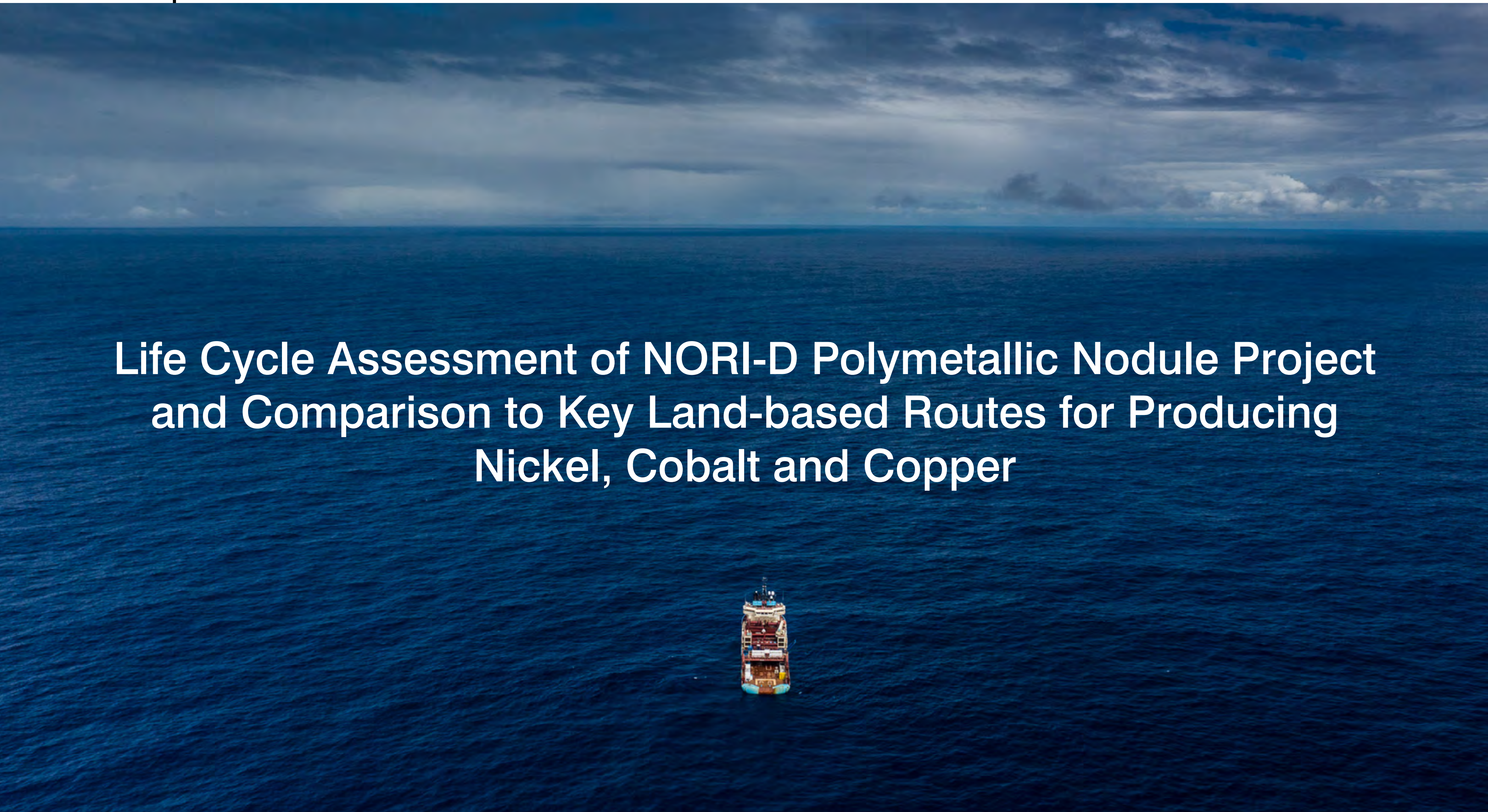


Life Cycle Assessment of NORI-D Polymetallic Nodule Project and Comparison to Key Land-based Routes for Producing Nickel, Cobalt and Copper

March 2023

This is a summary of the life cycle assessment (LCA) of the environmental impacts of the NORI-D polymetallic nodule project and comparison to producing the same energy-transition metals (nickel, cobalt, copper and Ni/Cu/Co matte) through conventional land-based production routes. This ISO-standards-compliant LCA completed by Benchmark Minerals Intelligence and reviewed by an independent third-party expert shows that the NORI-D Project performed better in each impact category analyzed than all the land-based routes chosen for comparison, except for the global warming potential (GWP) and water consumption of producing cobalt sulfate, in which one land-based route performed better.

Overview

The global energy transition is metal intensive.[1] International net-zero targets are accelerating the uptake of clean energy technologies, in turn creating exponential demand growth for energy-transition metals. In the near to medium term, an unprecedented ramp up of primary production of these metals is required to meet this demand and build up metal stocks that could be recycled in the future.

Land-based mining is the main source of primary production of energy-transition metals today. It tends to be carbon intensive, polluting and associated with controversial social issues such as displacement of indigenous peoples. In the quest to find alternatives with a better environmental and social impact profile, The Metals Company (TMC) is exploring the potential of an unconventional resource in international waters: polymetallic nodules (PMN). PMN found at depths of 4 kilometers (km) on the seafloor of the Clarion-Clipperton Zone (CCZ) contain abundant quantities of nickel (Ni), cobalt (Co), copper (Cu) and manganese (Mn), making them a potential new source of energy-transition metals. No commercial collection of PMN is currently taking place. TMC's first PMN project in the NORI-D Area of CCZ (NORI-D Project) is currently in the middle of the pre-feasibility study and comprehensive assessment of environmental and social impacts of potential future operations. Importantly, TMC's subsidiary NORI is conducting a formal Environmental and Social Impact Assessment (ESIA) specifically focused on the first step of the life cycle: collecting nodules from the seafloor. Once completed, this assessment will offer insights into impacts of the proposed nodule collection operations on deepsea biodiversity and ecosystem function.

While work on deepsea biodiversity and ecosystem function is still ongoing, the NORI-D Project has been defined sufficiently to assess the project's life cycle impacts across most conventional LCA impact categories. TMC engaged Benchmark to conduct an independent LCA of the potential environmental impacts of producing intermediate (NiCuCo matte) and final end-products (Ni and Co sulfate, copper cathode and manganese silicate) from NORI-D PMN, and to compare them to the impacts of producing the same or similar products from key land-based production routes.

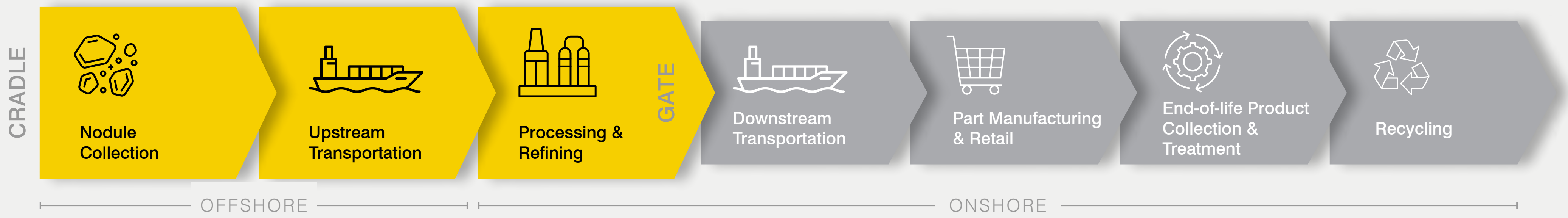
Benchmark conducted an independent LCA to:

- Assess NORI-D Project's potential environmental impacts of producing Mn silicate, NiCuCo matte, Ni and Co sulfate, and copper cathode
- Compare metals from the NORI-D Project vs. producing the same metals via key land-based routes

Benchmark went through an additional third-party verification to ensure compliance with ISO 14040 and 14044 guidelines and standards.

Scope

This LCA is a **"cradle-to-gate" analysis:** The "cradle" starts at raw material acquisition and ends with the "gate" – the final products of the onshore processing ready to be delivered from TMC's plant.



A system expansion approach was applied to account for products for which the production via alternative routes could be avoided. Benchmark went through an additional third-party verification to ensure this attributional LCA is compliant with ISO standards 14040 and 14044. This LCA overview provides a summary of the phases of the LCA and presents the methodology, key results and recommendations. It also provides an overview of the process and technology. The complete LCA can be found here.

1 IEA, 2021. *The Role of Critical Minerals in Clean Energy Transitions,* IEA, Paris.

Functional Unit

A functional unit is a quantified description of the function of a product that serves as the reference basis for all calculations regarding impact assessment. As the goal of the LCA is to provide an environmental profile of products from the NORI-D Project, the functional units have been set at:

1 kg of NiCuCo contained in **matte**

28 Ni Nickel 58.693 | 29 Cu Copper 63.546 | 27 Co Cobalt 58.933

1 kg of Ni contained in **nickel sulfate**

28 Ni Nickel 58.693

1 kg of Co contained in **cobalt sulfate**

27 Co Cobalt 58.933

1 kg of **copper cathode**

29 Cu Copper 63.546

Results for manganese silicate will be covered in a separate report. Manganese silicate from the NORI-D Project is expected to be a direct substitute for medium-grade manganese ore in the production of silicomanganese (SiMn) alloy. However, to fairly compare manganese silicate (a pre-reduced intermediate product with downstream advantages) to medium-grade manganese ore, Benchmark is working on additional analysis that will expand the LCA's system boundaries to include the production of SiMn alloy using NORI-D's pre-reduced manganese silicate from the NORI-D Project versus the incumbent land-based manganese ore.

POLYMETALLIC NODULE

Contains high grades of four key energy-transition metals

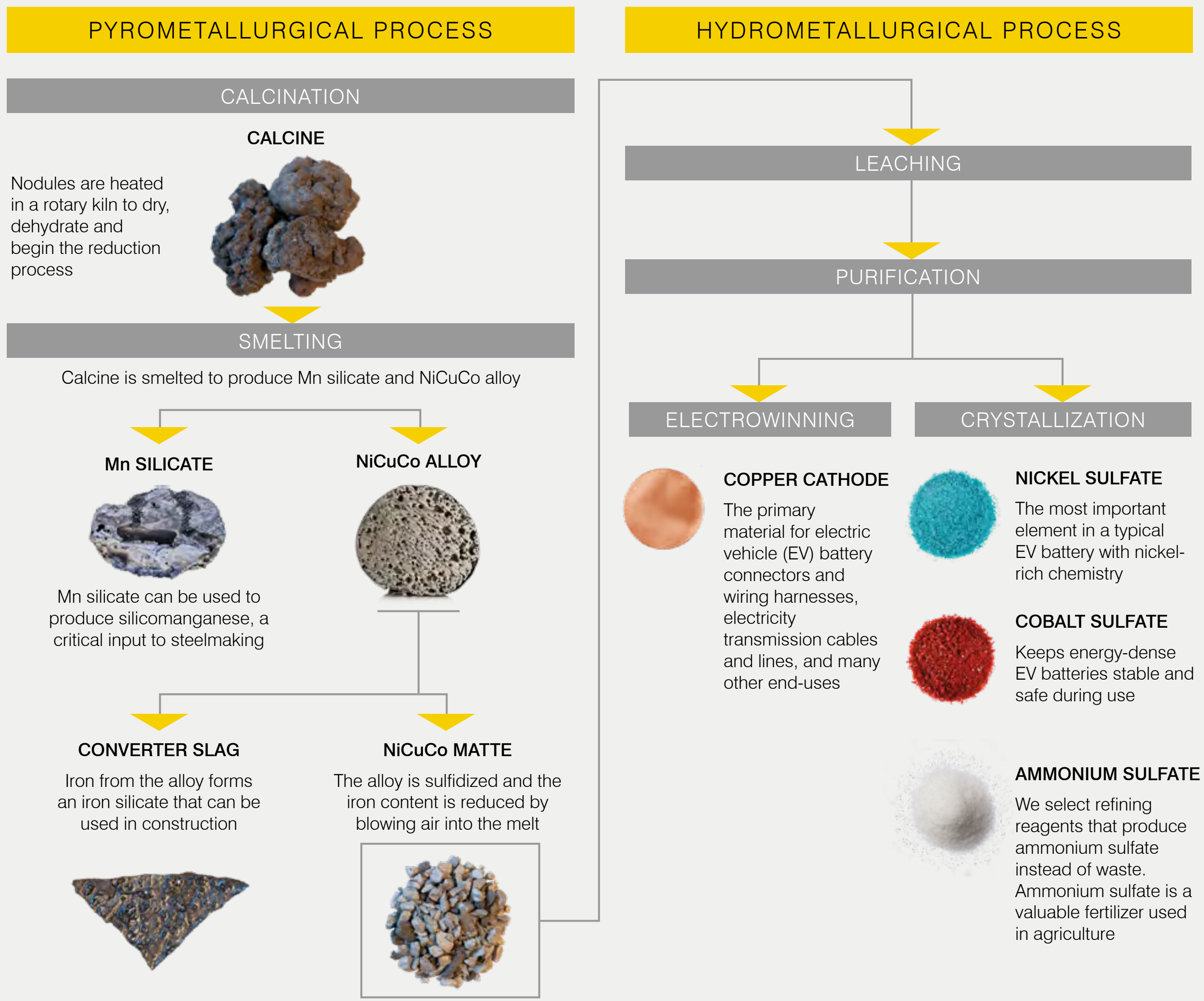
Ore grades

Ni	Cu	Co	Mn
1.39%	1.14%	0.14%	31%

NORI-D Process

The life cycle inventory (LCI) data comes from the product system, which is broken down into unit processes. This diagram represents the complete process steps for producing NORI-D Project's products – from collecting nodules far offshore from the seafloor in the NORI-D area to transporting them onshore, processing nodules into Mn silicate and NiCuCo matte and refining NiCuCo matte to produce Ni and Co sulfate and Cu cathode onshore.

Once collected, PMN are transported by ship to an onshore processing site, where pyrometallurgical steps are followed to generate NiCuCo matte and Mn silicate. The matte is then processed via a hydrometallurgical process to produce Ni and Co sulfate, and Cu cathode.



Hidden Gem – NORI-D Project's first production vessel

Hector – pilot seafloor collector tested in NORI-D area in 2022

Key Assumptions

FOR NORI-D PROJECT

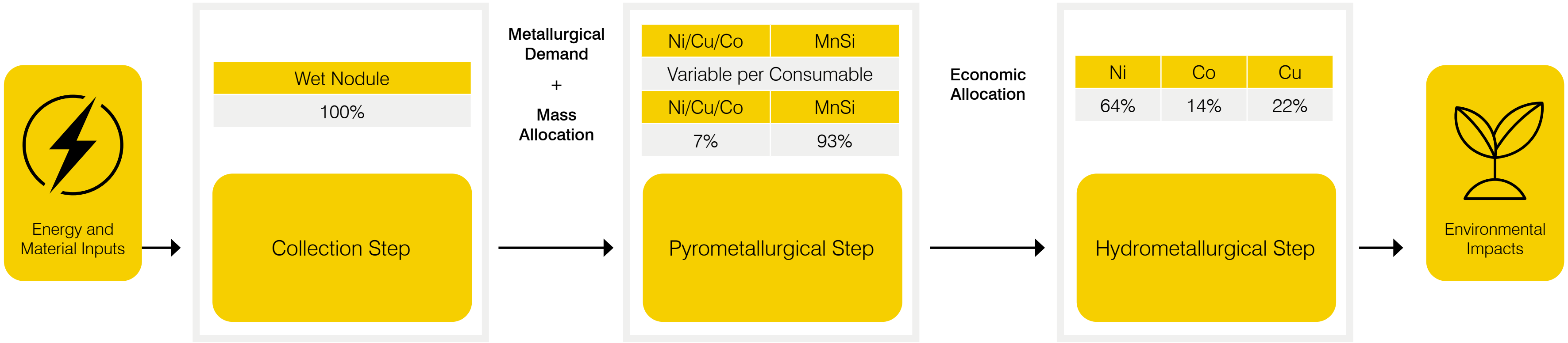
- Project data is based on the SEC S-K-1300-compliant Initial Assessment of the NORI-D Project that has been signed off by Qualified Persons (available here).
- LCI focuses on 16 years of steady-state production from the NORI-D Project, reaching an average production rate of 12.5 Mtpa of wet nodules (9.5 Mtpa of dry nodules)
- Offshore vessels use marine gas oil (MGO)
  - 3 production vessels with a total of 8 seafloor nodule collectors
  - 10 transfer vessels
  - 2 survey vessels
  - 1 support vessel
  - Number of transshipment vessels varies depending on onshore plant location
- Transfer vessels bring nodules from NORI-D to a port on the west coast of North America to be transferred to a larger one-way transshipment vessel. Offshore fuel usage and emissions estimates were developed by DRT.
- Three potential locations for the onshore metallurgical plant were analyzed:
  - **Texas:** Based on 100% **wind** energy, **7 vessels** for transshipment, **3,683 nautical miles** port-to-port
  - **India:** Captive **solar** scenarios with Energy Storage System (ESS), **9 vessels** for transshipment, **9,500 nautical miles** port-to-port
  - **Malaysia:** Based on 100% **hydropower**, **8 vessels** for transshipment, **7,300 nautical miles** port-to-port
- Oxygen is produced on site by a third party. The proxy for liquid oxygen from Ecoinvent is modified to represent this production. Transportation is excluded, and the electricity is produced by renewable sources in accordance with the location of the onshore operations scenarios.
- NORI-D nodules are processed to final marketed products using the near-zero solid waste flowsheet developed and pilot tested by TMC with conceptual engineering by Hatch.
- The onshore data for the NORI-D LCI came from a mass and energy balance model employing standard metallurgical engineering software (Metsim) to replicate the flowsheet and material flows created by Hatch. The basis for the model was commercial data for the analogous existing metallurgical operations, TMC test work, and data from piloting and literature. The stream flow information from the model was employed to represent a NORI-D nodule operation at a scale of 6.4 Mtpa of wet nodules (4.88 Mtpa of dry nodules), which was adapted for this LCA.
- Ammonium sulfate is a by-product of the hydrometallurgical step. Via system expansion, it is allocated as an avoided product to the NORI-D Project. Therefore, credit is given in accordance with the savings of the emissions avoided (in theory) in each impact category for not needing alternative processing to intentionally produce it.

FOR LAND-BASED ROUTES

- The land-based processing routes were modeled with background data (Ecoinvent) and foreground data from two expert chemical engineers in the nickel and cobalt industry.
- For suppliers of consumables, global averages were used. Electricity mixes are representative of the country identified for each route analyzed. No specific renewable energy source is applied.

Allocation

- According to the ISO 14044 standard, allocation should be avoided when possible. Due to the production of multiple products, the allocation was avoided by identifying sub-processes in the pyrometallurgical step and applying knowledge of the specific metallurgical and energetic demands of each of the products in the flowsheet. As a result, allocation was avoided for key inputs such as coal, natural gas, electricity, silica flux and sulfur. For the remaining inputs, such as water and electricity for an onsite fleet, mass allocation was used. Due to the importance of grade in the products analyzed in this LCA, the metal content is considered instead of full mass. For the hydrometallurgical step, economic allocation was applied.



- For the land-based production routes, all refining stages are economically allocated where more than one metal product is produced, using the same metal price as for the NORI-D Project model. For any credit assigned to a route, the same alternative production is chosen in routes that produce the same by-product (e.g., ammonium sulfate).
- The NORI-D production of Mn silicate is responsible for the majority of the pyrometallurgical emissions due to direct metallurgical demands. No other route is distributed to the same level of metallurgical accuracy due to data availability. However, none of the land-based models yield as voluminous a co-product in the intermediate stage as does the NORI-D Project model.

Sensitivity Analysis

The purpose of a sensitivity analysis is to investigate the effects of changes in input parameters on the final results and to ensure the robustness of the methodology and results. Four sensitivity analyses were conducted:

Location
Texas versus other possible geographies for onshore processing – India and Malaysia

Metal price variation
10-year average versus 2022 prices

Environmental credit
Ammonium sulfate credit via system expansion versus accounting for it as co-production

Allocation
Current allocation versus using economic allocation for all steps

The findings of the sensitivity analysis confirmed the validity of the decisions made and the model robustness. The sensitivity analysis indicated the results are sensitive to economic allocation and environmental credits, but not to the location of onshore production and variations in metal price.

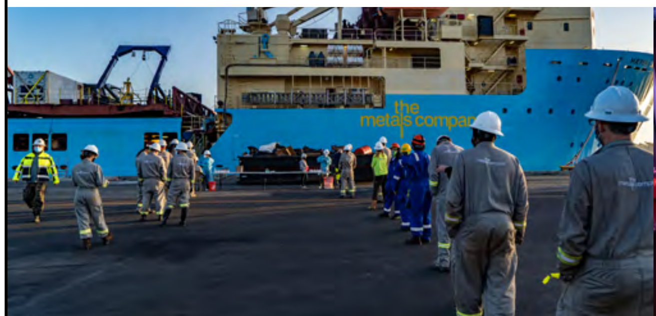
Details of the sensitivity analysis can be found in the full report.

Impact Categories

The seven midpoint impact categories below, all critical environmental impacts of the metal industry, are defined during the life cycle inventory analysis (LCIA) phase. The full list of impact categories within ReCiPe 2016 (a harmonized life cycle impact assessment method at midpoint and endpoint level) can be found in Appendix 1 of the full LCA report.

Impact Category (ReCiPe 2016)	Details
Global Warming Potential	Emissions included: carbon dioxide, carbon monoxide, methane, nitrous oxide, chlorofluorocarbons and hydrochlorofluorocarbons **(in kg CO_2 equivalent to air)**.
Stratospheric Ozone Depletion	Chemicals that cause the depletion of the ozone layer have chlorine or bromine groups in their molecules that interact with ozone (mainly) in the stratosphere. Ultimately, they cause human health issues because of the resultant increase in UVB radiation **(in mg CFC-11 equivalent to air)**.
Terrestrial Acidification	Atmospheric deposition of inorganic substances, such as sulfates, nitrates and phosphates, cause a change in the acidity of the soil. Major acidifying emissions include nitrogen dioxide (NO_x), ammonia (NH_3) or sulfur dioxide (SO_2). This can cause extinction of species, leading to damage to the terrestrial ecosystem **(in kg SO_2 equivalent to air)**.
Freshwater Eutrophication	Occurs due to the discharge of nutrients into soil or into freshwater bodies and hence in the subsequent rise in nutrient levels, e.g., phosphorus and nitrogen linked to algae blooms, tainted drinking water supplies, degradation of recreational opportunities, and hypoxia 'dead zone' lacking sufficient oxygen to support most organisms **(in g P equivalent to freshwater)**.
Marine Eutrophication	Occurs due to the discharge of nutrients into marine environments and hence in the subsequent rise in nutrient levels, e.g., phosphorus and nitrogen, setting off a chain reaction in the ecosystem that leads to acidification and the reduction of marine life **(in g N equivalent to marine water)**.
Particulate Matter Formation	Represents a complex mixture of organic and inorganic substances. PM2.5 can cause human health problems as it can deposit to the upper part of the airways and lungs when inhaled. Secondary PM2.5 aerosols are formed in air from emissions of SO_2, NH_3 and NO_x, among other elements **(in g PM2.5 equivalent to air)**.
Water Consumption	Attributed to the availability reduction of freshwater, which leads to impacts on human health and ecosystem quality **(in m³ water consumed)**.

Supplementary Research	Details
Waste Generation	Waste stream analysis does not form part of the third-party LCA but Benchmark included it as supplementary research to this study. Includes mine waste, mine and processing tailings,tailings bleed, slag and mobilized sediments (in kg of waste).



Comparison to Key Land-Based Production Routes

The results from the NORI-D Project LCA are compared to Benchmark's identified key routes for producing the same metals from conventional land-based ores. Production of these metals from deepsea nodules is compared side-by-side to production from land-based ores by using the most current data for analysis. Methodological choices have been replicated as accurately as possible to enable comparison. The routes analyzed are directly associated with 93% of global refined nickel production and 86% of global mined cobalt output for 2022.

Ore	Ore grade	Mine to intermediate region	Processing technology	Intermediate content	Refining region	Overall recovery rates	Methodology	Credit
Laterite	Nickel – 1.50% Cobalt – 0.02%	Indonesia	**RKEF** Rotary kiln-electric furnace (RKEF) & Peirce-Smith converters	Matte Nickel – 75% Cobalt – 0.71%	China	Nickel – 84% Cobalt – 59%	The refining of matte to metal is economically allocated	Sodium sulfate (by-product)
Sulfide	Nickel – 0.60% Copper – 0.10% Cobalt – 0.02%	Australia	**DON** Direct Outokumpu Nickel smelting process **Conventional** Flash furnance & Peirce-Smith converters	Metal (100%)	China	Nickel – 73% Copper – 73% Cobalt – 74%	The refining of matte to metal is economically allocated	Sulfuric acid (by-product) Co-generation of electricity Sodium sulfate (by-product)
Laterite	Nickel – 1.35% Cobalt – 0.08%	Indonesia Philippines	**HPAL** High-pressure acid leaching	MHP[2] Nickel – 42% Cobalt – 6% MSP[3] Nickel – 60% Cobalt – 5%	China Japan	Nickel – 85% Cobalt – 63% Nickel – 87% Cobalt – 74%	The refining of matte to metal is economically allocated	Ammonium sulfate (by-product)
Laterite	Nickel – 1.45%	Cuba	**Caron** Reductive roast and ammonium leaching	Metal (100%)	Canada	Nickel – 84.5%	No allocation needed	None
Sulfide	Nickel – 3.5% Cobalt – 0.2%	Canada	**POX** Pressure oxidation leach	Metal (100%)	Canada	Nickel – 86% Cobalt – 85%	Economic allocation	None
Mixed sulfide and oxides	Copper – 2.5-3% Cobalt – 0.3-0.4%	Democratic Republic of Congo (DRC)	**RLE** Roasters, leaching and electrowinning	Copper cathode Cobalt hydroxide	China	Copper – 90% Cobalt – 74%	Pre-refining the concentrate is economically allocated	None
Nodule	Nickel – 1.39% Copper – 1.14% Cobalt – 0.14% Manganese – 31%	Clarion-Clipperton Zone	**RKEF** Rotary kiln-electric furnace (RKEF) & Peirce-Smith converters	Matte Nickel – 41% Copper – 31% Cobalt – 3%	Texas	Nickel – 95% Copper – 86% Cobalt – 77%	Matte main inputs use metallurgical demand; remaining inputs are mass allocated Refining is economically allocated MnSi (co-product)	Converter slag (avoided product) Ammonium sulfate (by-product)

2 Mixed hydroxide precipitate
3 Mixed sulfite precipitate

Results

Below are the LCA results for NiCuCo matte, nickel sulfate, cobalt sulfate and copper cathode.

Summary: Environmental Impacts of NORI-D Project By Product

NORI-D Project products	NiCuCo matte	Nickel in nickel sulfate	Copper cathode	Cobalt in cobalt sulfate
Environmental Performance	**Best environmental performance** in all **7 impact categories** among the 3 processing routes analyzed	**Best environmental performance** in all **7 impact categories** among the 8 processing routes analyzed	**Best environmental performance** in all **7 impact categories** among the 4 processing routes analyzed	**Best environmental performance** in **5 of 7 impact categories** among the 8 processing routes analyzed
Overall Impact	On average **>90% lower emissions** than the conventional and DON processing routes in 4 of 7 impact categories, namely stratospheric ozone depletion, freshwater eutrophication, marine eutrophication and water consumption. And on average **lower emissions by >63% in GWP, >36% in terrestrial acidification and >44% in fine particulate formation**	On average **>80% lower emissions** than other routes in 5 of 7 impact categories, namely stratospheric ozone depletion, terrestrial acidification, freshwater eutrophication, marine eutrophication and fine particulate matter formation. And on average **>70% lower emissions in GWP and water consumption**	On average **>90% lower emissions** in 3 of 7 impact categories for stratospheric ozone depletion, freshwater eutrophication and marine eutrophication. And on average **lower emissions by >55% in GWP, 64% in terrestrial acidification and 43% in water consumption**	On average **>70% lower emissions** in 5 of 7 impact categories, namely stratospheric ozone depletion, terrestrial acidification, freshwater eutrophication, marine eutrophication and fine particulate matter formation. And on average **>44% lower emissions in GWP and water consumption**
Global Warming Potential (GWP)	**60% and 64% lower GWP** than conventional and DON processing routes respectively	Between **23-94% lower GWP** than other 7 processing routes analyzed	Between **11-78% lower GWP** than other 3 processing routes analyzed	Between **11-92% lower GWP** than other 7 processing routes and **58% higher GWP** than the RLE route
Notes	Lower electricity demand, use of renewable energy and differences in the mining process contributed to better performance. Since nodules are unattached to the seafloor, obtaining metal ores by collecting nodules avoided emissions from blasting in traditional terrestrial mining, one of the chief environmental hotspots in stratospheric ozone depletion, fine particulate matter formation and terrestrial acidification in conventional and DON processing routes. Sulfidic tailings are also avoided, leading to 97% lower freshwater eutrophication emissions.	In addition to renewable electricity and higher recovery rates, the main reason for NORI-D Project's lower emissions in most impact categories is because use of sulfuric acid in the MHP and MSP routes is respectively 5-6 times higher than that in the NORI-D Project. Another critical contributor to the better performance is the absence of blasting in the mining stage. TMC NORI-D's absence of sulfidic tailings has proved significant in lowering the freshwater eutrophication emissions and the absence of blasting in the mining stage is another critical contributor to the better performance.	NORI-D Project's emissions from electricity contributed to only 0-7% in six impact categories, thanks to an energy efficient process and the use of renewable electricity. Another factor is the emissions from blasting in Conventional and DON technologies make NORI-D Project perform better in ozone depletion, fine particulate matter formation and terrestrial acidification. Similar to the previous products, the absence of sulfidic tailings helps differentiate the NORI-D Project from other routes in terms of eutrophication emissions.	Although the Indonesian RKEF route is similar to NORI-D in terms of the pyrometallurgical process for converting ore to matte, emissions from the NORI-D Project are between 76-149% lower in all impact categories. This is due to an 18% higher cobalt recovery rate, an 81% lower energy consumption rate, the use of renewable electricity and an 87% lower coal consumption. As compared to the RLE route, TMC NORI-D Project has higher GWP due to emissions from coal combustion and 10% higher water consumption.

Matte

Global warming potential (kg CO_2 eq)

Australia | Sulfide | DON	13.64
Australia | Sulfide | Conventional	12.65
NORI-D | Nodules | RKEF/Peirce-Smith	4.91

Stratospheric ozone depletion (mg CFC-11 eq)

Australia | Sulfide | DON	16.2
Australia | Sulfide | Conventional	15.9
NORI-D | Nodules | RKEF/Peirce-Smith	0.74

Fine particulate matter formation (g PM2.5 eq)

Australia | Sulfide | DON	17.93
Australia | Sulfide | Conventional	16.99
NORI-D | Nodules | RKEF/Peirce-Smith	9.79

Terrestrial acidification (kg SO_2 eq)

Australia | Sulfide | DON	0.05
Australia | Sulfide | Conventional	0.05
NORI-D | Nodules | RKEF/Peirce-Smith	0.03

Freshwater eutrophication (g P eq)

Australia | Sulfide | Conventional	46.53
Australia | Sulfide | DON	46.20
NORI-D | Nodules | RKEF/Peirce-Smith	1.36

Marine eutrophication (g N eq)

Australia | Sulfide | Conventional	1.23
Australia | Sulfide | DON	1.21
NORI-D | Nodules | RKEF/Peirce-Smith	0.08

Water consumption (m^3)

Australia | Sulfide | DON	0.05
Australia | Sulfide | Conventional	0.04
NORI-D | Nodules | RKEF/Peirce-Smith	0.004

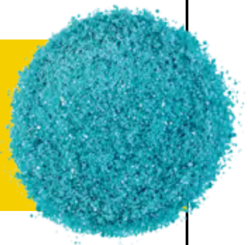
Matte Composition:

Australia | Sulfide | DON and Conventional:
Nickel – 63%
Copper – 11%
Cobalt – 1%

NORI-D | Nodules | RKEF/Peirce-Smith:
Nickel – 41%
Copper – 31%
Cobalt – 3%

Nickel

in nickel sulfate



Global warming potential (kg CO_2 eq)

Indonesia | Laterite | RKEF	101.9
Cuba | Laterite | Caron	64.4
Australia | Sulfide | DON	29.2
Australia | Sulfide | Conventional	28.5
Indonesia | Laterite | HPAL (MHP)	19.2
Philippines | Laterite | HPAL (MSP)	13.9
Canada | Sulfide | POX	7.9
NORI-D | Nodules | RKEF/Peirce-Smith	6.2

Stratospheric ozone depletion (mg CFC-11 eq)

Australia | Sulfide | DON	27.5
Australia | Sulfide | Conventional	27.1
Cuba | Laterite | Caron	17.3
Indonesia | Laterite | RKEF	14.1
Canada | Sulfide | POX	3.4
Indonesia | Laterite | HPAL (MHP)	3.1
Philippines | Laterite | HPAL (MSP)	3.1
NORI-D | Nodules | RKEF/Peirce-Smith	0.7

Fine particulate matter formation (g PM2.5 eq)

Indonesia | Laterite | RKEF	1,187.0
Indonesia | Laterite | HPAL (MHP)	262.0
Philippines | Laterite | HPAL (MSP)	160.0
Australia | Sulfide | DON	43.1
Australia | Sulfide | Conventional	42.9
Canada | Sulfide | POX	39.5
Cuba | Laterite | Caron	31.7
NORI-D | Nodules | RKEF/Peirce-Smith	9.2

Terrestrial acidification (kg SO_2 eq)

Indonesia | Laterite | RKEF	0.96
Indonesia | Laterite | HPAL (MHP)	0.69
Philippines | Laterite | HPAL (MSP)	0.53
Australia | Sulfide | Conventional	0.13
Australia | Sulfide | DON	0.13
Canada | Sulfide | POX	0.12
Cuba | Laterite | Caron	0.09
NORI-D | Nodules | RKEF/Peirce-Smith	0.03

Freshwater eutrophication (g P eq)

Indonesia | Laterite | RKEF	91.0
Australia | Sulfide | Conventional	76.4
Australia | Sulfide | DON	75.8
Cuba | Laterite | Caron	9.5
Indonesia | Laterite | HPAL (MHP)	9.1
Philippines | Laterite | HPAL (MSP)	5.2
Canada | Sulfide | POX	2.9
NORI-D | Nodules | RKEF/Peirce-Smith	1.0

Marine eutrophication (g N eq)

Indonesia | Laterite | RKEF	5.5
Australia | Sulfide | Conventional	2.3
Australia | Sulfide | DON	2.3
Canada | Sulfide | POX	0.2
Cuba | Laterite | Caron	0.1
Philippines | Laterite | HPAL (MSP)	-1.3
Indonesia | Laterite | HPAL (MHP)	-1.8
NORI-D | Nodules | RKEF/Peirce-Smith	-2.1

Water consumption (m^3)

Indonesia | Laterite | RKEF	0.31
Indonesia | Laterite | HPAL (MHP)	0.25
Philippines | Laterite | HPAL (MSP)	0.24
Cuba | Laterite | Caron	0.17
Australia | Sulfide | DON	0.15
Canada | Sulfide | POX	0.15
Australia | Sulfide | Conventional	0.13
NORI-D | Nodules | RKEF/Peirce-Smith	0.05

Land-based waste generation (kg)*

Australia | Sulfide | DON	545
Australia | Sulfide | Conventional	545
Cuba | Laterite | Caron	365
Indonesia | Laterite | HPAL (MHP)	337
Philippines | Laterite | HPAL (MSP)	337
Indonesia | Laterite | RKEF	244
Canada | Sulfide | POX	82
NORI-D | Nodules | RKEF/Peirce-Smith**	0

Marine waste generation (kg)*

Australia | Sulfide | Conventional	N/A
Australia | Sulfide | DON	N/A
Canada | Laterite | POX	N/A
Cuba | Laterite | Caron	N/A
Indonesia | Laterite | HPAL (MHP)	N/A
Indonesia | Laterite | RKEF	N/A
Philippines | Laterite | HPAL (MSP)	N/A
NORI-D | Nodules | RKEF/Peirce-Smith	137

* Waste stream analysis does not form part of the third-party LCA but has been included by Benchmark as supplementary research to this study. Nodule collection operations entrain underlying sediment, separate it from nodules and return it to the seafloor within meters of its origin. For the purposes of the LCA, this entrained sediment has been included under marine waste generation as a proxy for overburden given that nodule collection does not generate terrestrial waste such as mine waste, mine and process tailings and tailings bleed.

** 8 kg of converter slag suitable for construction applications is generated per kg of nickel.

Cobalt
in cobalt sulfate

Global warming potential (kg CO_2 eq)

Indonesia | Laterite | RKEF	212.02
Australia | Sulfide | DON	66.50
Australia | Sulfide | Conventional	62.69
Philippines | Laterite | HPAL (MSP)	43.05
Indonesia | Laterite | HPAL (MHP)	36.29
Canada | Sulfide | POX	18.43
NORI-D | Nodules | RKEF/Peirce-Smith	16.41
DRC | Mixed Sulfides | RLE	10.40

Stratospheric ozone depletion (mg CFC-11 eq)

Australia | Sulfide | DON	65.6
Australia | Sulfide | Conventional	64.4
Indonesia | Laterite | RKEF	28.9
Philippines | Laterite | HPAL (MSP)	9.16
Canada | Sulfide | POX	7.80
Indonesia | Laterite | HPAL (MHP)	5.51
DRC | Mixed Sulfides | RLE	3.51
NORI-D | Nodules | RKEF/Peirce-Smith	1.95

Fine particulate matter formation (g PM2.5 eq)

Indonesia | Laterite | RKEF	2497.2
Indonesia | Laterite | HPAL (MHP)	527.6
Philippines | Laterite | HPAL (MSP)	516.2
Australia | Sulfide | DON	92.6
Canada | Sulfide | POX	90.9
Australia | Sulfide | Conventional	88.9
DRC | Mixed Sulfides | RLE	34.0
NORI-D | Nodules | RKEF/Peirce-Smith	24.6

Terrestrial acidification (kg SO_2 eq)

Indonesia | Laterite | RKEF	2.00
Philippines | Laterite | HPAL (MSP)	1.71
Indonesia | Laterite | HPAL (MHP)	1.38
Canada | Sulfide | POX	0.29
Australia | Sulfide | Conventional	0.27
Australia | Sulfide | DON	0.27
DRC | Mixed Sulfides | RLE	0.09
NORI-D | Nodules | RKEF/Peirce-Smith	0.08

Freshwater eutrophication (g P eq)

Indonesia | Laterite | RKEF	190.7
Australia | Sulfide | Conventional	183.1
Australia | Sulfide | DON	181.8
Indonesia | Laterite | HPAL (MHP)	17.3
Philippines | Laterite | HPAL (MSP)	15.7
Canada | Sulfide | POX	5.5
DRC | Mixed Sulfides | RLE	4.6
NORI-D | Nodules | RKEF/Peirce-Smith	2.6

Marine eutrophication (g N eq)

Indonesia | Laterite | RKEF	11.59
Australia | Sulfide | Conventional	5.04
Australia | Sulfide | DON	4.95
Canada | Sulfide | POX	0.39
DRC | Mixed Sulfides | RLE	0.20
Indonesia | Laterite | HPAL (MHP)	-3.72
Philippines | Laterite | HPAL (MSP)	-3.93
NORI-D | Nodules | RKEF/Peirce-Smith	-5.71

Water consumption (m^3)

Philippines | Laterite | HPAL (MSP)	0.73
Indonesia | Laterite | RKEF	0.60
Indonesia | Laterite | HPAL (MHP)	0.46
Australia | Sulfide | DON	0.37
Australia | Sulfide | Conventional	0.32
Canada | Sulfide | POX	0.28
NORI-D | Nodules | RKEF/Peirce-Smith	0.15
DRC | Mixed Sulfides | RLE	0.13

Land-based waste generation (kg)*

Australia | Sulfide | DON	32,708
Australia | Sulfide | Conventional	32,708
Indonesia | Laterite | RKEF	25,761
Philippines | Laterite | HPAL (MSP)	2,594
Indonesia | Laterite | HPAL (MHP)	2,594
Canada | Sulfide | POX	1,439
DRC | Mixed Sulfides | RLE	1,115
NORI-D | Nodules | RKEF/Peirce-Smith**	0

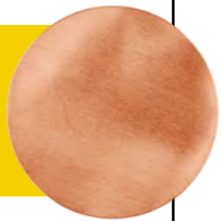
Marine waste generation (kg)*

Australia | Sulfide | Conventional	N/A
Australia | Sulfide | DON	N/A
Canada | Laterite | POX	N/A
DRC | Mixed Sulfides | RLE	N/A
Indonesia | Laterite | HPAL (MHP)	N/A
Indonesia | Laterite | RKEF	N/A
Philippines | Laterite | HPAL (MSP)	N/A
NORI-D | Nodules | RKEF/Peirce-Smith	1,665

* Waste stream analysis does not form part of the third-party LCA but has been included by Benchmark as supplementary research to this study. Nodule collection operations entrain underlying sediment, separate it from nodules and return it to the seafloor within meters of its origin. For the purposes of the LCA, this entrained sediment has been included under marine waste generation as a proxy for overburden given that nodule collection does not generate terrestrial waste such as mine waste, mine and process tailings and tailings bleed.

** 95 kg of converter slag suitable for construction applications is generated per kg of cobalt.

Copper
cathode



Global warming potential (kg CO_2 eq)

Australia | Sulfide | DON	12.75
Australia | Sulfide | Conventional	12.09
DRC | Mixed Sulfides | RLE	3.19
NORI-D | Nodules | RKEF/Peirce-Smith	2.84

Stratospheric ozone depletion (mg CFC-11 eq)

Australia | Sulfide | DON	12.20
Australia | Sulfide | Conventional	12.00
DRC | Mixed Sulfides | RLE	1.58
NORI-D | Nodules | RKEF/Peirce-Smith	0.34

Fine particulate matter formation (g PM2.5 eq)

Australia | Sulfide | DON	17.2
Australia | Sulfide | Conventional	16.6
DRC | Mixed Sulfides | RLE	15.8
NORI-D | Nodules | RKEF/Peirce-Smith	4.2

Terrestrial acidification (kg SO_2 eq)

Australia | Sulfide | DON	0.05
Australia | Sulfide | Conventional	0.05
DRC | Mixed Sulfides | RLE	0.03
NORI-D | Nodules | RKEF/Peirce-Smith	0.01

Freshwater eutrophication (g P eq)

Australia | Sulfide | Conventional	34.25
Australia | Sulfide | DON	34.04
DRC | Mixed Sulfides | RLE	4.09
NORI-D | Nodules | RKEF/Peirce-Smith	0.45

Marine eutrophication (g N eq)

Australia | Sulfide | Conventional	1.03
Australia | Sulfide | DON	1.01
DRC | Mixed Sulfides | RLE	0.10
NORI-D | Nodules | RKEF/Peirce-Smith	-0.99

Water consumption (m^3)

Australia | Sulfide | DON	0.05
Australia | Sulfide | Conventional	0.04
DRC | Mixed Sulfides | RLE	0.04
NORI-D | Nodules | RKEF/Peirce-Smith	0.03

Land-based waste generation (kg)*

Australia | Sulfide | DON	3,203
Australia | Sulfide | Conventional	3,203
DRC | Mixed Sulfides | RLE	113
NORI-D | Nodules | RKEF/Peirce-Smith**	0

Marine waste generation (kg)*

Australia | Sulfide | Conventional	N/A
Australia | Sulfide | DON	N/A
DRC | Mixed Sulfides | RLE	N/A
NORI-D | Nodules | RKEF/Peirce-Smith	183

* Waste stream analysis does not form part of the third-party LCA but has been included by Benchmark as supplementary research to this study. Nodule collection operations entrain underlying sediment, separate it from nodules and return it to the seafloor within meters of its origin. For the purposes of the LCA, this entrained sediment has been included under marine waste generation as a proxy for overburden given that nodule collection does not generate terrestrial waste such as mine waste, mine and process tailings and tailings bleed.

** 10 kg of converter slag suitable for construction applications is generated per kg of copper.

Interpretation

Production of all five NORI-D Project products has a better environmental performance than the traditional land-processing routes analyzed in almost all impact categories with the only exception of GWP and water consumption for cobalt produced via the RLE route where NORI-D presents higher emissions. The GWP of NORI-D products production is 11-94% lower than the land routes reviewed. NORI-D nodules can be collected without blasting or drilling, and no sulfidic tailings are produced. Other reasons for a lower environmental burden include differences in TMC's onshore processes, which encompass lower energy demand; TMC's commitment to use renewable electricity; high-revenue, high-volume co-products; and high metal recovery rates.

The combustion, production and distribution of bituminous coal, which is used as a reductant in the pyrometallurgical step, were the biggest drivers behind most impact category results for all five NORI-D Project products. The combustion of bituminous coal alone contributed to 63-65% of the GWP of all products; hence, direct emissions are the major source of GHG emissions for the NORI-D Project, making the pyrometallurgical stage the most environmentally impactful stage that needs to be addressed.

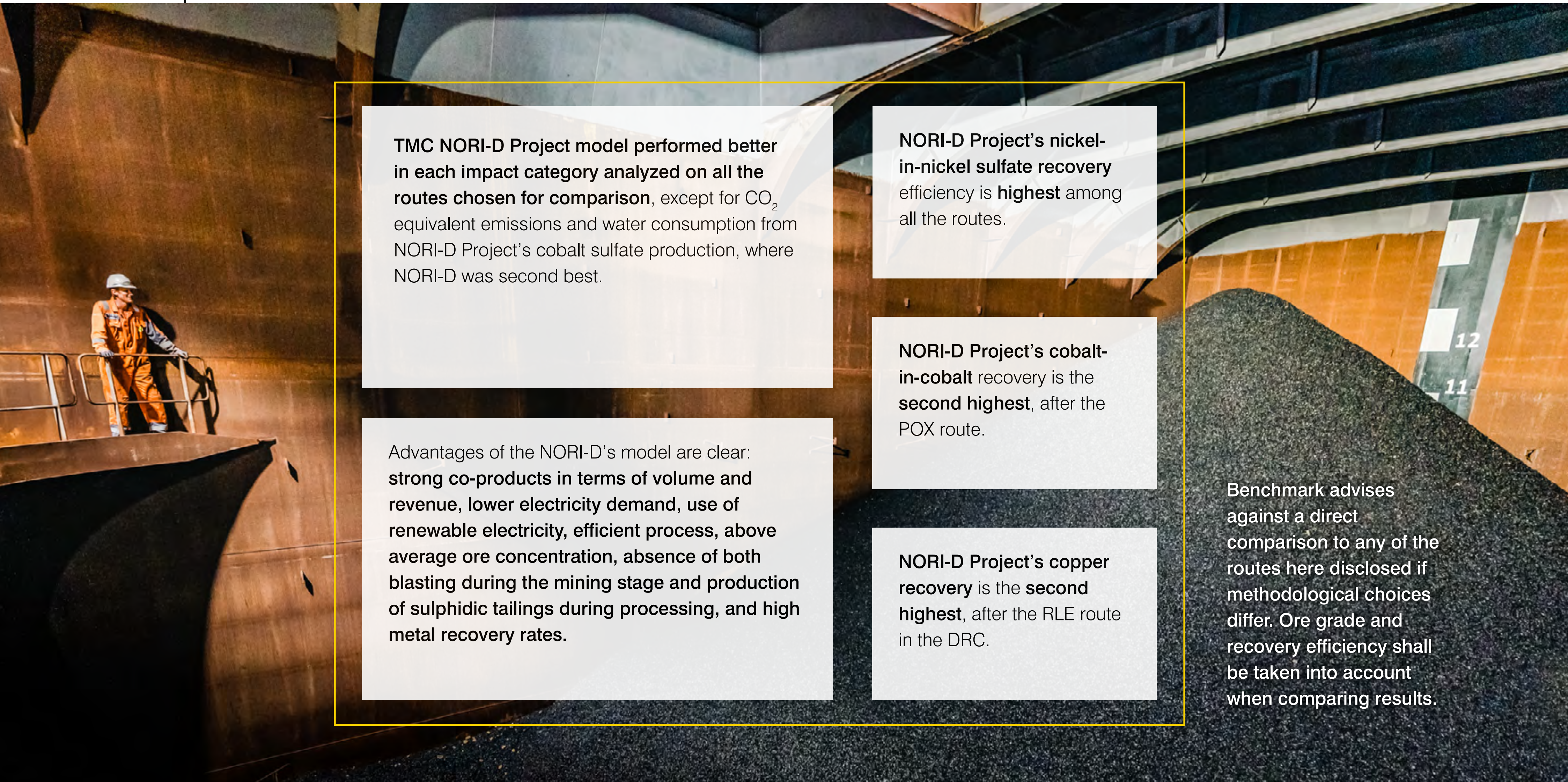
According to the waste stream analysis, TMC's processes have less hazardous impact on soil. The mobilized sediment offshore represents the highest volume of material displaced.

Benchmark Recommendations for NORI-D Project

In order to reduce overall emissions, it is most impactful to focus on finding a replacement for metallurgical coal as a reductant. Alternatives such as biomass pellets should be considered. Natural gas used for heat is also a significant source of GHG emissions.

Ammonia and sulfuric acid should be sourced from lower-impact suppliers or strategically engineered to be used in a more efficient fashion.

LCA Highlights: NORI-D Project vs. Key Land-based Routes



TMC NORI-D Project model performed better in each impact category analyzed on all the routes chosen for comparison, except for CO_2 equivalent emissions and water consumption from NORI-D Project's cobalt sulfate production, where NORI-D was second best.

Advantages of the NORI-D's model are clear: **strong co-products in terms of volume and revenue, lower electricity demand, use of renewable electricity, efficient process, above average ore concentration, absence of both blasting during the mining stage and production of sulphidic tailings during processing, and high metal recovery rates.**

NORI-D Project's nickel-in-nickel sulfate recovery efficiency is **highest** among all the routes.

NORI-D Project's cobalt-in-cobalt recovery is the **second highest**, after the POX route.

NORI-D Project's copper recovery is the **second highest**, after the RLE route in the DRC.

Benchmark advises against a direct comparison to any of the routes here disclosed if methodological choices differ. Ore grade and recovery efficiency shall be taken into account when comparing results.

the metals company