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Research Article

Assessment for Replacing Coal and Petroleum Product with Green Hydrogen for Steel and Iron Production

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Abstract

Among the leading global contributors to anthropogenic CO_2 emissions, the iron and steel industries are energy-intensive sectors. This is due to the fact that fuel and iron ore are reduced using non-renewable energy sources like coal and charcoal. A tonne of iron is produced, and that produces roughly 1.9 tonnes of CO_2 gas. It is necessary to switch to clean energy sources from conventional carbon-emitting sources in order to lower emissions from the iron and steel industry. Hydrogen is a substitute fuel that has the potential to replace carbon-emitting fuel in the iron and steel sectors, according to the present trend in clean energy development. Hydrogen can be employed as a reducing agent in blast furnaces as an auxiliary or as the only reducing agent in the direct reduction process, which is how iron and steel are produced. Water is the only byproduct of the electrolysis process, which creates green hydrogen using renewable energy sources. In the iron industry, using green hydrogen can lower intensive carbon emissions. Green steel or iron production costs can be competitive and less carbon intensive if the cost of producing green hydrogen is low. In this paper, the steel and iron production from green hydrogen is studied to contribute to developing the conceptual design along with challenges for handling the hydrogen in these industries and compared with the conventional carbon-based process. In addition, the economic assessment for the production of steel from a green hydrogen-based process.

1. Introduction

1.1. Background

Mining is the extraction of valuable materials from the earth. Coal accounted for 26.7% of global primary energy consumption. Coal is a fossil fuel that accounts for 2% of primary energy consumption in Nepal, mainly used by the industries for heating and boiling processes in brick, lime, and cement production as well as in the mining sector [1]. Mining processes include ore handling, concentration, screening, pelletizing, sintering, smelting through blast furnaces or direct reduction with electric arc furnaces, and reheating furnaces in which coal is used as a reducing agent and as a fuel. The mining produces toxic gases like carbon monoxide (CO) and carbon dioxide (CO_2) due to the burning of fossils fuel. Various fossil fuels like coal, petrol, natural gas etc based mining companies have been operating in Nepal for the past 200 years. The industry included slate, limestone, iron, copper, and cobalt. These businesses typically consume the same amounts of heat, electricity, and mechanical energy. There may be potential to increase energy efficiency through the adoption of

cleaner technology, renewable energy sources, and process optimisation. The mining and processing steps are frequently energy-intensive. The site's mining operations have been suspended since the new administration took office in 1951 due to legislative changes, lack of charcoal for smelting, technical challenges associated with deep-level mining, etc. Since 1961, the Nepal Geological Survey and the Nepal Bureau of Mines have been conducting mineral exploration and geological mapping. Mining corporations began to explore minerals and energy between the 1960s and 1984. The exploration boom was supported by government agencies such as the United Nations Development Programme and the Department of mines and geology. Iron Ores present in Nepal can be found in, Ramechhap; Labdi Khola, Tanahau; Jirbang, Chitwan, and Phalam Khani, Parbat. The government of Nepal has established Dhaubadi Iron Company Limited in Nawalpur for the extraction of iron from the Dhaubadi mine [2].

In mining, coal is used as a fuel and reducing agent forming carbon monoxide when burned and reacting with iron oxide to produce carbon dioxide in blast furnaces but when green hydrogen replaces coal, it only produces water vapor as a byproduct instead of carbon dioxide. Decarbonised explosives have a number of advantages in the mining industry. Primarily, it aids in lowering the carbon footprint of mining activities, a crucial aspect of climate change mitigation. Furthermore, it has the potential to mitigate the quantity of dust and fumes produced during blasting, which may pose a risk to both the environment and personnel. Ultimately, by lowering the energy needed to fracture rock and metal deposits, decarbonised explosives can also contribute to increased mining operations efficiency.

The use of coal in iron mining causes a huge carbon emission. The steel and iron industry accounts for about 8% of the total carbon emission in the world. To reduce carbon emission from iron extraction an alternative renewable source is needed and green hydrogen is regarded as the most viable option in today's scenarios. Green hydrogen produced from the electrolysis process and renewable energy have a low carbon print. The impact of hydrogen could be substantially higher. Green hydrogen can also be utilized as a raw material to create "decarbonized" explosives, which can subsequently be employed in mining operations. As a result, green hydrogen has the potential to improve the energy independence from foreign oil for the mining process [3]. Green hydrogen is created by splitting water with electrolysis and obtaining hydrogen from sustainable energy sources. Green hydrogen now makes up only 0.1 percent of the worldwide hydrogen market due to its high electricity consumption, which makes manufacturing prohibitively expensive [4].

The first experiment in large-scale direct reduction using pure hydrogen is now being carried out at the SSAB steel facilities in Sweden under the HYBRIT project. The direct reduction of iron ore using hydrogen and renewable energy is the foundation of the HYBRIT process; the hydrogen reacts with the oxygen in the iron ore to generate metallic iron and water. Approximately 80% of the overall production costs, or EUR 1,000 per tonne of crude steel, will go towards capital costs associated with setting up an electrolyzer, a direct iron processor, and a hydrogen storage facility. This will result in a steel price of EUR 1,200 per tonne. The Port of Amsterdam, by far the largest, is in the feasibility study phase of a 100 MW electrolyzer that would produce 15,000 tonnes of green hydrogen per year while also producing oxygen for the steel plant. The first pilot that has been installed and is running is H2FUTURE in Austria, where a Siemens-supplied 6 MW PEM electrolyzer is powering a Voestalpine steel plant using power from Verbund's virtually completely renewable portfolio. [5].

The mathematical calculation involved in the design of equipment and modeling of components is based on assumptions, a few outdated data, and published reports. The cost of equipment and raw materials are all assumed to be the approximate value. There is a lack of validation with experimental data.
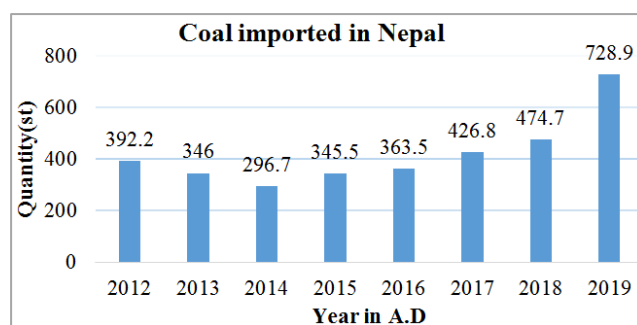
(a)
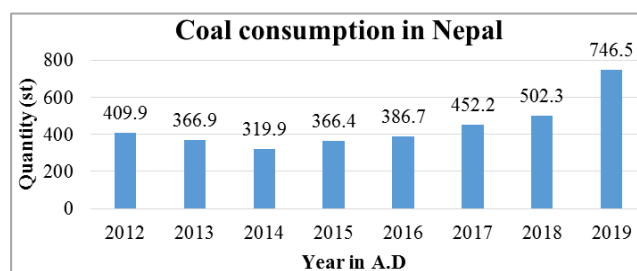
(b)

Figure 1. (a) Coal imported, (b) Coal consumption.

1.2. Research Objective

1) To explore the mining system in the case of Nepal, inspect the opportunities and challenges and investigate sectors of the iron mining system where coal can be replaced with green hydrogen.
2) To analyze the feasibility of replacing fossil fuels with hydrogen in iron mining for energy and carbon emission abatement.

3) To develop a systematic framework of mining with hydrogen as an energy source.
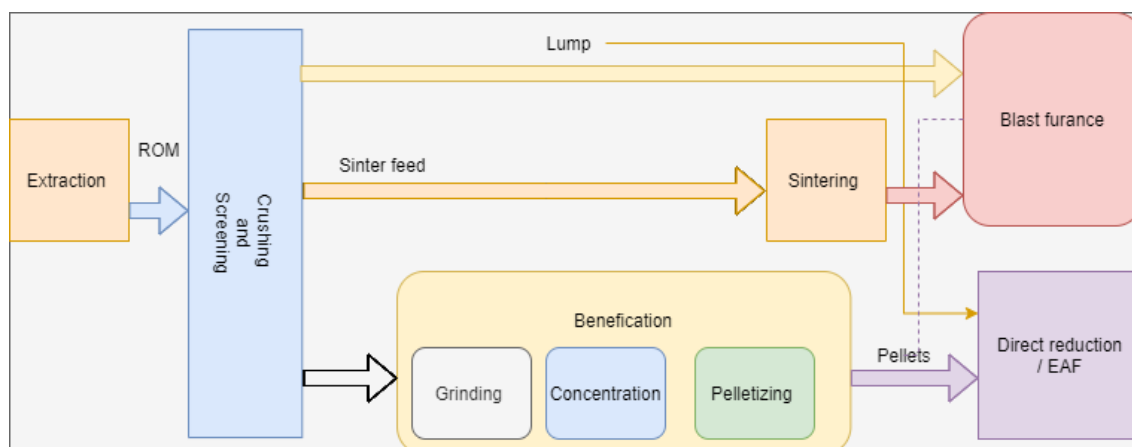
2. Literature Review

Figure 2. Iron production process [1].

2.1. Extraction

The mining process involves the excavation of large amounts of waste rock to remove the desired mineral ore [6]. An ore is a rock that contains enough metal to make it worthwhile extracting. Ores are extracted through different processes.

2.2. Crushing and Screening

In the minerals processing industry, crushing is the most important operation. The purpose of this operation is to create rock or (rarely) mineral fractions that can be used as raw materials in other industrial processes. Strength, size, and shape are the most common quality criteria [7]. Bypassing crushed ore through sieves, undersized material is separated into different parts. Lump or rubble ore (7 to 25 millimeters in size) is sorted from the fines in this way (less than 7 millimeters) [8].

2.3. Sintering

Sintering is the process of baking a powdered mix at high temperatures until it fuses, forming a porous mass that is subsequently deposited in a blast furnace. The goal of sintering ignition is to provide enough heat to the mixture's surface to ensure stable combustion. As NG gas is used as ignition fuel for better quality and higher heating values and fewer impurities of NG. Based on the fact that hydrogen is the cleaner fuel with a high calorific value, hydrogen as ignition fuel has greater potential to improve production efficiency and carbon emissions reduce [9].

2.4. Beneficiation

Beneficiation is the process of reducing ore size and separating gange from the ore. Because each iron ore deposit has its mineralogy, the beneficiation process is unique to each [10]. Under beneficiation grinding, concentration, and pelletizing are done.

2.4.1. Grinding

In the presence of agitated grinding media, the loose crusher products tumble freely inside the revolving mill. The diameter to length ratio of the cylinder and the type of grinding medium used are the main variations between these mills. As necessary for beneficiation, the grinding mill lowers feed particles from 5 to 20 mm to optimum sizes of 40 to 300 mm [11].

2.4.2. Concentration

The method of extracting iron begins with concentration by calcination, which is a thermal breakdown process in which a limited amount of oxygen is supplied to ores. Water and other impurities such as Sulphur and carbonates are removed during the concentration process. After that, the ore is combined with limestone and coke before being put into a blast furnace [12].

2.4.3. Pelletizing

Pelletizing is a process that involves combining extremely finely ground iron ore fines with additives such as bentonite, molding them into near oval/spherical balls with diameters ranging from 8 mm to 16 mm, and hardening them by the fire with a fuel [13]. The flexibility of pelletizing plant location is

limited due to the scarcity of NG in some areas and the difficulty of obtaining high calorific value gas. As a result, increasing the proportion of hydrogen in pelletizing plants will help to improve production efficiency, boost pelletizing plant flexibility, and minimize reliance on other fuels [9].

2.4.4. Blast Furnace

The reduction of iron ore to pig iron in a blast furnace is the most common steel manufacturing route in the iron and steel industry. The integrated plant's BF-BOF operation runs almost entirely on coal products, emitting 70% of CO_2 (BF iron making). Steel HM is produced by charging hot iron into a basic oxygen furnace (BOF) (BOF steel making). Coking, pelletizing, sintering, finishing, and associated power production are all included in a BF-BOF production plant [14].

2.4.5. Direct Reduction of Iron

With a reaction temperature below the melting point of iron, this iron production process directly reduces iron ore to a solid form. Syngas, a combination of H2 and CO, are created from natural gas (gas-based DRI) or coal (coal-based DRI) to produce reducing gases. Although DRI manufacture is more energy-efficient than pig iron production from BF, DRI sponge iron requires additional processing (usually EAF) before it can be sold [14].

3. Technical Analysis

3.1. Blast Furnace

The main chemical reactions in the furnace are
Here iron oxide (Fe_2O_3) reacts with coal (CO) and green hydrogen to produce iron (Fe).
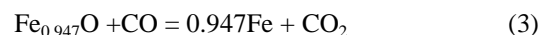
(i) oxidation of carbon by air in front of the tuyères to give C02 plus heat;

$$C + O_2 = CO_2 \quad \Delta H = -394000 \text{ Kj (Kg mole of } CO_2)^{-1} \quad (1)$$

(ii) endothermic reaction Of the CO_2 with carbon to produce CO, the principal reducing gas of the process:

$$CO_2 + C = 2 CO \quad \Delta H = 172000 \text{ KJ (Kg mole of } CO_2)^{-1} \quad (2)$$

(iii) reduction of iron oxides to give metallic iron:

$$Fe_{0.947}O + CO = 0.947Fe + CO_2 \quad (3)$$

$$\Delta H_{298}^0 = -1700010 \text{ KJ (Kg mole of } CO_2)^{-1}$$

$$1.2Fe_3O_4 + CO = Fe_{0.947}O + CO_2 \quad (4)$$

$$\Delta H_{298}^0 = 50000 \text{KJ (Kg mole of } CO_2)^{-1}$$

$$3Fe_2O_3 + CO = 2Fe_3O_4 + CO_2 \quad (5)$$
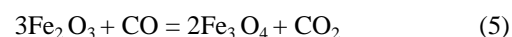
$$\Delta H_{298}^0 = -48000 \text{KJ (Kg mole of } CO_2)^{-1} \text{ [15]}$$

Let's assume 20 moles of coal and 80 moles of H_2 the extraction of iron

$$2Fe_2O_3 + 3CO + 3H_2 = 4Fe + 3CO_2 + 3H_2O + Fe_2O_3(\text{excess}) \quad (6)$$

For the calculations, we have taken the values of a, b, c, and d [16]. We had simply done it in excel. We need the value for calculating C_p because C_p is the function of a, b, c, and d.
As we know $C_p = A + Bx + Cx^2 + Dx^3$ so we need these values.

Table 1. Calculation of ΔH.

			t initial	298	K		
			Tstandard	298	K		
			T final	2273	K		
	N_{in}	N_{out}	v	A	B	C	D
Fe_2O_3	100	66.66667	2	11.812	0.009697	0	-197600
CO	20	0	3	3.507	0.003376	0.000000557	0
H2	80	0	3	3.468	0.03249	0.000000422	0
CO_2	0	20	3	4.467	0.005457	0.000001045	0
H2O	0	80	3	4.038	0.00347	0.00000145	0
Fe	0	66.66667	4	-0.111	0.06111	0	1.15

	N_{in}	N_{out}	v	A	B	C	D
			t initial	298	K		
			Tstandard	298	K		
			T final	2273	K		
del A	1528.78				del a	1192.446667	
del B	3.63642				del b	5.107206667	
del C	0.0000449				del c	0.0001369	
del D	-19760000				del d	-13173256.67	
del cp	0				del cp	16887232.71	
$H_1=$	0				$H_2=$	140569325.1	
$H_{rxn}=$	-24767.8						
total $\Delta H=$	140544557	J/mol					

3.2. Direct Reduction of Iron
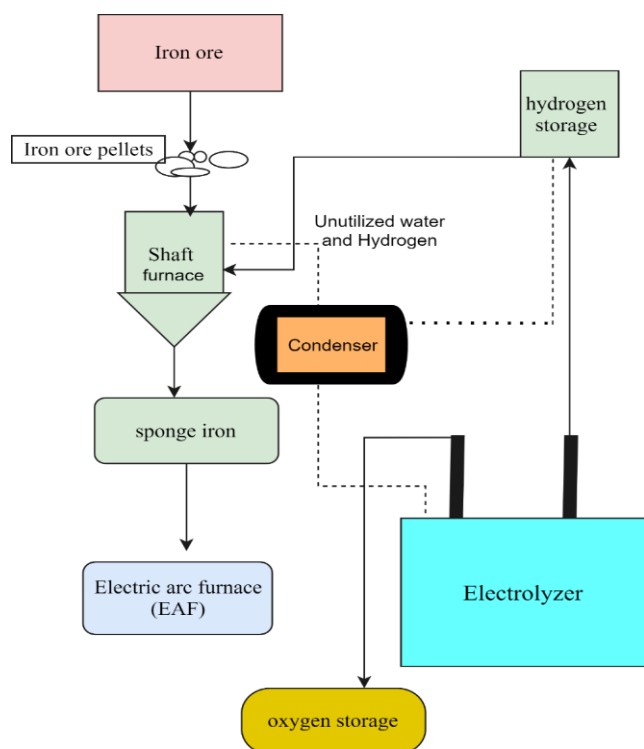
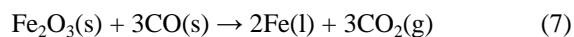*Figure 3. Process flow diagram of Hydrogen based DRI/EAF.*

The green hydrogen-based DRI-EAF system is illustrated in Figure 3. The hydrogen-based DRI system by-product is water hence, requires a water vapor removing system. The green hydrogen gas can be used in the vertical furnace similar to other gas-based processes. The water vapor after condensing can be sent to the electrolyzer for hydrogen generation. The heat accumulated from unreacted hydrogen and water can be reused in the furnace. Here the operating temperature of the shaft furnace is 1073 kelvin. In the shaft furnace reduction of iron takes place from which water vapor is the by-product and the product is sponge iron which is moved to EAF for further processing. During the electrolysis of water, produced oxygen can be stored and used for different applications. As estimated in 1 bar pressure and a temperature of 298 kelvin hydrogen is injected at the flow rate of $675m^3$ per ton of sponge iron. Here we have used a PEM electrolyzer because it has the advantages of fast start-up, no corrosion, simple maintenance, and fewer components At present, the most advanced equipment can produce hydrogen of $400m^3$/h [17]. Iron ore is pre-heated and fed into a reduction shaft, where it is converted to direct reduced iron (DRI) and further compacted to hot briquetted iron (HBI). Hydrogen generated from the electrolysis unit is pre-heated in a condenser before being supplied to the shaft where it acts as the reducing agent. Surplus hydrogen is recycled back to the shaft feed and generated water is supplied back to the electrolyzer. HBI is fed into an electric arc furnace (EAF) where it is melted and converted to liquid steel.
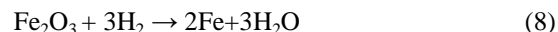
Recently in the Dhaubadhi VDC of Nawalparasi, an iron ore reserve has been found which deposits more than 8 million tons of iron ore [18]. For the extraction of Dhaubadhi iron mining we need 12million tons of coal which causes a huge carbon emission so for this green hydrogen is a better option for a carbon-neutral extraction process. Nepal with a potential of 3500 MW of surplus hydroelectricity by 2028 from which 3.15 million tonnes of green hydrogen can be produced. Not only Dhaubadhi we can extract other many iron mines that are found in our country without any fossil

fuel and also have the possibility to export hydrogen to our neighboring countries and increase our GDP. In the case of iron mining, there is a high probability that we can stand with the developed countries if we carried it on time.

As we know $C_p = A + Bx + Cx^2 + Dx^3$ so we need these values

With coal

$$Fe_2O_3(s) + 3CO(s) \rightarrow 2Fe(l) + 3CO_2(g) \qquad (7)$$

with hydrogen

$$Fe_2O_3 + 3H_2 \rightarrow 2Fe + 3H_2O \qquad (8)$$

Table 2. Values.

Cp data	a	b	c	d
Fe_2O_3	103.4	6.77×10^{-2}	-17.72×10^{-5}	0
CO	28.95	0.411×10^{-2}	0.3548×10^{-5}	-2.22×10^{-9}
Fe	31.873	-22.33×10^{-2}	-3.159×10^{-5}	40.076×10^{-9}
CO_2	36.11	4.233×10^{-2}	-2.887×10^{-5}	7.464×10^{-9}
H_2	28.84	0.00765×10^{-2}	0.3288×10^{-5}	-0.8698×10^{-9}
H_2O	18.2964	47.212×10^{-2}	-133.88×10^{-5}	1314.2×10^{-9}

4. Heat Capacities

Constants in equation $CP\ ig\ /R = C_p = A + Bx + Cx^2 + Dx^3$ for T (K) from 298 K to Tmax

Table 3. Values of a, b, c, d for calculating the C_P.

	ΔH kJ/gmol at 25 ℃
Fe_2O_3	-822.156
CO	-110.5
Fe	0
CO_2	-393.5
H_2	0
H_2O	-285.84

We need the valuea, b, c, d of for calculating C_p [19]

At 1073k

Now,

$$\Delta H_{fe2O3} = 1\text{mole} \times [\Delta H_{fe2O3}(\text{at } 298k) + \int_{298}^{1073} c_{p \text{ of fe2o3}} dt] \text{ where}$$
$$c_p = a + bt + ct^2 + dt^3$$

$$= -777.774 \text{ KJ/mol}$$

$$\Delta H_{fe} = 2\text{ mole} \times [\Delta H_{fe}(\text{at } 298k) + \int_{298}^{1073} c_{p \text{ of fe}} dt]$$

$$= 186.91 \text{ KJ/mol}$$

$$\Delta H_{co} = 3\text{ mole} \times [\Delta H_{co}(\text{at } 298k) + \int_{298}^{1073} c_{p \text{ of co}} dt]$$

$$= -259.54 \text{ KJ/mol}$$

$$\Delta H_{co2} = 3\text{mole} \times [\Delta H_{co2}(\text{at } 298k) + \int_{298}^{1073} c_{p \text{ of co2}} dt]$$
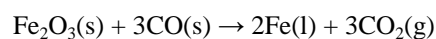
$$= -1056.604 \text{ KJ/mol}$$

$$\Delta H_{H2} = 3\text{mole} \times [\Delta H_{H2}(\text{at } 298k) + \int_{298}^{1073} c_{p \text{ of H2}} dt]$$

$$= 70.377 \text{ KJ/mol}$$

$$\Delta H_{H2o} = 3\text{mole} \times [\Delta H_{H2o}(\text{at } 298k) + \int_{298}^{1073} c_{p \text{ of H20}} dt]$$

$$= -382.250 \text{ KJ/mol}$$

Now, for

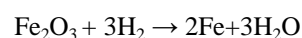$$Fe_2O_3(s) + 3CO(s) \rightarrow 2Fe(l) + 3CO_2(g)$$

$$\Delta H_{final} = \Delta H_{product} - \Delta H_{reactant}$$

$$= -206.2 \text{ KJ/mol (exothermic)}$$

then

$$Fe_2O_3 + 3H_2 \rightarrow 2Fe + 3H_2O$$

$$\Delta H_{final} = \Delta H_{product} - \Delta H_{reactant}$$

$$= 512 \text{ KJ/mol (endothermic)}$$

5. Cost Comparison

Here below there is a general cost comparison between the hydrogen and coal for the extraction of 1-ton sponge iron.

Electricity power consumption for 1 kg hydrogen production =power consumed by the appliance*no. of appliance*time (operating in hrs.) =39kwh.

Amount = power consumed*price per unit of electricity =USD 2.95

Table 1. General cost comparison of coal and green hydrogen for 1ton iron production.

Reducing agent	Raw materials	Rate (USD/ton)	Quantity consumed for the production of 1ton of sponge iron	Cost (USD/ton)	Total (USD/ton)
Green hydrogen gas	Hydrogen gas	3900	0.055	214.5	306.5
	Iron pellets	61.50	1.5	92.25	
Coal	Coal	88	1.125	99	191.25
	Iron pellets	61.50	1.5	92.25	

Hereby comparing the cost consumption of raw materials, we found that the cost of using hydrogen is nearly 1.6 times more expensive than the use of coal in mining.

6. Major Problems of Iron and Steel and the Role of Green Hydrogen in Nepal

The iron and steel industries are still beset by issues and are unable to operate at full capacity. The following are some of Nepal's iron and steel industry's issues: Inadequate and unreliable electricity supply—although the situation has improved in recent years. For years, there has not been an adequate supply of electricity for the iron and steel sectors Production costs are high due to the substantial import of raw materials from India [20].

In Nepal's existing iron and steel industry, Green hydrogen plays a critical role in booming the Nepalese iron and steel industries. It is a great option for high industrial heat generation due to its capacity to employ a power generating source and a high-temperature flame (2660 ℃ with oxygen and 2045 ℃ with air). The reduction of iron ore is the first step in the steelmaking process, and coke is currently utilized as the primary reduction agent inside the blast furnace. A large amount of CO_2 is emitted when coke is burned. Because hydrogen burns and produces just water vapor, it might be employed in existing iron and steel companies for high-heating processes. Hydrogen could be employed as a high-heat source in the steel industry, which is now reliant on high-quality coal to generate the high heat needed in smelting and billet heating in reheating furnaces. In Nepal's iron and steel industry, reliable electricity is still a challenge, thus most of them rely on diesel generators for backup power. In those industries, hydrogen could be employed as a backup power source, resulting in the utilization of clean energy.

7. Opportunity in Nepal

Nepal has a significant chance to decarbonize its existing iron and steel industries by producing raw iron using renewable hydroelectricity and green hydrogen. Nepal can lead the way in green steel manufacture using green hydrogen, with new iron mines being identified and being studied for the potential reduction of raw material from those mines. As of 2015, Nepal had 100.5 million tons of iron ore, and additional huge quantities of iron ores had just been discovered. Iron and steel goods were selected as one of the 13 exportable categories with a competitive advantage in Nepal by the Nepal trade integration system (NTIS). Iron and steel finished goods have become one of the most popular exports. The export proportion of this subsector has been extraordinary, according to Rastra Bank, with sustained domestic demand growth. Iron Ores present in Nepal are in Those, Ramechhap; Labdi Khola, Tanahau; Jirbang, Chitwan and Phalam Khani, Parbat [21]. The government of Nepal has established Dhaubadhi Iron Company Limited in Nawalpur for the extraction of iron from the Dhaubadi mine. With the opening of new green mining industries, Nepal will have a tremendous potential to reduce iron from ores using green hydrogen as a reducing agent and as a power generation option. Green hydrogen has the potential to be used in mining sectors to create raw iron without the usage of coke for reduction and heat generation.
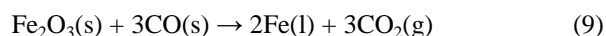
Table 5. Demand for sponge iron in Nepal.

Demand for Sponge iron in Nepal	
Year	Demand(MT)
2005	33,500
2020	500,000

Table 6. Demand for steel in Nepal/year.

The demand for steel in Nepal	
Year	Demand (MT)
1995	83,400
2000	147,000
2015	226,136
2020	2,200,000

With carbon

$$Fe_2O_3(s) + 3CO(s) \rightarrow 2Fe(l) + 3CO_2(g) \qquad (9)$$

For the extraction of 1ton iron, we need 750kg of coke and it produces about 1.178ton of CO_2.

And for 500,000 Mt sponge iron, we need about 375000t/annum of coke.

With hydrogen

$$Fe_2O_3 + 3H_2 \longrightarrow 2Fe + 3H_2O \qquad (10)$$

For the extraction of 1ton iron, we need 55kg of hydrogen i.e. 0.055T.

And for 500,000 Mt sponge iron, we need about 27500T/annum of hydrogen in the DRI plant in Nepal.

Nepal's Imports of Iron and steel were USD 1.08 Billion in 2019, according to the United Nations COMTRADE database on international trade. Nepal Imports of Iron and steel - data, historical chart, and statistics - was last updated in November of 2021 [22].
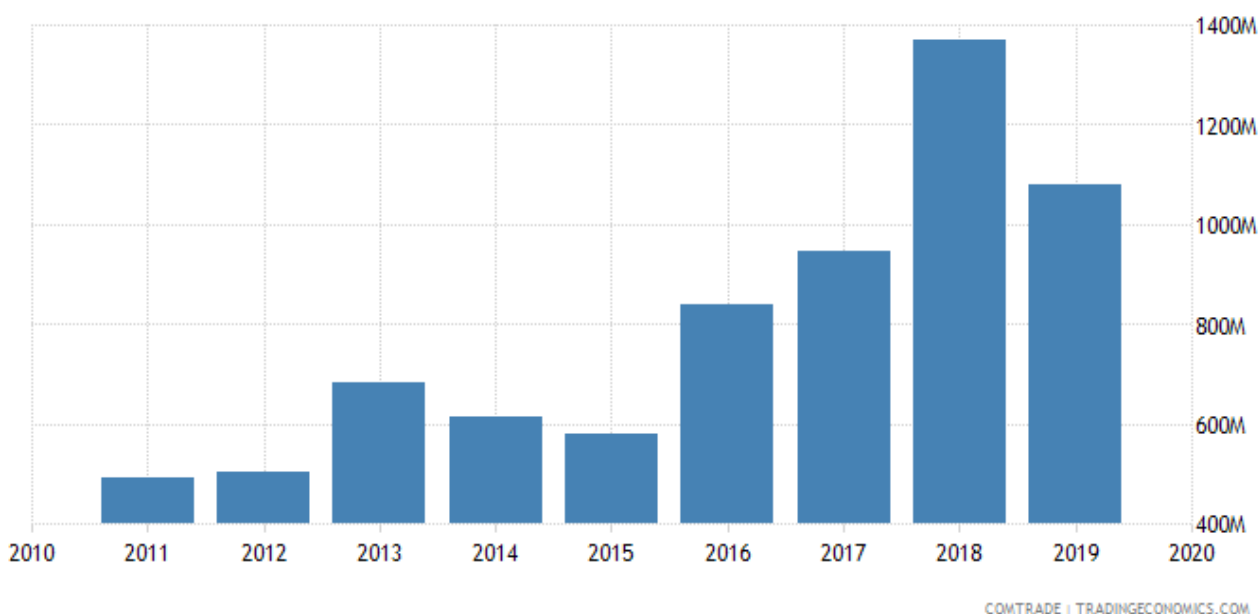
Figure 4. Import of coal in Nepal [22].

8. Hydrogen as an Energy Carrier

Since the 195 countries signed the Paris Agreement in 2016 intending to keep global warming and temperature rise well below 2 degrees Celsius, the globe has been looking for ways to cut CO_2 emissions. Over a quarter of worldwide carbon emissions are from oil and natural gas alone. To keep global warming below 2 degrees Celsius over pre-industrial levels, the world will need to cut CO_2 emissions by 25% by 2030 and reach net zero by 2070. In addition, if global warming is to be kept to 1.5 degrees Celsius above pre-industrial levels, the globe will need to slash emissions by 45 percent by 2030 and net-zero by 2050 [23].

Recently, hydrogen has gotten a lot of attention and focus around the world as a long-term potential energy carrier that might drastically lessen the negative environmental and socioeconomic effects of CO_2 emissions. By 2030, the cost of hydrogen production and application will be half of what it is

now, and with new green hydrogen technologies on the horizon, hydrogen will be the long-term weapon to combat the next generation's energy and climate crises. Hydrogen will play an essential role in the global energy supply chain, complementing and balancing renewable energy sources while also supplying flexible electricity to meet demand. It is a critical factor in transforming the existing energy system by supplying all of the energy demand while supplementing renewable and nuclear electricity. It has been employed in industry, but not as an energy carrier; instead, it has been used as a feedstock in the chemical and refinery sectors. However, many studies and inquiries into using hydrogen as an energy carrier and converting that energy to electrical and other forms are currently underway.

9. Environmental Analysis

Iron and Steel production has a multitude of environmental

consequences, including CO, SOx, NOx, and PM2 emissions, wastewater contaminants, hazardous wastes, and solid wastes. Coking and iron-making have the greatest environmental impact from integrated steel mills.

Carbon dioxide emissions from energy use account for nearly all of the greenhouse gas emissions involved with steel manufacture. Steel production consumes a lot of coke, which is one of the biggest pollution sources. Coke ovens emit air pollutants such as coke oven gas, naphthalene, ammonium compounds, crude light oil, sulfur, and coke dust. By calculating the extraction of 1-ton sponge iron there is an emission of about 1.7 tons of CO_2 [23]. In mining, coal is used as a fuel and reducing agent forming carbon monoxide when burned and reacting with iron oxide to produce carbon dioxide in blast furnaces but when hydrogen replaces coal, it similarly reacts with iron oxide to carbon monoxide, it only produces water vapor as a byproduct instead of carbon dioxide.
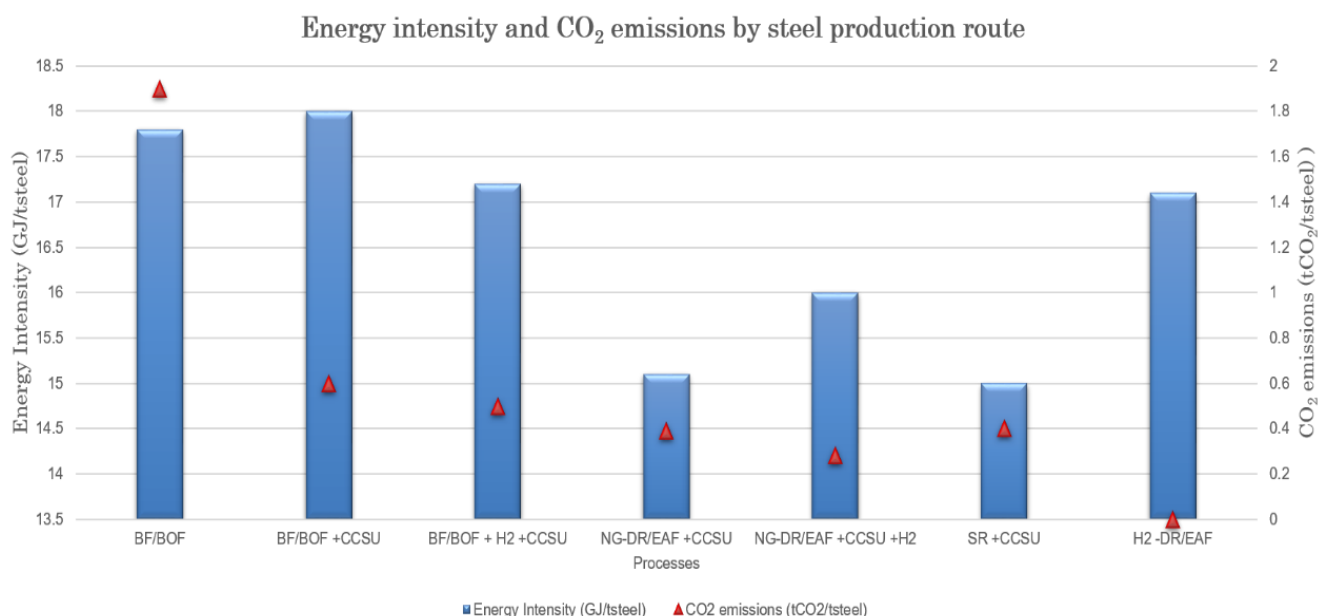

Figure 5. Process with energy intensity with carbon emission [23].

10. Conclusion

The total energy requirement of a hydrogen direct reduction steelmaking process is comparable to that of traditional steelmaking (blast furnace - basic oxygen furnace), but the process runs on electricity rather than coal and coke.

Technology is moving from coal to hydrogen, and the steel industry, in particular, has adopted the Direct Reduction Method. This is a significant step towards decreasing carbon emissions and promoting sustainability. As a clean reducing agent, hydrogen is being introduced into steelmaking processes to address the carbon-intensive nature of old technol-

ogies While the reaction between green hydrogen and iron oxide has been proven to be endothermic, the reaction between iron oxide and coal has been demonstrated to be exothermic. The cost of mining with hydrogen is over 1.6 times higher in Nepal than it is with coal. From this paper, got to know that green hydrogen is better than coal in the production of iron because of its environmentally friendly nature and there is a huge opportunity for Nepalese to be independent in terms of green energy. According to the analysis, the future of hydrogen direct reduction steelmaking is better, given successful technology and process development and favorable market conditions in terms of relative electricity and carbon emissions prices.

Conflicts of Interest

The authors declare no conflicts of interest.

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