

## Nickel and the promise for environmental sustainability: Is it viable?

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In this paper, we aim to provide an in-depth discussion of nickel's crucial position in the manufacturing sector in the context of the United Nations' Sustainable Development Goals (SDGs), which represent growing environmental imperatives. These SDGs have gained unprecedented urgency due to looming concerns of incompleteness. It should be emphasized that the information compiled herein is derived from authoritative sources and is limited in its ability to give comprehensive coverage within the scope of this article. The raised issues are of broad interest in terms of environmental dynamics in the global nickel mining, extraction, and refining arenas. As a result, the content given below may not precisely comply with the local situations dictated by geographical, geological, and socio-economic characteristics. The fundamental goal of this discussion is to clarify the economic-environmental interaction and the pragmatic meanings of the term "sustainable" in the context of the nickel industry.

Nickel, characterized by its silver-white appearance, chemical symbol Ni, and atomic number 28, is a metal endowed with lustrous aesthetics and a specific weight akin to copper. It belongs to the iron group, alongside Iron (Fe), Cobalt (Co), Gadolinium (Gd), and Dysprosium (Dy), owing to its exceptional attributes of hardness, malleability, and ductility. Notably, the melting point of nickel stands at 1455°C.

Under normal environmental conditions, nickel exhibits remarkable resistance to oxidation, rendering it indispensable in coin minting, stainless steel manufacturing, and the production of high-strength, high-performance engine components (Bloch et al., 2007), as well as other critical components demanding exceptional reliability. Nickel used for stainless steel refining accounts for roughly 68% of global nickel production; the other 11% is used in the fabrication of superalloys with stringent physical and chemical requirements, particularly corrosion resistance under specialized conditions (Government of Canada, 2023). Beyond these applications, nickel also plays an integral role in creating magnets (AlNiCo), soft magnetic materials (NiFe Permalloy), and electrodes.

From an environmental standpoint, nickel plays a critical role, owing to its significant contribution to the creation of rechargeable batteries, a source of dispute in the competitive landscape of electric vehicle (EV) manufacturing. It is worth noting that, despite being a

resource used by humans for around 3500 years, nickel's significance has never reached the current peak of attention and demand for extraction as it does today.

### **Nickel as a raw material for commodity production**

The acquisition of nickel predominantly emanates from mining operations, with a substantial focus on laterite ores, rich in nickel constituents such as limonite (nickeliferous limonite,  $(\text{Fe,Ni})\text{O}(\text{OH})$ ) and garnierite (nickel silicate hydrate,  $(\text{Ni,Mg})_3\text{Si}_2\text{O}_5(\text{OH})_4$ ). Another ore type with a high nickel content is sulfide magma, predominantly composed of pentlandite,  $(\text{Ni,Fe})_9\text{S}_8$ .

While ores containing oxides and hydroxides are processed using hydrometallurgical methods, sulfide-rich ores undergo either pyrometallurgical or hydrometallurgical treatment. Notable industrial nickel producers include Russia, with an annual output exceeding 260,000 tons, followed closely by Australia and Canada, with annual yields of approximately 200,000 and 130,000 tons, respectively. (Please note that these production figures are rounded approximations.)

The burgeoning prominence of nickel as a raw material commodity in the electric vehicle (EV) battery manufacturing sector has elevated its appeal to unprecedented levels. In 2022, the global production of raw nickel reached 3.03 million tons, marking a continual upswing in nickel supply chains since 2010 (Garside, 2023a). However, it is imperative to underscore that a mere 15% of the annual production of raw nickel is dedicated to satisfying the heightened demand in battery production, which utilized 450,000 tons of nickel in 2022, out of a total consumption of 3.03 million tons.

As estimated by the U.S. Geological Survey, the three nations boasting the most substantial nickel reserves globally are Indonesia (22%), Australia (22%), and Brazil (17%) (U.S. Geological Survey, 2022). The world total nickel reserves are estimated at approximately 95-100 million tons (Garside, 2023b; Government of Canada, 2023). The confluence of elevated consumption levels and robust commodity prices has established nickel as a preeminent global market commodity, with a market size estimated at 20.04 billion USD (Grand View Research, 2023).

### **The promise of environmental sustainability and Nickel's role**

Nickel's link with the Sustainable Development Goals (SDGs) is not coincidental but is firmly based on its diverse applications in industries that support sustainable development objectives. These encompass the production of rechargeable batteries, components for wind turbines, photovoltaic solar cell panels, apparatus for bioenergy plants, carbon capture and storage equipment, nuclear power plants, and ecologically sustainable modern construction, among others. The ascendance of electric vehicles (EVs) in the transition away from fossil fuel-driven engines further underscores nickel's significance, especially in the context of the two predominant types of rechargeable batteries—Nickel Cobalt Aluminum (NCA) and

Nickel Manganese Cobalt (NMC)—both possessing substantial nickel utilization rates of 80% and 33%, respectively, with undeveloped hybrid formulations aiming for 80% nickel utilization (Nickel Institute, 2023).

These promising sustainable technologies have propelled nickel to the forefront of the climate change era. Governments and corporate enterprises have begun to compete for dominance in nickel-derived product mining, refining, and production. However, it is necessary to acknowledge that promises are for the future, whereas actions and adverse consequences to the environment are occurring or have already occurred. The impending question is: “What happens in the world of Nickel?”

### **The predicament of Nickel and the asymmetry of value systems**

The public's attention has recently been placed on nickel mining ventures in Indonesia, which is currently positioned as one of the world's leading nickel reserves, alongside Australia. According to US Geological Survey data for 2022, Indonesia alone provided approximately 50% of the world's nickel ore (Ruehl & Dempsey, 2023). Nevertheless, the extraction, processing, separation, and refining processes can cause adverse impacts on the environment, especially when carried out on a massive scale. These projects have resulted in considerable deforestation, particularly in ecologically rich areas, directly threatening and destabilizing the ecological balance.

It is worth noting that these projects are supported by large automobile corporations with the promise of promoting electric vehicles—a promise synonymous with reduced greenhouse gas emissions. Those corporations include, but are not limited to, Ford (USA), Vale (Brazil), Tsingshan (China), and Jardine Matheson (Hong Kong) (Ruehl & Dempsey, 2023).

According to published data, 76,300 hectares of tropical rainforest, almost the size of New York, have been lost to deforestation throughout 329 concession areas. Around 23,000 hectares of the deforested areas have been cleared from 2019 onwards, corresponding with an increase in demand for electric vehicles and nickel battery manufacture. Notably, when Financial Times investigative journalists attempted to speak with representatives of these automobile investors and joint ventures, they received no response (Ruehl & Dempsey, 2023).

In theory, all these corporations have espoused commitments to reforesting these areas, yet the reality seems to be far more intricate. Lands rich in laterite ore reserves are challenging to reforest, and primary forests require decades, if not centuries, to regenerate and fulfill their role as effective carbon sinks (Cole et al., 2014). Disrupting the ecological equilibrium will immediately leads to direct emissions from the soil, whereas whether the forest can be regenerated is still elusive. Additionally, it takes decades for the forest's carbon capture and storage to become efficient (Waring et al., 2020).

Furthermore, nickel mining consumes a large amount of water. According to IEA data from 2021, extracting one kilogram of nickel requires around 0.053 cubic meters of water, which is comparable to the water consumption of cobalt (0.057 cubic meters/kg) (IEA, 2021). Assuming that laterite ore mining in 2022 totaled around 2.2 million tons, total water usage would be around 1 million cubic meters. The amount of water required for nickel processing in 2022 would be roughly 530,000 cubic meters (Northey & Haque, 2013). However, this is only an approximated number as accurately quantifying water requirements for nickel mining is a complex endeavor contingent upon ore type, terrain, and processing technology.

The extraction and processing of nickel also require a significant amount of electricity. Researchers cannot ignore the energy source used in the commercial nickel manufacturing process since it has direct ramifications for greenhouse gas emissions. For example, the energy required to produce finished nickel metal is 174 GJ/ton, which equates to around 48.3 thousand KWh. Even the lowest-grade ferronickel consumes 60 GJ/ton, or approximately 16.7 thousand KWh per ton of product (Wei et al., 2020). As a result, research from the electric car industry estimates that manufacturing an 80 kWh lithium-ion battery pack for a Tesla Model 3 would make the metallurgical industry release 2.5 to 16 tons of CO<sub>2</sub> (Crawford et al., 2022).

Tailings are another environmental consequence that not only leaves a long-lasting imprint on native flora and fauna ecosystems but also frequently sparks legal conflicts and socioeconomic problems. Regulatory systems for managing these types of waste, whether solid or liquid, vary and are difficult to be enforced. Tailings from nickel mining have a long history of issues due to nickel's heavy metal properties with adverse impacts on the environment. When exposed to the atmosphere for extended periods of time, they undergo chemical interactions with oxygen, producing poisonous acids that are harmful to most life forms. When tailings are dumped into ponds or landfills, they frequently infiltrate and overflow, releasing hazardous heavy metal elements to arable land and groundwater. Effective treatment is limited by economic issues. Many mining enterprises prefer to settle fines during mining operations rather than investing in full treatment from the start as it is more cost-effective.

The discrepancy in commodity value and environmental effect is starkly evident, so the causes underpinning these disparities cannot be disregarded because they will shape what the human desire: sustainability. Consequently, the next section will apply the "semiconducting principle of monetary and environmental values exchange" to clarify and connect the discourse to commercial transactions (Vuong, 2021).

### **Business, Profit, and Temporal Considerations**

Through the facts, data, and logical arguments presented above, the paper is aiming to accentuate uncertainty and contradiction of the promise of utilizing nickel resources for environmental sustainability.

Firstly, it is imperative to acknowledge that prior to any financial investment or concerted effort geared toward ecosystem restoration, a requisite phase of destruction invariably takes place. In the Indonesian context, this destruction translates into the decimation of tens of thousands of hectares of longstanding, ecologically diverse, and balanced tropical rainforests.

Secondly, while the promise of curtailing CO<sub>2</sub> emissions and other greenhouse gases is fundamentally oriented toward the future, forest loss will immediately release CO<sub>2</sub> to the atmosphere. Moreover, emissions stemming from electricity consumption, water extraction, transportation, and a variety of other operations during mining, separation, and refining must also be considered. Meanwhile, the actual amount of Ni used in recent decades, when the demand for electric vehicle batteries increased, only accounted for around 10-15% of total nickel demand.

Thirdly, the feasibility of environmental pledges contingent on nickel exhibits variation, influenced by several factors: a) the protracted timeline involved; b) the market risks that mining and nickel-consuming enterprises must confront directly; c) the financial viability that mining and nickel-driven projects will achieve in the forthcoming years.

In essence, the fulfillment of pledges to ecological-environmental values is heavily dependent on the economic status of the entities involved. At this point, it is worth noting that legal frameworks established at the start of a project frequently lack the detail needed to regulate the wide range of emergent possibilities. Profit calculation for businesses is inherently complex, and it is frequently met with unanticipated variations in political and economic landscapes. The equation between economic benefits and environmental loss is still a challenge that will take decades to solve, or whether the equation can be solved remain unanswered. After tens of thousands of hectares of forest were removed, the extraction of soil and rock, followed by ore extraction, separation, refining, logistics, and transportation, among various other activities are usually the priorities before we can talk about the restoration of the environment in mining areas.

Consider a scenario that encapsulates how financial risks can inexorably lead to environmental risks. First and foremost, let us scrutinize the international nickel price chart.

Large price oscillations invariably bring forth both opportunities for profit and perils for nickel production enterprises. As evidenced by the chart, nickel prices reached their peak at \$48,560 per ton on March 7, 2022, mere weeks following the eruption of the armed conflict between Russia and Ukraine. However, nine months hence, on December 7, 2022, nickel prices decreased to \$31,280 per ton, constituting a staggering 55% decline in value. The available data highlights the occurrence of a new record low price for raw nickel on October 11, 2023, equivalent to a modest \$18,080 per ton. This value represents only 37% of its highest-recorded valuation (Trading Economics, 2023).



Nickel Price Trends and Projections (Source: Trading Economics [14])

Assuming that businesses had meticulously calculated their investment values, factoring in obligations for ecosystem restoration and commitments at the apex of high price levels. In such a scenario, when prices plummet to a third of their peak value, the paramount concern inevitably becomes the survival of the enterprise, rather than the restoration of ecological values that have already degraded. If these diminished prices fail to cover the costs, businesses are confronted with an unenviable option: suspending production to safeguard capital. This unsettling possibility has recently become a stark reality within another critical industrial sector, zinc. On September 12, 2023, Reuters reported that Almina-Minas do Alentejo in Portugal would halt zinc and lead production at the Aljustrel mining base from September 24, 2023, until the second quarter of 2025 due to a steep decline in zinc prices. Zinc prices on the London Metal Exchange (LME) had plummeted by approximately 30% since January 2023, reaching a mere \$2,500 per ton by the end of September (Reuters, 2023).

Logically, when production comes to a halt, environmental commitments will be given an exceedingly low priority, both from a financial and temporal standpoint, because halting production stems from losses and an inadequate cash flow.

Returning to the aforementioned chart, the straight-line projection at the terminus signifies the envisioned decline in nickel prices as "stable." This development magnifies the risk that environmental commitments may remain unfulfilled. Moreover, it generates an illusion of oversupply within the nickel market, when in actuality, the aggregate nickel reserves stand at just under 100 million tons. Price fluctuations in the market indirectly diminish the

perceived value of forthcoming environmental commitments through the cash flow dynamics of businesses.

Even when the argument posits that environmental disruptions or rehabilitation are merely "temporary," the associated costs are undeniably steep. Recent research suggests that even a temporary temperature increase of 2°C can engender enduring repercussions for oceans, with consequences resonating for centuries. This is due to a decrease in oceanic oxygen levels, leading to the contraction of habitats for myriad marine species, persisting long after CO<sub>2</sub> levels have peaked and subsided (Santana-Falcón et al., 2023; Ziehn et al., 2023).

Forests, characterized by their immutability in the face of loggers' advances, can be vanquished at a remarkably swift pace. Recent data from Bolivia underscores this stark reality, with a 32% upsurge in deforestation in 2022 compared to the preceding year. This surge in deforestation catapulted Bolivia to third place in global deforestation rankings, trailing only Brazil and the Congo (Graham, 2023). However, when being calculated relative to national land area, Bolivia easily surpasses Brazil, with deforestation rates four times greater (Reuters, 2023). The rationale behind this deforestation frenzy is the conversion of forests into expanses for soybean cultivation. While this has facilitated a burgeoning soybean industry, transforming soybeans and their derivatives into the third-largest export of the country, reaping revenues totaling \$2 billion, the correlation between this revenue and environmental degradation remains a contentious issue. The long-term consequences are shrouded in uncertainty, but one certainty is that the forest may require centuries to regenerate, and the ever-intensifying climate variability complicates predictions regarding future crop productivity and quality (Raza et al., 2019).

Replacing "soybeans" with "nickel," the fundamental dynamics remain largely unchanged. The critical question persists: Where is the environment in the solution that is said to protect the environment through nickel? Currently, in the environmental-economic equation, the clearest change is the positive increase in the mining and manufacturing industry's profit, while environmental values are negative. The concept of an "ecological surplus" has never been as pertinent and valuable as it is today (Nguyen & Jones, 2022; Vuong, 2021). "Are humans in a toxic, abusive relationship with nature? Love is strange" (Vuong, 2023)

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