

4.5. GREEN STEEL

4.5.1. Current situation and the sector role

Ferrous metallurgy (including iron ore mining and processing, ironmaking, steelmaking and steel rolling) is a fundamental sector of the economy in Ukraine.

From year to year, it creates a significant economic impact. **In 2020 its aggregate share in GDP accounted for 9.5%, or EUR 12.4 billion** (including GDP generated by iron and steel companies themselves, supply chain and consumer spending of workers). The metallurgy sector and related industries employed 530 thousand people in Ukraine in 2020. Taxes paid by iron and steel companies amounted to EUR 3.1 billion in 2021.

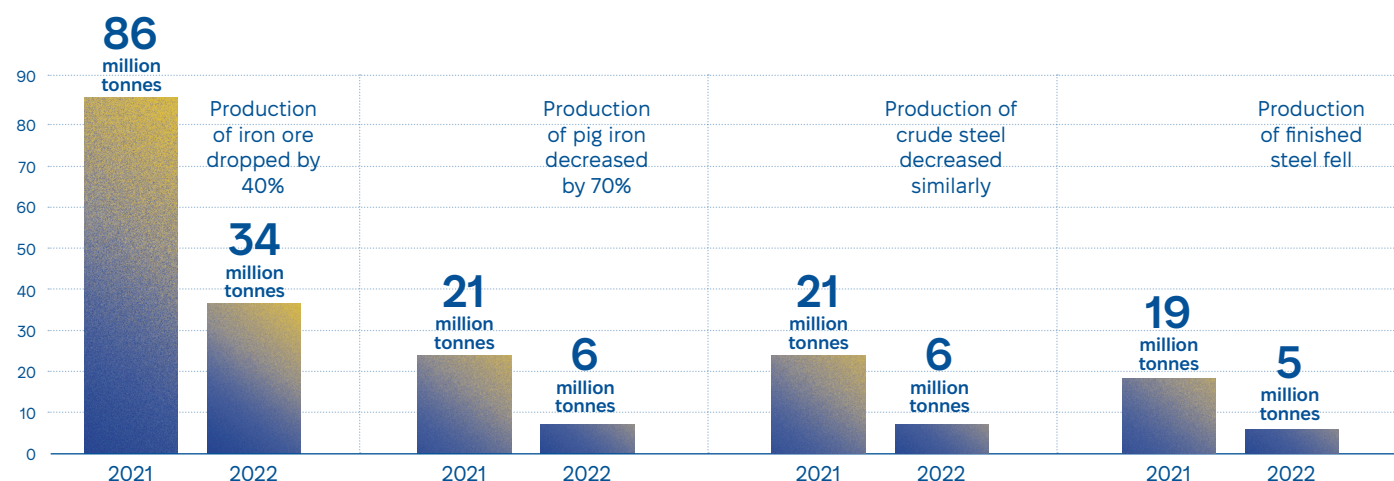
Pre-war, one-third of Ukraine's exports was generated by the metallurgy sector: in 2021 Ukrainian iron and steel companies received EUR 20.1 billion of export revenues. Iron and steel companies are also the largest consumers in other sectors. In 2021, iron and steel companies accounted for 119.4 million tonnes of railway traffic (38% of the total volume) and 57.4 million tonnes (37.4%) of cargoes handled at Ukrainian seaports. Iron and steel companies were responsible for 18.7% of total electricity

consumption and 6% of natural gas consumption in Ukraine in 2021.

The metallurgy sector also contributes to development of high-value-added industries, namely by consuming around 9% of machinery output in Ukraine. At the same time, the sector is one of the largest CO₂ emitters (15% of Ukraine's greenhouse gas emissions in 2020) and polluters (SO_x, NO_x, hard particles), largely due to reliance on coke and coal in blast furnace ironmaking, generally outdated equipment and lack of incentives and large capital requirements for environment-related investments.

Ukraine's metallurgy sector has a significant impact not only within the country but also globally. **As of 2021, Ukraine was 5th largest exporter of iron ore, 4th largest exporter of iron ore pellets, 3rd largest exporter of pig iron and slabs.** Ukraine was also the 6th largest exporter of finished steel to the EU. Such reliance on exports is largely explained by Ukraine's relatively shallow local market for steel: steel consumption prewar was a mere 4 to 5 million tonnes per year, and it roughly halved during the war.

Figure 1: The impact of war on the metallurgy sector of Ukraine in 2022



In the first 9 months of 2023, the situation has not significantly improved, with production of pig iron, crude steel and finished steel amounting to 81-83% of 2022 values for the same period.

AVAILABILITY AND COST OF FINANCING AMID SIGNIFICANT CAPITAL REQUIREMENTS.

This has been significantly exacerbated by the war: first, increased country risks made foreign investments and access to capital markets unavailable, and financing costs prohibitively high; second, companies of the

sector faced significant cash flow constraints due to lower production, low domestic consumption, inability to export and/or high logistics and other costs.

Significant and ongoing decrease in iron ore, iron and steel production is attributable to multiple factors caused by war:

- Logistics limitations resulting in significant increase in logistics costs for exporters.
- Lower prices and demand for iron and steel products due to decrease in production in Europe and globally;
- Disruptions of energy supply following mass missile and drone strikes by Russia.
- Occupation of and damages to iron and steel assets.

Approximately half of Ukraine's total ironmaking and steelmaking capacities and approximately 5% of iron ore mining capacities are located in territories occupied by Russia since February 2022;

- Additionally, the sector also faces the following significant challenges: - Availability and cost of financing amid significant capital requirements

4.5.2. Prospects and potential for the sector

Demand for green steel

Steel production globally is responsible for 7% to 9% of the total greenhouse gas emissions, so unsurprisingly this is one of the sectors where push for decarbonization is the strongest. There are three key drivers for decarbonization of steel sector:

- Regulations. Rising CO2 emission prices, spread of emission trading schemes, and regulation like the EU's Carbon Border Adjustment Mechanism (CBAM) and the Paris Climate Agreement increase pressure to cut emissions. At the same time, green stimulus programs like the European Green Deal and government support facilitate decarbonization
- Increasing investor sustainability focus. Investors show growing consideration of CO2 emission footprint in financing decisions and cost of financing

(e.g., BlackRock climate push, green bonds)

- Changing customer requirements. Steel customers have increasing awareness of environmental impact (e.g. Daimler aiming to be 100% carbon-neutral by 2039, and many other steel-consuming companies have made commitments to cut their scope 3 emissions)

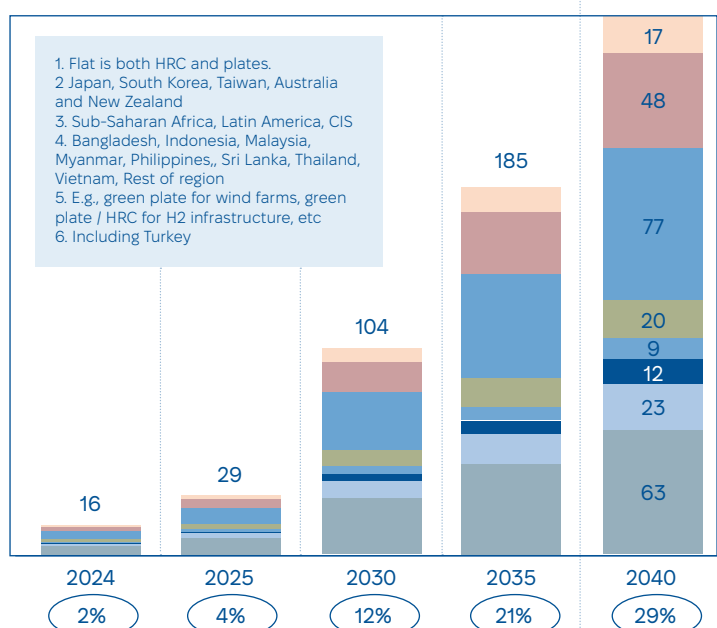
The European Union is at the forefront of steel decarbonization, with EU-wide 55% emission reduction targets by 2030 and rising ETS CO2 prices in combination with melting free emission allowances (roughly halving by 2030 and zeroing by 2034) put steel players under pressure to decarbonize over the next decade.

In the first 9 months of 2023, the situation has not significantly improved, with production of pig iron, crude steel and finished steel amounting to 81-83% of 2022 values for the same period.

Figure 2: Global low-CO2 flat steel demand¹, million tonnes

2023 Q4 Further Acceleration Scenario

○ % low-CO2 demand out of total flat steel demand

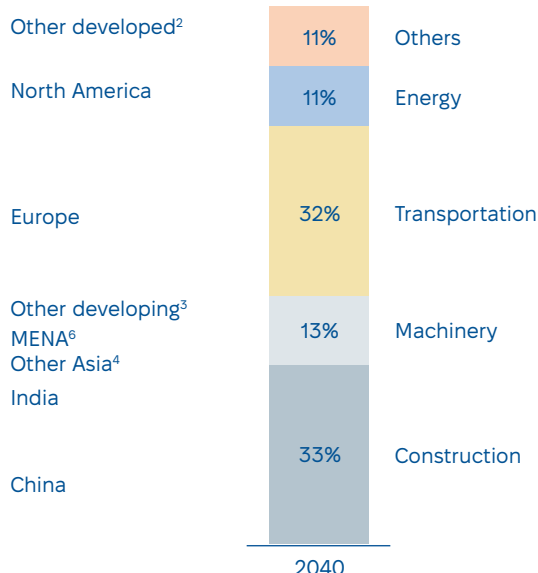


Regional

270-290

Industrial segment

270-290

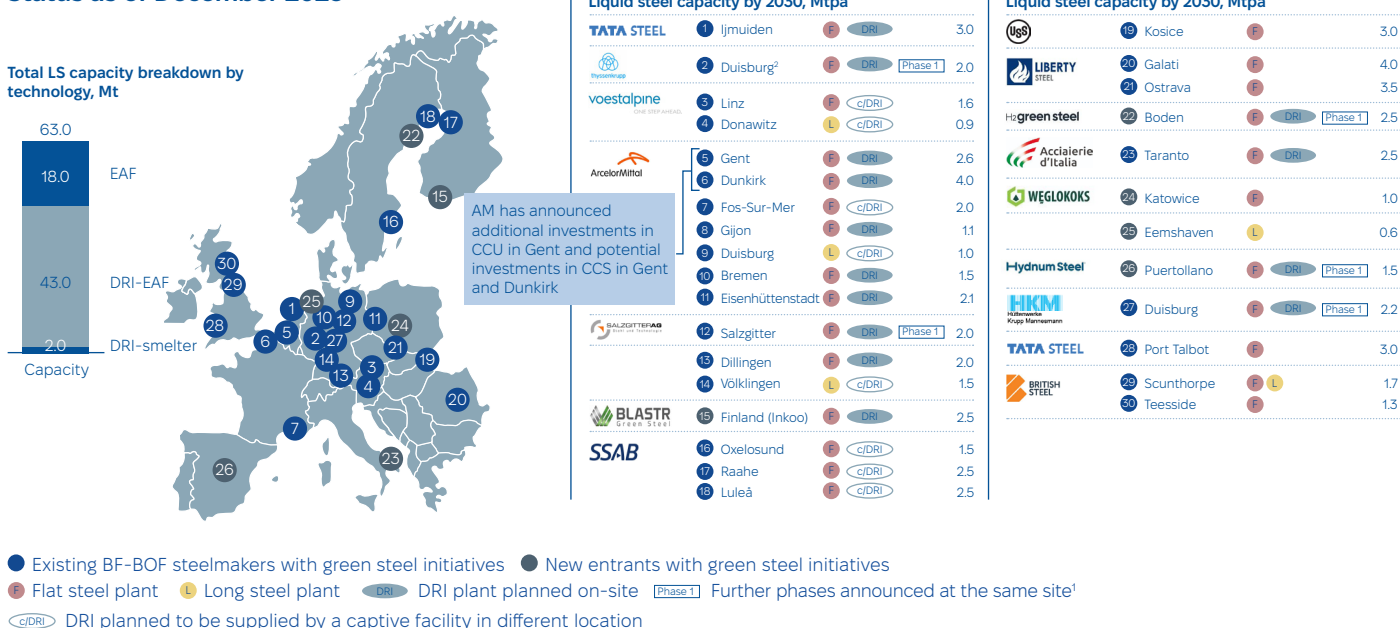


GREEN STEEL SUPPLY

- ON THE GREEN STEEL SUPPLY SIDE, ~30 NEW PROJECTS WERE ANNOUNCED IN EUROPE, WITH TOTAL PRODUCTION CAPACITY OF >60 MILLION TONNES PER YEAR.

Figure 3: Announced green steel projects in Europe

Status as of December 2023



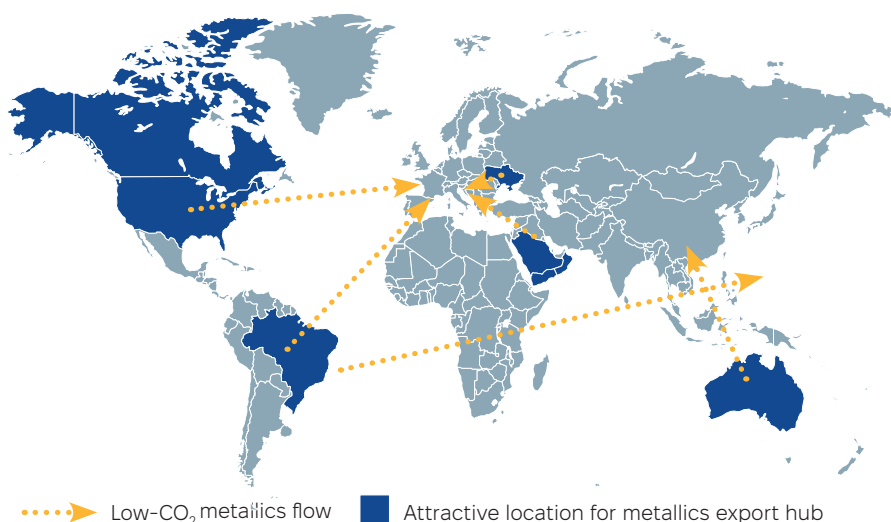
An extensive green capacity build-out in Europe countries would be challenging due to multiple factors, including:

1 Lack of DR-quality¹ iron ore. As most of the projects assume a shift from hot metal production in the blast furnace to direct reduction of iron in shaft DR-module, they will require higher quality iron ore (DR-grade pellets) which is already in short supply globally and is expected to be in even higher deficit as the geological resources and mining of iron ores suitable for direct reduction is limited.

2 High cost and potential lack of supply of clean energy. The population density and growing concerns about land use have made it more challenging to find adequate areas for onshore wind and solar power. Siting issues may arise, especially as turbines get bigger, which could lead to stronger local opposition ("not in my backyard"). Long lead times for permitting and the complexity of the grid are also hindering the build-out of renewable energy and increasing its cost.

Considering the combined impact of these factors, Europe might become a net importer of green iron (likely in the form of HBI) and/or green steel. Admittedly, imports of green HBI may be more desirable for Europe (compared to green steel imports) as it will allow to keep the majority of green steel production, where European players has strong capabilities, end-customer base and sizable employment. Europe could source a significant part of its green metallurgy demand from a limited number of countries with high-quality iron ore resources and cost-competitive clean energy. Such potential "green HBI hubs" include Brazil, Canada, US, Australia, Gulf states (with imported iron ore) and Ukraine.

Figure 4: Potential HBI export hubs



¹DR-quality / DR-grade - Higher quality pellets (higher grade, lower carbon) for produced DRI / HBI

Ukraine's potential as a green HBI supplier to Europe

Ferrous metallurgy (including iron ore mining and processing, ironmaking, steelmaking, and steel rolling) is a fundamental sector of the economy in Ukraine. In 2020 its aggregate share in GDP accounted for 9.5%, or USD 13.7 billion (including GDP generated by iron and steel companies themselves, supply chain, and consumer spending of workers). Metallurgy sector and related industries employed 530 thousand people in Ukraine in 2020. Taxes paid by iron and steel companies amounted to USD 3.5 billion in 2021.

Pre-war, one-third of Ukraine's exports was generated by the metallurgy sector: in 2021 Ukrainian iron and steel companies received

USD 22.2 billion
of export revenues

UKRAINIAN IRON ORE MINING AND PROCESSING IS DIVIDED BETWEEN A HANDFUL OF MAJOR PLAYERS, INCLUDING (IN ALPHABETICAL ORDER):

- **ArcelorMittal Kryvyi Rih:** ArcelorMittal subsidiary operates an iron ore mine in Europe, located near the city of Kryvyi Rih. It supplies iron ore to its steelmaking operations as well as to external customers.
- **Black Iron:** Canadian iron ore exploration and development company, advancing its 100% owned Shymanivske project located in Kryviy Rih.
- **DCH Sukha Balka:** DCH Sukha Balka is a subsidiary of the investment company DCH. The company's main mining and steel assets are located in the Dnipropetrovsk region, and it produces high-quality iron ore.
- **Ferrexpo:** one of the largest producers and exporters of iron ore pellets in Ukraine. Ferrexpo's raw material base includes 9 iron ore deposits with estimated resources of 19.7 billion tonnes. The company operates several mines in the Poltava region, including the Poltava, Yeristovo, and Belanovo mines. Ferrexpo is the world's third largest exporter of iron ore pellets.
- **Metinvest:** in addition to its steel production operations, Metinvest also has significant iron ore mining assets. The company's mining division includes several iron ore mines in Ukraine, such as the Ingulets Mining and Processing Plant, Northern Mining and Processing Plant, and Central Mining and Processing Plant. The company also owns a share of Southern Mining and Processing Plant.

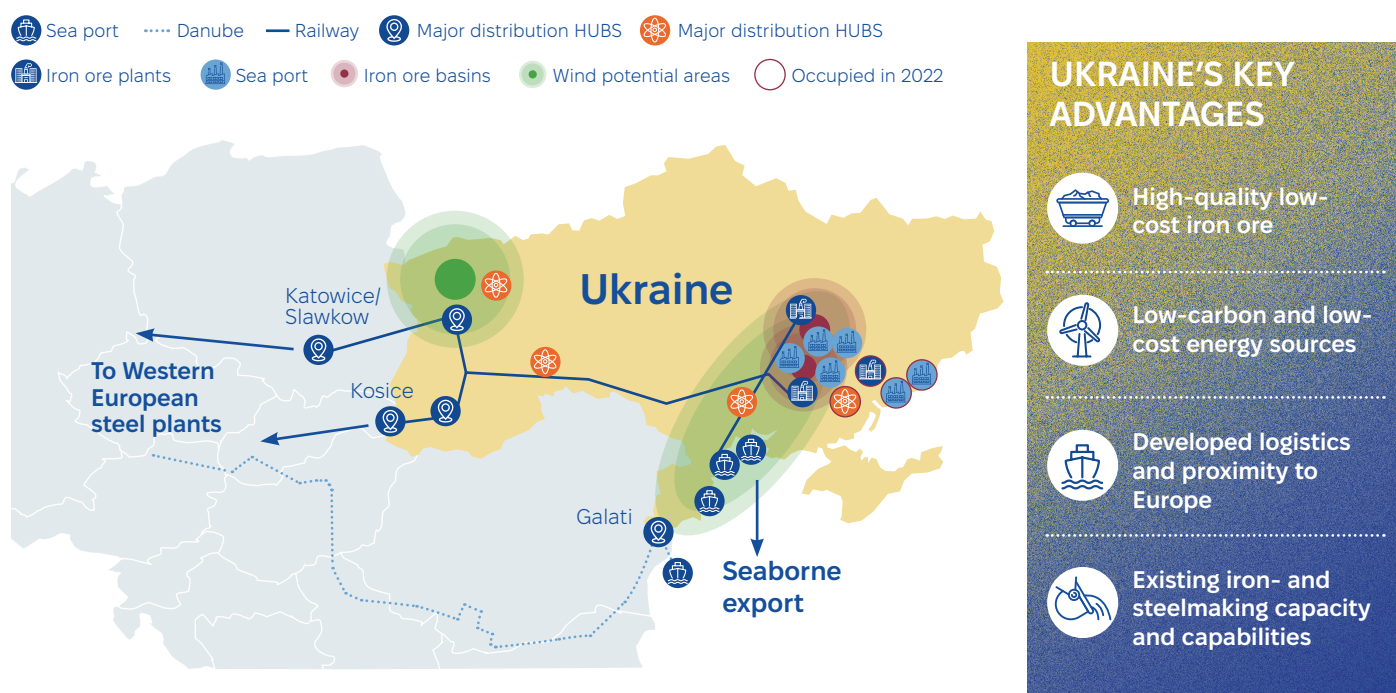
SOME OF THE PROMINENT COMPANIES IN THE UKRAINIAN IRON AND STEEL SECTOR INCLUDE (IN ALPHABETICAL ORDER):

- **ArcelorMittal Kryvyi Rih:** a subsidiary of the global steel giant ArcelorMittal, operating in Kryvyi Rih. It is one of the largest steel producers in the country and a major player in the international steel market.
- **Dnipro Metallurgical Plant (DMZ):** DMZ is one of the leading steel producers in Ukraine, specializing in long steel products such as bars, wire rods, and sections.
- **Interpipe:** Ukrainian industrial company that specializes in the production of seamless and welded pipes and railway products. Interpipe is among the world's top 10 largest exporters of seamless pipes. The company is also the world's third-largest producer of forged railway wheels.
- **Metinvest:** Metinvest is one of the largest Ukrainian vertically integrated mining and steel companies. A significant part of Metinvest's steelmaking capacity in Ukraine was damaged or occupied during the war (Azovstal Iron and Steel Works, Ilyich Iron and Steel Works).
- **The war had a significant impact on Ukraine's iron and steel capacity.** Currently, only 5 of Ukraine's 13 available blast furnaces are in operation, as well as two electric arc furnaces at Dnepropetsstal and Interpipe Steel. According to the Deputy Minister of Economy, currently, 90% of the country's iron ore assets are located in controlled territories, Ukraine also controls about 50% of steel smelting capacities. The steel sector of the country suffers not only from the destruction of enterprises in the east but also from the narrowing of logistics routes. Due to the war, Ukrainian steelmakers reduced production of pig iron and steel by 70-85%.

Capital investment in the industry has also decreased due to the war. The dynamic of capital investments in the largest metallurgical companies of the mining and metallurgical complex of Ukraine was as follows:

- **Metinvest invested USD 354 million in 2022 (-72.3% compared to 2021).** Metinvest Group has been recognized as one of the largest investors in Ukraine in 2022-2023, ranking second in the Ukrainian edition of Forbes' 20+5 largest investors in the country. The company's top investment projects in 2023 included the launch of new longwalls at Pokrovsk Coal Group enterprises, modernization and repair of chambers at Kametstal and Zaporizhstal, as well as energy projects. In 2024, the planned capital investment is about USD 319 million.
- **Ferrexpo invested USD 161 million in 2022 (-55.4% compared to 2021).** In 2023, the company's capital investment amounted to USD 101 million, including sustaining and optimisation projects.
- **ArcelorMittal invested USD 112.8 million in 2022 (-63.6% compared to 2021).** In 2023 the company invested USD 130 million, and announced plans to increase this amount by 20% to USD 155 million in 2024.
- **Interpipe invested USD 21 million in 2022 (-66.7% compared to 2021).** Interpipe's capital investments in the first 9 months of 2023 amounted to USD 17.57 million, up 16.9% compared to 2022.

Figure 5: Ukraine is well-positioned to become a key supplier of green HBI to Europe



This position is based on many competitive advantages, including:

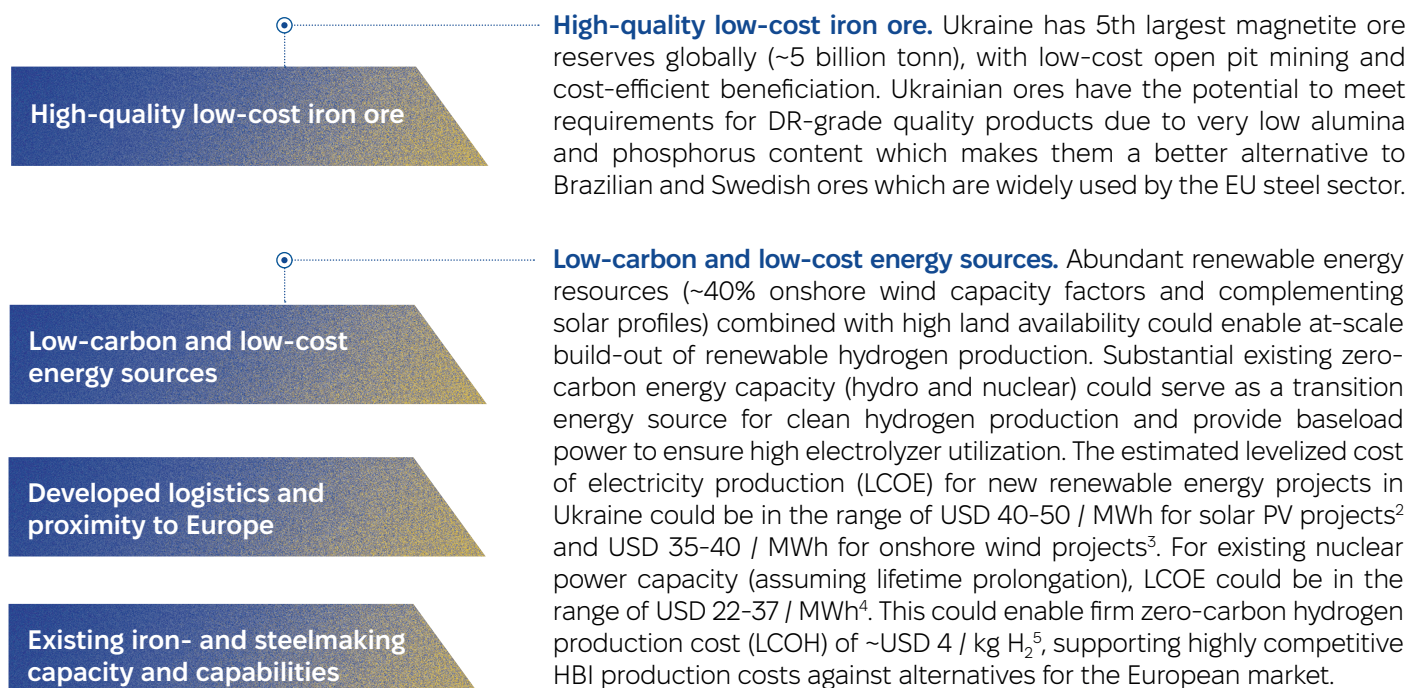
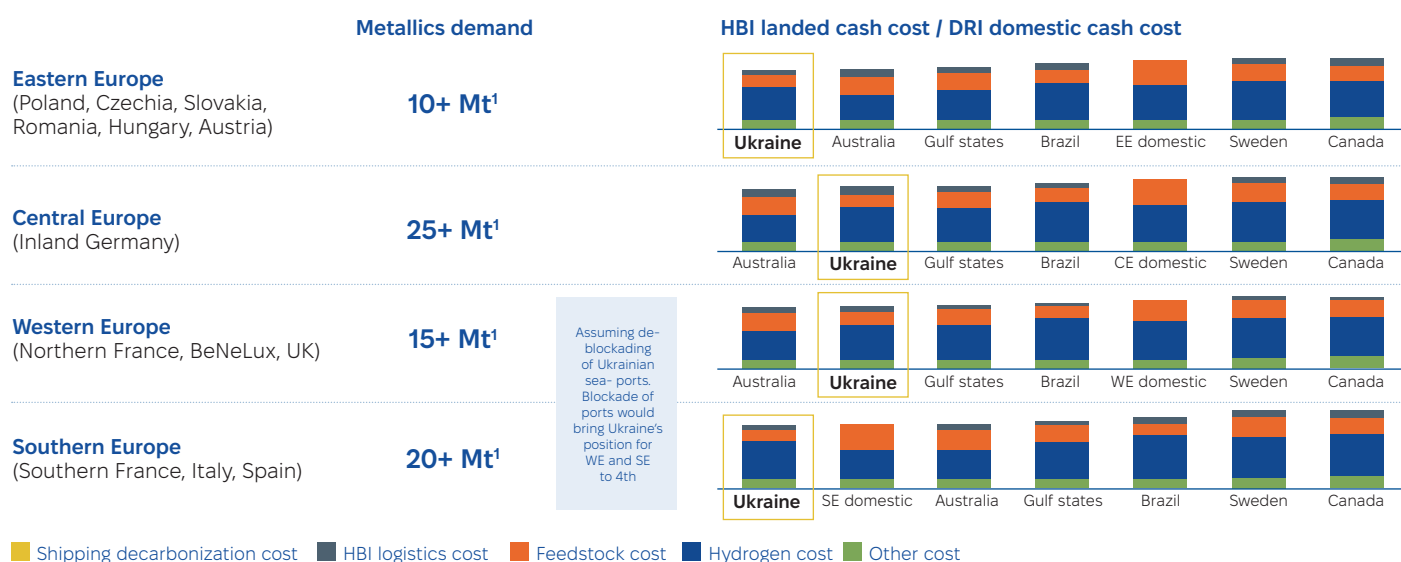


Figure 6: Comparison of landed cost of HBI from Ukraine and competitive locations

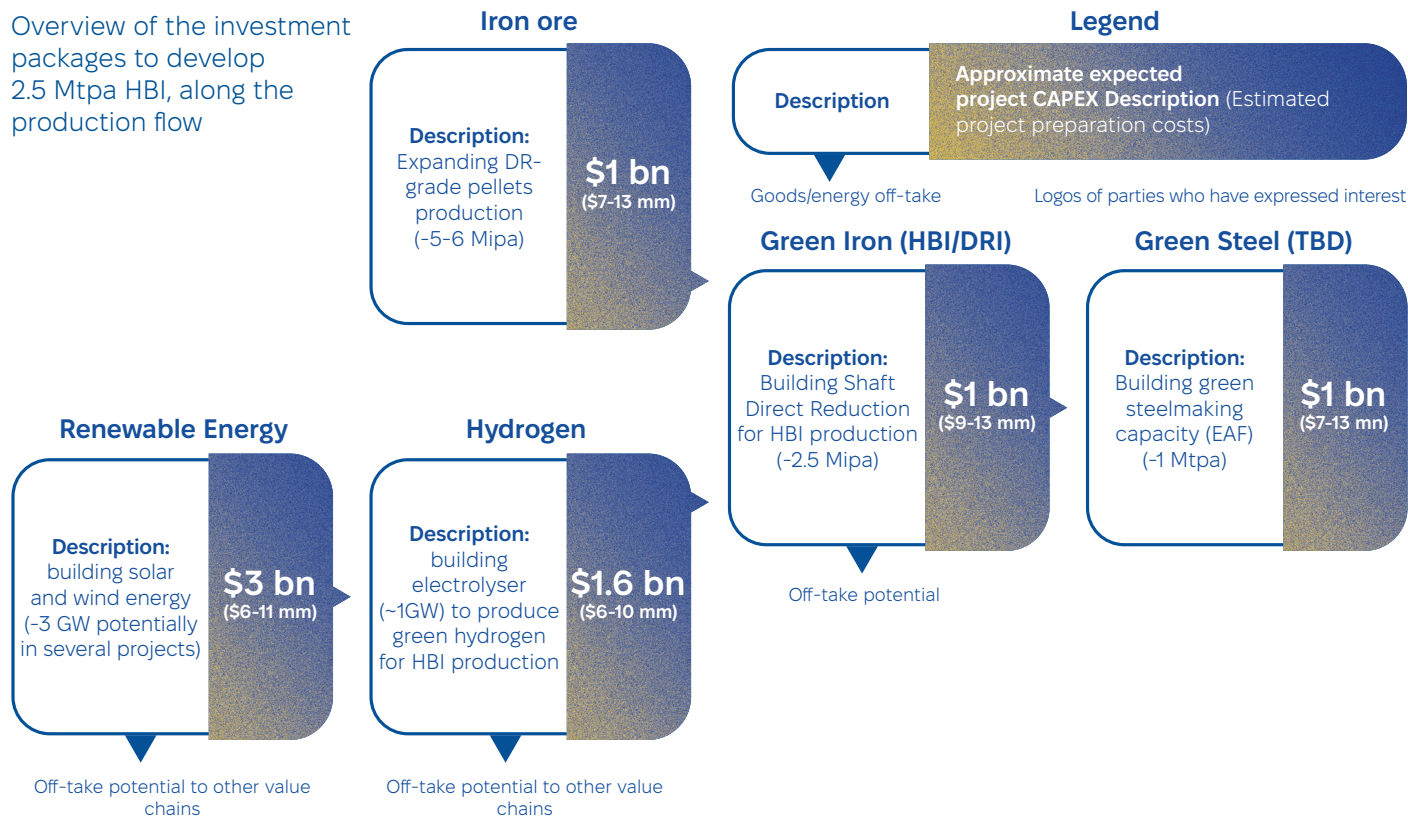


1. Expected metallics demand in 2030 based on current pig iron consumption, reduced by net scrap export. Key assumptions: hydrogen use 56 kg / + DRI /HBI, yield 1.45 t pellets to 1 t DRI/HBI, shipping decarbonization cost is +20-40% of maritime transportation costs. Including labour, electricity and O&M costs
 2. Including labour, electricity and O&M costs
 3. LCOH based on 1300 USD / kW Electrolyzer CapEx, hybrid onshore wind + solar PV energy, including firming costs for HBI production

OPPORTUNITY OVERVIEW

Ukraine's favourable positioning as well as the ongoing momentum in the market present an attractive opportunity for investment into build-out of the entire green iron and steel value chain in the country. Following is the illustration of how potential investment projects and the value chain could look like.

Figure 7: Illustrative green iron and steel value chain in Ukraine



²Assuming 1-axis tracking, 19-21% capacity factor, CapEx of ~USD 0.6 k / kW, OpEx of ~2% of CapEx per year, WACC of 8%

³Assuming Vestas 136 4000 turbines at 120 m hub height, 35-42% capacity factor, CapEx of ~USD 1.3 k / kW, OpEx of ~1.3% of CapEx per year, WACC of 8%

⁴Assuming 85% capacity utilisation, CapEx required to prolong block lifetime of ~USD 0.3 k / kW, variable OpEx of USD 17 / MWh electricity, decommissioning cost of USD 350-1,100 / kW, WACC of 5-10%

⁵Assuming large Alkaline electrolyzer technology, 55-63% onshore wind and 37-45% solar PV in the energy mix, 2.1-2.7 renewable energy to electrolyzer capacity oversizing, 68-76% capacity utilization, CapEx of ~USD 1.3 k / kW, OpEx of ~3% of CapEx per year, WACC of 8%

Key opportunities would include:

- **Build-out of greenfield mining capacities.** Ukraine has potential to further increase high-quality iron ore production. Additional volume (especially if combined with beneficiation and pelletizing capacities) could allow to expand production of DR-grade iron ore pellets, which are expected to become an increasingly important commodity in low-carbon iron and steel value chains, including in the EU.
- **Build-out of iron ore advanced beneficiation capacities (greenfield and / or brownfield).** As mentioned before, Ukrainian ores have very low alumina and phosphorus, while silica content remains the most challenging. To decrease silica content in Ukrainian pellets, advanced beneficiation capacities need to be built out, including magnetic separation, vertical mills and flotation technology.
- **Build-out of pelletizing capacities (greenfield and / or brownfield).** As mentioned, the share of direct reduction ironmaking is expected to increase in low carbon iron and steel value chains, DR-grade pellets are expected to become a commodity in high demand. Ukrainian ores have the potential to be beneficiated to the requirements for DR-grade feedstock. To produce DR-grade pellets from such feedstock, new pelletizing capacities are required.
- **Build-out of green ironmaking capacities (e.g., green hydrogen-based DRI / HBI production).** Ukraine is well positioned to become a key supplier of HBI to Europe due to the availability of high-quality low-cost iron ore, high potential for competitive zero-carbon energy production, logistical proximity to Europe and competitive labour resource.
- **Build out of green hydrogen production.** This is required to supply hydrogen for green direct reduction ironmaking. For one 2-2.5 million tonnes per year direct reduction plant, approximately 1-1.5 GW of electrolyzer capacity is required. Renewable energy generation capacity of 2-3 GW is required to supply electricity to such electrolyzer (potentially a mix of onshore wind and solar PV technology, with additional balancing by battery storage if economically feasible). To enable flat profile of hydrogen supply to the direct reduction plant, additional hydrogen storage build-out may be required.
- **Build-out of EAF capacities (including substituting existing OHF and BOF capacities and / or building greenfield capacities).** Electric arc furnaces using clean electricity will likely substitute other steelmaking technologies and will complement hydrogen-based DRI / HBI production to decarbonize the sector and provide “green” steel inputs for production of finished steel.
- **Build-out of finished steel production (heavy plates, HRC, CRC, coated plate, rails, heavy and medium sections).** Ukraine’s finished steel production before the war was focused mostly on lower value added products, with several higher-end steel products (e.g. coated and galvanized coils) being in deficit and imported from Turkey and China. With the damage and loss of control over a number of production assets during the war and the expected demand for reconstruction, there will be a likely deficit in Ukraine of a number of steel products including heavy plates, thinner hot-rolled and cold-rolled coils, galvanized and coated coils, rails, heavy and medium sections. Therefore, there is a potential business case for building rolling mills producing these products for internal consumption and potential export to fill the market gaps due to loss of supply from Ukraine and Russia after the start of the war.

4.5.3. Required unlocks to realise the opportunities in the sector

To enable further progress and facilitate development and implementation of projects building out green iron and steel value chain in Ukraine and export to Europe, various technical, regulatory, and financial bottlenecks must be addressed.

TECHNICAL AND ECONOMIC FEASIBILITY ASSESSMENT

A major consideration for potential investors is the technical and economic feasibility of at-scale renewable energy, hydrogen, green HBI and steel production in Ukraine and its delivery to Europe. Feasibility studies are required to evaluate project viability.

FINANCING

Securing financing (including for the project preparation) is one of the key challenges, given Ukraine’s risk profile due to the war.

Project preparation costs vary for different parts of the value chain. For renewable energy projects, pre-FID financing could be in the range of USD 2-4 million per GW installed capacity. For electrolyzer build-out, project preparation costs could be in the range of USD 6-10 million per GW electrolyzer capacity. For green HBI, such costs could be USD 7-10 million per typical plant.

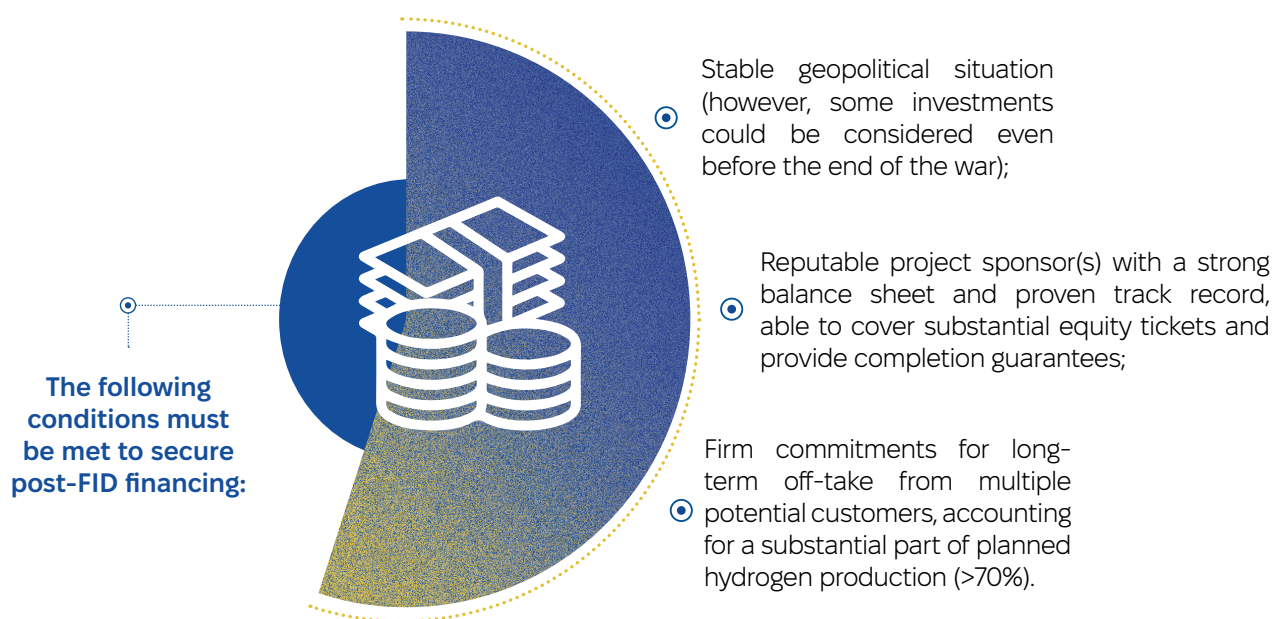
The proposed projects will likely require financing from both private and public finance. The participation of

public organisations will be vital for securing capital at non-prohibitive interest rates and crowding-in private capital. IFIs will have a vital role to play in providing risk mitigation and blended finance instruments, as well as technical assistance. National development finance institutions (DFIs) and export credit agencies (ECAs) can also play an important role in providing additional capital. A syndicate of private banks will be required to provide commercial financing, led by a major international project finance specialist organisation.

A range of financial support mechanisms from public organisations can be used to reduce project risks.

Grant funding is available across multiple IFIs during the ongoing war for the project preparation stage.

Various IFIs have proposed equity, debt, guarantees and insurance mechanisms available specifically for Ukraine that could be applied to the proposed project and help to de-risk investment. The EU Ukraine Facility Pillar 2 is set to unlock a further EUR 7 billion for the provision of guarantees to mobilise investment into reconstruction efforts, substantially increasing availability of financing, including for renewable energy sector and green iron and steel, which are designated as priority sectors under Ukraine Plan.



STAKEHOLDER CO-ORDINATION

To implement a large-scale green HBI or green steel production and export project in Ukraine, coordinated effort of industrial and energy companies across the entire value chain is required. Alignment between renewable energy and hydrogen production, HBI producers and potential HBI off-takers could help resolve the “chicken-and-egg» dilemma typical for such projects. Long-term off-take will be critical to secure financing.

The cooperation between players across green iron and steel value chain could take form of a platform for project preparation and development, leading up

to creation of a consortium of industrial and energy companies. Cooperation agreements with increasing degree of commitment (e.g., Letters of Intent, Memoranda of Understanding, etc.) could be concluded between platform participants at each stage of project development.

The financial structure of the proposed green iron and steel projects in Ukraine could take several forms depending on the prevailing conditions at the time of FID and will necessarily be a tailor-made arrangement between the parties involved.

REGULATORY ALIGNMENT AND REFORMS

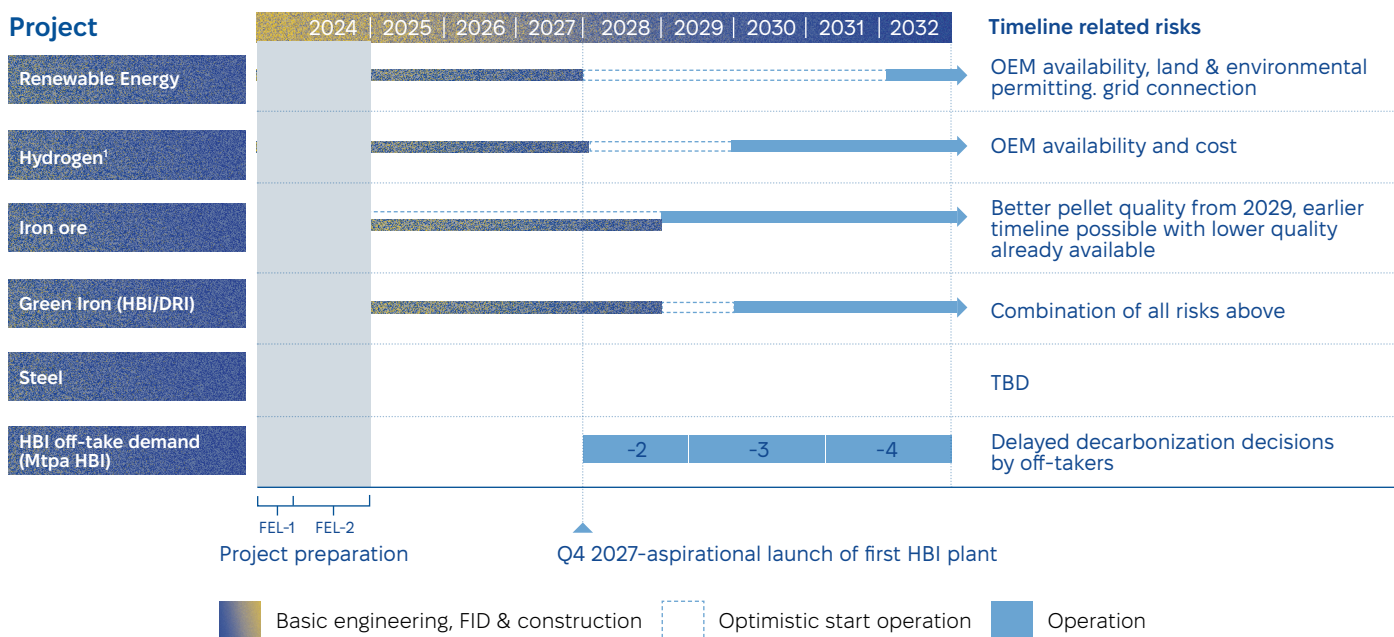
To support the build-out and operation of green iron and steel value chain in Ukraine, a number of regulatory changes are required, including:

- Stable and transparent regulations and tax regime;
- Streamlining of process to obtain land rights, permits and grid connection for renewables projects;
- Ensuring functioning of PPA system;
- Implementation of certificates of green origin for renewable electricity;
- Dedicated regulation governing hydrogen production, transmission and distribution, and use in Ukraine is required, including alignment with EU standards and regulations.

ROADMAP FOR DEVELOPMENT

Build-out of green iron and steel production in Ukraine and export to Europe can be accomplished over the several years.

Figure 8: Preliminary high-level timeline for project implementation



At-scale production of green iron and steel in Ukraine will create new jobs and economic opportunities in the country. At the same time, Europe will benefit from

a reliable and cost-efficient source of green metallics to enable **European steel sector decarbonization, de-facto creating a “win-win”**.

Sidebar: Potential green iron and steel projects in Ukraine

Metinvest: concentrate flotation and new pelletizer based on one of the existing iron ore mines

Project description: The Project aims to build DR-grade pellets production at one of Metinvest’s existing facilities, where it will partially replace outdated pelletizing machines. The project consists of 2 parts: building advanced iron ore beneficiation (flotation) to produce 70-71% Fe DR-grade concentrate (pellet feed) and building new state-of-the-art 6 million tonnes pr year pelletizer

Participating companies:
Metinvest Holding

Investment need: ~ USD 1 billion

Project status: Feasibility study

Expected date of commercial launch: 2028-2029

Greenfield 2-2.5 Mtpa HBI production

Project description: Building a Midrex Flex module to produce HBI using up to 100% renewable hydrogen to supply Ukrainian and European green steel industry

Participating companies: Ukrainian iron and steel player / international investor (similar projects have been contemplated by Ferrexpo, Metinvest and international steel players)

Investment need: ~ USD 1 billion

Project status: Pending feasibility study

Expected date of commercial launch: 2031

Interpipe: green EAF flat steel production

Project description: The project focuses on increasing production of green HRC in Ukraine by increasing production capacity to capitalize on European and Ukrainian market demand. It involves building two elements: Electric arc furnace (EAF) to produce liquid steel – powered by the grid; and 1 million tonnes per year endless strip production (ESP) line, including a coating plant, to convert liquid steel into HRC, bypassing need to store, re-heat and re-roll slabs

Participating companies:
Interpipe Ukraine

Investment need: ~ USD 1 billion

Project status: Pending feasibility study

Expected date of commercial launch: 2028