

NICKEL-COBALT-COPPER OPENING KEYNOTE

HEAP LEACHING – LOW COST, LOW CO₂ TECHNOLOGY FOR RECOVERING NICKEL AND COBALT PRODUCTS FROM LATERITE ORES

By

Anne Oxley, ^{1,2}

¹Brazilian Nickel, UK

²Scientific Associate of the Natural History Museum, UK

Presenter and Corresponding Author

Anne Oxley
aoxley@brnickel.com

ABSTRACT

Heap leaching is a low cost and inherently low carbon footprint process to recover nickel and cobalt from laterite ores. In comparison with other processing methods for laterites, it is a simple delinked process that has a straight forward ramp-up to steady state production, allowing both lower capital and operating costs.










Located in north-eastern Brazil, Brazilian Nickel's (BRN) Piauí Nickel Project (PNP) heap leach operation aims to be the first large scale commercial nickel and cobalt heap leach facility in the world. The first smaller scale commercial plant, the PNP 1000, produced first nickel product in June 2022 and is ramping-up to produce approximately 1,400 tpa Ni and 35 tpa cobalt in intermediate nickel and cobalt hydroxide products. The next scale of operations will be construction of the full scale plant to produce circa 25,000 tpa Ni and 1000 tpa Co contained in separate hydroxide products. The full scale operation is targeted to begin production in 2025.

Intermediate nickel and cobalt products, such as those produced at the PNP, are now the preferred product for the electric vehicle (EV) battery market. They are easily re-dissolved, either to form sulphates or direct to precursor, for the cathode active materials for the EV batteries.

Advantages of heap leaching for EV battery raw materials include lower capital intensity, lower operating costs, smaller environmental footprint and reduced CO₂ emissions. On the latter, the PNP has been independently benchmarked and will potentially produce one of the lowest carbon-intensity products in the nickel industry, and BRN is looking at innovative ways to reduce or eliminate the CO₂ emissions with a view to becoming a net carbon zero or even carbon negative producer.

Keywords: Nickel Laterite, Heap Leaching, Low Carbon, Carbon Capture, Nickel, Cobalt, Battery Raw Materials, EVs.

Why Heap Leaching ?

-  **Lowest capital cost of the hydromet processes**
-  **First quartile operating costs**
-  **Stable known Ramp-up**
-  **Simple flexible process, (but needs know-how)**
-  **Resource utilization maximised**
-  **Low energy intensity**
-  **Low CO₂**
-  **All residues are dry – no tailings dam**
-  **Low construction risk**

Nickel Laterite Heap Leaching Development

BRN brings together a team of experts that have been at the forefront of the development of nickel laterite heap leaching, leading projects at...

Project	Country	Dates	Largest Test/Production	Stage
Bitinçka	Albania	1999-2008	Bottle Rolls & Columns	PFS
Çaldağ	Turkey	2003-2010	Pilot Plant	BFS & FEED
Cerro Matoso	Colombia	2005-2010	Pilot Plant	BFS
Acoje	Philippines	2007-2010	Pilot Plant	PFS
Piauí	Brazil	2013 – present	Demo Plant Small Scale Production	Detailed Engineering



Bitinçka



Çaldağ



Cerro Matoso






Acoje



Piauí Nickel Project






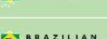





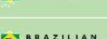





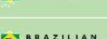


Piauí Nickel Full Scale Project Overview

The PNP, located in NE Brazil, is expected to produce an average of 26ktpa nickel and 1.0ktpa cobalt over the first 10 years of mine life from peak production

	Located in Piauí State, Brazil	<ul style="list-style-type: none"> • Established mining jurisdiction • 6 key ports, 11 inland routes and 3 international airports
	Peak and Average Production	<ul style="list-style-type: none"> • Peak production in 2027: 34ktpa nickel, 1.2ktpa cobalt • Average production in 2027-2036: 26ktpa nickel, 1.0ktpa cobalt
	First Large Scale Production	<ul style="list-style-type: none"> • Current production expectations: <ul style="list-style-type: none"> • First nickel in Q2 2026 • First cobalt in Q1 2027
	Mining and Processing Methods	<ul style="list-style-type: none"> • Mining method: Open pit • Processing method: Heap leach
	Current Status	<ul style="list-style-type: none"> • Early production: PNP1000 completed • Feasibility Study: Completed in July 2022 for Full-Scale PNP • Licenses: Awarded the 5 necessary Preliminary Licenses ("LP")

Piauí Nickel Project History

The PNP deposit is a nickel-cobalt laterite deposit that has undergone extensive exploration work and drilling since its discovery in the 1970s

Project Location		Past Drilling Campaigns at the Project																												
		<table border="1"> <thead> <tr> <th>Years</th> <th></th> <th>Total Drilling</th> </tr> </thead> <tbody> <tr> <td>1973-74</td> <td>Rio Doce Geologia e Mineração</td> <td>1,435m</td> </tr> <tr> <td>2003</td> <td> VALE</td> <td>2,346m</td> </tr> <tr> <td>2004-05</td> <td> VALE</td> <td>53,827m</td> </tr> <tr> <td>2006</td> <td> VALE Vale Test Mine Excavated</td> <td>-</td> </tr> <tr> <td>2008</td> <td> VALE</td> <td>19,518m</td> </tr> <tr> <td>2016</td> <td> BRAZILIAN NICKEL PLC BRN Demo Heap Sampling</td> <td>737m</td> </tr> <tr> <td>2021 & 2023</td> <td> BRAZILIAN NICKEL PLC PNP1000 Grade Control Drilling</td> <td>9,460m</td> </tr> <tr> <td colspan="2">Total Drilling</td> <td>87,323m</td> </tr> </tbody> </table>		Years		Total Drilling	1973-74	Rio Doce Geologia e Mineração	1,435m	2003	 VALE	2,346m	2004-05	 VALE	53,827m	2006	 VALE Vale Test Mine Excavated	-	2008	 VALE	19,518m	2016	 BRAZILIAN NICKEL PLC BRN Demo Heap Sampling	737m	2021 & 2023	 BRAZILIAN NICKEL PLC PNP1000 Grade Control Drilling	9,460m	Total Drilling		87,323m
Years		Total Drilling																												
1973-74	Rio Doce Geologia e Mineração	1,435m																												
2003	 VALE	2,346m																												
2004-05	 VALE	53,827m																												
2006	 VALE Vale Test Mine Excavated	-																												
2008	 VALE	19,518m																												
2016	 BRAZILIAN NICKEL PLC BRN Demo Heap Sampling	737m																												
2021 & 2023	 BRAZILIAN NICKEL PLC PNP1000 Grade Control Drilling	9,460m																												
Total Drilling		87,323m																												
																														

Piauí Nickel Project Timeline

Shovel ready project with first production of products essential to the clean energy transition and EV battery value chain within 3 years

- Feasibility Study, completed in July 2022, confirms the technical and economic viability of the Project
- Installation / construction licence application has been submitted in Q4 2022 with approval expected Q2/Q3 2023
- Project has received a "Laudo de Serviço Mineral" which reinforces the national public interest in the Project
- Front End Engineering Design (FEED) completion expected Q1 2024
- Construction expected to start Q2 2024
- Ongoing discussions with key suppliers suggest that first nickel production is expected Q2 2026

Laudo de Serviço Mineral – issued in August 2022 by the Agência Nacional de Mineração ("ANM"), which is a Brazilian federal agency.



The document reinforces the national public interest of the Project and mining concession license, and can be used to support any judicial proceedings should a landowner deny land access required for the Project (to be used only when good faith negotiations have not succeeded)

Project Timeline



PNP 1000

De-risking of the heap leach process through the operation of PNP1000 and introduction of products into the battery metal supply chain

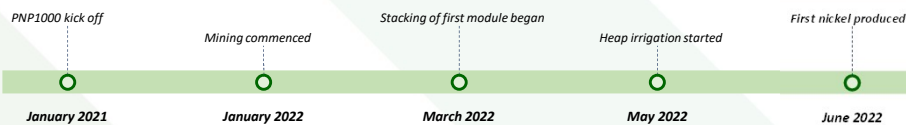
Commentary

- PNP1000 construction commenced in January 2021 and the first nickel product was produced in June 2022
 - PNP1000 has a production capacity of 1,400tpa of nickel contained in NHP and 35tpa of cobalt contained in CHP
- Fully Licenced
- While PNP1000 is on a smaller scale, the systems and processes installed are transferable to the Full-Scale operation
 - Heap height is the same at 4.5m
- The people recruited and trained for the PNP1000 will form the core of the expanded workforce for the Full-Scale Project, allowing significant experience to be carried over

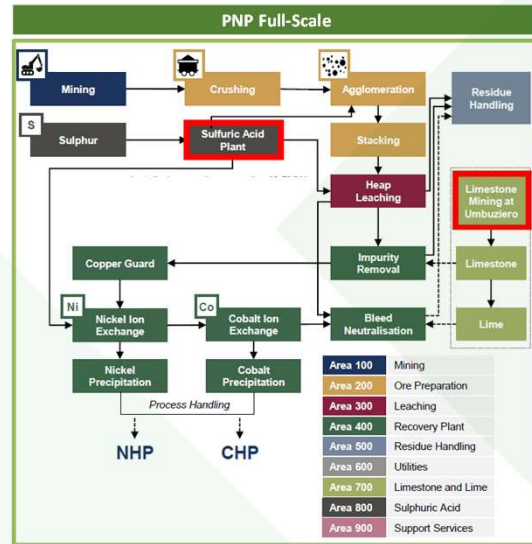
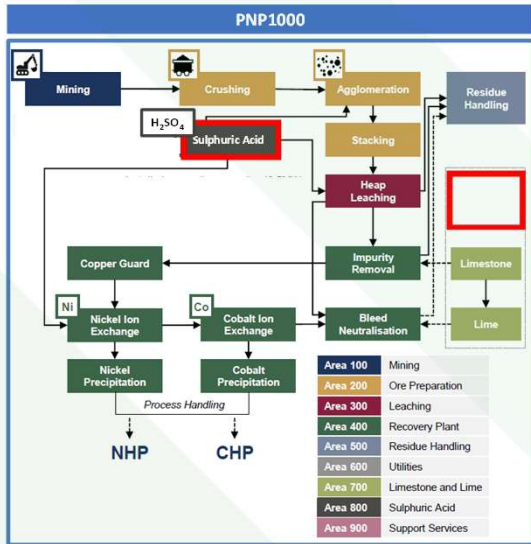
PNP1000



PNP1000 Key Milestones



PNP1000 Full-Scale Project Comparison



PNP1000 - Mine



PNP1000 – Leach Pad



PNP1000 from the Demo Heaps



PNP1000 – Downstream Plant



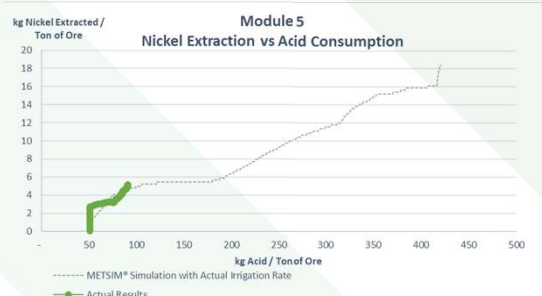
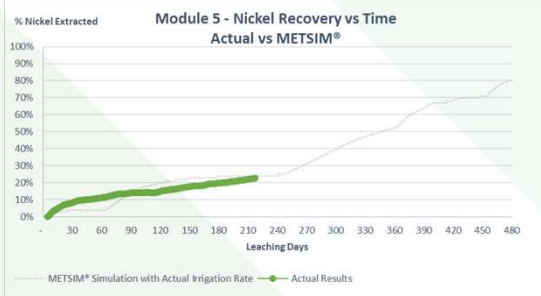
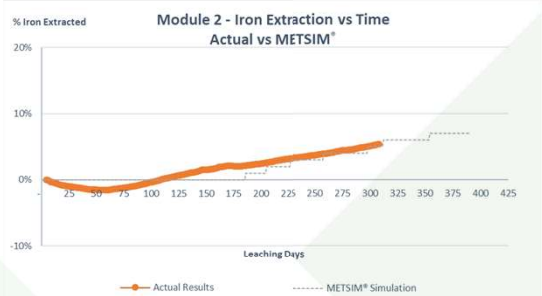
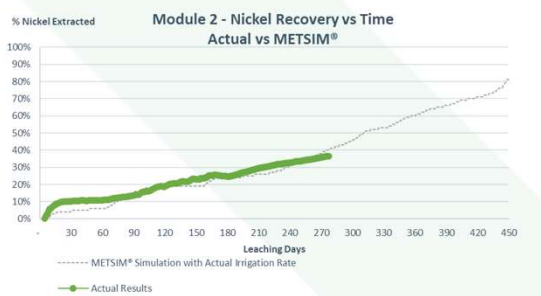
PNP1000 – Solid Waste



PNP1000 – Product

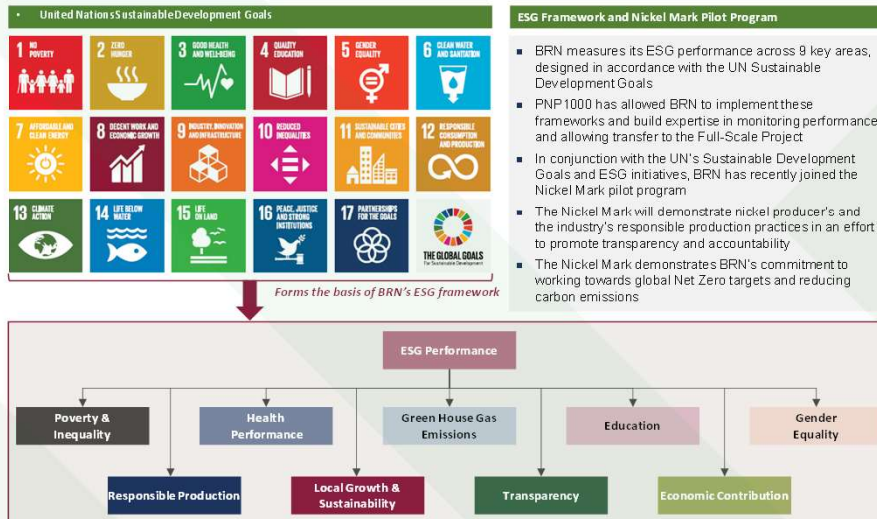


PNP1000 Results



ESG is an Integral Process

Robust framework designed in accordance with the UN sustainable development goals



ESG is an Integral Process

ESG is an integral part of the PNP, with key permitting, social, environmental and governance plans already in place

<p>Permitting</p> <ul style="list-style-type: none"> Mining concession in place Main LPs awarded in January 2020 following local community engagement ESIA completed with 21 E&S action plans approved by the environmental authority (SEMAB) for the LPs award Installation licenses—applied in Q4 2022 and expected in Q2/Q3 2023 to allow construction start Water extraction permit and power connection permit obtained 	<p>Social</p> <ul style="list-style-type: none"> PNP1000 had high levels of local employment with >75% of current workforce hired locally (c.300 people) On average, local employees are paid 76% above Brazilian minimum wage Provided free 3 month technical training course to +130 local candidates Member of Paradigm for Parity <ul style="list-style-type: none"> c.33% of current workforce is female Major positive social impact in a poorly developed region 	<p>Public Hearing for Environmental Licensing</p> 
<p>Energy, Water and CO₂</p> <ul style="list-style-type: none"> Carbon free power to be provided from on-site sulphuric acid plant, with excess power to be sold back to the grid The PNP's processing technology is a significantly less energy intensive way to produce nickel and cobalt High water use efficiency with filtering, recycling, no effluent discharge and no wet tailings dams Low scope 1 and 2 CO₂ emissions of 11.95t CO₂ / t NiEq 	<p>Governance</p> <ul style="list-style-type: none"> Sustainability management system heading to full compliance with IFC performance standards Looking to become ESG accredited in the near term 	<p>Daily Safety Meeting</p> 

Source: Brazilian Nickel management team

Environmental

The Project's Environmental Management Plans provide a framework to identify, monitor and mitigate environmental impacts across all stages of the Project

Commentary

- Minimised energy intensity
 - PNP produces all power from the acid plant and sells excess power back to the grid (HPAL the same size would require 3x more energy)
- Increased resource utilisation,
 - Less mine waste and longer operational life
 - All ore above cut-off grade is processed and no blending/separation of ore types required
- Minimal water use and acid consumption
- Only solid residues
 - No tailing dams required and no deep sea disposal

Effluent Monitoring



Propagation of Native Tree Species Seedlings



Only Solid Residues



Source: PNP July 2022 Feasibility Study

Social

The local community is actively engaged to ensure a major positive social impact in the surrounding region

Commentary

- Strong relationships and engagement with local communities
- High levels of local employment
 - >75% of current workforce hired locally
- Member of Paradigm for Parity
 - c.33% of current workforce is female
- Major positive social impact in a poorly developed region

Building Community Relationships



Training Courses for Local Candidates

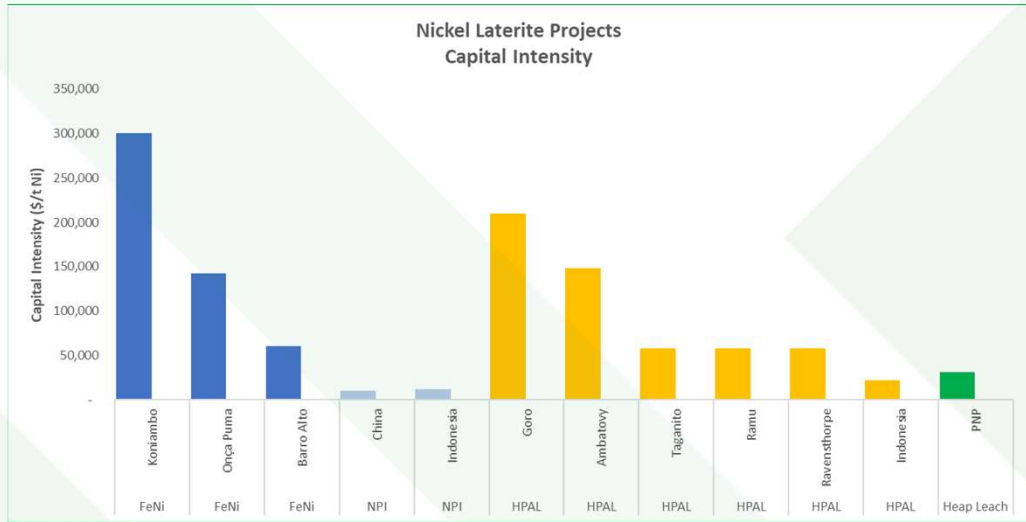


Daily Water Sprinkling to Suppress Dust on Project Access Roads



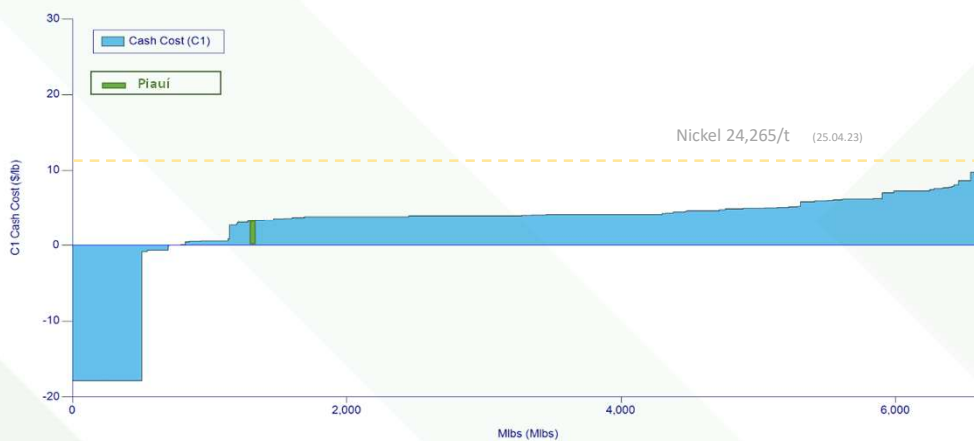
Source: PNP July 2022 Feasibility Study

Full-Scale Capital Intensity



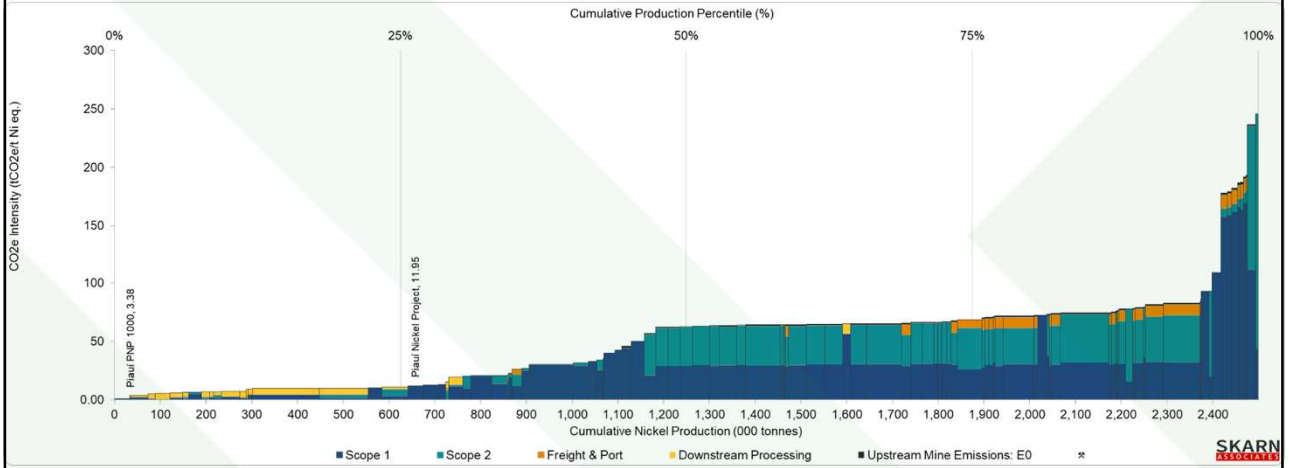
Source: Wood Mackenzie, BRN

Full Scale Operating costs (C1)

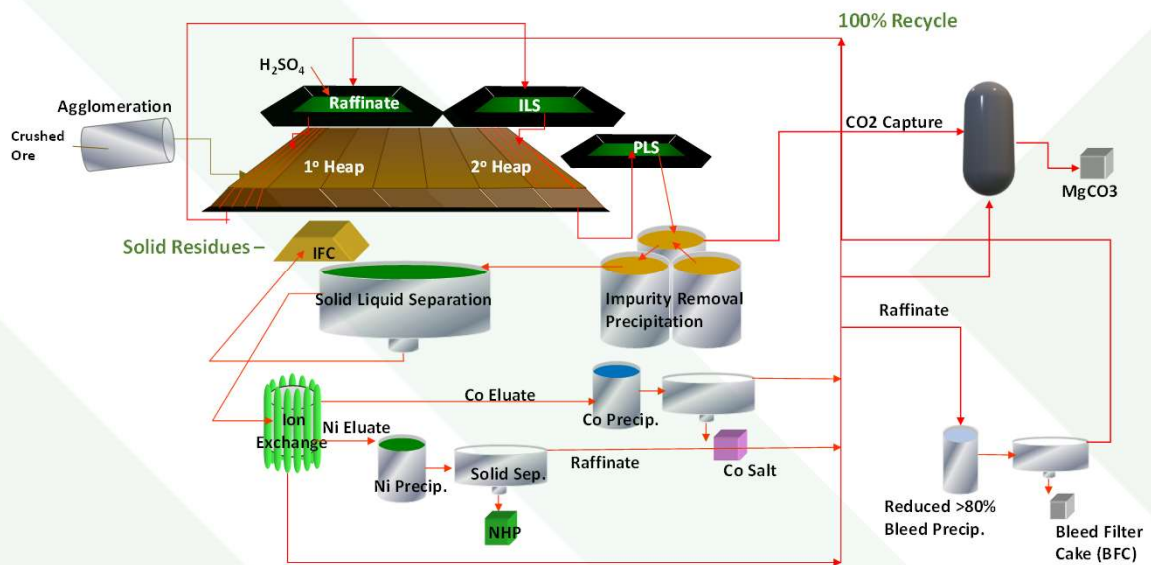


Source: Wood Mackenzie Ltd. Dataset: 2022 Q1

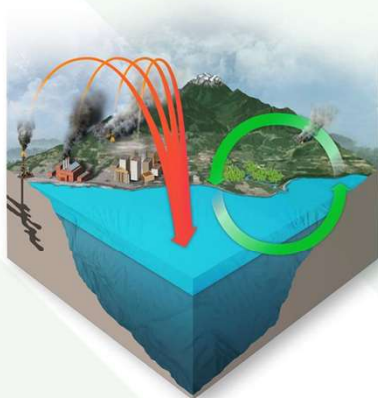
CO2e Intensity Benchmark



CO2 Reduction Schematic



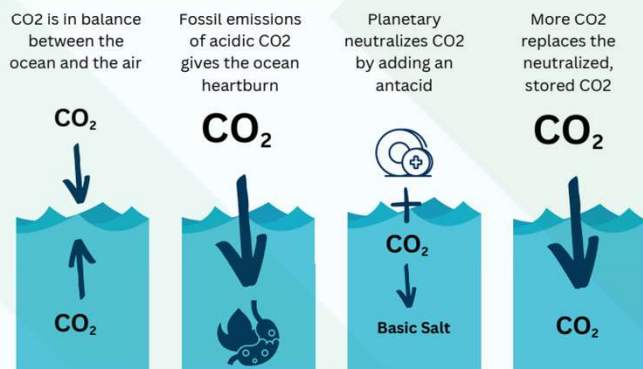
CO2 Reduction Partners PLANETARY



- 1) The oceans are the key regulate the Earth's climate
- Absorbing 40% of all human made CO2 emissions
- Causing widespread ocean acidification and devastating marine ecosystems

2) Planetary is pioneering solution which involves adding alkaline material to the ocean to:

- Restore ocean chemistry and the marine environment
- Enhance the ocean's natural ability to absorb and permanently store CO2 from the air



How it could work



BRAZILIAN NICKEL

Heap Leach

Low CO₂ Nickel & Cobalt

Magnesium Waste

Capture CO₂ emissions through:

PLANETARY



Magnesium Hydroxide

Land based CCS

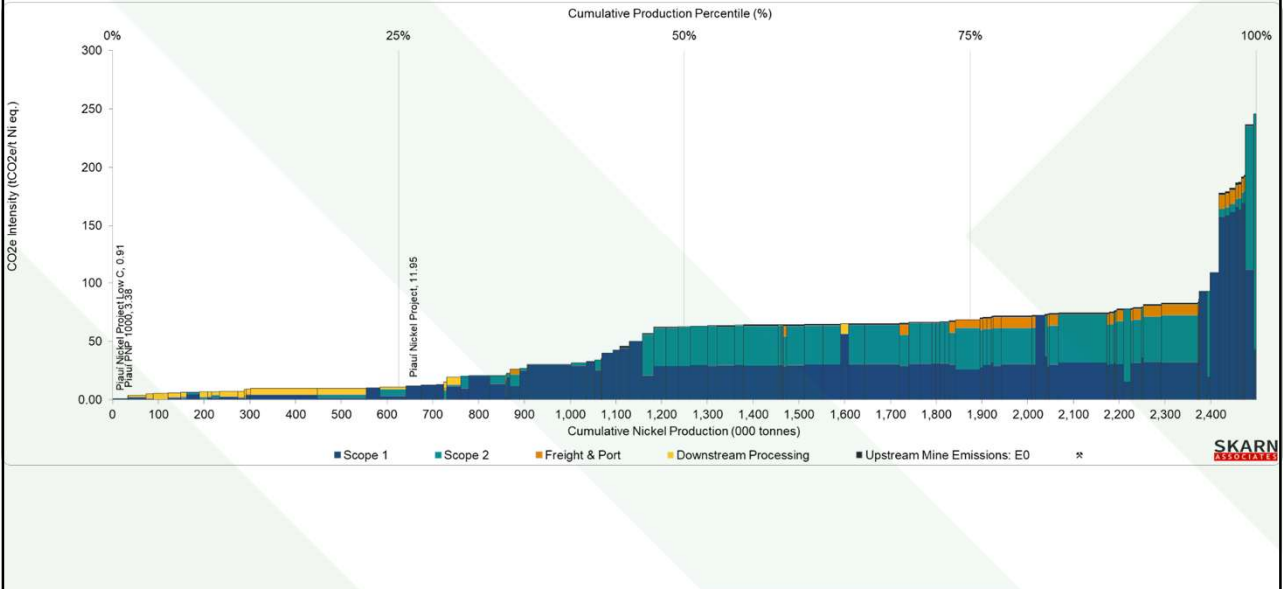
- Use Magnesium hydroxide to capture and store point source emissions onsite as carbonate

Ocean CDR

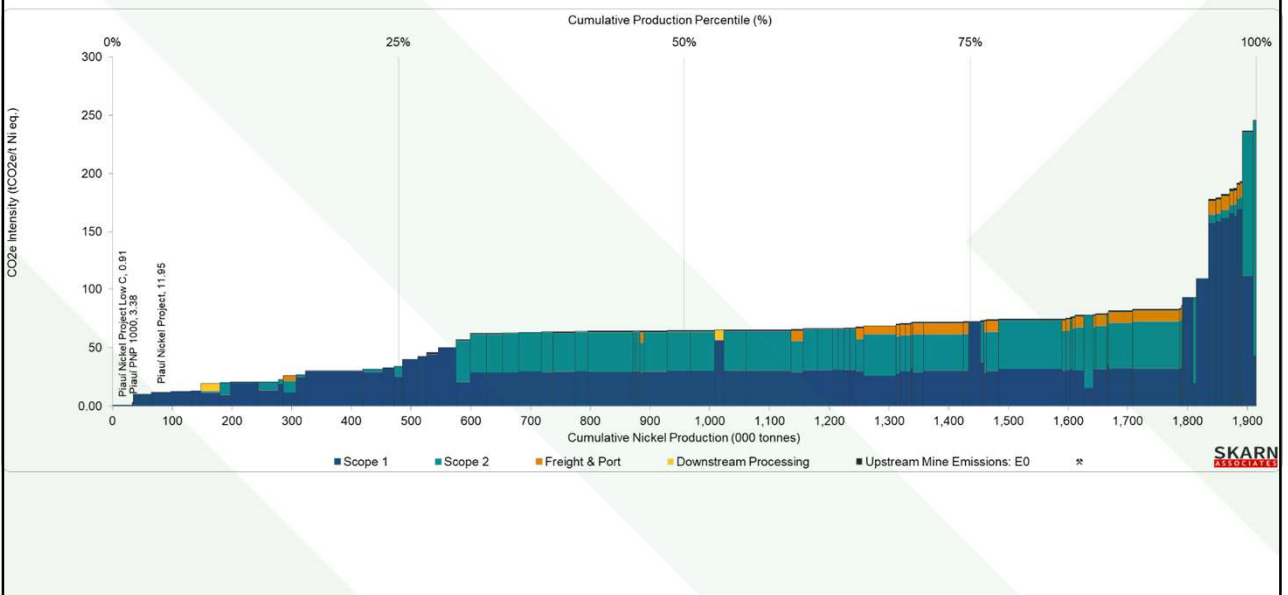
- Use Magnesium hydroxide to draw CO₂ out of the air and store it safely in ocean chemistry as bicarbonate

Sold as clean fuel ← Clean Hydrogen → On-Site Use

CO2e Intensity Benchmark



CO2e Intensity Benchmark Laterites



Laterite Deposits

Growth potential through project replication of the transformative heap leach process on a pipeline of other nickel laterite deposits globally

Global Nickel Laterite Deposits

- Nickel laterite
- Nickel laterite studied by the Brazilian Nickel team

Commentary



- The PNP process was developed from different pilot plant tests all over the world, including projects in Colombia, Turkey and the Philippines
- This process was later replicated in the PNP Demonstration Plant and showed that target nickel extractions could be met, and even exceeded, with low acid consumption and attractive leach kinetics
- The countries currently under active consideration by Brazilian Nickel are Brazil, Australia and the United States