



Integrating Clean Energy into Mining Operations

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Integrating Clean Energy in Mining Operations: Opportunities, Challenges, and Enabling Approaches.

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Integrating renewable energy into mining operations: Opportunities, challenges, and enabling approaches

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ABSTRACT

Mining is one of the most energy-intensive industries worldwide. It also provides a critical source of raw materials for the manufacturing, transportation, construction, and energy sectors. Demand for raw materials is projected to increase as the world population grows and energy-intensive economies become middle-income countries. This growth in mineral demand, coupled with falling mineral ore grades, will likely increase the mining industry's energy demand, used for activities across exploration, extraction, beneficiation, and processing, and refining. At the time of this writing, mine operations are—due to their remoteness—dependent on fossil fuels such as diesel, heavy oils, and coal. In principle, mining could use energy recovery, renewable energy, and carbon capture to supplement, replace, or mitigate the impact of fossil fuel use. However, a combination of renewable energy technologies would be required. We explore challenges, opportunities, and enabling approaches to integrate renewable energy technologies into mining operations by examining the literature, including academic work, technical reports, and data produced by operational agencies. We find that despite numerous opportunities, technical know-how still needs to be considered, but solutions can likely be developed in the mining industry. Further research should focus on identifying specific opportunities, technologies, and implementation strategies across the value chain of a variety of minerals with similar operational profiles.

1. Introduction

The mining industry, defined by the activities covered such as exploration, extraction, beneficiation, processing, and refining, provides a critical source of raw materials for many industries such as manufacturing, transportation, construction, energy, and the mining industry itself. It is anticipated that demand for raw materials will increase as the population grows and many low-income economies shift to middle-income status [1]. The increase in mineral demand, combined with declining mineral ore grades, is expected to increase energy demands of the mining industry, which will potentially require already large greenhouse gas footprints [2,3]. Materials derived from mining processes are heavily embodied in the global energy mix and continue to play a critical role in the future of humanity [4]. Correspondingly, the environmental impacts of these mining activities will need to be addressed. In principle, mining could use energy recovery, renewable energy, and carbon capture to lower its energy consumption and decrease greenhouse gas emissions. A combination of renewable-energy technologies will be required to fully address energy-related challenges facing the mining industry.

2.1. Research issues and motivation

This paper explores the challenges, opportunities, and enabling approaches to integrate renewable technologies into mining operations. It aims to combat an increasingly expanding greenhouse gas profile, the mining industry is increasingly adopting renewable energy to power its operations. This uptake in adoption has been driven by several factors, including energy costs, corporate environmental goals, and local socioeconomic considerations. In 2015, there were 600 MW of renewable energy projects used on or serving mine sites. By the end of 2019, there were nearly 9 GW of renewable energy projects installed or planned for mine sites around the world [5]. This growth, however, has not been without headwinds. Around-the-clock mining operational loads, the distinctive nature of energy demand, inflexible manufacturing

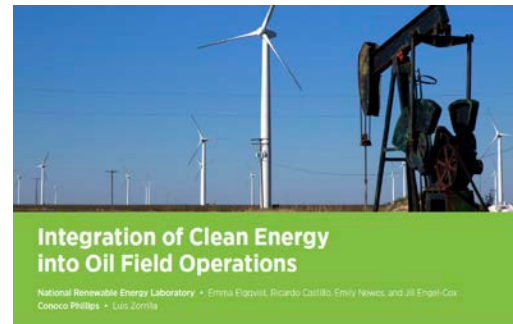
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Integrating Clean Energy in Mining Operations

JISEA Technical Report, 2020

Integrating Renewable Energy in Mining Operations

Applied Energy 2021



Integration of Clean Energy into Oil Field Operations

National Renewable Energy Laboratory • Emma Elgqvist, Ricardo Castillo, Emily Newnes, and Jill Engel-Cox
 Conoco Phillips • Luis Corral

Summary of Findings

Integrating clean energy into oil and gas operations could reduce emissions and maximize higher-value use of produced hydrocarbons. In this published study, analysts from the Joint Institute for Strategic Energy Analysis (JISEA) and the National Renewable Energy Laboratory (NREL) evaluated clean-power technologies for an oil field in the Delaware Basin using NREL's iEGIST tool. The analysis evaluated different configurations of distributed energy resources based on the technologies available and the load they could satisfy, available land, and hypothetical carbon pricing. The analysis is part of a collaboration program with industry to understand site-specific energy consumption and prices in the oil and gas supply chain and determine under what conditions clean energy systems are economically attractive. This work was sponsored by a consortium including ConocoPhillips, Baker Hughes, Extraction Oil & Gas, Kinder Morgan, and the Intermountain Natural Gas Association of America Foundation.

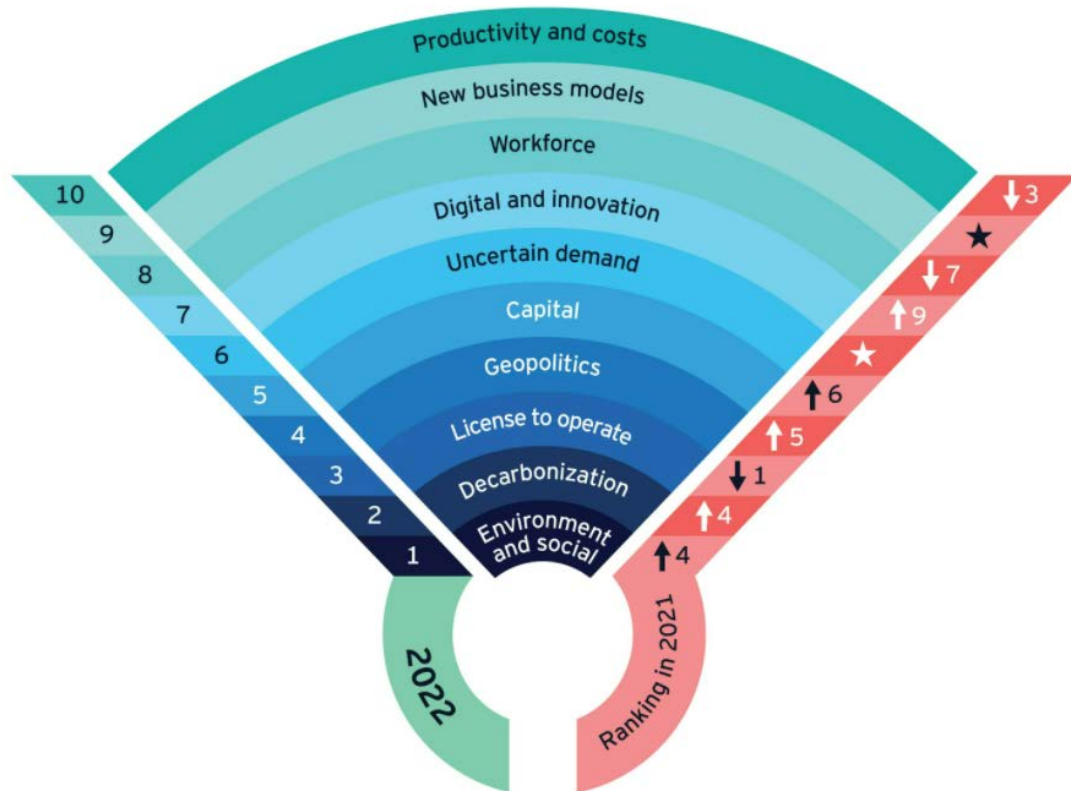
Snapshot

- Smaller renewable energy technologies are cost-effective, larger systems generating 50% of the site's load offset significant amounts of carbon dioxide (CO₂), but at an added cost.
- For grid-connected systems, the low-cost industrial electricity rates (\$0.03 per kilowatt-hour [kWh]) paid by these facilities reduces the net present value of collocated renewable power installations beyond economic viability.
- A calculated cost of emissions reduction (S_{ERC}) based on renewable energy generated indicates that a cost of carbon of \$30/CO₂e would result in a breakeven point for a renewable energy system generating 50% of the site's load (assuming the system could net meter excess generation).
- We performed a case study to understand the benefit of enhancing microgrids as an enabling platform to increase energy resilience and optimize deployment of distributed energy resources (DERs) for grid- and non-grid-connected systems. These systems can help overcome operational challenges and progress toward sustainability goals, when paired with renewable sources of energy.



Series on Oil and Gas, see <https://www.jisea.org/clean-energy-opportunities-in-the-oil-and-gas-sector.html>

Clean Energy in the Mining Industry



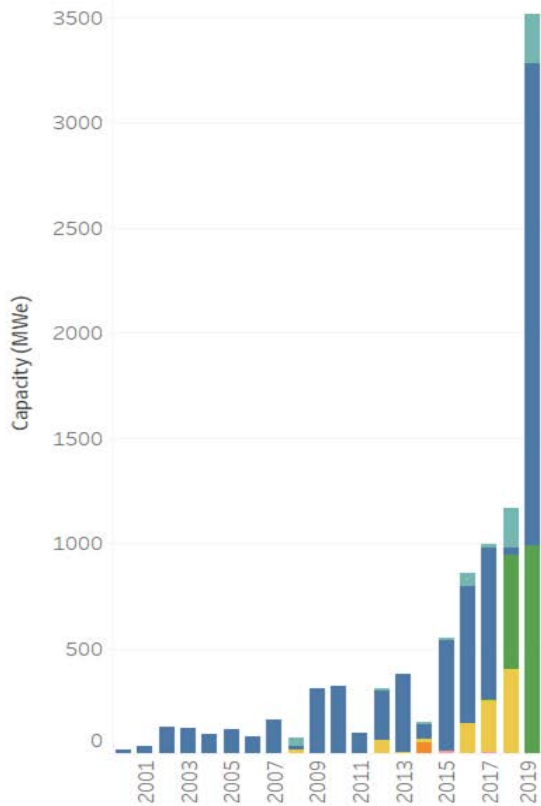
↑ Up from 2021 ↓ Down from 2021 — Same as 2021 ★ New to the radar

Clean energy deployment addresses EY's top three business risks to the mining industry

Source: [Mitchell 2021](#)

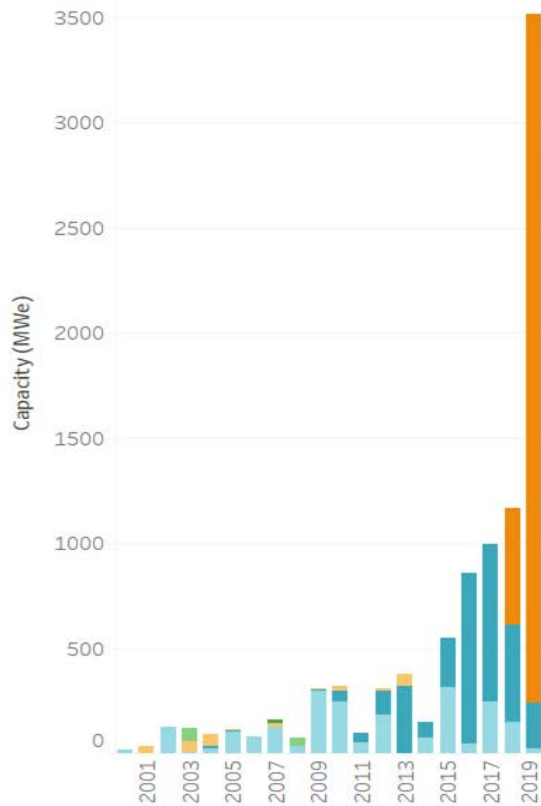
Project Status

Year of Estimated date



Project Type

Year of Estimated date



Project Status

- Announced
- Commissioned
- Financed
- Financing secured
- Partially commissioned
- Permitted

Project Type

- Biomass & Waste
- Geothermal
- Hybrid
- Small hydro
- Solar
- Wind

In 2015 there were about **600 MW** of renewable energy projects serving mine sites

In 2020, over **5 GW** cumulative of renewable energy projects serving mining operations have either been installed or are planned

Global Renewable Energy Projects Serving Mining Operations

Source: BNEF 2019

Carbon Reduction and Net-Zero Goals

21 of 30 largest mining and metals companies have set some kind of net-zero emissions target

Climate goals of top 30 metals and mining companies

Institution name	Market cap (\$B)	Climate goal	Scope 1 & 2	Scope 3
Existing net-zero target				
● BHP Group	134.21	BHP is party to a net-zero pledge by members of the International Council on Mining & Metals.* Additionally, BHP is "pursuing the long-term goal of net-zero Scope 3 greenhouse gas emissions by 2050.*"	Target 2050	Target 2050
● Rio Tinto Group	109.65	Rio Tinto is party to a net-zero pledge by members of the International Council on Mining & Metals.* The company targets a 50% reduction in Scope 1 and Scope 2 emissions by 2030.	Target 2050	Not addressed**
● Vale SA	70.83	Vale is party to a net-zero pledge by members of the International Council on Mining & Metals.* Vale set an interim target of a 15% reduction in its Scope 3 emissions by 2035 and to become carbon neutral by 2050.	Target 2050	Target carbon neutral by 2050
● Glencore PLC	62.61	Glencore is party to a net-zero pledge by members of the International Council on Mining & Metals.* Glencore aims to achieve "net-zero total emissions by 2050."	Target 2050	Target 2050
● Freeport-McMoRan Inc.	47.76	Freeport-McMoRan is party to a net-zero pledge by members of the International Council on Mining & Metals.* It separately pledged to "develop a more robust understanding of how we can move beyond our aspirational vision to a science-based net-zero pathway."	Target 2050	Not addressed
● Anglo American PLC	43.52	Anglo American is party to a net-zero pledge by members of the International Council on Mining & Metals.* Additionally, Anglo American targets carbon-neutral Scope 1 and 2 emissions by 2040 and to have Scope 3 emissions by 2040.	Target 2040	Halve Scope 3 emissions by 2040
● Newmont Corp.	43.46	Newmont is party to a net-zero pledge by members of the International Council on Mining & Metals.* The company's ultimate goal is to be "carbon neutral" by 2050.	Target 2050	Target 2050
● Fortescue Metals Group Ltd.	33.35	Fortescue is targeting net zero Scope 1 and Scope 2 emissions by 2030 and net-zero Scope 3 emissions by 2040.	Target 2030	Target 2040
● Barrick Gold Corp.	32.18	Barrick Gold is party to a net-zero pledge by members of the International Council on Mining & Metals.* The company's ultimate "vision is net-zero greenhouse gas emissions by 2050 achieved primarily through [greenhouse gas] reductions and certain offsets for hard to abate emissions."	Target 2050	Target 2050

Source: [Kuykendall 2021](#)

Clean Energy in Mining

Mine Energy Loads and Sources

Mining process	Activities and Equipment	Fuel Source
Exploration, Extraction and Auxiliary Operations	Ventilation: HVAC	<ul style="list-style-type: none"> • Electricity • Natural Gas
	Drilling: Loader trucks, diamond drills, rotary drills, percussion drills, drill boom jumbos	<ul style="list-style-type: none"> • Electricity • Diesel • Compressed Air
	Dewatering: Pumps	<ul style="list-style-type: none"> • Electricity
	Digging: Hydraulic shovels, cable shovels, continuous miners, longwall mining machines, drag lines, front-end loaders	<ul style="list-style-type: none"> • Electricity • Diesel
	Power supply: Generators	<ul style="list-style-type: none"> • Fossil Fuel
Material Handling	Discrete transportation systems: Haul trucks, service trucks, bulldozers, pickup trucks, bulk trucks, load-haul dumps, shuttle cars, hoists	<ul style="list-style-type: none"> • Diesel • Electricity
	Continuous transportation systems: Conveyor belts, pumps, pipelines	<ul style="list-style-type: none"> • Electricity
Beneficiation and Processing	Comminution	<ul style="list-style-type: none"> • Electricity
	Crushing: Crushers	
	Grinding: Mills	
	Separations: Physical: Floating, centrifuge; and Chemical: Electrowinning	<ul style="list-style-type: none"> • Electricity • Fossil Fuels
	Drying, Firing, Smelting: Oven/Furnace	<ul style="list-style-type: none"> • Fossil Fuels
	Refining e.g. Electrolytic refining, fire refining	<ul style="list-style-type: none"> • Electricity • Fossil Fuels

Every mine operation has different requirements, but in general and across sites, **electricity** comprises the largest energy demand

Most of that electricity is derived from **fossil fuels**

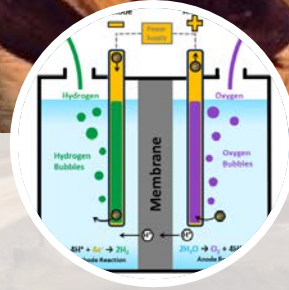
Clean Energy Applications in Mining



Renewable onsite electric loads



Zero-emissions mobility



Green hydrogen applications



Low emission process heat and feedstocks

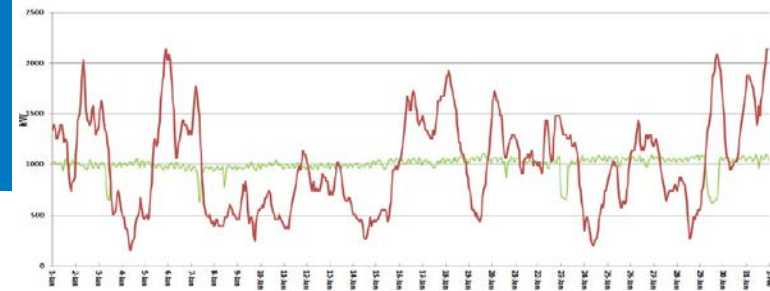
High

Technology Readiness Level

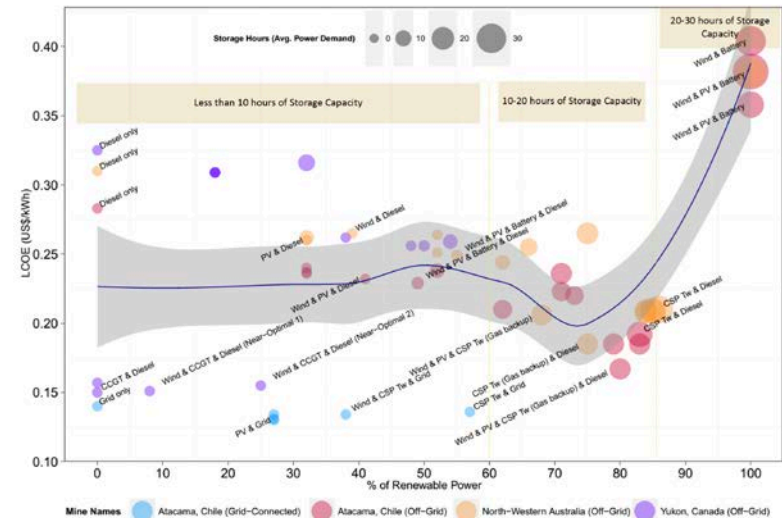
Low

Supplying Onsite Electric Loads

- Wind, solar, and—in some cases—energy storage—are commercial technologies that can offset diesel-fired electric generation
- Variability of generation is a challenge since mine sites often have consistent 24/7 loads.
- Long term energy storage or dispatchable modular power systems needed to enable higher levels of renewable energy
- Breakthrough technologies include electrolytic hydrogen, flow batteries, and small modular nuclear reactors



Wind generation curve overlaid on mine load curve
Source: Hatch 2019



Technology levelized cost of energy as a function of renewable power and storage for four mine sites
NREL | 10

Source: [Guilbaud 2016](https://www.guilbaud.com)

Zero Emissions Mobility

- Electrifying transport reduces both GHG and air emissions
- Can also facilitate deeper integration of variable renewable generation by having vehicle batteries act as storage devices, or having electrolyzers produce H₂ for use in haul trucks
- While trolley assist and other electric transport (e.g., conveyors) have a market track record, Li-ion and H₂ are still emerging technologies for heavy off-road vehicles

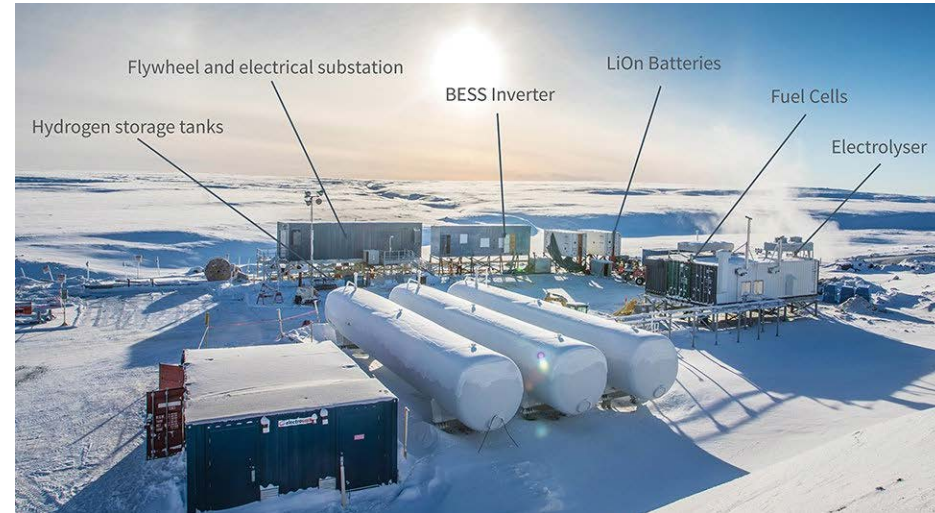


Hydrogen fuel cell excavator prototype

Source: [JCB](#)

Green Hydrogen

- H₂ can be used as an energy carrier for electricity generation, storage, mobility, process heat, or as a feedstock
- H₂ prices, supply chain, and technology readiness are still major barriers
- While some mining companies are investing heavily in an H₂ future, most analysts believe that low-cost green hydrogen at least a decade out from this reality



Glencore Raglan Mine
Source: [Engineering News 2020](#)

Process Heat and Feedstocks

- Many low- and no-carbon thermal technologies, such as concentrating solar, have not been commercially demonstrated for mining applications, but R&D is accelerating
- Electrification of process heat can be a pathway to incorporating renewable generation, both on mine sites and on the grid generally
- Alternative fuels and feedstocks for mineral processing require additional R&D to ensure process efficiency and product quality
 - E.g., H₂ reduction of iron ore



High-temperature heat pump



Biomass



Electric boiler



Solar thermal

Small modular reactor
(Source: Nuscale)

Challenges and Opportunities for Integration

Conclusion

Renewable energy technologies need mined materials, and mining operations can benefit from using renewable energy

Barriers:

- Conflicting business models between mine operators and renewable energy developers
- Lack of renewable energy expertise and demonstrations in the mining industry
- Land constraints and suitability

Enablers:

- Aligning incentives and using innovating contract structures
- Designing mine site energy management and making loads more flexible
- Capacity building and training
- Technology development and R&D
- Supply chain certification
- Policy and regulatory measures
- Collaboration!

Thank you!

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