

Tsasilile Igogo
Joint Institute for Strategic Energy Analysis

Introduction

- Increase in mineral demand and declining mineral ore grades is expected to increase the energy demands and greenhouse gas (GHG) footprint by mining activities (Norgate et al.2010; and Lezak et al., 2019).
- This poster focuses on Iron and steel industry because it is the widely produced and consumed mineral in the world (see Figure 1).

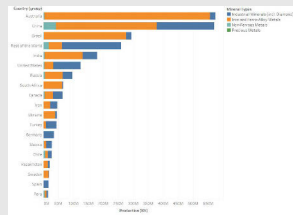


Figure 1. Leading Minerals Producers
Source: Data is from the World Mining Database.

Challenges of Using Renewable Energy

- Technical challenges:
 - ✓ Feed stock demand
 - ✓ High temperature process heat demand



Figure 3. Steelmaking
Source: Graph adapted from <https://www.worldcoal.org/>

- Variability of wind and solar
- Mining/plant design and investment structure

Other challenges:

- Conflicting business models
- Lack of technology proof of concept
- Lack of renewable energy awareness and expertise
- Challenge for green supply chain certifications
- Land constraints
- Supply chain

Enabling Approaches

- Research and development
 - ✓ Clean Hydrogen
 - ✓ Increase temperature produced by other renewables
- Alignment of business model and incentives
- Capacity building
- Addressing supply chain certification challenge
- Pooling resources
- Policy and regulations

Energy and GHG Intensity

- High volume of global production of iron and steel, and the nature of steel making process make iron and steel production, one the highest consumer of energy and producer GHG emissions within industries.

Table 1. Energy Use and GHG Impacts for 'Cradle-to-Gate' of Select Metals

Commodity	Feed	Process/route	GER (KWh/t)	GHG (Mt CO ₂ e/Mt)
Iron	N/A	Open-cut	43	0.01
Stainless steel	Multiple ores	Electric Furnace and Argon/Oxygen decarburisation	22,000	6.80
Steel	Iron ore (64% Fe)	Integrated route (BF and BOF)	6,440	2.30

Multiple ores under stainless steel represent pig iron (34% Fe), chromite ore (27.0% Cr, 17.4% Fe), laterite ore (2.4% Ni, 13.4% Fe), multiple ore for steel

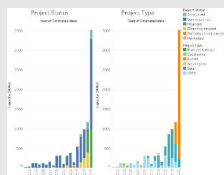
Source: Norgate et al., 2007

- For example, in 2018 crude steel production was about 1,808 million tons (World Steel Association, 2019a).
- If it is assumed that the energy and emission intensity of steel provided by Table 1 is roughly equivalent to what it is in 2018, it implies steel industry used about 11, 644 TWh of energy and produced about 3,616 million Mt of CO₂ emission in 2018.

Renewable Use Trend by Miners

- Prior to 2000, the use of renewables in mining operations was nearly non-existent.
- Recent years have seen an uptick in renewable energy adoption by mining companies, with a notable spike in commissioned projects in 2019.

Figure 2. Global Renewable Project by Mining Companies



Source: BNEF, 2019

- Despite this increase in renewable project installations, the aggregate amount of energy generated by these projects is still a fraction of total energy consumed by the mining industry (BNEF, 2019).

Renewable Integration Opportunities

- Table 2 shows of the mining process/operations that could be supported by renewable

Table 2. Mining Processes and Associated Fuel Sources

Mining Process	Activities and Equipment	Fuel Source
Exploration and Auxiliary Operations	Ventilation: Fan system Drilling: Loader trucks, diamond drills, rotary drills, percussion drills, drill boom jacks	Electricity Electricity, Diesel, and Compressed Air
Materials Handling	De-watering: Pumps Digging: Hydraulic shovels, cable shovels, continuous miners In-pit crushing, conveyor systems, drag lines, front-end loaders Discrete: transportation systems: Road trucks, service trucks, bulldozers, pickup trucks, ball trucks, load-haul dumps, shuttle cars, hauls	Electricity and Diesel
	Continuous: transportation systems: Conveyor belts, pumps, pipelines, belts Crushing: Crushers Grinding: Mills	Diesel and Electricity
Beneficiation and Processing	Separation: Physical: Flotation, centrifuge, and Chemical Electrowinning Roasting: Furnace Refining: Electrolysis and Electro-winning	Electricity Electricity Fossil Fuels Electricity and Fossil Fuels

- Disaggregated energy data of iron and steel provide a better understanding of opportunities for renewable use in the industry. Source for steel disaggregate data is limited therefore, this part is going to focus on iron production.

Table 3. Disaggregated Energy Use by the Iron Mining Across the Value Chain

Energy Type	Unit	Activity	Process						Energy Intensity (kWh/tonne)		
			Exploration and Auxiliary Operations	Materials Handling	Beneficiation and Processing	Roasting	Refining	Other			
Renewable	MWh	Drilling	1,200						1.2		
		Crushing	340						0.34		
		Grinding	2,485						2.485		
		Flotation	2,000						2.000		
		Other	1						1		
		Fossil	MWh	Drilling							0
				Crushing							0
				Grinding							0
				Flotation							0
				Other							0
Total	MWh			Drilling	1,200						1.2
				Crushing	340						0.34
				Grinding	2,485						2.485
				Flotation	2,000						2.000
				Other	1						1
		Total	MWh	Drilling	1,200						1.2
				Crushing	340						0.34
				Grinding	2,485						2.485
				Flotation	2,000						2.000
				Other	1						1

Source: Data obtained from Katta et al., 2020 as compile from several sources such as Natural Resources Canada, US Department of Energy and other studies.
Notes: 1 KWh is equivalent to 3412.14 Btu.

- From table 3, high temperature processes like firing and drying uses fossil fuel. These activities will hard to replace with renewable sources under current technologies (see Table 4).

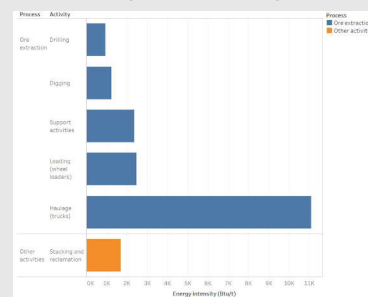
Table 4. Maximum Temperature Supported by Renewable Technology

Category	Technology type	Temperature levels
Renewable source	Biomass, boiler	Low
	Biomass, high temperature	Medium
	Biomass, CHP	High
	Biogas, anaerobic digestion	High
	Solar PV	High
	Wind	High
	Heat pump	Low
	Geothermal direct use	Low
	Deep geothermal	Medium
	Solar thermal	N/A
Energy storage	Hydrogen	N/A
	Pump storage	N/A
	Battery storage	N/A

Source: Data from IRENA, 2015; University of Australia, 2019; and Environmental Protection Agency. Note: Low temperature (150 °C), medium temperature (150 °C – 400 °C), and high temperature (>400 °C). *High temperature level production using solar and wind is not yet commercially available. **Hydrogen energy – refers to clean hydrogen generated from renewable electricity and water which is still uneconomical at the moment.

- However, other fossil fuel activities such as digging, drilling, haulage and loading can be electrified by renewable sources.

Figure 4. Diesel Use in Iron Mining



Source: Data obtained from Katta et al., 2020 as compile from several sources such as Natural Resources Canada, US Department of Energy and other studies.