NDC ASPECTS

Policy Brief

EU Green iron imports for a more competitive EU steel industry and economy and accelerated, lower cost decarbonization

Issue #14 / September 2024

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NDC ASPECTS has received funding from the European Union's Horizon 2020 Research and Innovation programme under grant agreement No 101003866

Key messages

Green iron imports rooted in comparative advantages of different geographies are technically achievable and economically sound. Lower EU prices of green iron, green hydrogen and green electricity as economic inputs result in:

- Enhanced Competitiveness of the EU steel sector, downstream industries, and overall European economy
- Stimulated economic development and jobs
- Accelerated and lower cost decarbonization and energy transition in EU and globally
- Increased energy security: GH2 embodied in HBI is easier import and store than pure GH2 and carriers such as ammonia
- Potential negative impacts of reduced investments/jobs in the primary iron stage in the steel production chain is outweighed by benefits in the rest of the steel industry and economy.

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Primary steel constitutes 57% of EU steel production. It is predominantly manufactured in integrated iron and steel works (IISWs) where iron ore, mainly imported, is reduced using coke in blast furnaces (BFs) to molten iron, which is then transferred directly to basic oxygen furnaces that have to be close-by, yielding primary crude steel. Decarbonization can be achieved using green hydrogen direct reduction iron (GHDRI) furnaces that reduce the ore in solid state producing solid iron. This can be transported long distances in the form of hot briquetted iron (GHBI) to electric arc furnaces (EAFs) that convert it to primary crude steel. Ironmaking and steelmaking can thus be separated, disrupting the traditional BF/BOF IISWs configuration, offering the opportunity to re-arrange current value chains. This GHBI is poised to become a commodity, in competitive global and internal EU markets and replacing BF iron as the primary input in primary steelmaking.

Globally, plans have been announced to build 22 full commercial scale hydrogen direct reduced iron (HDRI) furnaces, marking the first commercial deployment of this technology. Due to comprehensive EU support, including subsidies, carbon pricing, lead market measures and protection, 17 of these furnaces will be in the EU, with most expected to be operational in the next three to five years, representing a substantial investment in long-lasting infrastructure. This will be transformational for the EU industry.

As this innovative technology matures, rather than exclusively placing all future HDRI furnaces in the EU, this brief argues that it is economically and strategically beneficial for the EU to support developing a green iron value chain to import a substantial proportion of GHBI instead producing GHDRI locally when this involves imported hydrogen. GHDRI plants can be located in iron-ore exporting regions with abundant, lower-cost renewable energy for green hydrogen production. Instead of importing iron ore and green hydrogen, GHBI could be imported from a diversity of suppliers, both increasing security of supply and resulting in a more competitive EU steel sector.

The steelmaking stage of the EU production chain encompasses numerous specialized products, offers significant employment, and adds much higher value compared to the iron-making stage. It is most efficiently situated near end-markets. In contrast, iron can function more as a generic commodity, with ironmaking representing lower value-addition and fewer jobs in comparison.

High growth in demand for green electricity for gH production and gH itself are expected over coming decades to meet emissions targets and are expected to be in relative short supply and costly, with a massive build of renewable energy, gH infrastructure and gH imports required. GHBI imports can alleviate pressures, reduce prices and increase availability of green electricity and gH in the EU.

In short, support for locating some GHDRI furnaces outside the EU, will enable many EU steelmakers to import more competitively priced GHBI, fostering a more competitive EU steel industry, supporting the continent's energy security, reducing prices of green electricity and green hydrogen and making more of these available for other higher value applications, and facilitating cost-effective and expedited decarbonization within the EU and globally. It is economically logical and strategically advantageous from energy security and climate perspectives (see graphic on last page that shows alternative routes and configurations).

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EU steel Industry at the crossroads

The steel industry is an important sector of European industry contributing €140 billion (Bn) of Gross Value Added and employing 130,000 people directly and 2,600,000 indirectly. Ample and diverse steel product supplies will remain crucial for industries such as automotive, machinery, energy, transport and other infrastructure and defense.

Steel is potentially fully recyclable and as of 2022, some 43% of total crude steel (CS) production of some 160 Mega tonnes per annum (Mtpa) is produced in electric arc furnaces from recycled steel scrap. This CS is called secondary steel. The EAF production process can largely be decarbonized with low-emissions electricity. Just about all the other 57% of CS production is produced in BF/BOFs from iron ore and coke with a small amount in DRI furnaces mainly from iron-ore and fossil gas. Coke, a special form of coal, is mainly imported as is most of the iron ore: around 150Mt iron ore and 35Mt of coke imported annually.

Actions needed by EU policy makers

- EU industrial strategy coordinated with energy, trade and climate policies integrating green iron imports in the steel value chain. This will need to create a level playing field for GHDRI production inside and outside the EU.
- Climate and development diplomacy and strategic partnerships with GHBI manufacturing partners similar to hydrogen initiatives.
- Cooperate in international standards for green iron and steel.
- Develop proactive policies for the primary steel sector to address job losses.
- Green iron finance and technology exchanges have the potential to be a model-case of international climate policy cooperation.

While steel is potentially fully recyclable it takes decades for in-use-steel stocks (for e.g. in infrastructure and buildings) to become available for recycling and also new measures, such as keeping copper out of scrap from vehicles, need to be introduced to keep it 'un-polluted'. As a result, demand for primary steel is forecast to persist. By 2050 a 50/50 ratio of primary/secondary steelmaking is expected, with demand levels for primary steel in 2050 anticipated to be similar to today. These are long term forecasts with associated uncertainty, but the relevant robust conclusion is that there will still be a large primary steel demand in the EU in 2050.

GHG emissions from BF/BOFs can be reduced somewhat but cannot be easily eliminated. The environmentally friendly alternative process route to BF/BOFs with minimal emissions, which is predominantly considered by European companies, involves the use of DRI furnaces using gH as described in the introduction above.

Similar to the replacement of BF/BOFs by GHDRI/EAFs, the introduction of GH and GDRI and GHBI into primary steel production chains can be achieved in numerous different ways within existing decarbonization pathways. (See basics of decarbonization in the introduction on page one and the steel production process flow figure 1). Some more likely examples are as follows. The HBI can supplement feed to BFs and BOFs, incrementally decarbonizing

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their product. It can be used as a substitute for scrap steel. New GHDRI furnaces can initially be fed with fossil gas, a first step to decarbonization, with H2 being introduced in increasing amounts. The H2 can also be gradually decarbonized, first sourced from using fossil-gas steam reforming plant ('grey H2') and then GH2 from electrolysers fed with green electricity (GE). This GE can also be the result of a steadily decarbonizing electricity supply. In short, there are many options and permutations of these, but **ultimately full decarbonization will most likely involve a substantial capacity of GHDRI furnaces, some in the EU, others elsewhere in the world and GHBI will be a global commodity, similar to iron ore.**

While DRI plants do not have to be close to EAFs, in the first wave of HDRI furnace investments announced for the EU, the physical distancing of DRI plants from crude steel production plants has been limited and the legacy BF/BOF arrangement of integrated iron and steel works (IISWs) being replicated, with HDRI plants close to the EAFs they will feed, directly, with DRI in hot sponge iron form. While this has some efficiency benefits it is questionable whether the perpetuation of this close physical vertical integration be beneficial overall. For example, there are process and product flexibility benefits and competitive market benefits for EAFs to have multiple suppliers of GHBI and HDRI plants having multiple buyers of their product.

This evolution of overall EU industry configuration echoes previous developments in the steel industry over past decades where IISWs were retained in the EU while the USA evolved to more use of scrap as an input and a shift to EAF-based 'mini-mills'. The separated DRI/EAF reconfiguration is already envisioned by a few European actors (H2 green steel, Gravity) and might transform more radically the EU steel industry as it switches to decarbonized steel, hence opening the door to international exchanges of green iron.

The EU already has a fleet of 150 EAFs at 126 widely spread sites as potential customers for GHBI. By comparison, there are 25 BF/BOF sites, historically located according to the logic of coal and iron supplies and BF/BOF production requirements, concentrated in a few EU regions. Many of these furnaces are due to retire or require costly refurbishment soon. This is thus a moment for re-consideration of the logics of location.

The next section of this brief addresses the three core techno-economic questions around the distribution of locations of GHDRI furnaces inside and outside the EU, the comparative benefits of locating a substantial proportion in iron-ore exporting regions with low-cost abundant clean electricity and the timing and sequencing of these new investments.

Furthermore, the brief discusses policy aspects to consider for the EU to reap the potential advantages of the shift to the HDRI-EAF route as well as a re-arrangement of the location of primary iron making distant from steelmaking. It is important to note that this will involve much more than a process of technology change. The shift will require a disruption of entrenched production chains and associated technological clusters, techno-cultural and political ecologies of an industry which has been deeply entangled in historical EU political, industrial and transformative energy developments. Key aspects of this are touched on in the last section of this brief.

The shift involves disrupting entrenched production chains, associated technological clusters and political ecologies deeply entangled in the EU's historical, political, industrial, and energy system developments. This is now outlined in the rest of this brief along with a policy analysis and recommendations.

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Implication of green iron imports

EU economic benefits

A significant portion of Electric Arc Furnaces (EAFs) and Blast Furnaces/Basic Oxygen Furnaces (BF/BOfs) is situated in the **regions of the EU where hydrogen transport costs make HDRI cost-non-competitive**. These regions are expected to maintain **their** status as the largest hub for steel product manufacturing and the primary geographic area for the demand **for** GHBI in primary crude steel production. While competitive costs for producing green primary crude steel and GHBI can be achieved in certain EU regions, notably Spain and Scandinavia, due to similar comparative advantages as potential GHBI exporters like Morocco, Algeria, and South Africa, these EU regions will not be able to meet the demand for GHBI in the northeastern EU.

A substantial number of EAFs and BF/BOfs are concentrated in the northeastern regions of the EU. These areas are anticipated to remain the primary hub for manufacturing steel products and the core for the main demand for GHBI for primary crude steel production. While certain EU regions, including Spain, France and Scandinavia, can achieve competitive costs for producing GHBI, leveraging similar comparative advantages as potential GHBI exporters such as Morocco, Algeria, and South Africa, these EU regions will not suffice to meet the demand for GHBI in the northeastern EU.

Moreover, adequate volumes of domestically produced green hydrogen (GH2) will not be available, leading to plans for substantial import infrastructure for GH2. Despite this, utilizing imported GH2 and imported iron ore for GHDRI production in the northeastern EU will make most GHDRI, and consequently, green primary crude steel produced in that area, non-competitive in terms of cost. The most economical option would be importing GHBI, for most cost-effective green primary crude steel production.

Furthermore, there will be a shortage of domestically produced GH2, necessitating the development of extensive import infrastructure for GH2. Despite these efforts, the use of imported GH2 and imported iron ore for GHDRI production in the North Eastern parts of the EU would render the majority of GHDRI, and consequently, green primary crude steel produced in that region, non-competitive in terms of cost. Importing GHBI emerges as the most economical option for achieving cost-effective green primary crude steel production.

Importing green iron at a lower cost than local production, as the main input for primary steelmaking, will reduce costs throughout the steel production chain and industries reliant on steel products. This cost reduction could potentially lead to expansion in these industries, generating positive economic multipliers.

Demand pressures on constrained GE and GH2 supplies will be relieved thereby increasing supply and reducing prices of these decarbonization factors to other industrial sectors and services (e.g. EAF steelmaking, most industries, transport), hence reducing costs, increasing competitiveness, supply security and accelerating decarbonization.

Failure by the EU to contemplate the reconfiguration of the primary steel production chain facilitated by the technology transition may result in the intercontinental transport costs of GH2 dedicated for GHDRI embedding a lasting cost differential. This differential would exist between GHDRI produced in exporting countries with affordable renewable energy and domestic iron ore and GHDRI produced at an EU location using the same iron ore. This situation could establish a permanent structural competitive advantage for imported GHDRI, and likely extend

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to green steel production in the exporting country or other nations utilizing that GHDRI as feedstock.

EU energy security benefits

Green hydrogen (GH2) is crucial for the EU to meet its decarbonization goals, particularly within the industrial sector. GH2 could account for 4-20% of EU final energy consumption by 2050 with absolute volumes ranging from 200 to 1,600TWh In 2030, 2040 and 2050 it is estimated that total-industry/steel-demand for green iron could be 293/55, 836/144 and 1200/179TWh respectively (Anthony Wang et al., 2021:14,15).

A very rapid ramp up is required involving vast investments in renewable energy generation, GH2 production and GH2 logistics infrastructure. Shortages are expected. Moreover, since the Russian invasion of Ukraine, the EU has recognized the importance of diversity of supply. GH2 supply security will become synonymous with energy security. Owing to the inherent properties of the different gasses, GH2 transport and storage are far more challenging technically than natural gas and costly to secure.

The EU is establishing agreements with developing countries with potential abundant cheap renewable energy to establish GH2 production there and import the GH2. The 2023 RepowerEU strategy includes the idea of *"securing strategic partnerships with Namibia, Egypt and Kazakhstan to ensure a secure and sustainable supply of renewable hydrogen"* (2023 REPowerEU). The EU will need to support investments and construction of new GE and GH2 production in those countries where GH2 production costs are lower than in the EU. Investments in costly logistics infrastructure will be necessary. Seaborn GH2 import supply chains will additionally include inefficient and costly conversion and de-conversion of the gaseous GH2 for transport.

Rather than importing all the GH2 designated for GHDRI production, some of the GH2 could be utilized locally in those exporting countries possessing iron ore resources to convert the iron ore into GHBI. Considering that a significant portion of EU primary iron production relies on imported ore, if the GH2 exporting country also has access to low-cost iron ore, **the GH2 could be effectively imported into the EU embodied in the GHBI**. This embodied energy essentially carries a comparatively negative cost for transport, given that it HBI has the same amount of iron as iron-ore but weights 35% less. Furthermore, the existing transport infrastructure for iron ore can be easily adapted for GHBI. HBI is significantly more cost-effective and easier to store than hydrogen. Thus, GHBI serves as a substitute for a considerably more expensive green hydrogen energy supply and storage, providing enhanced security. **EU supply security benefits of substituting a portion of planned GH2 imports with GH2 imported embodied in GHBI.**

- Demand for imports of a substantial amount of an expensive and difficult to transport energy carrier, namely GH2, would be met via an alternative method.
- Supply security of GHBI imports would much higher than GH2 because of much more technically less costly and risky transport and storage of GHBI along entire supply chain.
- The GHBI would increase effective diversity in the energy supply chains for industry decarbonization
- A portion of costly GH2 logistics infrastructure investments could be avoided, or this frees up space for use of gH in other sectors (i.e. energy production)

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Security of supply of GHBI

In the new era characterized by heightened challenges and risks in global supply chain security, alongside European strategic autonomy policies, concerns may arise regarding the potential increase in risks to the supply of iron for steelmaking and a growing dependency on imports if GHDRI production is located outside the EU. Contrary to this perception, a well-managed approach to importing HBI can actually reduce the risks associated with disrupting primary steelmaking linked to iron ore and iron imports. The existing dependency on iron ore is already low due to the abundance of international sources for iron ore, which can be easily stockpiled.

During the initial phases, when there are few GHBI exporters, the EU will primarily produce primary iron from iron ore imports, maintaining low disruption risks. As GHBI gradually substitutes iron ore imports, the number of GHBI exporters will be increasing, creating a situation of dependency similar to that on iron ore today: dependency but low-risk dependency. However, the risks associated with iron ore and HBI imports for EU steelmaking will decrease even further for several reasons.

Firstly, iron ore exhibits a wide range of qualities, and specific characteristics are required by individual BF/BOF primary steelmaking plants. In contrast, GHBI is likely to be a more homogeneous commodity for steelmaking, giving EU-located EAF primary steelmakers a wider choice of suppliers.

Secondly, a mass equivalent of approximately 30%-40% less green HBI compared to iron ore will require transportation and stockpiling.

Thirdly, although transporting GHBI poses more challenges than iron ore, these are minor, and solved, but the long distance transportation of green hydrogen (GH2) is considerably more expensive and susceptible to disruptions and has challenges not yet solved for scales that are forecast. Consequently, GHDRI production located in the EU would be vulnerable to supply disruptions of GH2 imports which are substantial.

Finally, during the crucial initial stages of setting up DRI production, many plants are intending to use natural gas as the reductant, rather than hydrogen, which will be phased in over time. Just like hydrogen, natural gas faces the risk of supply disruptions. In the scenario where the DRI plants are distributed across various exporting countries, the transport and storage security of HBI far surpasses that of natural gas.

EU risks

- **Employment implications**

Employment related to new GHDRI plants in the EU, and the EU located elements of the energy generation systems (GE and GH2) that serve them, will be lower if GHBI is sourced from production located outside the EU. However, these are both very low employment intensive industries and overall the EU steel industry in particular, and economy in general will benefit. While this has not yet been modelled it would make sense that net employment benefit is the most plausible result.

- **Potential downsides from an energy security perspective:**

To a limited extent keeping the imported or domestically produced GH2 non committed to GHBI production would make it available for other uses in the EU – yielding some more flexibility for the EU energy system.

In the initial stages, a threshold of lead-demand for GH2 for GHDRI is necessary to establish the anchor demand to

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kick-start GH2 infrastructure in the EU. However, this is tactical timing/sequencing issue that can easily be solved. For example, GHBI imports can be sequenced to commence after the threshold demand for import pipelines and the necessary economies of scale for the European Hydrogen Backbone (EHB) have been secured.

GHBI Exporting country benefits

Developing countries lack lead markets for the initial large-scale investments in higher-cost green primary iron or steel plants, along with the financial and policy resources needed for kick-starting local GHDRI production. Initiating GHDRI production involves significant and risky upfront investments in these contexts. Also, the economic rationale behind allocating substantial subsidies as has been required in EU GHDRI plants, is fundamentally different in countries with large basic services and infrastructure backlogs and fiscal constraints.

By anchoring GHDRI investments in export markets, the availability of GHDRI in exporting countries would be accelerated, facilitating earlier local green steel production. The steelmaking stage requires much smaller minimum plant sizes and these can utilize a portion of the local GHBI production. This acceleration would yield similar positive effects in these countries as observed in the EU industries and consumption sectors mentioned above.

EU GHBI import Policy issues

Policy background to GHDRI

Primary iron production facilities represent significant capital assets with extended economic lifespans, typically lasting 20 years or more. Numerous BFs in the EU are approaching the end of their lives. The announcement of investments in the 17 new EU GHDRI plants was contingent on substantial policy interventions. The production of green primary crude steel is considerably more expensive than conventionally produced primary steel, and carbon pricing, on its own, had proved insufficient to drive the transformative change in the GHDRI process.

The EU has put in place a comprehensive set of measures to support the decarbonization of the European economy and industry sector in particular, including among support for innovation in heavy industry production processes as well as carbon pricing. This, in the first instance enabled the investments at EU locations resulting in the announcement of plans to invest in the 17 EU plants in the short term. This has been a remarkable development for this industry not long ago labelled as hard to abate. From the measures introduced so far, it appears that EU industrial policy and GH2 policy has assumed that the whole iron and steel production chain should be retained in the EU and so GHDRI would be locally produced and based on this a huge hydrogen investment strategy is planned. It would seem that the policy is based on the premise that it is necessary to keep the primary iron production step in the EU as an element of “re-industrialization”.

However, re-industrialization cannot mean that every industry that can be located in the EU, even with large subsidies, should be. The economics presented in the earlier sections poses questions regarding such a policy position. Possibly the rate and scale of this initial success was not anticipated at the time the policies were being devised and implemented. The success has been difficult to achieve for years and because of this the focus was initially on just getting commitments to investments in EU located plants. However, the rate of remarkable successes in technology developments were also not anticipated and neither were some external developments such as energy security and other challenges associated with the invasion of Ukraine and other global supply chain

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issues. The ongoing evolving context has created new possibilities that were not initially anticipated.

This achievement, which has been elusive for years, focused initially on securing commitments for investments in EU-based plants. However, the unexpectedly rapid and substantial successes in technological advancements, along with unforeseen external factors such as energy security concerns and global challenges related to events like the invasion of Ukraine and other supply chain issues, have altered the context significantly. The ongoing evolution of this context has introduced new possibilities that were not initially foreseen.

When considering the evolving comparative costs of new techno-economics, recent successes in EU primary steel decarbonization, and the aforementioned policy context, it is evident that significant benefits could arise from importing from plants situated outside the EU, which was not initially foreseen. Additionally, it is apparent that the developing countries hosting such plants currently lack the resources to establish favorable conditions for investment in the short term. Consequently, if the EU aims to reap the advantages of importing GHBI, it needs to update its techno-economic and policy analyses and assess the potential net benefits for the EU of assisting in the creation of these conditions. This evaluation should include an examination of whether the EU possesses the necessary resources and whether the potential benefits justify the expenditure from an EU perspective.

Policy questions on EU GHDRI imports

The contextual background for the policy questions can be distilled from the preceding sections based on three key factors. Firstly, from a techno-economic standpoint, there is a strong likelihood that the EU could reap significant benefits with minimal, if any, associated costs and risks, all of which can be effectively mitigated.

Secondly, achieving success in the EU has proven to be a formidable task, made possible only through the region's multifaceted capabilities. The implementation of a comprehensive policy package is essential to persuade steelmakers to invest at scale in the new HDRI technology, and much of this effort is still a work in progress. The corollary to this is that exporting countries would also need to establish comprehensive policy packages, tailored to their specific circumstances and international trade requirements.

Thirdly, cooperation with the EU is essential for developing countries to embark on such endeavors. The EU meeting decarbonization targets and avoiding stranded assets necessitate careful decision-making over the next few years, guided by medium/long-term strategies. The EU steel industry faces the critical decision of determining the extent to which it produces GHDRI locally versus importing it.

As the EU places a heightened focus on the low-carbon transition of its industry and asserts European strategic autonomy, the options for importing GHBI should be meticulously assessed in the light of industry, economic, and strategic developments, aligning with the current policy objectives of the EU. The techno-economic overview suggests substantial potential contributions to the European industrial transition with only minor negative impacts, which can be mitigated through active public policy. Realizing these benefits necessitates policy adjustments and alignment across existing industrial, trade, economic, and climate policies.

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EU GHBI policy recommendations

Making Green Iron imports work in Europe will require an alignment of different public policies. Some avenues could be explored based on the recently adopted EU policies for the industrial decarbonization. The EU should:

- Consider in an updated industrial strategy with different scenarios involving green iron imports in the steel value chain and its contribution to the overall EU socioeconomic, climate and strategic autonomy objectives.
- Develop partnerships with countries where current exporting-oriented projects exist such as, Australia, Brazil, Namibia and South Africa.
- Explore the inclusion of green iron as a derivative of hydrogen in the international part of its hydrogen bank initiative (H2 global) to open the door for the joint purchase by EU economic actors.
- Promote international agreements on standard rules for the definition of green iron and green steel with a high level of social and environmental integrity
- Anticipate and plan transition policies for the primary steel industry including the reconversion of blast-furnace sites and workers.
- Engage relevant industries to obtain industry analyses and plans of future industry trajectories.

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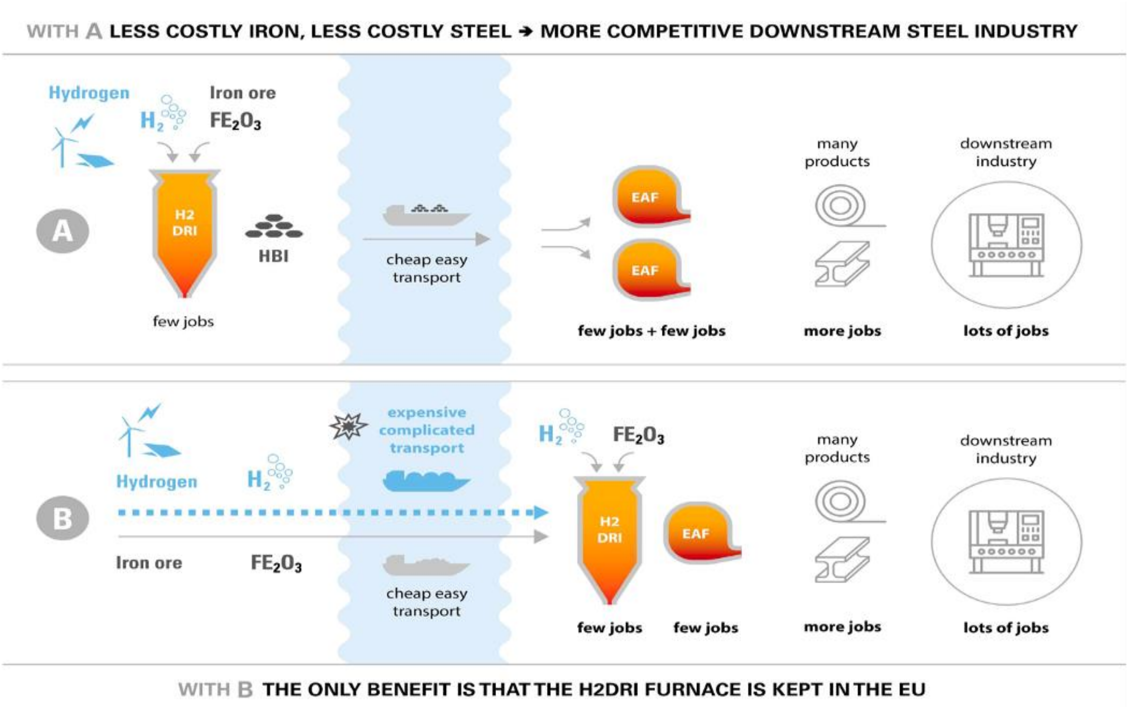

Figure - Alternative locations for green iron manufacture

There are many complex options for steel production chains. We present here only the key elements of the major production routes relevant to options analyzed in this brief.

Acknowledgements

We would like to express our sincere gratitude to all those who contributed to the development of this policy brief across Work Packages under the NDC Aspects Project: Tomas Wyns, Annika Tönjes, Georg Holtz, Süheyb Bilici, Stefan Kronshage, Robin Koening, Lauren Harry-Villain, Wolfgang Obergassel and Sebastian Oberthuer.

Special thanks go to Bryce McCall and Chris Bataille for developing the initial Green Iron techno-economic concept with us in *2019 Trollip, McCall and Bataille (2019)*, Lukas Hermwille and Henri Waisman for the related political concepts, Simon Otto for detailed review comments, Marta Torres Gunfaus for making this multi-institutional process work in many ways, Gauri Khandekar for arranging policy discussions and production of the brief and Bettina Lê for last minute crucial help with production.

NDC ASPECTS has received funding from the European Union's Horizon 2020 Research and Innovation programme under grant agreement No 101003866

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The following two key references form the basis of the concepts behind this Policy Brief

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