RECENT GROWTH OF NICKEL LATERITE PROCESSING IN INDONESIA

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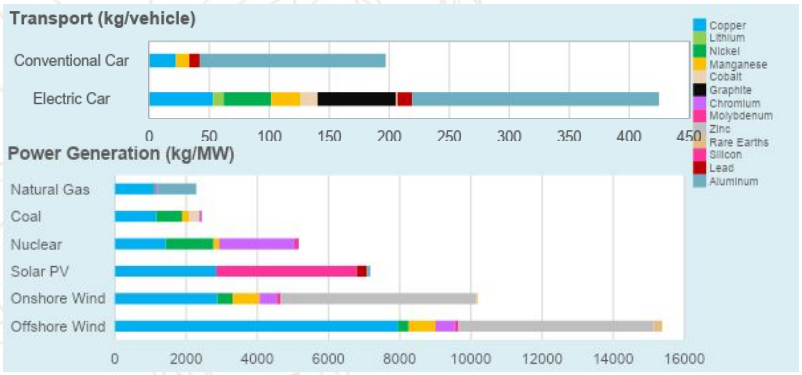
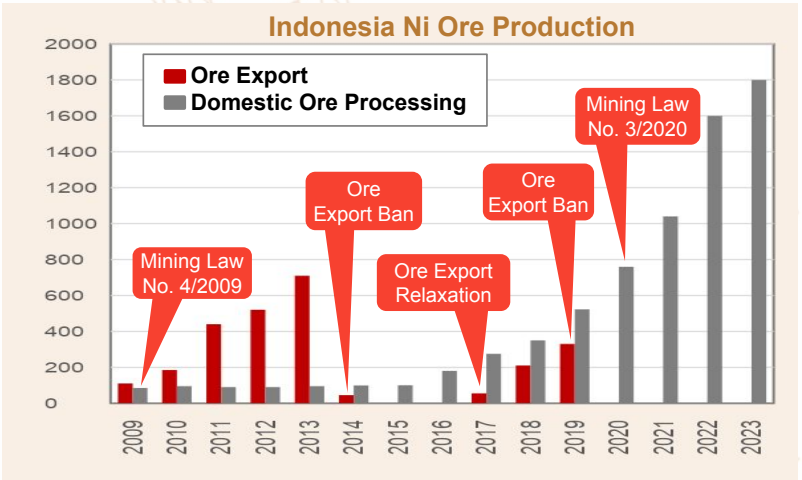
- Indonesia Nickel Laterite Resources and Reserves
- Indonesia Nickel Laterite Mineralogy
- Nickel Laterite Mining in Indonesia
- Nickel Laterite Processing in Indonesia
- Directions / Strategies of Indonesian Nickel Industry
- Concluding Remarks

Background

- Nickel is vital element in electric mobility, renewable energy, and other strategic technologies.
- Indonesia has emerged as a major nickel producer in recent years due to the implementation of a nickel ore export ban policy, supported by massive foreign investment.
- Indonesia currently dominates nickel mining production representing more than half of the global supply.
- More than 50 nickel processing plants are in operation in Indonesia producing nickel intermediate products.

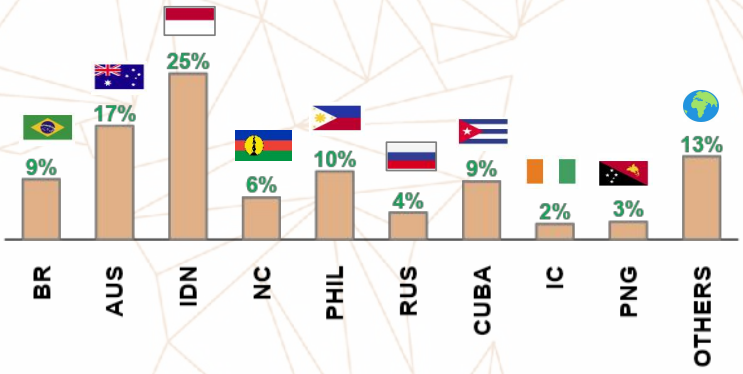




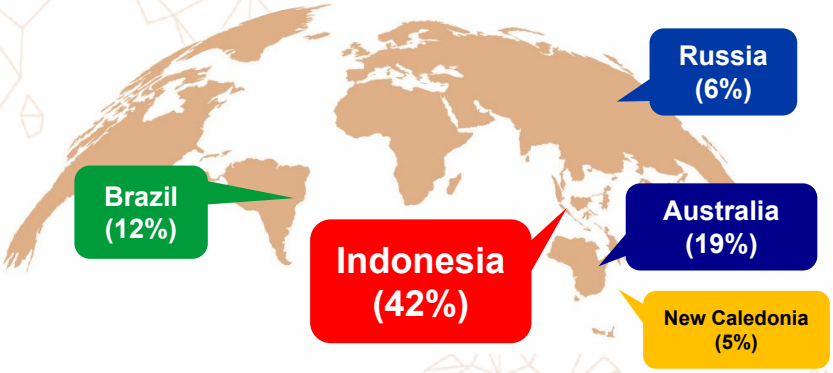
Sources: 1) https://www.climatechange.ie/iea-mineral-supplies-for-electric-cars-must-increase-30-fold-to-meet-climate-goals/ (with further data processing)
2) U.S. Geological Survey, 2024, Mineral commodity summaries 2024: U.S. Geological Survey, p 12., https://pubs.usgs.gov/periodicals/mcs2024/mcs2024.pdf

Indonesia Nickel Laterite Resources and Reserves

World Nickel Laterite Resources 2023: >180 Million Ton Nickel



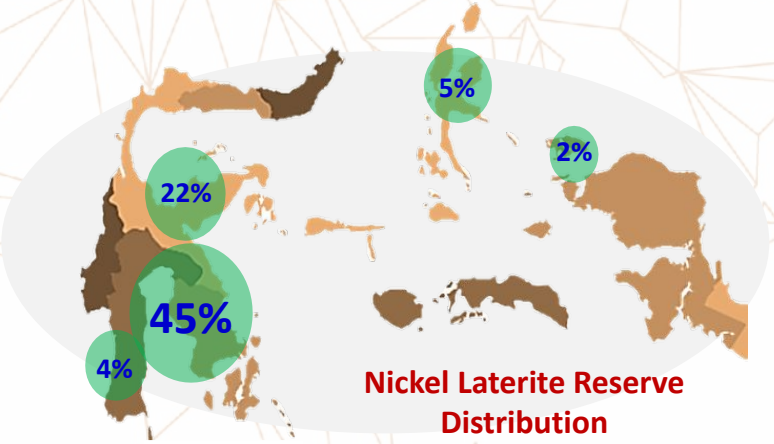
World Nickel Reserves 2023: >130 Million Ton Nickel



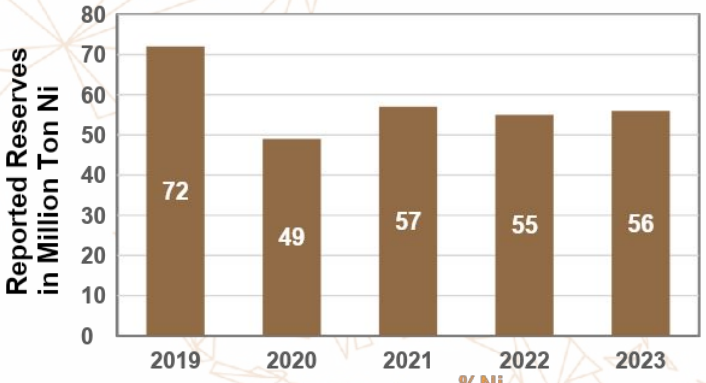
- Indonesia is placed number one rank in nickel laterite resources and reserves.
- Indonesia is reported to hold 25% of global nickel laterite resources which equates to ~45 Million tons Ni.
- According to the latest report by the Indonesia Geology Agency, verified nickel laterite resources reach ~73 Million ton Ni.
- Indonesia owns around 42% of world's nickel reserves which equates to ~55 Million ton Ni.

Sources: 1) https://nickelinstitute.org/en/about-nickel-and-its-applications/
2) U.S. Geological Survey, 2024, Mineral commodity summaries 2024: U.S. Geological Survey, p 12., https://pubs.usgs.gov/periodicals/mcs2024/mcs2024.pdf
3) Indonesia Geology Agency, Centre for Mineral Resources, Coal & Geothermal, Updating the potential, resources and reserves and nickel greenfield in Indonesia – May 2024

Indonesia Nickel Laterite Resources and Reserves

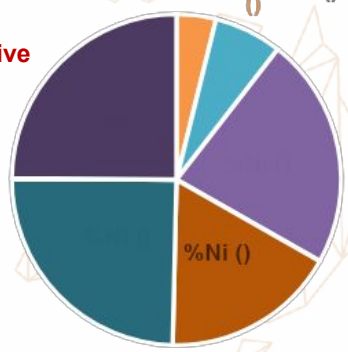


Nickel Laterite Reserve Distribution in Indonesia 2023



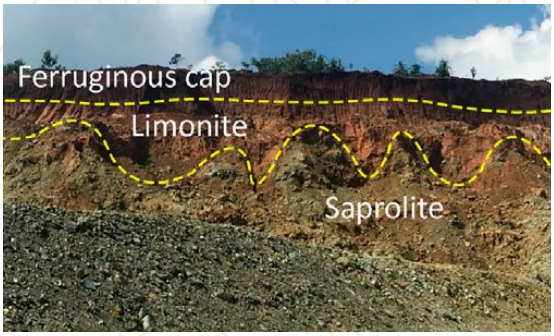
- The nickel deposits are concentrated in Sulawesi, Maluku, and West Papua Islands.
- Indonesia historical data shows steady reported metal reserves at around 50 Million ton Ni for the last 4 years.
- The Indonesia nickel laterite reported reserves is dominated with ore containing more than 1.2% Ni.

Ni grade (Amount relative to reserve)

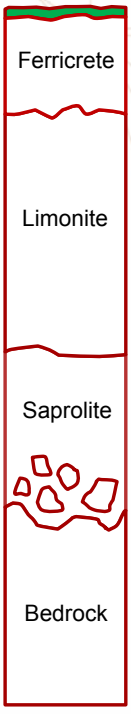


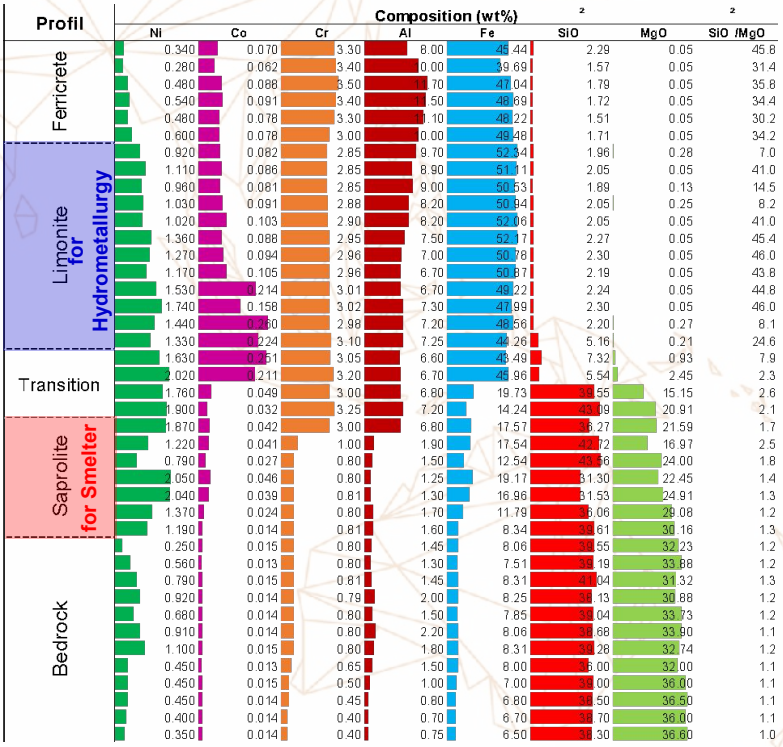
Sources: 1) Centre for Mineral Resources, Coal & Geothermal – December 2023
2) Indonesia Geology Agency, Centre for Mineral Resources, Coal & Geothermal, Updating the potential, resources and reserves and nickel greenfield in Indonesia – May 2024

Indonesia Nickel Laterite Mineralogy



- Nickel laterite consists of different layers with different mineralogy.
- Limonite and Saprolite are valuable feedstocks for nickel industries.
- Due to the different ore characteristics, different processing routes are required.



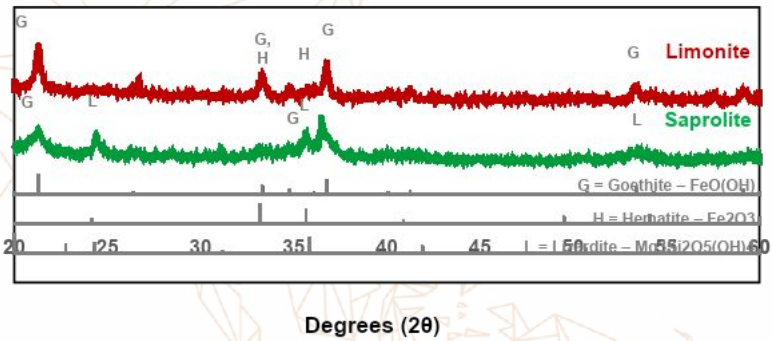


Sources: 1) Choi Y, Lee I and Moon I (2021) Geochemical and Mineralogical Characteristics of Garnierite From the Morowali Ni-Laterite Deposit in Sulawesi, Indonesia. Front. Earth Sci. 9:761748. doi: 10.3389/feart.2021.761748.
2) M.F. Azim et al., Geochemical and Physical Characteristics of Nickel-Cobalt Laterite Deposits on Maniang Island, Kolaka, Southeast Sulawesi: Proceedings PIT IAGI 51st, 2022.

Indonesia Nickel Laterite Mineralogy

Chemical Compositions of Saprolite Ore

	Obi Island %	North Morowali-1 %	North Morowali-2 %	East Luwu %
Ni	1.70	1.79	1.99	1.68
Co	0.08	0.03	0.04	0.07
Fe	16.08	12.9	17.55	19.86
SiO_2	32.9	47.3	35.39	36.46
Al_2O_3		3.12	3.21	3.11
MgO	26.5	20.1	17.93	15.50
Mn		0.22	0.35	0.48
Cr		0.62	0.77	0.93
Ca	0.12	0.42	0.20	0.36
Moisture	35%	27%		



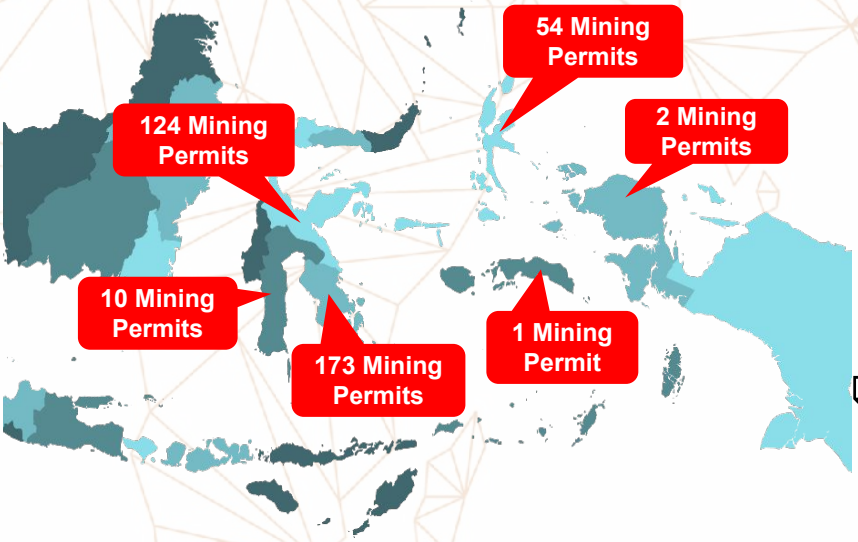
Chemical Compositions of Limonite Ore

	Obi Island %	North Morowali %	Bulong %	Cawse %	Murrin Murrin %	Moa Bay %	Taganito %
Ni	1.35	1.13	1.11	1.0	1.24	1.35	0.98
Co	0.17	0.11	0.08	0.07	0.089	0.12	
Fe	41.2	32.3	20.8	18.0	21.7	45	
SiO_2	15.2	20.7	42.9	42.5	42.1	8.3	
Al	3.0	4.23	2.75	1.71	2.51	4.8	1.87
Mg	1.60	2.76	4.62	1.58	4.02	0.55	1.16
Mn	0.97	0.83	0.36	0.17	0.40		
Cr	1.0	1.69	0.6	0.92	0.88	2.0	
Ca	0.02	0.11	0.03	0.03	0.53		
Moisture		40%	<35%	<10%	~30%	>20%	

- Saprolite is dominantly composed of magnesium silicate minerals, such as serpentine – $Mg_3Si_2O_5(OH)_4$. Limonite is dominantly composed of iron oxide minerals, such as goethite – FeO(OH).
- The Cut-off Grade (COG) of the saprolite ore is 1.3%Ni and the average ore grade in pyromet plants feed is 1.6%Ni.
- The COG of limonite ore is 0.7%Ni with average Ni content in hydromet plants feed around 1.1%Ni.

Sources: 1) T. Gultom and A. Sianipar, High pressure acid leaching: a newly introduced technology in Indonesia. IOP Conf. Series: Earth and Environmental Science 413 (2020) 012015 IOP Publishing. doi:10.1088/1755-1315/413/1/012015.
2) Zhang, Y., Qie, J., Wang, X.F. et al., Mineralogical Characteristics of the Nickel Laterite, Southeast Ophiolite Belt, Sulawesi Island, Indonesia. Mining, Metallurgy & Exploration 37, 79–91 (2020). https://doi.org/10.1007/s42461-019-00147-y
3) J.H. Kyle, Pressure Acid Leaching of Australian Nickel/Cobalt Laterites. Nickel '96. Kalgoorlie, 27-29 Nov 1996; 4) https://news.metal.com; 5) https://www.mysteel.net/news/5046573-china-nickel-ore-market-2023-review-and-2024-prospect

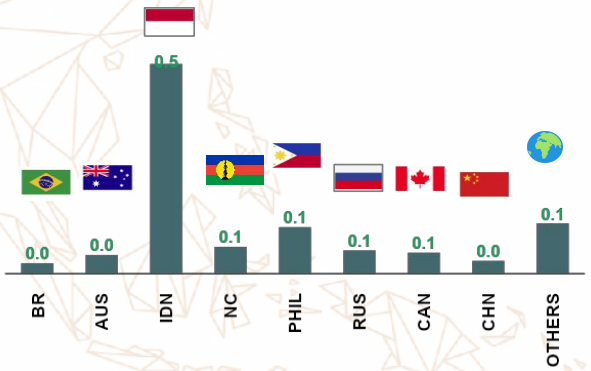
Nickel Laterite Mining in Indonesia



Top 3 Companies with Largest Mining Area*

VALE antam weda bay nickel

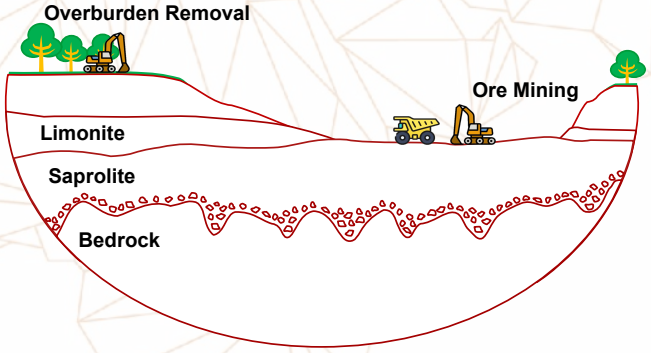
Mining Production 2023: ~3.6 Million Ton Nickel

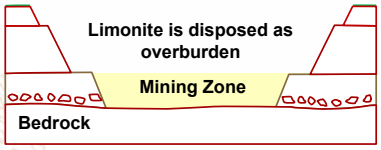


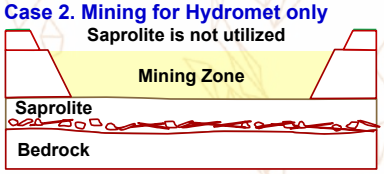
- Mining and exploration areas are spread in Central Sulawesi, South Sulawesi, South-East Sulawesi, Maluku, North Maluku, Papua, and West Papua Islands.
- Total mining permits reaches 364.
- Total mining area covers ~900,000 hectares.

Sources: 1) U.S. Geological Survey, 2024, Mineral commodity summaries 2024: U.S. Geological Survey, p 12., https://pubs.usgs.gov/periodicals/mcs2024/mcs2024.pdf
2) Ministry of Energy and Mineral Resources of Republic of Indonesia, 2024

Nickel Laterite Mining in Indonesia







Top 3 Mining Permits with Largest Production in 2023

weda bay nickel

PT SULAWESI CAHAYA MINERAL (SCM)

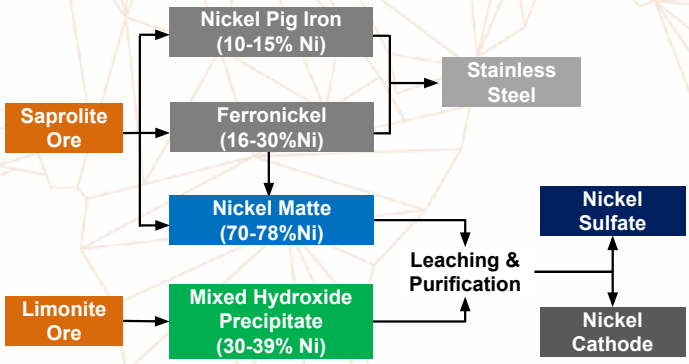
TBP
Trimegah Bangun Persada

- Prior to the availability of High-Pressure Acid Leaching (HPAL), limonite ore was disposed as overburden.
- The mining operation was mainly focusing on the saprolite ore for the Rotary Kiln-Electric Furnace plants.
- With the availability of HPAL, total mining of saprolite and limonite ores is encouraged.
- This optimized mining method lowers the production cost of limonite ore.

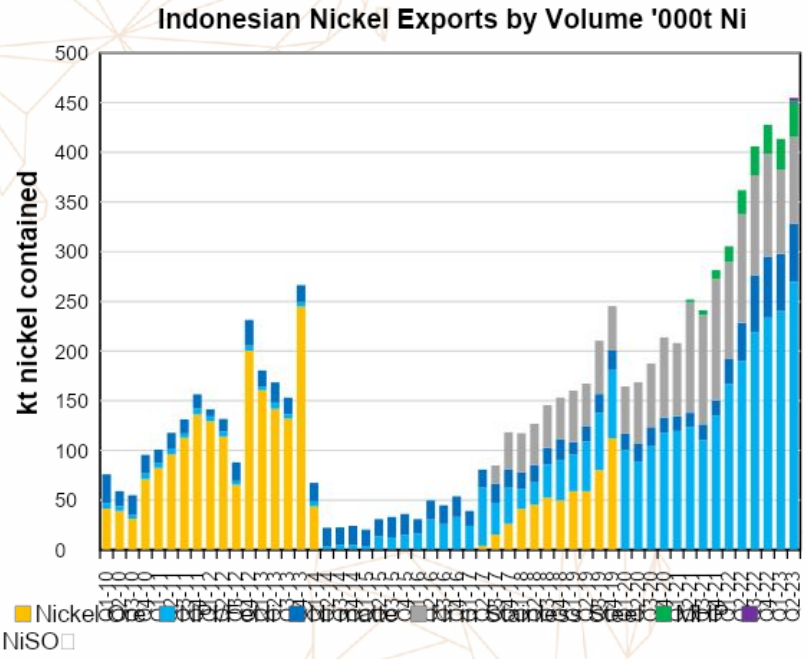
Sources: 1) A. Matano, Nickel laterite mining, 2019

Nickel Laterite Processing in Indonesia

Processing Routes of Laterite Ores



- Dominant utilization of Saprolite Ore is for the production of Nickel Class 2 (NPI and FeNi).
- Indonesia contributed more than 75% of global NPI production in 2023.
- The utilization of Limonite Ore is for the production of Nickel Class 1 (MHP).
- Production of Nickel Class 1* in Indonesia reached more than 20% of total nickel products in 2023.

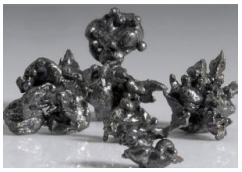


Nickel Class I = Ni matte, Ni hydroxide, Ni sulphate, electrolytic Ni, Ni powder, Ni briquettes, Ni carbonyl.
Nickel Class 2 = NPI and FeNi. The product is used mainly in stainless steel production.

Sources: 1) TDM, INSG, Macquarie Commodities Strategy, October 2023

Nickel Laterite Processing in Indonesia - Products

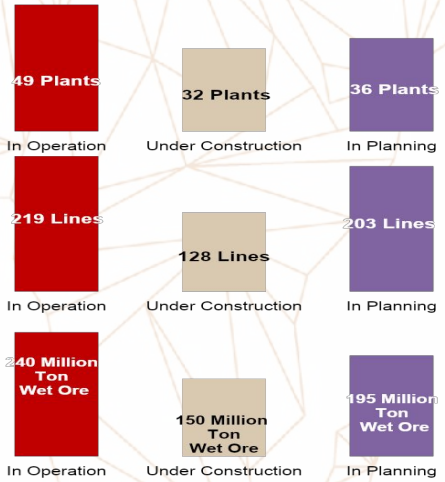
Element	Example of Composition				
	Nickel Pig Iron	Ferronickel	Nickel Matte	Mixed Hydroxide Precipitate	$NiSO_4 \cdot 6H_2O$
Ni	10-15 %	16-30 %	70–78 %	30–39 %	> 22 %
Fe	remaining	Remaining	< 4%	< 0.5 %	< 5 ppm
S	0.40 %	< 0.05 %	~20 %	3–5 %	
Mn				4–9 %	< 5 ppm
Mg				3–5 %	< 10 ppm
Co	0.29 %	0.36 %	< 1 %	2–5 %	< 50 ppm
Cu				1–4 %	< 5 ppm
Zn				1–4 %	< 5 ppm
Cr	0.55 %	0.08 %			< 5 ppm
C	0.25 %	< 1.2 %			
Si	0.45 %	0.4 %			< 10 ppm
P	0.02 %	< 0.02 %			
Al				< 0.5 %	< 5 ppm
Na					< 20 ppm
Ca					< 10 ppm
Cd					< 5 ppm
Pb					< 5 ppm
H_2O				35–45 %	


Sources: 1) Taken from various data

Nickel Laterite Processing in Indonesia - Pyromet Plants

Indonesia Ni Pyromet Plants in 2023



- **Previous fiscal incentives (Tax Holiday, Tax Allowance) led to exponential growth of smelters.**
- **Despite Indonesian authorities had previously ban new pyrometallurgical facilities in 2022, the construction of pre-approved capacities is still allowed.**
- **Recent trend is shifting NPI/FeNi (Ni Class 2) to Ni matte (Ni Class 1).**

Top 3 Smelters with Largest Capacities in 2023

OSS PT OBSIDIAN STAINLESS STEEL

PT. GUNBUSTER NICKEL INDUSTRY

INDONESIA TSINGSHAN STAINLESS STEEL

Key Locations

IMIP = Indonesia Morowali Industrial Park
IWIP = Indonesia Weda Bay Industrial Park

Sources: 1) Coordinating Ministry for Maritime Affairs and Investment - Republic of Indonesia, Industrialization of minerals in Indonesia now and in the future, 2023

Pyromet Plants – Rotary Kiln-Electric Furnace (RKEF)

- Rotary Kiln – Electric Furnace technology dominates the pyro processing of saprolite ore.
- There is a wide range of furnace capacities from as small as 18 to 80 Mega Watts.
- Feed ore must be strictly controlled in terms of Ni content, SiO_2/MgO ratio, and Fe/Ni ratio.
- Most plants have dedicated power plants, while few procure electricity from the national grid.

Pyromet Plants – RKEF : Process Flow

- **Rotary Dryer**
  - Partial elimination of moisture from ~40% to ~20%

$$H_2O_{(moisture)} \rightarrow H_2O_{(gas)}$$

- **Rotary Kiln**
  - Elimination surface & crystalline water

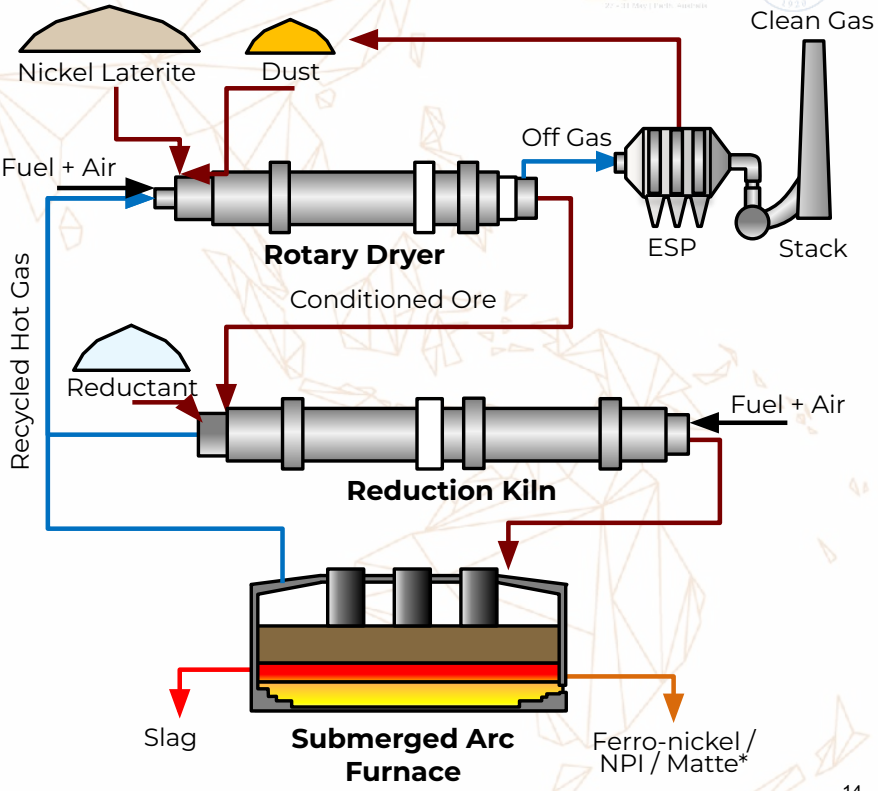
$$2\,(Mg_{1-x-y},Fe_x,Ni_y)_3Si_2O_5(OH)_{4\,(serpentine)} \rightarrow 3\,(Mg_{1-x-y},Fe_x,Ni_y)_2SiO_{4\,(olivine)} + SiO_{2\,(quartz)} + 4H_2O_{(gas)}$$

  - decomposition of minerals & partial reduction of oxides

$$\tfrac{1}{2}\,(Mg_{1-x-y},Fe_x,Ni_y)_2SiO_{4\,(olivine)} + (x+y)\,C_{(coal)} \rightarrow \tfrac{1}{2}(1-x-y)\,Mg_2SiO_{4\,(olivine)} + \tfrac{1}{2}(x+y)\,SiO_{2\,(quartz)} + Fe_xNi_{y\,(metal)} + (x+y)\,CO_{(gas)}$$

- **Electric Furnace**
  - Reduction of oxides to metal & slag-metal separation

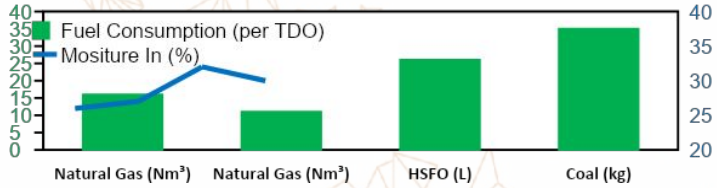
$$Mg_2SiO_{4\,(olivine)} + y\,SiO_{2\,(quartz)} + Fe_xNi_{y\,(metal)} \rightarrow 2MgO\text{-}(1+y)SiO_{2\,(slag)} + Fe_xNi_{y\,(molten)}$$



*Matte is produced via sulfur

Pyromet Plants – RKEF : Rotary Dryer

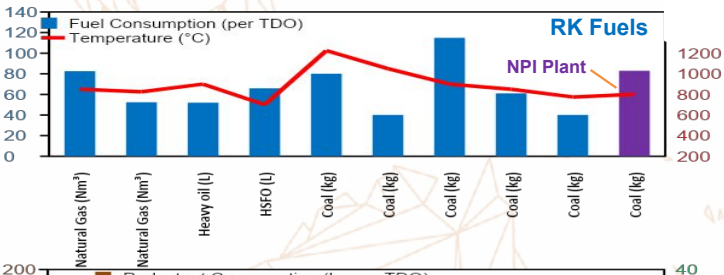
- Rotary Dryer (RD) uses hot gas to dry wet ore.
- Hot gas enters around 800°C and exits around 120°C.
- Different types of fuel (pulverized coal, natural gas, HSFO, etc) can be used to generate hot gas in boiler / stove / hot gas generator.
- Some NPI smelters reuse off-gas from Rotary Kiln and Electric Furnace as sources of hot gas.
- RD approximate dimension φ=5 m, L=50 m

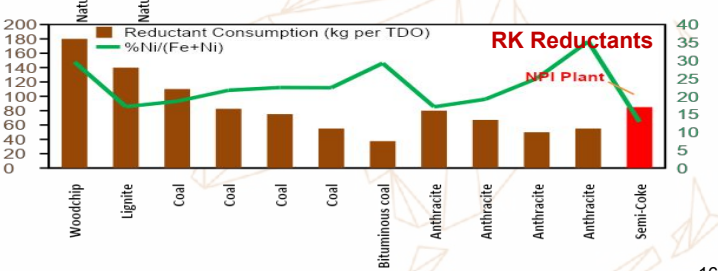


Sources: 1) A.E.M. Warner, C.M. Díaz, A.D. Dalvi, P.J. Mackey, and A.V. Tarasov. JOM World Nonferrous Smelter Survey, Part III: Nickel: Laterite. JOM, 2006

Pyromet Plants – RKEF : Rotary Kiln

- Rotary Kiln (RK) is cylindrical steel structure lined with Al_2O_3-rich castable heated by a burner.
- Solid material temperature in RK reached 700-900°C.
- Different types of fuel can be used, such pulverized coal, coal gasification, natural gas, HSFO, etc.
- NPI smelters utilize semi-coke as reductant.
- RK approximate dimension φ=5 m, L=100 m





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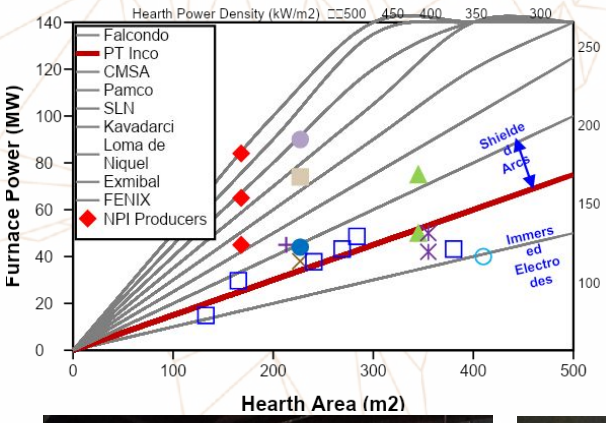
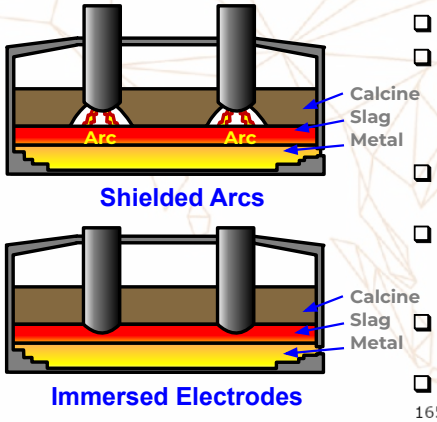
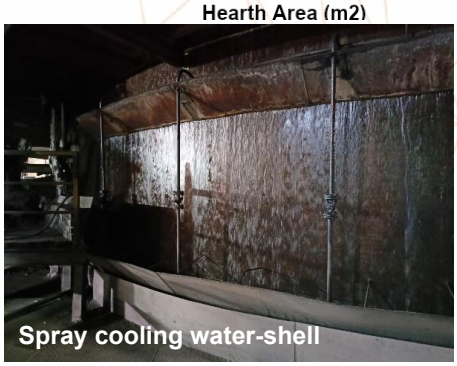
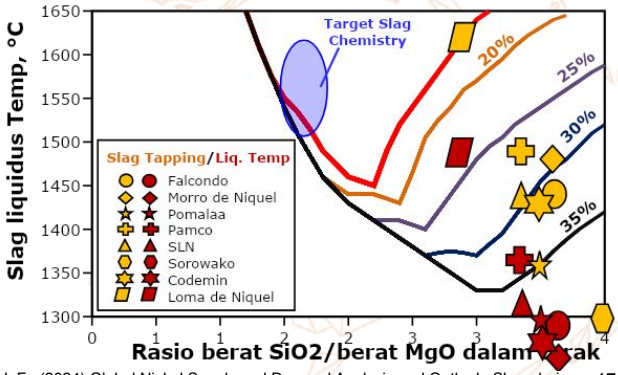
Pyromet Plants – RKEF : Electric Furnace





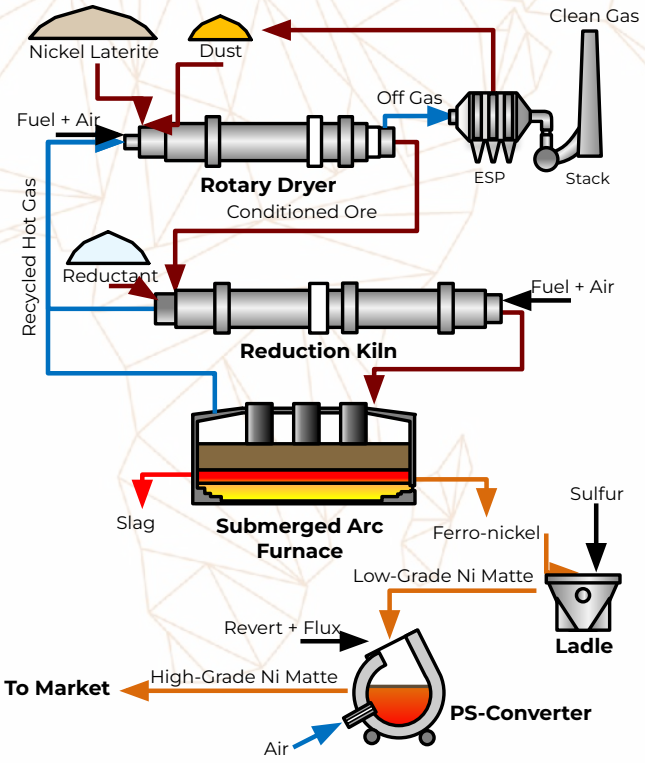
- Furnace operating temperature around 1500°C.
- Most NPI smelters operates in immersed electrodes to have a lesser power fluctuation and has simplified shell configuration without plate or finger copper coolers.
- In 2023, the Indonesia total NPI production reached ~1.4 Million t-Ni/yr.
- Part of the molten NPI is delivered to a stainless-steel plant within the industrial complex.
- Other part of the NPI is shipped overseas in the form of ingots.
- Some NPI has been converted to Ni matte.





Sources: 1) https://www.sec.gov/Archives/edgar/data/1322422/000119312509009939/dex99106.htm 2) J. Fu (2024) Global Nickel Supply and Demand Analysis and Outlook. Shanghai Metals Market Webinar

Pyromet Plants – RKEF : FeNi to Matte



- Prior to 2022, matte was only produced by PT Vale Indonesia at Sorowako site.
- Due to high nickel matte profit margin, several companies has shifted from initially producing NPI (Ni Class 2) to producing Ni matte (Ni Class 1).
- The shift has been done through the addition of sulfur into the alloy and performing converting process in PS-converters.
- In 2023, the total nameplate capacity of the matte conversion facilities reached ~285 kt-Ni/yr with utilization rate at ~55%.

Sources: 1) J. Fu (2024) Global Nickel Supply and Demand Analysis and Outlook. Shanghai Metals Market Webinar

Pyromet Plants – RKEF : Waste Management

- **Significant waste generated at a smelter plant is slag. In case of NPI production, around 5 tons of slag is generated for every ton of metal product.**
- **Nickel slag is not considered as toxic and hazardous waste based on Indonesia Gov. Reg. No 22 Year 2021. This is confirmed by its TLCP* result which is below safe limit.**
- **The slag is commonly transported by trucks to an assigned dumping location where it is used as construction base for new plant area.**

* Toxicity Characteristic Leaching

RKEF Project Data

Plant Name	Location	Capacity, t Ni/yr	Year	Capex USD, millions	Unit Capex USD/t Ni/yr, thousands	Product
Onca Puma	Brazil	52,000	2011	3,200	62	FeNi
Barro Alto	Brazil	40,000	2011	1,900	48	FeNi
Koniambo	New Caledonia	30,000	2013	7,000	116	FeNi
Hengjaya Ni (TS/NIC)	Indonesia	16,500	2017	200*	12	NPI
Ranger Ni (TS/NIC)	Indonesia	16,500	2017	286*	17	NPI
Bahodopi (Vale/Tisco/Xinhai)	Indonesia	73,000	2025	2,200	30	FeNi

* Not including power plant

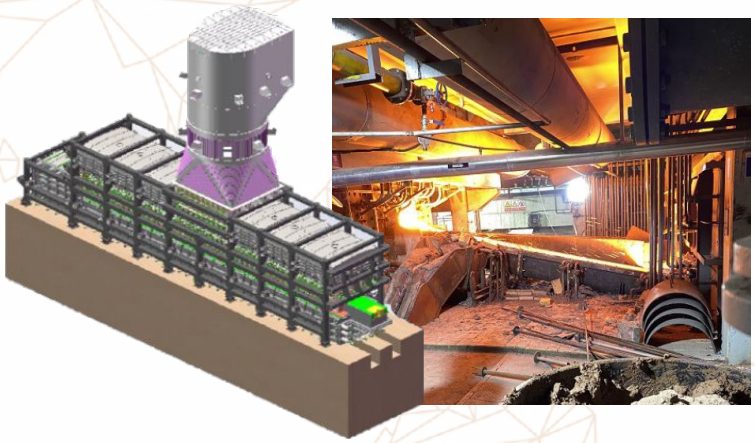
Sources: 1) https://nickelindustries.com/carbon/wp-content/uploads/2021/04/3-10-2019-Presentation-to-Investors.pdf
2) https://vale.com/in/w/financial-results-3q22#:~:text=The%20project%20estimated%20CAPEX%20is,400%20million%20for%20the%20mine

Pyromet Plants – Other Technologies

Blast Furnace (BF)

- BF is a conventional technology that has been utilized in Indonesia since the implementation of the export ban.
- Two BF plants are still in operation and four plants had been shutdown.
- Existing plants have total capacity between 100 and 500 kton Nickel Pig Iron / yr.

Oxygen-Rich Side-Blown Furnace (OESBF)

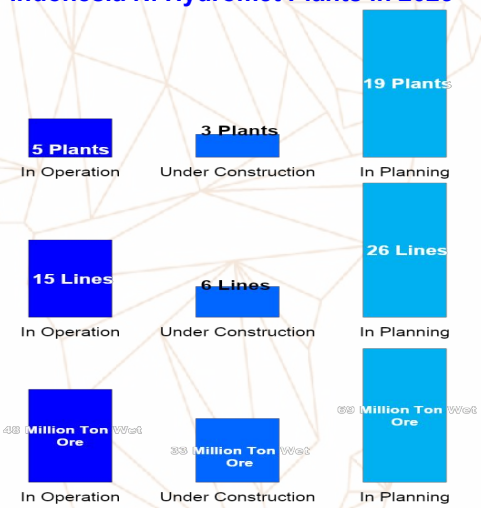


- OESBF is a new technology in Indonesia.
- One OESBF facility is already in operation and five OESBF facilities are under construction.
- Existing OESBF plant produces nickel matte product.
- Capital intensity of OESBF is claimed to be 9,000 USD/ton Ni/yr

Sources: 1) https://www.centralomega.com/id/release/news/progres-pembangunan-smelter
2) W. Yang (2023). Development and application of oxygen rich side blown bath melting technology for smelting high grade nickel matte in laterite nickel ore. Nickel and Cobalt Industry Chain Summit

Nickel Laterite Processing in Indonesia - Hydromet Plants

Indonesia Ni Hydromet Plants in 2023



HPAL Companies in Operation in 2023

PT Halmahera Persada Lygend

QMB New Energy Materials

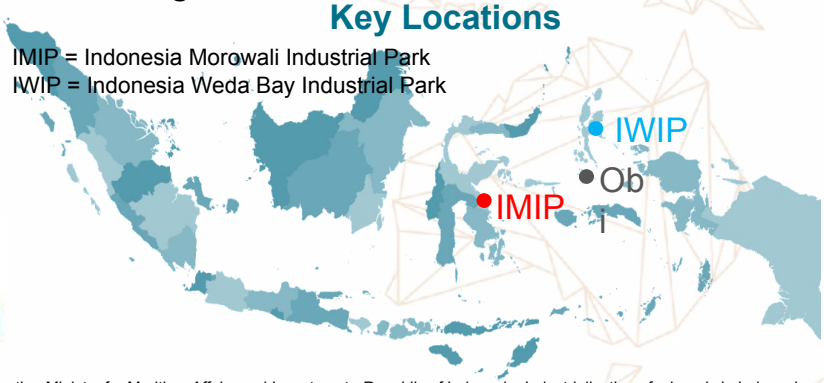
HUAYUE

HUAFEI

- Attractive pricing and royalty has boosted limonite processing.
- Fiscal incentives are available to accelerate HPAL development.
- The HPAL technology has enabled the total processing of all laterite layers.
- One company has advanced to further processing of MHP to $NiSO_4$ and $CoSO_4$.
- Indonesia government has strict rules on the disposal of HPAL tailing.

Key Locations

IMIP = Indonesia Morowali Industrial Park
IWIP = Indonesia Weda Bay Industrial Park

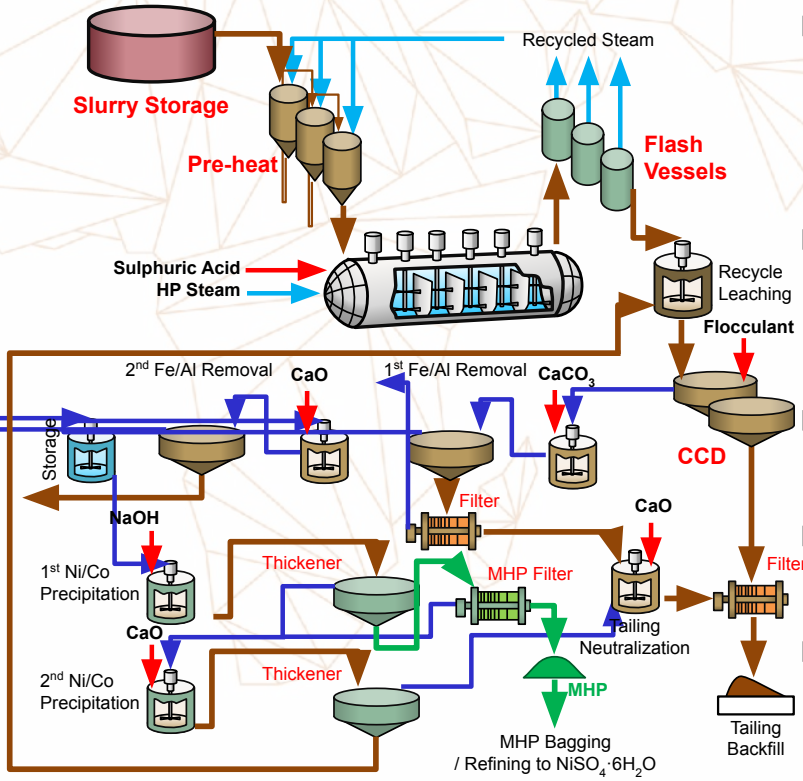


Sources: 1) Coordinating Ministry for Maritime Affairs and Investment - Republic of Indonesia, Industrialization of minerals in Indonesia now and in the future, 2023

Hydromet Plants – High Pressure Acid Leaching (HPAL)

- High Pressure Acid Leaching technology dominates the hydro processing of limonite ore.
- It is only suitable for processing limonite (mainly goethite mineral) because of its low Mg content and high Fe content.
- It can extract Ni and Co with a higher dissolution rate in a shorter time and lower acid consumption.

Hydromet Plants– HPAL : Process Flow



- **Pressure Acid Leaching**
  - Dissolution of Ni-Co, and precipitation of Fe

$$NiO_{(s)} + 2H^{+}_{(aq)} \rightarrow Ni^{2+}_{(aq)} + H_2O_{(aq)}$$
$$CoO_{(s)} + 2H^{+}_{(aq)} \rightarrow Co^{2+}_{(aq)} + H_2O_{(aq)}$$
$$2FeOOH_{(s)} + 6H^{+}_{(aq)} \rightarrow 2Fe^{3+}_{(aq)} + 4H_2O_{(aq)}$$
$$2Fe^{3+}_{(aq)} + 3H_2O_{(aq)} \rightarrow Fe_2O_{3(s)} + 6H^{+}_{(aq)}$$

- **Fe, Al, Cr Neutralization**
  - Elimination of Fe, Al and Cr impurities

$$Fe^{3+}_{(aq)} + 3OH^{-}_{(aq)} \rightarrow Fe(OH)_{3(s)}$$
$$Al^{3+}_{(aq)} + 3OH^{-}_{(aq)} \rightarrow Al(OH)_{3(s)}$$
$$Cr^{3+}_{(aq)} + 3OH^{-}_{(aq)} \rightarrow Cr(OH)_{3(s)}$$

- **MHP Precipitation**
  - Precipitation of Ni and Co hydroxide

$$xNi^{2+}_{(aq)} + (1\text{-}x)Co^{2+}_{(aq)} + 2OH^{-}_{(aq)} \rightarrow (Ni_x,Co_{(1-x)})(OH)_{2\,(s)}$$

- **Re-Leaching**
  - Dissolution of MHP

$$(Ni_x,Co_{(1-x)})(OH)_{2\,(s)} + 2H^{+}_{(aq)} \rightarrow xNi^{2+}_{(aq)} + (1\text{-}x)Co^{2+}_{(aq)} + 2H_2O_{(aq)}$$

- **Production of Ni-sulfate and Co-sulfate**
  - Separation and Recovery of Ni-Co as sulfates

$$Ni^{2+}_{(aq)} + SO_4^{2-}{}_{(aq)} + 6H_2O_{(aq)} \rightarrow NiSO_4{\cdot}6H_2O_{(s)}$$
$$Co^{2+}_{(aq)} + SO_4^{2-}{}_{(aq)} + 7H_2O_{(aq)} \rightarrow CoSO_4{\cdot}7H_2O_{(s)}$$

Hydromet Plants– HPAL : Autoclave

- Leaching at a temperature of 240-270 ºC (by steam injection), pressure 33-55 bar.
- The main leaching reagent is sulfuric acid.
- Performed in a titanium-lined autoclave (φ=~5 m, L=~40 m).
- Ni and Co recovery up to 95-96% can be achieved in just ±1 hour.
- Existing plants have 3-4 HPAL lines with capacity per line around 15,000 to 20,000 t-Ni/yr.
- Most plant is equipped with a dedicated sulfuric acid plant.
- The sulfuric acid plant produces residual steam which can be utilized for heating other process units and power generation.
- Indonesia total MHP production reached around 186 kt-Ni/yr in 2023.

Sources: 1) Indonesia Nickel Miners Association (2024) Indonesia's Nickel Strategy: Navigating Price Challenges And Sustaining Industry Growth.

2) https://www.kompas.id/baca/nusantara/2023/04/16/babak-baru-hilirisasi-nikel-di-pulau-obi

Hydromet Plants– HPAL : Waste Management

- Around 1.3 ton of tailing (dry basis) is generated for every ton of limonite processed.
- Three common tailing management methods for leaching waste:
  - Dry tailing storage
  - Storage in tailing ponds / dams
  - Deep sea tailing placement
- In Indonesia, deep sea tailing placement of HPAL tailing is not permitted by the Ministry of Environment and Forestry.
- The current practice for HPAL tailing handling in Indonesia is through dry tailing storage.

HPAL Project Data

Plant Name	Location	Capacity, t Ni/yr	Year	Capex USD, millions	Unit Capex USD/t Ni/yr, thousands	Product	Ramp-Up
Coral Bay Line 1	Philippines	10,000	2004	180	18	MSP	Fast
Coral Bay Line 2	Philippines	12,000	2008	370	31	MSP	Fast
Ravensthorpe	Australia	50,000	2008	3,900	78	MHP	Slow
Ramu	PNG	31,150	2011	2,100	67	MHP	Slow
Goro	New Caledonia	60,000	2012	6,000	100	MHP	Very Slow
Ambatovy	Madagaskar	60,000	2012	7,200	120	Metal	Slow
Taganito	Philippines	36,000	2013	1,700	47	MSP	Fast
Gördes	Turkey	10,000	2014	360	36	MHP	Slow
PT HPL Phase 1	Indonesia	35,574	2021	684	19	MHP	Very Fast
PT HPL Full Phase	Indonesia	55,875	2023	1,061	19	Sulfate	Very Fast
PT QMB	Indonesia	50,000	2022	998	20	MHP	Very Fast
PT Huayue Nickel Cobalt	Indonesia	55,655	2022	1,230	22	MHP	Very Fast
PT Huafei Nickel Cobalt	Indonesia	120,000	2023	2,080	17	MHP	In-Progress
PT Obi Nickel Cobalt	Indonesia	65,000	2024	1,100	17	MHP	In-Progress

Sources: 1) https://nickelindustries.com/carbon/wp-content/uploads/2021/04/3-10-2019-Presentation-to-Investors.pdf
2) Macquarie Research, CLSA 3) Global Mining Research, 2018

Hydromet Plants – Other Technology

Step Temperature Acid Leach (STAL) Technology

- **Process concept by PT Hydrotech Metal Indonesia**
  1. **Sulphation Roasting (In Rotary Kiln)**

     $NiO_{(s)} + H_2SO_{4(aq)} \rightarrow NiSO_{4(s)} + H_2O_{(g)}$

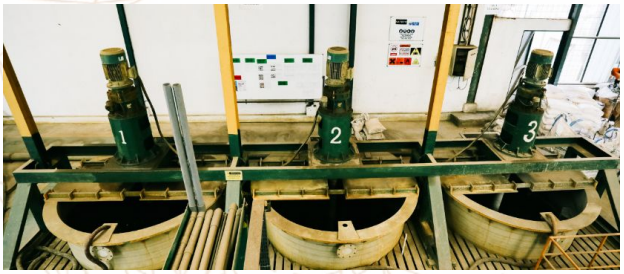
     $Fe_2O_{3(s)} + 3H_2SO_{4(aq)} \rightarrow Fe_2(SO_4)_{3(s)} + 3H_2O_{(g)}$

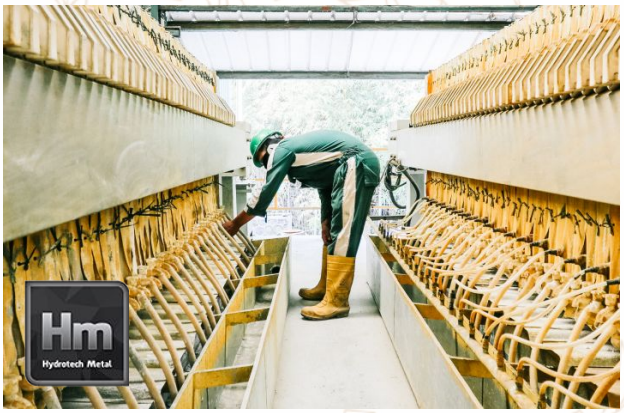
     At T > 600 °C : $Fe_2(SO_4)_{3(s)} \rightarrow 3SO_{3(g)} + Fe_2O_{3(s)}$

     $NiO_{(s)} + SO_{3(g)} \rightarrow NiSO_{4(s)}$
  2. **Water Leaching (In Leaching Tank)**

     $NiSO_{4(s)} + H_2O_{(l)} \rightarrow NiSO_{4(aq)} + H_2O_{(aq)}$
- **A similar concept has already been applied commercially for processing REE concentrates.**
- **The advantage of this process is that it operates at atmospheric pressure and its efficiency is not affected by the profile of the laterite ore.**
- **The application of this concept is already in pilot plant stage and is seeking opportunities to move to the commercial stage.**

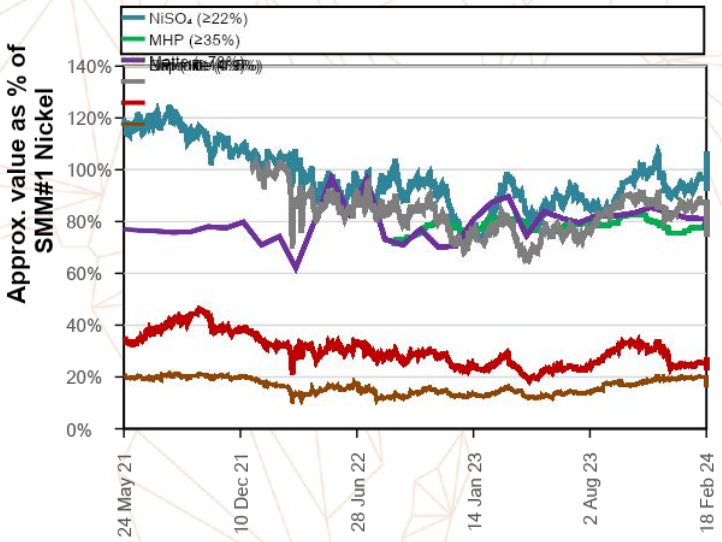
STAL Technology's Pilot Plant

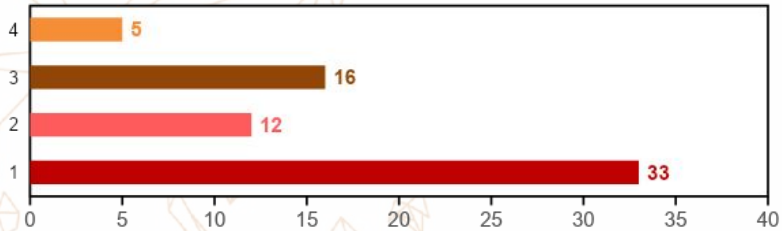


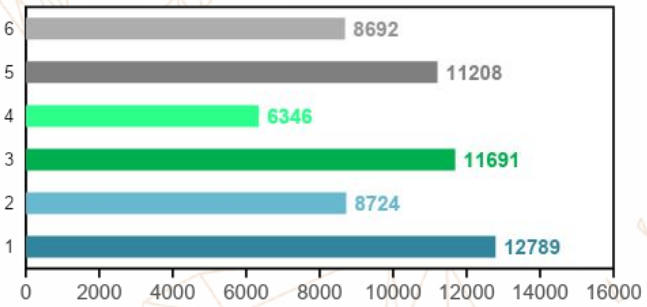


Sources: 1) https://hydrotechmetals.com/
2) https://staltechnology.com/stal_technology

Ni Payability, Selling Price and Cash Cost of Various Products





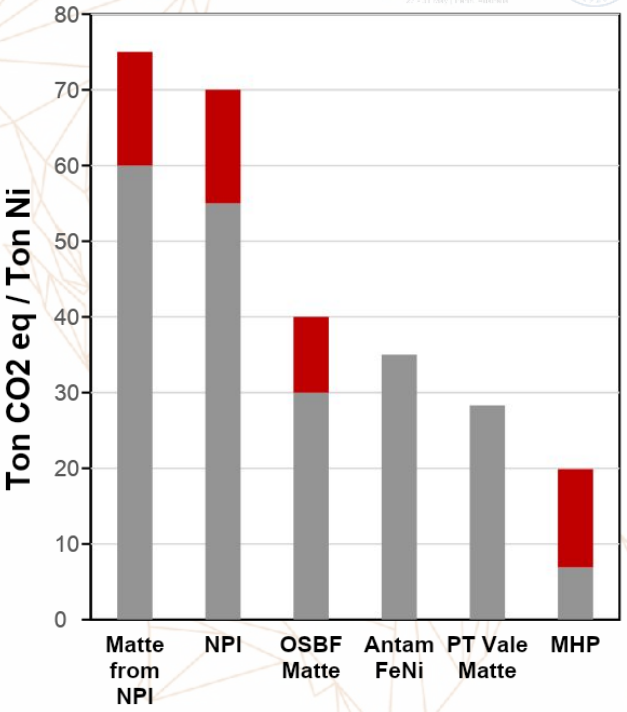


- Between 2021-2024, the Ni payability in ore is between 10-40%.
- The Ni payability in NPI dropped to 69% in December 2022 and rose back to around 70% in June 2023.
- The Ni payabilities in Nickel matte and MHP have been steady at around 80%.
- $NiSO_4$ is always highly priced with Ni payability fluctuates around 80 and 120%.
- Some of miners and processors in Indonesia maintain positive margins amidst drops in nickel prices.

Sources: 1) https://www.metal.com/Nickel 2) Indonesian Central Statistics Agency. Accessed 2024

Directions / Strategies of Indonesian Nickel industry

- Several strategies are already implemented / being tested to reduce emissions in nickel industry in Indonesia including:
  - Implementing heat recovery solutions to reduce coal consumption;
  - Use of biomass and biocarbon as a coal replacement;
  - Use of biofuels to reduce the emissions of vehicles and stationary equipment;
  - Use of conveyor belts or slurry pipeline for material transport to minimize vehicle emissions and dust pollution from material transportation;
  - Minimizing dependency on coal-fired power plant through substitution of energy source / power plant fuel;
  - Reducing the use of limestone;
  - Using electrification for transport vehicles;
  - Increasing efficiency of processes, machinery, and equipment.
- In addition, it is worth noting that the ore export ban policy also contributes to minimizing the carbon footprint associated with the transport of the low-grade ore materials.



Sources: 1) McKinsey cite in T. Nugraha (2024) Evaluation of the Implementation and Development Direction of Nickel Downstreaming. Coordinating Ministry for Maritime Affairs and Investment of the Republic of Indonesia
2) https://wwwcdn.imo.org/localresources/en/OurWork/Environment/Documents/SecondIMOGHGStudy2009.pdf; 3) https://tbpnickel.com/sustainability/climate-change/greenhouse-gas-emissions;

Concluding Remarks

- **Indonesia has experienced significant growth in nickel laterite processing, driven by strategic initiatives.**
- **The government's policies, such as the nickel ore export ban, have attracted substantial foreign investment.**
- **The policies lead to the establishment of numerous nickel processing facilities. As a result, Indonesia has become a dominant player in global nickel production.**
- **Future government's supportive policies, coupled with innovative practices and research, will aim to ensure the sustainable operation and development in Indonesia nickel industry.**

THANK YOU FOR YOUR ATTENTION

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