into account market advantages resulting from low-carbon production in the future (demand for green steel in construction and industry). Poland may become more competitive in international markets, because green steel is more and more popular, and consumers increasingly appreciate products with a low carbon footprint.
- **Outlays on the green transformation of the steel industry,** including on the infrastructure, will benefit not only the steel sector but also other industries. The green transformation of the sector will support the development of, inter alia: energy sector (renewable energy, nuclear energy), transmission networks and pipelines, construction and industry (green steel), as well as decarbonisation of other high-emission industries using the same infrastructure (e.g. cement industry).
- **Investments in low-emission technologies are associated with positive macroeconomic multipliers**, so they increase production and employment growth not only in the steel industry, but also in the entire value chain and the broader economy. This applies to outlays both in the steel industry and in the related infrastructure, e.g. for the transmission of hydrogen or carbon capture, transmission and storage.
- **Successful green transformation of the steel industry will improve the image of Poland** as a country that cares about the environment and adapts to changes and challenges. This will facilitate attracting investors and support the development of other economic sectors based on green technologies.

Table 6. Scenarios of the transformation of the steel sector in Poland.

	Positive scenario	Negative scenario
Development of the steel sector	→ Expansion of the production capacity using low-carbon technologies → Production increase → Improved strategic security of the country	→ No investments in green technologies and sector modernisation → Insufficient production despite growing needs → Increase of strategic risk (e.g. as a result of disturbances in global steel markets)
Trade	→ Steel import reduction → Improvement of the trade balance	→ Increasing dependence on imports → Increasing steel trade deficit
Competitiveness	→ Development of low-carbon technologies -> increase of competitiveness of the steel sector → Possibility to compete in international markets due to green steel production	→ No investments in green technologies and sector modernisation → Loss of clients to competitors from the countries more advanced in decarbonisation
Impact on other sectors	→ Benefits for other sectors due to infrastructure investments (energy sector, construction, industry)	→ Slowing down the decarbonisation of other sectors of the economy → Loss of opportunity to develop new branches based on green technologies
Macroeconomic effects	→ Increased production and employment growth → Positive macroeconomic multipliers	→ Economic development slowdown → Lower macroeconomic multipliers
Image of the country	→ Improvement of the image of Poland as a country that cares about the environment and adapts to changes	→ Deterioration of the image of the country as not adapted to market requirements and decarbonisation

Source: WiseEuropa.

Steel production technologies part 4

Electric Arc Furnace (EAF)

Essence: EAF uses an electric arc to melt raw materials including scrap. The use of electricity for heating in this process allows for controlled production of various types of steel. It is excellent for the production of special-purpose steel and alloys.

Differences: EAF is more energy-efficient than traditional furnaces because heating is controlled based on electricity with relatively low losses. EAF is more suitable for recycling of materials, which makes it appropriate for economies that have a long history of industrialisation.

Description: An energy-efficient process allowing rapid steel production by melting of raw materials using electricity. It allows for fast recycling of scrap, providing flexibility in the production of various types of steel. It is very effective for the production of special-purpose steel and alloys. The obvious advantage of the EAF technology is the use of steel scrap as the main raw material, as a result of which this process is more suitable for the recycling of materials. Recycling technologies include the processes of steel scrap sorting, teeming, cleaning and alloying to obtain high-quality raw material for steel production, which allows using this raw material and makes the entire process more economically efficient. Steel recycling is more environmentally friendly and energy-efficient than the production of steel from iron ore, as it requires much less energy and generates fewer greenhouse gas emissions.

Future: These technologies have a lot of potential in the global steel industry, which will undergo the gradual electrification transformation. This applies especially to OECD countries, including Poland, where the supply of scrap is sufficient to cover a large part of the demand for steel from industry and construction. At the same time, in the future, the EAF technology may rely to a greater extent not only on steel scrap but also on iron ore, provided that it is integrated with DRI-H2 furnaces.

Advantages	Disadvantages
• Very flexible and fast, allows the production of various types of steel • Energy efficient compared to some traditional processes • Very appropriate for steel scrap (recycling)	• Requires large amount of electricity (preferably cheap) • Requires large amount of steel scrap • Noise and light emission during the process

3.3. Negative scenario – green transformation failure

The alternative scenario is the failure of the green transformation of the steel sector in Poland in the years 2030-2050, which may have various negative consequences not only for the sector but also for the entire Polish economy, including:

- **Failure to meet growing needs and increase in strategic risk** – together with the projections of the growing demand for steel in Poland, it is necessary to ensure steel supplies for the purposes of, inter alia, infrastructure investments, housing construction and orders from industry. Lack of actions to expand the low-emission industrial base of the Polish steel industry will increase the already high dependence on imports, deepen the negative trade deficit in steel products and worsen the strategic situation of the Polish economy, which will be much more exposed to the negative consequences of disruptions on global steel markets.
- **Deterioration of the competitiveness of the steel industry and loss of jobs** – lack of investments in green technologies and modernisation of the steel sector will result in lower competitiveness in international markets. Tightening emission regulations in the European Union will hinder the export of steel from Poland to other EU countries. At the same time, domestic producers will lose customers to companies from other countries that will adapt to low-emission technologies faster. This is because due to the carbon footprint standards in these sectors, the demand from industry and construction will gradually shift towards green steel.
- **Slower development of other sectors and lower multipliers** – lagging activities in the steel sector may indirectly contribute to slowing down the decarbonisation of other sectors of the economy due to shortages of green steel in the domestic market. Poland may also lose the opportunity to develop new branches based on green technologies.
- **Development slowdown** – insufficient investments will hamper not only the development of the steel sector but also other industries, negatively affecting the demand for electricity and hindering the transformation of industries related to the steel sector, e.g. cement or chemicals. The lack of modern, low-emission steel industry will impede the development of companies in the steel sector value chain. In particular, regions, where existing production capacities will be liquidated, may take a hard hit.
- **Deterioration of the image** – Delaying changes means time losses, as a result of which the Polish industry will be perceived as not adapted to market requirements. This could negatively impact the country's international reputation and deter investors from many industries, taking into account decarbonisation trends in most advanced economies around the world.

4. CONCLUSIONS

The steel industry has been a source of fundamental raw material for the development of the global economy since the beginning of the Industrial Revolution in the 18th century. In all countries that entered the path of industrialisation in the past, both the demand for steel and its production increased significantly. In recent decades, we can notice a steel boom in the countries of East and South Asia, but also in Central Europe, where the economic growth brought about by the collapse of the communist system after an initial decline was associated with a significant increase in demand for steel products. This also applies to Poland, where demand for steel has tripled over the last thirty years. The trend is expected to continue in the coming years due to planned infrastructure investments, further development of residential construction and demand from the industrial processing sector. However, as a result of the restructuring of obsolete steel plants in the 1990s, Poland is currently a net importer of steel, and the demand for this raw material is twice as high as its domestic production, and exceeds its production capacity.

Consequently, the future of the Polish steel industry depends on investments that both increase its production capacity and enable carbon-free production of steel. This is because sustainable development of the steel sector requires a combination of traditional production methods with modern low-emission solutions. Increasing steel production while reducing greenhouse gas emissions will be facilitated by the cooperation of various industrial sectors (energy, metallurgy, cement, chemicals, etc.) and the support of an appropriate industrial policy that takes into account economic and environmental requirements and thus supports not only innovations but also the development of modern production capacity.

In case of Poland, the easiest way to low-emission transformation of the steel sector is to invest in electric arc furnaces. The EAF route allows steel to be produced with lower CO_2 emissions compared to traditional production methods. Poland is able to produce a few dozen percent more steel through this route, using the existing resources of steel scrap as the main raw material, of which it is currently a net exporter.

However, for the primary steel production, the decarbonization of existing blast furnaces and construction of new ones using low-emission technology will be vital. In the first case, the carbon capture and storage (CCS) technology may be a key. In the second case, to achieve a sustainable steel sector, it will be important to develop direct reduction of iron (DRI) technology using hydrogen as a reducing agent, which will make the entire process much less emission-intensive.

Spis wykresów

WiseEuropa Foundation

WiseEuropa is an independent think-tank specialising in macroeconomics, as well as economic, European and foreign politics.

WiseEuropa's mission is to improve the quality of national and European politics and the economic environment by basing them on sound economic and institutional analysis, independent research and assessment of the political impact on the economy. The Institute engages citizens, entrepreneurs, experts and public policy makers from Poland and abroad in a joint reflection on the modernisation of Poland and Europe and their role in the world. WiseEuropa's goal is to work for an active and committed role for Poland in the open, sustainable, democratic development of Europe. WiseEuropa's core activities focus on stimulating and inspiring public debate on the future of Poland and Europe.

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On 20 March 2024, at the Polish Climate Congress, the WiseEuropa Foundation was awarded the title of Energy Transition Leader 2024. The competition jury included representatives of the Polish Climate Congress, the Polish National Energy Conservation Agency and the National Centre for Research and Development.

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