Presentation of the Chapter on “Iron and Steel”

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“Towards Low-GHG Emissions from Energy Use in Selected Sectors”

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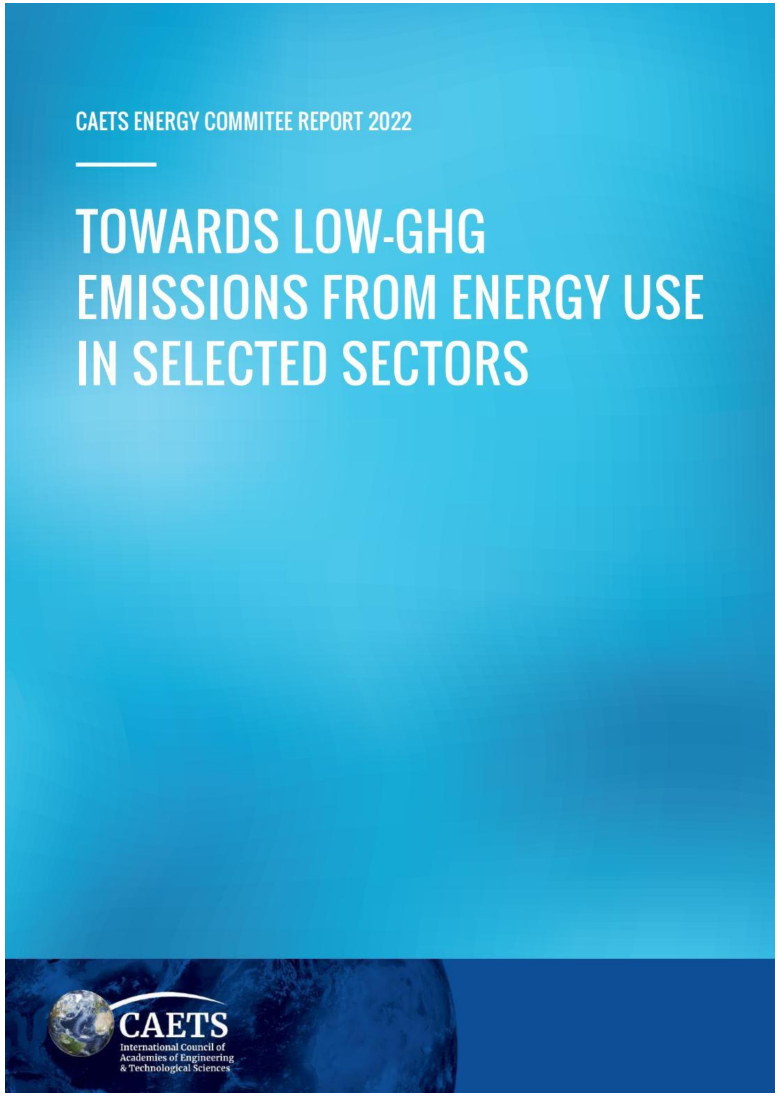
TOWARDS LOW-GHG EMISSIONS FROM ENERGY USE IN SELECTED SECTORS



- **Executive summary** *Yves Bamberger (France)*
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- **Chapter 6. Iron and Steel industry** *Woong-Seong Chang (Korea) Alvarez Pelegry Eloy (Spain)*
- **Chapter 7. ICT** *Erol Gelenbe (France) Brunilde Sanso (Canada)*
- **Chapter 8. Conclusions** *Yves Bamberger*
- List of the 69 authors; list of other contributors, reviewers (internal – external)
- Annexes: data and information by countries and sectors

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The authors regret the passing away of **Professor Benjamin I. Imasogie**, a deeply engaged member of the Working Group. They acknowledge his valuable contribution by dedicating this chapter to him.

Structure of the chapter

- Executive Summary
- Introduction
- Current situation of the sector
- Existing, forthcoming and possible breakthrough solutions
- Recycling: scrap metal combined with direct reduction or arc furnaces
- Challenges related to the decarbonisation of the manufacturing processes
- Case Studies: China, Japan, Korea, Sweden, USA, EU
- Key Messages and Recommendations….

Introduction

- This chapter introduces **current process technologies** already resulting in lower greenhouse gas emissions than previous ones, already existing but still not widely deployed, as well as radically new technologies, deployed on the scale of pilot projects, e.g., **hydrogen-based melting and reduction processes**.
- Case studies illustrate these revolutionary processes, which do, however, depend on the availability of **'green' hydrogen**, produced via water electrolysis using **low-carbon electricity**, which does not come for free and is mostly available in an intermittent mode.
- Furthermore, the chapter analyses the **recycling of steel (scrap)**, which raises its own issues as different steel products for different uses incorporate a variety of other elements, such as manganese, copper, nickel, etc. to acquire the required characteristics, which cannot be easily separated from scrap. Electricity also plays a major role in recycling scrap, using EAF.
- Last not least, it also touches on societal acceptability, in particular in relation to **Carbon Capture and Storage (CCS)**. It should be mentioned that the advancement of steel materials may indirectly result in further reductions in CO2 emissions.

Current situation/Interactions

- In 2021, the production of crude steel increased to around 1,950 million tonnes, and demand for steel is expected to inevitably increase as populations grow and nations around the world seek to improve their standards of living. Also shall be crucial and necessary for energy transition as an infrastructure enabler.

- The production of steel remains a CO_2 - and energy-intensive activity. In 2019, to produce some 1, 880 Mt steel, the iron and steel sector accounted for around 10,000 TWh of global energy consumption, which represented 20% of the industrial energy use and 8% of the total final energy use.

- On average, every metric ton of steel produced led to the total emission of 1.85 tons of CO_2 , including direct process emissions (1.4 tCO_2) and indirect emissions such as associated with electricity from the grid; the direct emissions from the steel industry were of the order of 2.6 $GtCO_2$, representing between 7 and 9% of global anthropogenic CO_2 emissions.

Current situation/Interactions

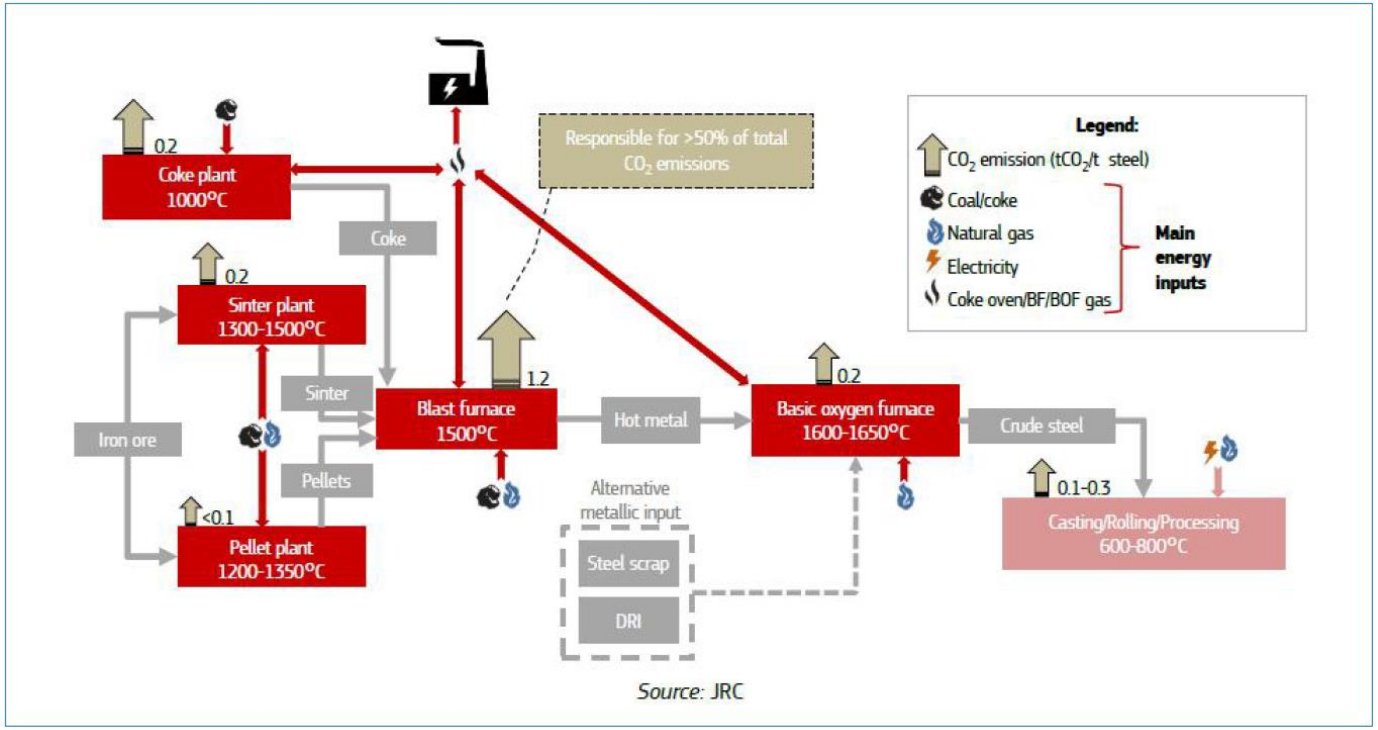


Fig. 6.12. Simplified flow diagram and CO_2 emissions of the BF-BOF route, not including the EAF

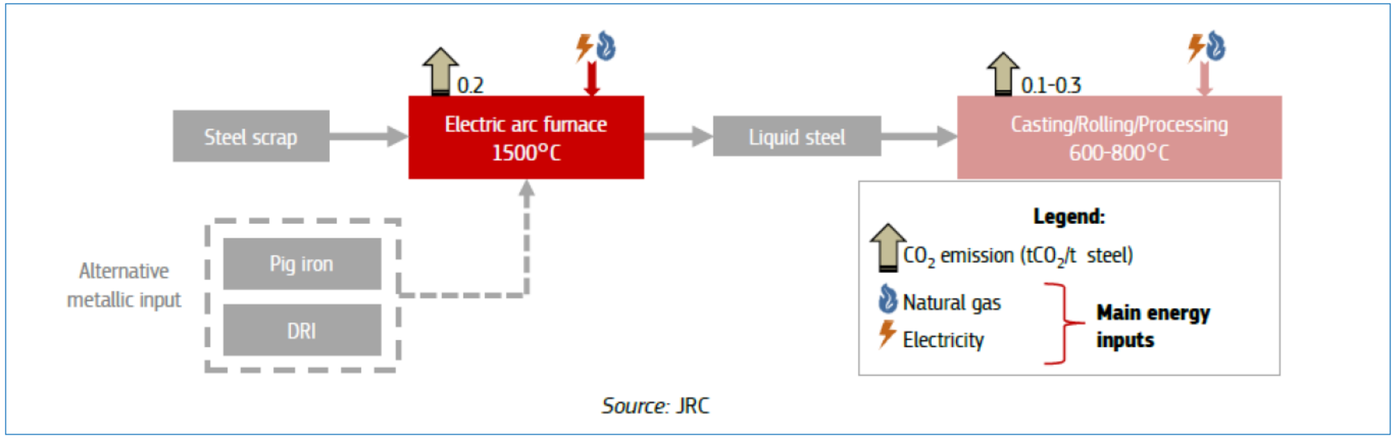


Fig. 6.13. Simplified flow diagram and CO_2 emissions of the EAF route

Existing, forthcoming and possible breakthrough solutions

- Steelmakers use and consider various existing and forthcoming solutions, such as making the maximum use of scrap, bio-coke injection, CCUS strategies, the direct reduction of iron ore with hydrogen, etc. in order to find pathways to decarbonisation.
- In line with the strengthening of environmental regulations, further developments are expected to be required in power-saving technologies involving for example VOC control technology, electric furnace heating technology, and preheating methods, along with processing technology to remove impurities from iron-based scrap.

	Strategy	Examples	Current Outlook
BF / BOF Efficiency Programmes	Make efficiency improvements to optimise BF / BOF operations	Increased Scrap in BOF, Scrap Charging in BF, Fuel Changing in BF	Technology readily available, often extensive retrofitting
Biomass Reductants	Use biomass as alternative fuel source	Tecnored process	Available in localised regions where biomass is available – South America & Russia
Carbon Capture & Usage	Capture CO_2 emissions and create new products	Bioethanol production from CO_2 emissions	Yet to be proven at industrial scale within steel industry. Some examples within Cement.
Electric Arc	Maximise recycling via EAF	EAF used to melt scrap	Technology available at scale
DRI & Electric Arc manufactured by NG	Replace some scrap with DRI	DRI plants already utilise NG	Technology available at scale
DRI manufactured by Hydrogen in EAF	Replace NG in DRI process with Hydrogen	Midrex Process running on Hydrogen HYBRIT process running on Hydrogen	High-cost technology requiring significant investment in both Hydrogen generation & DRI capacity

Potential technology pathways for existing and forthcoming solutions

Recycling:
scrap metal combined with direct reduction or arc furnaces

- Globally, the route to decreasing emissions is likely to be a transitional one; regional interests, geographical and local conditions, and technological availability being the limiting factors that impede the rate of progress.

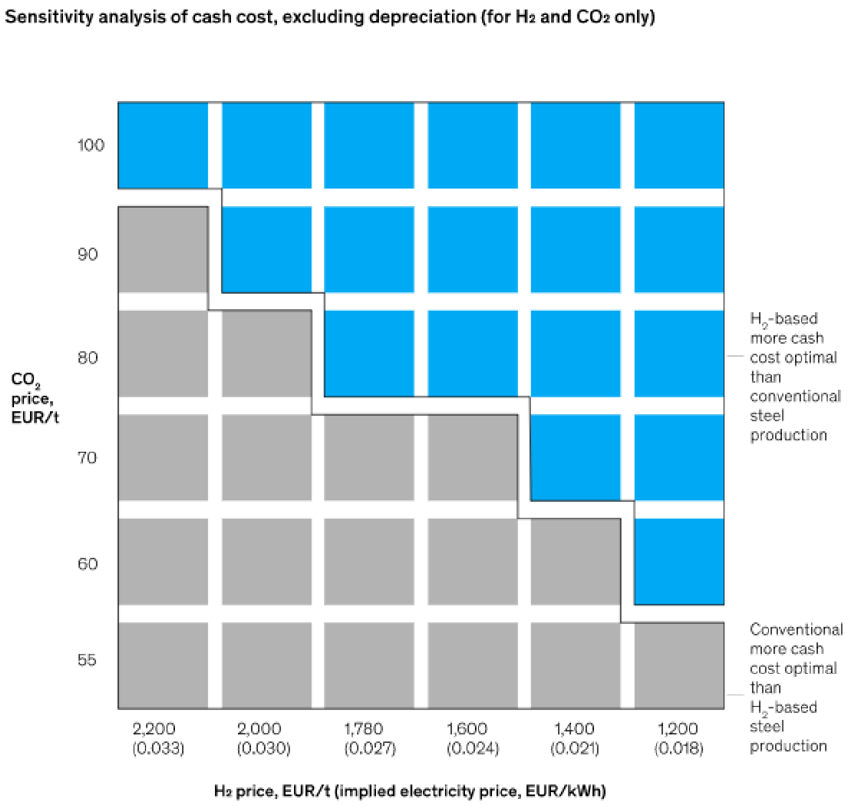
- The use of ferrous scrap gradually increases along with the growing emphasis on greenhouse gas regulations. Integrated steel mills typically use about 15% of scrap on average together with molten hot metal. Increasing the use of scrap can reduce the amount of greenhouse gas generated per tonne of molten steel.

Challenges: decarbonisation of the manufacturing processes

- Hydrogen has been proven within several routes of introduction to the steel manufacturing process. These methodologies increase the cost of the steel manufacturing process and require significant investment to retrofit existing infrastructure to handle hydrogen either as an injectant in the blast furnace as a replacement for Pulverized Coal Injection (PCI).

- Today, the cost/price of low-carbon hydrogen is very high compared to either grey (from methane) or blue (produced with gas and CCS). The price, however, is expected to decrease over the coming decades.

- The total electricity needed to produce two million tonnes of hydrogen-based steel is about 8.8 TWh. With the current cost of CO2 emission taxes increasing towards EUR 100/tCO2 , and the cost of H2 production reducing as manufacturing methodologies mature, H2-based steel production could soon become more cost-optimal than conventional steel production.



Hydrogen Price vs. CO2 price

https://www.mckinsey.com/~/media/McKinsey/Industries/Metals%20and%20Mining/Our%20Insights/Decarbonization%20challenge%20for%20steel/Decarbonization-challenge-for-steel.pdf

Case Studies

- Worldwide case studies have also been introduced in the report. In the Republic of Korea, POSCO plans to build its Hydrogen Reduction (HyREX) pilot plant for low-carbon ironmaking based on fluidised bed reduction technology by 2028.

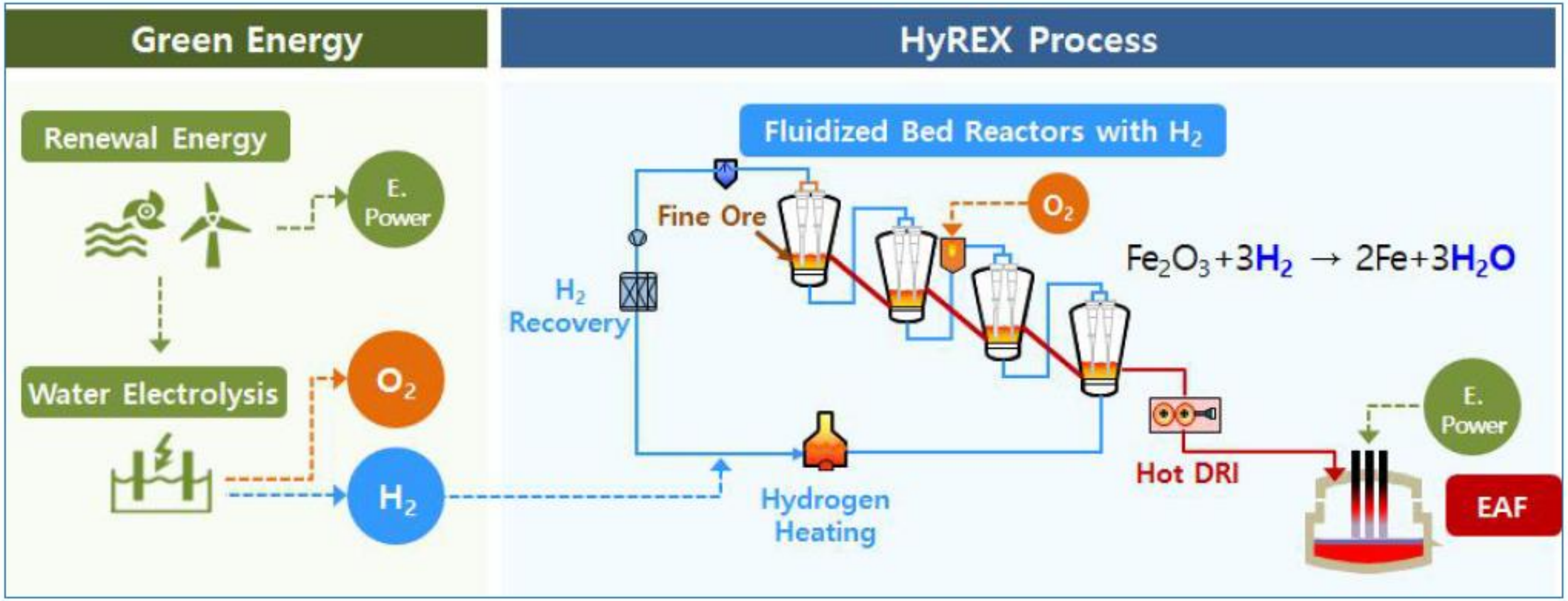


Fig. 6.27. The HyREX Process using 'green' energy

Case Studies

- Swedish SSAB, LKAB and Vattenfall use the Hydrogen Breakthrough Ironmaking Technology (HYBRIT) to eliminate the formation of CO2 by using low-carbon hydrogen as reductant and energy source. In the case of HYBRIT, sponge iron is produced with hydrogen gas as the reductant. Using this technology, SSAB has decided to phase out all of its five blast furnaces before 2030 in Sweden and Finland.

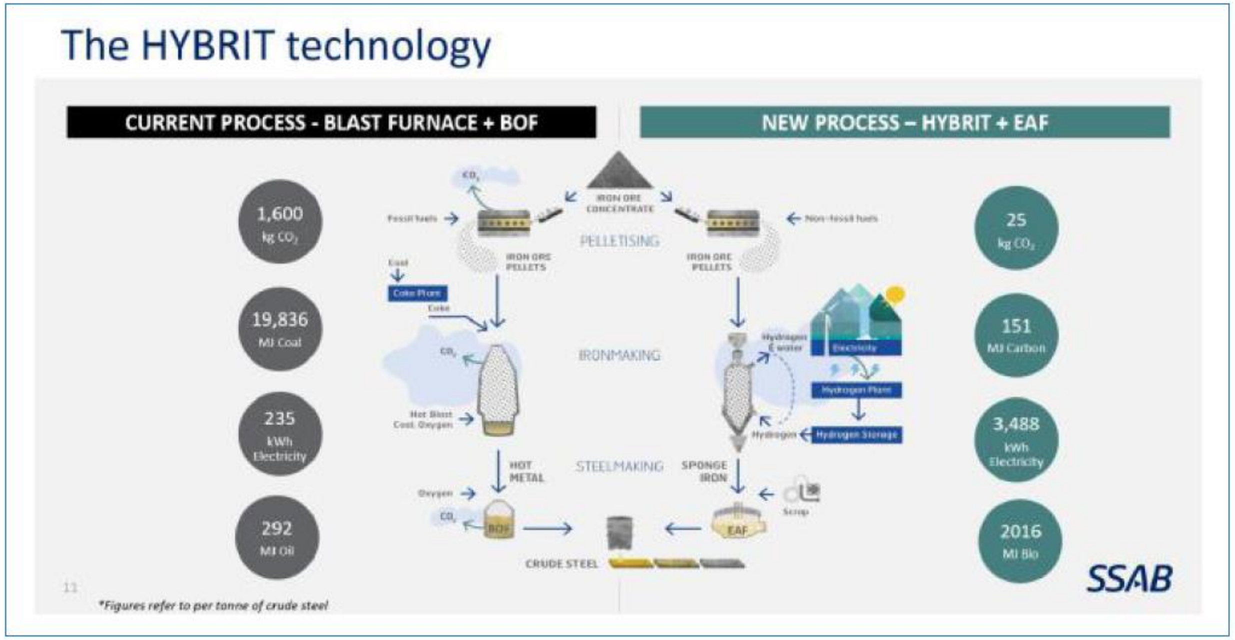


Fig. 6.28. HYBRIT flow diagram

- In China, Baowu's hydrogen-based shaft furnace direct reduction technology, and the hydrogen metallurgy demonstration project of the HBIS group, which has an expected annual output of 1.2 million tonnes hydrogen steel are being promoted. In addition, significant advances are being made by world-leading steel makers in the Japan, USA and Europe

Key Messages and Recommendations

1. The steel industry plays a prominent role in today's world, in terms of production volumes and sales (1950 Mt in 2021). The steel industry is at the same time a major source of CO_2 emissions: in 2020, its total direct emissions were of the order of 2.6 $GtCO_2$, representing between 7% and 9% of global anthropogenic CO_2 emissions. Mining of minerals represent small portion of the total emissions in the supply chain.

2. In the energy transition economy towards global decarbonisation, steel is a necessary material in a wide range of applications. The use of steel is expected to continue to increase in the future, even with recycling and the more widespread use of scrap metal as a raw material. In addition, market demand for low-carbon steel is already rising and highly valued.

3. In the existing production processes, coal is the dominant energy source, accounting for about 16% of global coal demand in 2019. On the whole, the BF / BOF route is mainly used, representing 73.2% of the production processes worldwide vs. 26.3% for the EAF, although there are substantial differences across regions and countries.

4. The increased use of EAF and the use of scrap will contribute to decreasing carbon emissions. Technologies that contribute to improving the quality of final products from scrap may be further developed.

Key Messages and Recommendations

5. Although there is no single final scenario, the direct reduction of iron ore (DRI) using low-carbon hydrogen is now regarded as the most viable option and the long-term solution to achieving carbon-neutral steel production. Various processes are under development and at pilot scale: their economic viability will certainly be proven before 2030. The availability and cost of low-carbon hydrogen will be key for the massive implementation of these processes.

6. Existing technologies with an appropriate Technology Readiness Level (TRL) already contribute to decreasing CO2 emissions. Such technologies are related to energy efficiency, the use of biofuels, utilisation of residual energies, electrification, and direct reduction of iron ore by gas instead of coal.

7. CCS in combination with steel production has not yet been proven on an industrial scale. This could change during the course of this decade with several projects at different stages of implementation in different countries.

8. Huge investments are needed to replace or renew facilities, and such long leading time may imply stranded assets.

Key Messages and Recommendations

1. On increasing scrap use

We recommend expanding the use of steel scrap, which may be regarded as an important green resource for reducing greenhouse gas emissions, through not only the adoption of common rules and specifications but also the development and implementation of new scrap processing technologies to improve the removal of impurities.

2. On modifications that allow existing facilities to reduce CO2 emissions

Considering the urgency of reducing CO2 emissions and the lifetime of many existing facilities, we recommend implementing every possible and economically affordable, even marginal, reduction of CO2 emissions for existing steel plants: partial electrification in heating, the use of biomass, utilisation of residual energies, better command-control, etc.

3. On a potential acceleration of the timing of CO2 emissions reduction

We recommend that the existing important projects and demonstration plants that will lead to scalable breakthroughs at industrial and commercial levels be sufficiently incentivised and promoted so as to rapidly deploy in the 2030s or even earlier if possible.

Key Messages and Recommendations

4. On Research and Development

Funding for long term research – typically 10 years or more – and knowledge development needs to be secured and creative and unique solutions should be supported. We therefore recommend that support for pilot and test facilities be maintained or even increased, and more resources be made available for basic and applied research and up-scaling, as well as to enforce collaborative research involving the industry on a global scale.

5. On Education and Training

We recommend taking advantage of the gradual changes ahead and the associated development of new knowledge and skills needed to design, build and operate this new world of iron and steel. This would attract more young people to this sector, which is considered less attractive than others in many countries. As practical knowledge is likely to originate at the engineering level, we recommend promoting the ‘spill-over’ effects from such knowledge to universities and other institutions.

Key Messages and Recommendations

6. On Permitting

New or rebuilt process facilities, new technologies, the use of hydrogen and increased demand for electricity, etc. – these all require political approval from the authorities. In order to foster the necessary investments and accelerate their realisation, we recommend that the permitting processes be clear, appropriate, stable and efficient, i.e. simplified and accelerated in many countries.

7. On global cooperation and partnerships

The steel industry is a globally competitive and capital-intensive industry. We recommend supporting cooperation and partnerships in the development of new technologies and sharing experience and costs in order to accelerate development, make technology licensing available at a fair price and, at the same time, ensure competition

THANK YOU!

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