Green Steel and Future Steel Visions

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Abstract — Steel is one of the most traded commodities in the international arena. People discuss the steel industry's enormous carbon footprint and consider alternative production modes. Green steel is a slogan expressing environmentally friendly steel production with reduced carbon emissions.

Since our country is one of the important steel-producing countries in the world, it is necessary to carry out studies on green steel production and to follow the studies carried out in other countries. In this study, policies and studies in the field of green steel are examined in detail, together with examples. It is aimed to convey this information to steel producers in our country regarding the subject.

Keywords— Green steel, CO_2 emission, climate change

I. Introduction

It is a slogan that expresses environmentally friendly steel production as the answer to the question of what is green steel. "Green steel" can be expressed as a label that is easy to apply but much more difficult to obtain. Besides, «Green steel» refers to steel production with carbon emissions (carbon footprint) that can be monitored, as much as possible with reduced carbon emissions.

The 2050 targets for future investments in the steel industry should be analyzed. The presented methodology can be used to define what "green steel" is and what policies will be needed to comply with climate goals. The methodology is built on a life cycle perspective. Connects the 2050 targets and possible technical pathways for the steel industry

Climate change has an increasing place in the global political agenda (Fig.1). Many governments are announcing ambitious environmental targets, raising the need to develop low carbon versions of the steel material.

With the increasing importance of renewable energy and the recent commitments of many automakers around the world to switch to electric motors, heavy industries such as steel, cement and petrochemicals that require excessive heat are likely to be one of the next targets of the world (Fig.4).

Fig. 1. Temperature index of global

II. CO_2 emissions in steel production

Fig. 2. CO_2 emissions in steel production

Fig. 3. CO_2 emissions in green steel production

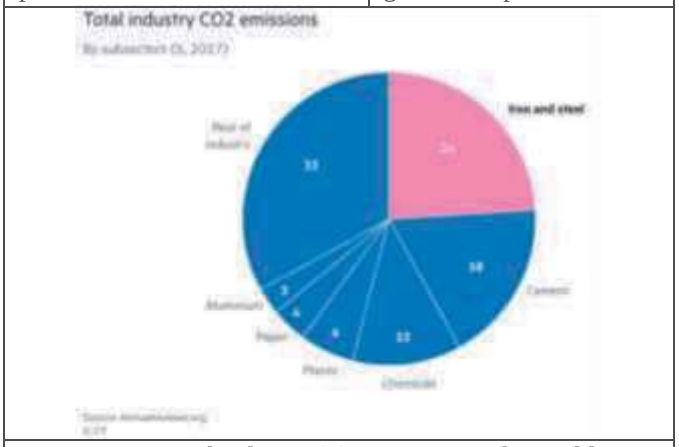

Fig. 4. Total industry CO_2 emission in the world

By 2020, steelmaking is estimated to be responsible for 7 to 9 percent of direct fossil-fueled greenhouse gas emissions. Making 1 ton of steel produces about 1.8 tons of carbon dioxide (Fig.2,3,4).

Since the beginning of the Industrial Revolution (about 1750), human activity has generated a 45% increase in atmospheric carbon dioxide concentration from 280 ppm in 1750 to 415 ppm in 2019.

Steel is essential for modern life. A huge carbon footprint of the steel industry is discussed and alternative production methods are evaluated.

To understand how to reduce emissions from steelmaking, you must understand how it is produced. The basic understanding of this subject is that there are two main processes for steel production. One of them is called blast

furnace (BF) - basic oxygen furnace (BOF) method, the other is electric arc furnace (EAF).

When we mine iron ore, it is obtained inbound with plenty of oxygen. It is necessary to eliminate the oxygen in the iron. Most of the emissions from steelmaking come from the industrial process using coal as the carbon source that removes oxygen from iron ore in the following chemical reaction in a blast furnace (Fig.5):

Fe_2O_3 (s) + 3 CO (g) → 2 Fe (s) + 3 CO_2 (g)

Then we get steel by adding alloying elements, carbon, chromium, zinc, and other elements.

About a tenth of global greenhouse gas emissions come from steel. Good recycling practices will reduce the steel industry's environmental impact. Thanks to better recycling, infinite recyclability of iron can be used. This means that less iron ore has to be processed than greenhouse gas-intensive processes.

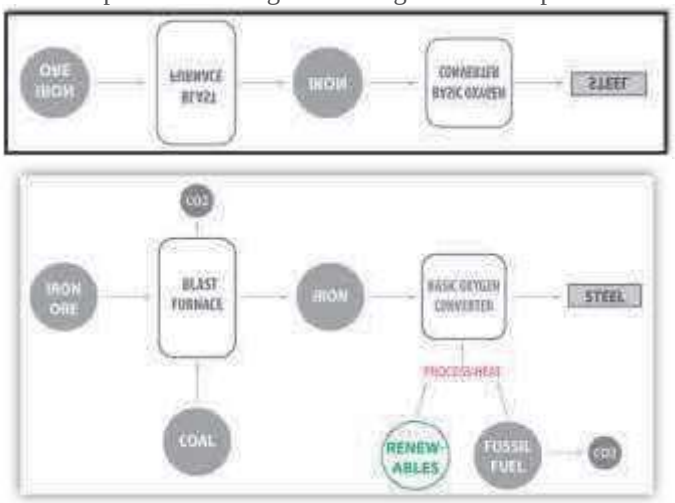

Fig. 5. Steel production from iron ore

III. Policies on green steel

The Paris Agreement is an agreement within the United Nations Framework Convention on Climate Change, concluded in Paris in 2015, and its purpose includes taking necessary measures to keep global warming below 2 °C, e ven operating below 1.5 °C. It started in 2020.

According to the International Energy Agency, to meet global climate and energy targets, steel industry emissions must fall by at least half by the middle of the century, and then it is aimed to be reduced to zero.

There is a widespread consensus that if we want to contribute to achieving the climate targets set in the Paris agreement, it is not enough to increase efficiency in the blast furnace alone. Different and groundbreaking technologies are urgently needed.

Some of the world's largest steelmakers, including ArcelorMittal, Thyssenkrupp, and Baowu Group in China, are working on various stages of transforming their lab concepts into an industrial reality. Some even announced targets for "net-zero" emissions.

US president Joe Biden has proposed to set up a climate research agency with goals that include "the decarbonization of industrial heat needed to make steel, concrete and chemicals", s well as rejoining the Paris climate agreement, which pledges to reduce global temperature increases to well below 2 °C.

"You cannot expect steel to move forward at its current pace and then reach net zero in emission," says Carole Ferguson, head of investor research at CDP, the climate assessment group. Honestly, I think it's not fast enough. He says you need to start investing now to be able to make the transition.

Without incentives, green steel is extremely expensive for producers. This is why decarbonization of heavy industry is said to be difficult. Trials of several different technologies are really expensive for a single firm unless there is a big profit. Technologies and policies that can help promote environmentally sustainable production processes are needed.

It is stated that the European governments have accepted the absence of taxes in this area to support the growth of renewable energy.

In addition to funding for sustainable projects under the "European Green Deal", it is stated that plans are being prepared for a "carbon limit adjustment mechanism" to apply a CO_2 load to certain goods currently entering the union. The idea is to avoid other cheap foreign products by protecting companies that invest in expensive green technologies.

Some manufacturers state that from a cost perspective and economic analysis they have yet to see the right conditions to facilitate a wholesale change across the industry.

"These technologies will increase the cost of our steel. It's not cheap and our customers should be prepared to pay for it," says Lakshmi Mittal chairman of the board.

IV. Studies on green steel

In 2003, the World Steel Association (worldsteel) launched the "CO_2 Breakthrough Program", an initiative to exchange information about regional activities around the world.

Five key directions identified from ore-based steelmaking pathways to breakthrough technologies to reduce CO_2 emissions (Fig.6):

Coal
Hydrogen
Electrons
Biomass
Carbon capture and storage

Energy-saving potential technologies in 2016, it is shown in fig. 7.

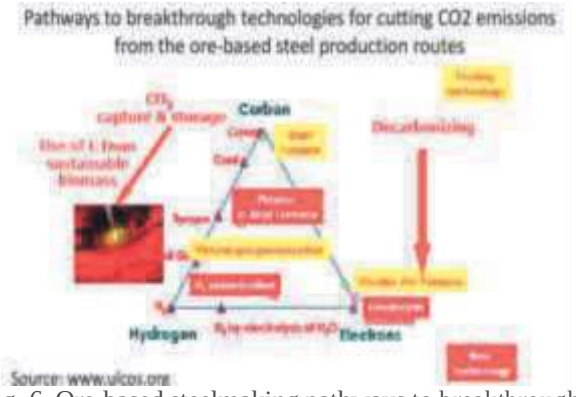

Fig. 6. Ore-based steelmaking pathways to breakthrough technologies to reduce CO_2 emissions

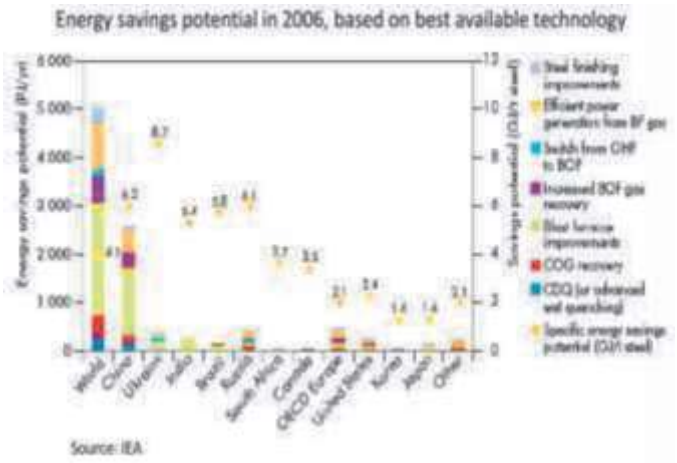

Fig. 7. Energy-saving potential technologies

As the steel industry is one of the largest emitters of CO_2 contributing 7-9% of global greenhouse gas emissions, it is imperative to find a low carbon process for primary steel production to stick to a 1.5 °C path.

Several non-coal-based technologies for primary steel production are currently being tested and are the most advanced hydrogen-based direct reduction method.

In the United States and the European Union, the transition to hydrogen-based steel production represents an opportunity for new assets to instantly reduce CO_2 emissions by 20% and 40%, respectively.

Given that electricity and coking coal prices are not interdependent, the additional 20% cost of hydrogen-based steel production can be met with electricity prices of $ 15-20 / MWh or less. This is a cost level already achieved by many renewable power plants today. While this may seem promising, all-steel mills of all companies currently investing in or committed to zero carbon technology represent only 8% of global steel production. A market and financial intervention are needed to accelerate the deployment of low carbon technologies. Because it is stated that the transition speed should be 100 times the current situation to stick to the targeted path of 1.5 °C.

Another important statement of intent last year announced China's "carbon neutral" target by 2060. This will require major improvements in steel mills, which are responsible for about a third of the country's industrial emissions. The superpower in Asia has a very significant influence on the global market as the source of half of the world's steel.

The most ambitious plans are the principle of converting iron ore to metal, using "clean" hydrogen gas as a new alternative energy source (Fig 8).

"In the laboratory setting, it is known that H_2 is in principle capable of reducing iron ore to metallic iron under the right conditions." But so far no one has done this on an industrial scale," says Lutz Bandusch, ArcelorMittal's senior manager.

It has been announced that it will begin trials using hydrogen gas to reduce iron ore at a pilot plant of SSAB in Lulea, northern Sweden. It is said that this process will cause almost no CO_2 emissions apart from the by-product water vapor. This focuses on reorganizing an existing system called direct reduced iron, which accounts for a small percentage of steel production worldwide. Natural gas is normally injected into DRI furnaces. Instead, SSAB will use clean hydrogen gas produced in a facility called an electrolyzer that runs on renewable electricity.

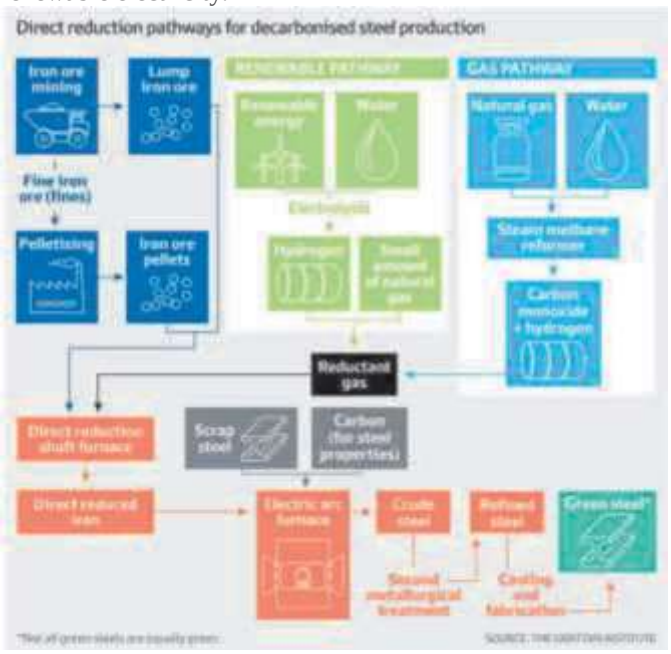

Fig. 8. Decarbonized steel production based on H_2

If at one end of the goal is the complete elimination of CO_2, other initiatives aim to prevent the escape of gases or to design intermediate solutions that can reduce emissions over time.

ArcelorMittal is building a plant at its Ghent factory in Belgium that will transform toxic waste wood into "bio-coal" with a lower CO_2 footprint to replace part of its structure in its blast furnaces. At the same facility, ArcelorMittal announced that it will spend € 165 million at the plant to capture waste gases.

In August last year, Thyssenkrupp announced plans to build a plant in Germany that could produce "carbon neutral" steel by 2025 using hydrogen from renewable energy sources instead of coal.

Chinese Baowu Group, one of the world's largest steelmakers, says the industry is working to reduce greenhouse gas emissions.

The US-based company Boston Metals, which left the Massachusetts Institute of Technology and supported by Bill Gates, says it has developed a technology to make brand new emission-free steel using electricity. In a method that is not different from aluminum production, it consists of a steel shell with 2 m edges, which it calls "molten oxide soup", including iron ore, where the current is passed through a cell. Far away from the blast furnaces up to 35 meters high that can be seen in large steel mills, the idea is that Boston Metal will supply small modular units to production sites that can be scaled to demand. Chief executive officer Tadeu Carneiro describes this as "the reverse of the battery". He says, "We're injecting electricity."

"The cell will produce a very pure iron that you can add other elements to get your high-quality steel," he says.

Fig 9 and 10 are shown in CO_2 emissions from different steelmaking pathways and their estimated utilization rates up to 2060.

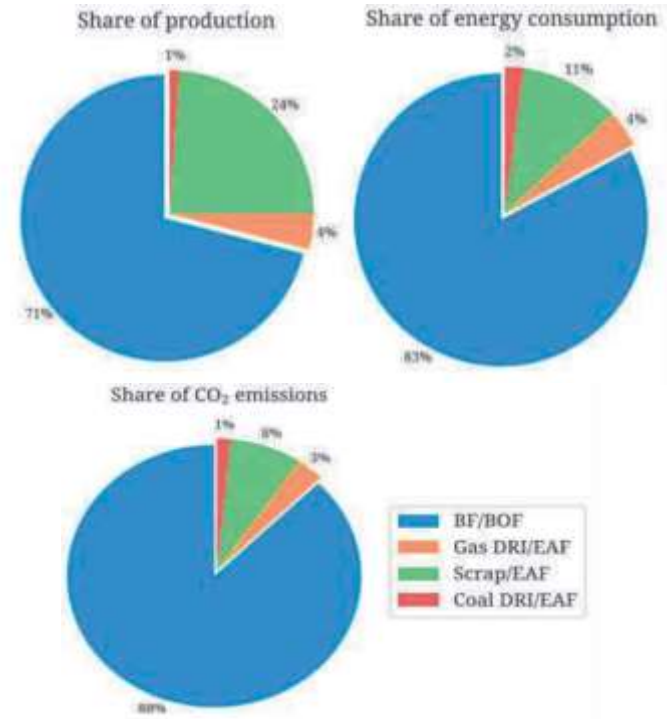

Fig.9. Share of CO_2 emissions from a) production, (b) energy consumption, and (c) different steelmaking pathways (the blast-furnace (BF), basic oxygen furnace (BOF), direct reduced iron (DRI), electric arc furnace (EAF))

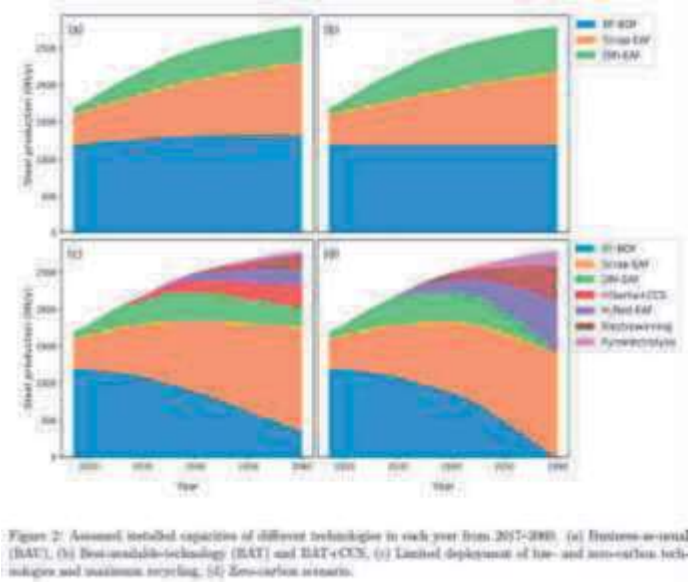

Fig. 10. Installed capacities of different technologies were assumed each year between 2017 and 2060. (a) Business as usual (BAU), (b) Best available technology (BAT) and BAT + CCS, (c) Limited use of low and zero-carbon technologies and maximum recycling, (d) Zero-carbon scenario.

V. CONCLUSION

Steel is one of the most traded commodities in the international arena. Our country is one of the important steel-producing countries in the world. Studies on green steel production must be carried out in our country and should follow the studies carried out in other countries. This study has been prepared to raise awareness on the "green steel".

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