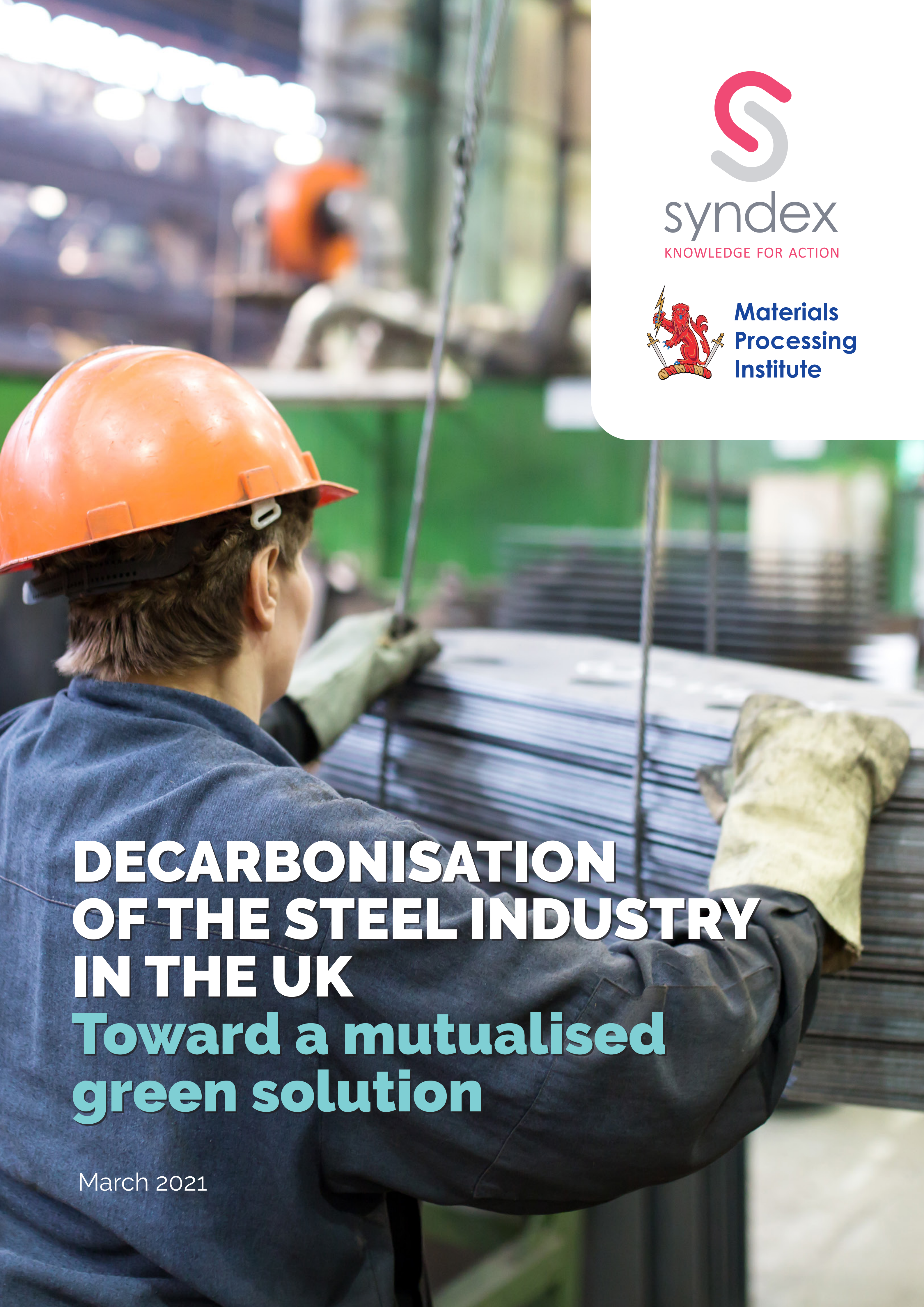

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Materials Processing Institute

DECARBONISATION OF THE STEEL INDUSTRY IN THE UK

Toward a mutualised green solution

March 2021

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ABOUT SYNDEX

Syndex UK is the leading consultancy for workers representatives in the UK. With 450 employees, 45 years existence, Syndex is the one-stop consultancy for workers representatives. Syndex has offices in France, Poland, Romania, Spain, Belgium, Germany, UK and Ireland delivering services to more than 2000 clients every year. Syndex has developed a strong experience in the steel industry in the UK and has advised the unions in every major steps of the industry since 2014. Syndex UK and Ireland is specialised in the support to European workers councils and unions at the national and local level with a focus on restructuring, merger and acquisitions, strategic changes. Syndex is an employee-owned company.

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ABOUT MATERIALS PROCESSING INSTITUTE

The Materials Processing Institute is a research and innovation centre serving global steel and materials organisations that work in advanced materials, industrial decarbonisation, the circular economy and digital technologies.

The Institute has served as the UK's national steel innovation centre since 1944 having been set up by Sir Winston Churchill's wartime government just before D-Day to equip the British steel industry for post-war reconstruction. It celebrated its 75th anniversary in 2019.

Through collaboration with its customers, the Institute provides a range of technology and R&D based services and consultancy. It also has pilot and demonstration facilities and an SME Technology Centre to support supply chain businesses with the development of new technologies and products.

The Institute works across sectors and industries including: steel, metals and alloys, chemical processes, aerospace and defence, energy, mining and quarrying, construction, rail, transport, and infrastructure, offshore, subsea, and nuclear.

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TRENDS AND INCENTIVES FOR DECARBONISATION

#1 SOCIAL PRESSURE AND COSTS OF EMISSIONS

The steel industry is the biggest industrial emitter of CO_2 in the UK. With growing concerns from the public in relation to climate change and the net zero target by 2050 adopted by parliament in 2019, the steel industry is under pressure to act fast. Tata Steel and British Steel with their blast furnaces in Port Talbot and Scunthorpe are facing a significant challenge. This pressure will come from the communities but also from the industry itself. Today, worldwide, on average 1.85 tonnes of CO_2 are emitted for every tonne of steel (Wordsteel). The global steel industry emits 2.8bn tonnes of CO_2. To comply with the Paris Agreement, the emissions must fall to 600mt CO_2 maximum by 2050. Based on a forecasted production of 2,500 million tonnes in 2050 (+55% compared to 2015), this means that the emissions per tonne must be reduced by 90% to 0.2 tonnes of CO_2 per tonne of steel. The price of CO_2 will also significantly increase. Some countries have already set a price of the emission per tonne in excess of £50 by 2025 and a price above £100 in 2050 is a conservative estimate. Based on historical steel prices and margins, most of the steel producers would become non profitable. .

#2 COSTS OF DECARBONISATION AND THE CHALLENGES FOR THE PRIVATE SECTOR AND PUBLIC AUTHORITIES

Eurofer believes that the European steel industry could achieve carbon emissions cuts of 95% by 2050. This will nevertheless result in an increase in the total cost of production of 35-100% per tonne of steel by 2050, with a requirement for

400 TWh of CO_2-free electricity, seven times the current consumption of the sector.

#3 COMPETITORS' STRATEGY AND JOURNEY TOWARD GREEN STEEL AND FOSSIL-FREE STEEL

The current stock of blast furnaces and DRI furnaces is still young, notably in Europe, and this technology will remain the main source of steelmaking for at least the next 20 years. In most of the scenarios[1], traditional scrap based EAF will account for less than 40% of production by 2050 (versus 22% today). Iron ore will remain a key raw material for the industry. UK producers must factor this in with the design of their strategy towards low emission steel making or even fossil-free steel.

The UK is a net exporter of scrap and there is potential to increase the scrap usage of the UK industry within a strategy aiming at replacing the high level of imports by a higher proportion of local production. Nevertheless, recycling of scrap is currently inhibited by low quality of end-of-life scrap as well as the lack of scrap enhancement capabilities to address the issue of contamination. In the longer term, scrap availability will be a significant constraint. In the EU 28, scrap availability will increase by 1.1% per year until 2050, a higher growth than steel production (+0.5%/year) but will not be sufficient to cover the need of the industry (Eurofer). Globally the supply of scrap will become a more significant issue. This will surely drag up the price of scrap. Scrap-based production could be put under pressure from iron ore-based producers. This risk is one of the reasons why most of the EU producers are favouring technologies allowing a dual supply. The other reason is that, despite significant progress, scrap-based EAFs are not all capable of producing all grades of steel. This is a significant limitation, particularly for the flat products for the automotive sectors and packaging.

All big European steelmaker (TKS, Arcelor, Salzgitter, Voestalpine and SSAB) are now engaged in the development of a DRI-Hydrogen solution including for most of them a transition from blast furnaces to EAF over the next 20 years. Hydrogen is also used by some steel producers as a replacement for Pelletised Coal Injection (PCI).

UK STEEL INDUSTRY AND THE CHALLENGES OF DECARBONISATION

#1 A DECISION MUST BE TAKEN RAPIDLY

The UK steel industry is mainly based on BF/BOF technology, with two big players, Tata Steel and British Steel, facing a similar challenge: deciding now the technology for the future. Both must decide soon whether or not to invest in their coking plants. Assuring the long-term sustainability of the coke ovens will cost hundreds of millions of pounds.

1. Like in the Sustainable Development Scenario of the International Energy Agency.

On top of this, both companies will have to invest in the relining of some of their blast furnaces during the next decades and in some cases to rebuild them if they want to continue with the current technology. This choice would require the development of a CCS or CCU solutions, to comply with net zero emission target by 2050. In order to meet the intermediate targets of emissions reduction (2030), the industry would have to start to invest in CCS/U solutions. The transition to a DRI/Hydrogen solution seems more secure as it could be developed in tranches starting with the implementation of proven technology. It would allow the use of blast furnaces until the end of their life and does not require an immediate, or irreversible decision in relation to blast furnaces.. In all the scenarios, the amount of investment will be significant (c. £400-£500m CAPEX for 1mt of steel), which is unaffordable by the UK producers given their weak financial situation.

#2 RESPONSE OF THE GOVERNMENT

The UK government pledged to contribute towards the transition to carbon-free steel through direct (co-) financing of available technologies. Until recently, the UK steel industry has benefited from EU funds for research on alternative technologies, through the ULCOS programme (Ultra-Low CO_2 steelmaking), which was, however, rather modest: the total budget was €35 million, including €20 millions of EU contributions.

The *Industrial Decarbonisation & Energy Efficiency Roadmaps to 2050*, published by the UK Department of Energy and Climate Change and the Department for Business, Innovation and Skills in March 2015, listed a range of decarbonisation options in the steel production process chains, grouped into two main categories:

- Incremental options, which are characterised by smaller CO_2 savings coming from different parts of the production process.
- Disruptive options, consisting of breakthrough technologies, including the rebuild or retrofit of integrated sites based on advanced technologies such as Hisarna, Corex, Finex (Smelting reduction ironmelting) or carbon capture.

The disruptive options were said to require a high capital investment with a low return on investment rate and therefore a limited incentive for investment from the industry. The role of the government in supporting investment in disruptive technologies was therefore presented as central.

In 2019, the UK government took a further step by announcing a £250 million funding to help the UK steel industry transition towards low-carbon alternatives. The new **Clean Steel Fund** included a new solution, not analysed in the *Industrial Decarbonisation & Energy Efficiency Roadmaps to 2050*: hydrogen.

The Clean Steel Fund targets three types of initiatives, on which the government has received comments from the industry:

- Switching to lower carbon fuels, including hydrogen, biomass and renewable electricity.
- Carbon capture, usage and storage.
- Energy and material efficiency.

#3 STRENGTH AND WEAKNESSES OF THE UK STEEL INDUSTRY IN TACKLING DECARBONISATION

The UK steel industry has a number of strengths and opportunities that could facilitate its transition towards a carbon-free steel production.

Firstly, *the scrap availability* is high in the UK. The country has a mature infrastructure which is generating more 10 Mt of scrap steel annually, and the forecasts project that the amount should only increase in the near future. The UK steel industry consumes around a quarter of the internally produced scrap, the rest being exported. The UK only uses 2.7 Mt of recycled steel scrap (1.7 Mt by the EAF steelworks of Celsa, Liberty Rotherham, Outokumpu and Sheffield Forgemasters, and 1 Mt by the integrated steel plants Tata Steel Port Talbot and British Steel Scunthorpe). The development of scrap processing methods that allow for a more efficient metal separation should allow for a higher scrap consumption by the UK steel producers internally and provides a potential for switching towards a more EAF-based steel production.

Secondly, the main steel producers in the UK are *international players*, integrated in international supply chains and having access to recent know-how in terms of carbon efficient steel production.

Thirdly, there is a growing *need to secure a sustainable internal production of steel in the UK*. The country is a net steel importer, and its steel deficit exceeds £2 billion per year. Since 2014, imports cover around 60% of the total home market. There is a huge potential to protect the internal market and to deliver additional steel to UK customers from UK sites. Available production capacities and the price of steel are the main impediments for the time being.

Although there is clear potential to develop an internal sustainable steel industry, there are a number of weaknesses that impede a fast and efficient deployment of alternative solutions:

- High energy prices limit the development of EAF route and of DRI-based solutions for the Blast Furnace route (although gas availability internally is a positive factor).
- The access to raw and pre-processed materials for the integrated steel production is limited. The UK is importing iron ore and the development of an internal DRI production facility is subject to securing a stable flow of iron ore to the country.
- Alternative energy technologies such as hydrogen production are insufficiently developed, and investment costs are unclear.
- The R&D in the steel industry, although benefitting from some previous projects at European level (e.g. ULCOS, Hisarna) is insufficient and the visibility of induced costs by new carbon-free technologies is very low.

#4 CARBON BORDER ADJUSTMENTS

UK carbon dioxide emissions from industry have fallen by 52% since 1990[2]. However, this has been accompanied by a significant reduction in the UK industrial base and an increase in imported emissions, in both materials and manufactured goods. Steel sections produced within the UK results in 50% less CO_2 emitted than steel sections sourced from the EU[3]. In tackling the challenge of decarbonisation in the steel industry, and industry more widely, we need policy that consciously seeks to ensure that we do not simply offshore manufacturing and emissions, as we have done in the past. One alternative to consider is the use of carbon border adjustments for imported materials and manufactured goods, ensuring that domestic producers are not at a competitive disadvantage, as compared with producers based in territories that do not apply the same high environmental standards as the UK.

2. https://www.aldersgategroup.org.uk/asset/1697.

3. https://britishsteel.co.uk/who-we-are/sustainability/#:~:text=Steel%20transported%20within%20the%20UK%20produces%20%2050%%20less,times%20less%20than%20steel%20sourced%20from%20mainland%20Europe

POTENTIAL ALTERNATIVES: CRITICAL REVIEW

#1 CARBON CAPTURE, USAGE AND STORAGE : UK GOVERNMENT SUPPORT

Although CCUS has for more than 10 years already been presented as the main solution for the decarbonisation of industry, as of 2020 there were no operational CCUS sites in the UK. Key barriers to the deployment of CCUS are high infrastructure costs, low return of investment, lack of industry incentives and concerns around safety. Formally, the UK government supported the development of CCUS, but there have been many policy delays in the past. In 2007 and 2012 the government cancelled its own initiatives for the establishment of the UK's first Carbon Capture Storage site. In 2017, the government launched a CCUS Cost Challenge Taskforce in 2017 to provide advice on the steps needed to reduce the cost of deploying CCUS in the UK, and in November 2018 the CCUS Deployment Pathway was launched. Lately, the funding of CCUS solutions was part of wider funding schemes (Industrial Strategy Challenge Fund and Industrial Energy Transformation Fund) as well of CCUS specific grant schemes: CCUS Innovation Programme, Carbon Capture Usage and Demonstration Programme, the Carbon Capture and Storage Infrastructure Fund. The latter announced an £800 million investment to establish CCS in at least two UK sites, one by the mid-2020s, a second by 2030. However, it is not clear if the sites will be close enough to the steel-producing facilities so that the steel industry could benefit from the new CCS capacities.

There is also a 'moral hazard' consideration around CCS. The costs of installing and running a CCS network are beyond the means of an individual company in the steel industry and indeed economies of scale will likely require multiple operating units to feed into a single CCS network. This creates an expectation that CCS infrastructure will be publicly funded, in the same way that roads and railways are publicly funded. However, the addition of CCS to an existing blast furnace producing site 'locks in' the current technology, reducing incentives to invest. This would perhaps not be a problem if taken in isolation, except that switching to new low carbon technologies, also results in gains in productivity and, potentially, capability. There is therefore a risk with CCS that the industry risks stagnating in terms of its global competitiveness. This aspect needs to be fully explored alongside the technology requirements.

#2 TRADITIONAL EAFS COULD FACE THE LIMIT RANGE OF STEEL PRODUCED

There are four EAF steelworks in the UK: Celsa, Liberty Rotherham, Outokumpu and Sheffield Forgemasters, producing altogether 1.6 Mt of steel per year. The traditional EAF route is less carbon intensive than the integrated Basic Oxygen Steel Furnace (BOF) route. Steel industry sources suggest that the use of EAF can reduce carbon intensity to 280-750 kg/tonne compared to more than 2t CO_2/ tonne in an integrated steel plant. The difficulty stems mainly from the technical aspects of steelmaking. The EAF route has a more limited grade range of steels (some qualities can be provided only by primary steelmaking) and it depends on the efficiency of scrap processing in upstream (collection and sorting technologies are critical, as scrap might contain nickel, chrome or molybdenum which change the physical properties of steel).

It is true however that the limitations associated with EAFs are being rapidly overcome, with some of the most highquality steel for the automotive sector now produced via the electric arc furnace in the USA. Issues concerning tramp elements are being addressed by greater investment in advanced scrap sorting technology, though for bulk manufacture. The production of highquality steel for the automotive sector requires nevertheless a significant quantity of ore based metallics via Hot Briquetted Iron (HBI) or Pig Iron and sometimes both like in the case of Nucor or Big River Steel for which scrap represents below 70% of the load.

A combination of directly reduced iron and scrap would seem like a most sustainable strategy for a high quality EAF steel producer. There remains the issue of nitrogen, for which there is currently no commercialised solution. However, potential technologies have reached the pilot and demonstration phase at the Materials Processing Institute in the UK. The most critical issue remaining being the range of steel for packaging, a key product for the UK industry.

#3 DRI: MAINSTREAM SOLUTION IN EUROPE BUT WITH THE CHALLENGE OF INVESTMENT AND ELECTRICITY PRICE

The advantage of Directly Reduced Iron (DRI) is that it is compatible with both Blast Furnaces and EAFs (and therefore compatible with scrap) and it allows for a gradual transition towards carbon-free steel production.

DRI can be produced using either natural gas or hydrogen, with the World's first hydrogen based DRI plant (using a 70% hydrogen enriched gas feed), anticipated to be operational in China during 2021. Emissions from this plant are estimated at 0.25t CO_2/t iron[4]. If hydrogen is produced using renewable electricity, the whole process is considered carbon-free. In the UK however this route is for the time being difficult to implement from a financial standpoint, due to volatile and high costs of electricity[5] and the significant capital investment. A UK steel industry source estimated that a 600MW electrolyser would cost £600 million and allow a potential reduction of 2MtCO_2e. An alternative approach would be to produce hydrogen using steam methane reforming (as is the predominant process currently in use) and to link these plants to carbon capture and storage network with the limit of a CCS technology mentioned above.

The hydrogen DRI process is highly energy intensive. According to available research, for hydrogen direct reduction (H-DR) steelmaking, 3.5 MWh electricity is consumed per ton of steel, which means that for 6Mt steel (roughly the equivalent of the steel produced in UK's Basic Oxygen Steel Furnaces), more than 20 TWh electricity is necessary. This is equivalent to around 6.5% of all electricity produced, 17% of all renewable electricity produced and 23% of all electricity supplied to industry in the UK. To be competitive green hydrogen DRI would need a price of renewable energy below £25/MWh with a carbon price at £50. Green hydrogen DRI is expected to be cash cost competitive between 2030 and 2040 in Europe and even before in countries with the most developed sources of renewable energy.

#4 INVESTMENT IN ENTIRELY NEW FACILITIES

It has been explained that transition and adaptation of existing blast furnace facilities is both urgent, as a consequence of the capital investment cycle time, and expensive. Estimates of £400m to £500m per million tonnes of installed steel capacity are not unreasonable. Comparing this option with the most efficient steel producing technologies in the world, an 'out of the box', three million tonne per year strip steel plant, such as that operated by Big River Steel at Arkansas in the USA, can be purchased and installed for c.£1.6bn.

It is clear therefore that in addition to the decarbonisation imperative, there is an economic consideration arising from the deployment of the latest steel manufacturing technologies. Nevertheless, the incentive to invest in a brand-new capability, with a significant CAPEX required in a very short time is low for most of the UK companies which are financially struggling and rather cash constrained. The social impact as well as the cost, of a swift change to a technology allowing to produce 3Mt of steel with 600 employees must also be considered. Given the trade deficit of the UK for steel, the development of new state of the art capabilities could be achieved in parallel to the conversion of the current steel plants and the utilisation of their current assets as long as possible to spread the financial and social costs over the years.

4. https://www.tenova.com/news/detail/first-hydrogen-based-dri-plant-in-china/#:~:text=First%20Hydrogen-based%20DRI%20Plant%20in%20China%20The%20world%E2%80%99s,ENERGIRON%20technology.%20Monday,%20November%2023,%202020%20|%2010:07

5. As of January 21st, 2021, the price of month-ahead electricity contract in the UK wholesale market was £66.96/MWh, which is 190% higher than £23.10/MWh on May 28th, 2020. Assuming an electricity price of price of £60/MWh, the cost of the electricity of the H-DR route could reach £ 210 / t steel. For comparison, at $100-110 /t coking coal price, the cost of coking coal in the production of BF steel is around £ 55 / t.

A COMMON DRI HYDROGEN-BASED FACILITIES FOR THE INDUSTRY

#1 DRI IS THE MOST ADAPTED SOLUTION TO CHALLENGES OF THE UK INDUSTRY

The hydrogen DRI technology seems the most adapted solution for the UK industry. This technology would allow to:

- Start developing a DRI gas-based steelmaking with a proven methodology with a very limited technological risk with an immediate impact on CO_2 emissions.
- Compensate for the decrease of productivity of the coke ovens in Port Talbot and Scunthorpe by adding DRI to the blast furnaces (up to 25%) and therefore allow a smooth transition with a significant CAPEX avoidance on the life extension of the coke ovens.
- Preserve the full range of steel produced and the downstream capabilities.
- Switch to hydrogen when the technology will be proven (SSAB intends to sell the first fossil-free steel in 2026).
- Decide to transition to grey hydrogen first or to wait until 2030 when green hydrogen is expected to become the cheaper source of hydrogen.
- Transition more gradually to a new technology (EAF based) and therefore protect the workforce during a fair and just transition which could span between now and 2035 when the technology could be available or later depending on the end of life of blast furnaces.

The absence of redundancies during the transition is a condition of the support by the stakeholders without which the changes would have a high probability to fail.

#2 BUILDING BRIDGES AMONG POTENTIAL PARTNERS

A DRI facility could be of interest for the whole of the industry including the current EAF based producers. Nevertheless, most of the players are too small not only to cover the CAPEX requirement but also to legitimate the investment in a large facility. Voestalpine 2mt of HBI in Texas which started production in 2018, had a total cost of US$1.1bn.

As a first step, a DRI facility could be built separately by a third party and sell its production to the different players. This could allow to develop in parallel a hydrogen facility by another partner. The industry would then mutualise the risks and benefits of the development of the new technology. This would reduce the CAPEX required up front and could also facilitate to support from the government. This support will be key as none of the private producers will be in position to afford the costs of the transition, in the UK as any countries in Europe.

The support to the development of a DRI-Hydrogen facility in the UK will benefit the entire economy as it will allow a significant step toward critical mass for the hydrogen in the UK.

ACHIEVING A JUST TRANSITION

Perhaps the greatest challenge around all of this is how to implement the new low carbon technologies, whatever they are, in such a way as to achieve a just transition for employees and communities. Most options for decarbonisation also result in increased productivity and potential loss of front-line jobs. The challenge facing the sector is that any investment which does not also increase productivity will leave the steel plant unable to compete in the global steel market, or else be displaced by a potential inward investor in the UK, which could be devastating for existing steel communities

The consequence of this analysis is that decarbonisation of the steel sector and choices made by individual companies, need to be taken into consideration alongside the UK's wider industrial strategy, particularly with regard for investment and growth in new jobs in the green economy but also with a specific effort on the procurement strategy and the supply chain to support the development of local production as part of a greener solution.

The improved competitiveness of the UK steel industry must become the foundation of new era of growth particularly in the downstream activities where thousands of jobs could be created. The decarbonisation model favoured in this paper, a DRI-hydrogen- EAF based solution, would take a decade, meeting all milestones of the Paris agreement but allowing a smooth and just transition for the workforce.

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