COMPANY PROFILE

TRINITAN
GREEN ENERGY
METALS

Advancing Nickel Production for the Global EV battery Industry

DEVELOPED BY

SUSTAINABLE ENERGY FOR ALL

Table of Contents

Renewable Energy Manufacturing in Indonesia: Advancing Nickel Production for the Global EV battery Industry

The SEforALL team meets with TGEM at the company's facility in August 2023.

Our foundational research report, Renewable Energy Manufacturing: Opportunities for Southeast Asia, highlights the potential for scaling-up homegrown renewable energy supply chains in the region by fostering the essential financial, technical, and socio-economic foundations for local battery, solar photovoltaic (PV), and electric two-wheeler industries. Doing so could generate an estimated 6 million renewable energy jobs by 2050.

The research identifies four core pillars to success in growing green manufacturing in Southeast Asia: supporting policy and regulations that promote local manufacturing, developing a skilled workforce to support the industry, unlocking investment by supporting new private and public sector partnerships, and supporting regional supply chains and intra-ASEAN trade of manufacturing inputs.

In line with our focus on innovation, circularity, and engagement of local companies in R&D, we developed this company profile to underscore the significance of showcasing best practices of exemplary innovations in the battery supply chain and catalytic partnerships to support the growth and expansion of local manufacturing. In the context of Indonesia and its battery manufacturing capabilities, this company profile showcases Trinitan Green Energy Metals (TGEM) - a company based outside Jakarta that pioneers innovative solutions and sustainable practices within the critical minerals industry, in particular nickel refining and processing.

TGEM has adopted Step Temperature Acid Leach (STAL) technology, marking substantial progress in the field of critical mineral refining, particularly high-purity nickel production, which is an essential component for electric vehicle (EV) batteries. Through the adoption of STAL technology, TGEM advances resource conservation, efficient waste management, and reduction in emissions through its closed-loop industrial practices. This company profile not only creates awareness of how sustainability efforts can be integrated into the nickel refining processes, and subsequently the global EV battery industry, but also calls attention to the financial requirements and strategic considerations essential for the successful realization of such a project.

Background

TGEM is a producer of high-purity nickel in the form of mixed hydroxide precipitate (MHP), which has applications across various segments of the EV battery manufacturing industry. While this industry typically has significant negative environmental impacts (e.g., greenhouse gas emissions, resource depletion, pollution of ecosystems, ecotoxicity), TGEM has adopted sustainability measures to mitigate its footprint. Notably, the company has developed an almost closed-loop waste management system and employed artificial intelligence to assess and minimize negative environmental impacts.

The company has secured a long-term MHP offtake agreement from a Japanese trading company for the South Korean market and is actively exploring potential partnerships in downstream processes to enhance nickel value creation. TGEM employs STAL technology, specifically designed to enhance the efficiency of metal and mineral refining processes while fostering environmental sustainability. This technology, developed by TGEM's technical subsidiary (Hydrotech Metal Indonesia (HMI)), can be adapted to a wide range of mining conditions and has been patented in Canada, Indonesia, Japan, New Caledonia and the Philippines.

TGEM operates a commercial STAL MHP facility with an annual production capacity of approximately 3,200 tons of MHP. The company is set to expand its operations through two integrated nickel processing ecosystems: STAL One Ecopark and the Indonesia Green Nickel Integrated Technology Ecopark (IGNITE). STAL One Ecopark, located in Bogor, will be devoted to the development, testing, and enhancement of innovative technologies across the entire nickel value chain. The facility is expected to annually produce approximately 10,000 tons of MHP, along with valuable by-products. IGNITE will be a replicable and scalable counterpart to the STAL One Ecopark. It will be situated in Sorong, Southwest Papua, Indonesia, with an anticipated annual production capacity of 400,000 tons of MHP.

The Nexus: Nickel and EV batteries

The global EV market experienced exponential growth, accounting for 14% of total vehicle sales in 2022 compared to a 4% market share in 2020. [1]In 2022, the leading regions for EV sales were China, Europe, and the United States, collectively representing approximately 95% of the global EV market.[2] The uptake of EVs in emerging markets and developing economies, excluding China, is still relatively modest. However, it is expected to increase as these countries implement targets and policies to promote EV growth. Despite rising battery prices due to increased raw material costs, global investments in EVs and charging infrastructure increased by 56% in 2022, reaching approximately USD 466.1 billion.[3] The expanding EV market increases the demand for batteries and critical raw materials such as nickel. In 2022, approximately 10% of the global demand for nickel came from EV batteries, with the majority sourced from Indonesia, which possesses the world's largest nickel reserves of approximately 21 million tons in lateritic form.

Figure 1 illustrates the global distribution of laterite and magmatic sulphide nickel deposits. About 60% of the global nickel reserves presently originate from laterite deposits found in countries such as Indonesia, the Philippines, and New Caledonia, while the remainder is obtained from magmatic sulphide ores in countries such as Canada, Russia, and South Africa.[4] Magmatic sulphide ores contain high-purity nickel (Class I with a nickel content above 99%) which is used in battery production. Laterite ores have low-grade nickel (Class II with a nickel content below 99%), which is mainly

[1] IEA (2023). Global EV Outlook 2023: Catching up with climate ambitions. https://www.iea.org/reports/global-ev-outlook-2023

[2] ibid

used in the production of stainless steel. Class I nickel is typically not directly obtained from laterite deposits due to the relatively low nickel content. However, with more complex refining processes such as STAL, Class I nickel can be obtained from these deposits. By 2025, the demand for Class I nickel for EV batteries is expected to be more than 15%.[5] With the increasing consumer demand, there is an expected shortage of Class I nickel sourced from magmatic sulphide deposits. As a result, the bulk of the additional nickel supply will predominantly come from lateritic deposits.

Class I nickel is an essential component of EV battery production, as it makes up about 72% of the battery cathode. Nickel is used in the cathode of lithium-ion batteries to improve the voltage, energy density, and subsequently increase the driving range of EVs while keeping costs down. Besides, nickel enhances the efficiency of EV batteries, improves thermal stability, prolongs battery life span, and ultimately optimizes EV performance. As such, it is essential in the transition to cleaner forms of transport.

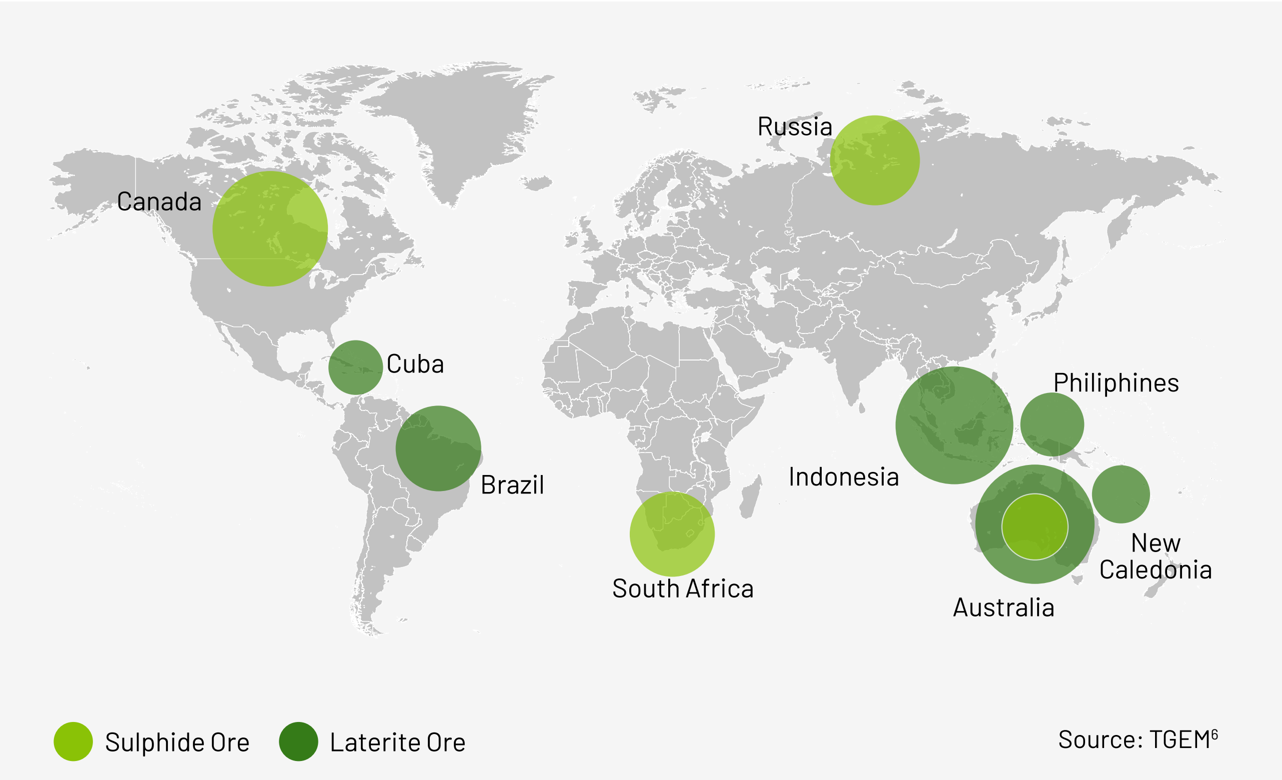


FIGURE 1: Global distribution of laterite and magmatic sulphide nickel ores

Notes: The global reserves of laterite ore amount to approximately 178 million metric tons, surpassing the 118 million metric tons of sulphide ore resources. Indonesia's laterite reserves are ~19% followed by Australia's ~18% and the Philippines ~10%.[7] South Africa has sulphide ores of ~28%, Canada ~19% and Russia ~17%.[8]

[3] REN 21 (2023). Renewables 2023 Global Status Report. https://www.ren21.net/

[4] Garvin, M. & Simon, J. (2014). 'A detailed assessment of global nickel resource trends and endowments', Economic Geology, 109, 1813–1814. https://doi.org/10.2113/econgeo.109.7.1813

[5] DERA (2021). Batterierohstoffe für Die Elektromobilität; DERA Themenheft: Berlin, p. 26.

[6] TGEM (2023). Critical material producer for the global EV battery industry. www.tgem.group

[7] Gavin M. & Simon, J. (2014). 'A Detailed assessment of global nickel resource trends and endowments', Society of Economic Geologists, Inc. Economic Geology, v. 109, pp. 1813–1814

[8] TGEM no. 6

STAL Technology

High-Pressure Acid Leach (HPAL) and STAL are two distinct technologies used in the extraction and processing of nickel from lateritic deposits. HPAL uses sulphuric acid as a leaching agent under high pressure, typically around 50 bar, and temperatures reaching approximately 255ºC to accelerate chemical reactions that occur during the leaching process, thus, maximizing the extraction of nickel from ores.[9] While HPAL is known for its high energy requirements, it can extract high volumes of Class I nickel from ores with complex mineral compositions or high impurities by breaking down minerals and impurities that are more resistant to milder processes. Indonesia intends to construct 12 HPAL facilities with a targeted annual production capacity of approximately 370,000 tons by the year 2025.

STAL technology produces Class I nickel in the form of MHP from low-grade to high-grade laterite deposits. The process entails crushing ores and leaching them at varying temperatures using sulphuric acid in a stepwise manner. STAL is a milder process compared to HPAL but requires temperatures ranging 300ºC-700ºC to maximize the recovery of nickel from lateritic ore. This process operates under normal atmospheric pressure (i.e., 1 atmosphere), utilizing standard equipment and less sulphuric acid. Unlike HPAL, STAL requires a longer duration to complete the leaching process due to the slower reactions and gradual temperature adjustments, which enable a more controlled dissolution of nickel and other metals from the ore. Besides, depending on the mineral composition and impurity levels of ores, the optimal temperature may vary, which can result in a longer overall process time. However, the STAL process is more effective in recovering nickel from lateritic ores because it extends the leaching time and raises temperatures to an optimal level, leading to higher nickel extraction rates.

STAL is exceptionally suitable for extracting both limonite and saprolite ores commonly found in laterite deposits.[10] Its temperature range and low-pressure conditions align remarkably well with the chemical composition of the low-grade limonite ore, making it an ideal choice for efficient extraction. For a long time, nickel was only extracted from high-grade saprolite ore using HPAL, while the limonite ore was considered overburden due to its low nickel content.[11] However, with STAL, Class I nickel can now be extracted from low-grade limonite ore.

STAL One Ecopark and IGNITE value proposition: closed-loop nickel refining ecosystems

TGEM's state-of-the-art modular STAL technology enables rapid attainment of peak production capacity while delivering high yields of up to 95%. With an output capacity of 2,450 tons per year, the STAL module is suitable for small and medium-scale mines that cover an area of under 250 hectares and have low-grade ore reserves as illustrated in Figure 2. Miners with mining business licenses for production operation (also known as Ijin Usaha Pertambangan Operasi Produksi (IUP)) can collaborate to create a STAL smelter as long as they are situated in proximity.

[10] Limonite and saprolites are types of nickel-bearing ores found in laterite deposits in Indonesia. Limonite ore is found in the upper layers of laterite deposits closer to the surface and is more abundant (i.e., it is 80% of the laterite deposit). Limonite is considered a low-grade ore reserve because of low nickel content- less than 1.7%. Conversely, saprolite is a high-grade ore reserve because of high nickel content- more than 1.7%. It is found below the limonite layer and is less abundant (i.e., 20% of the laterite deposit).

[11] Nickel Institute (2016). The life of Ni. https://nickelinstitute.org/media/1190/thelifeofni.pdf

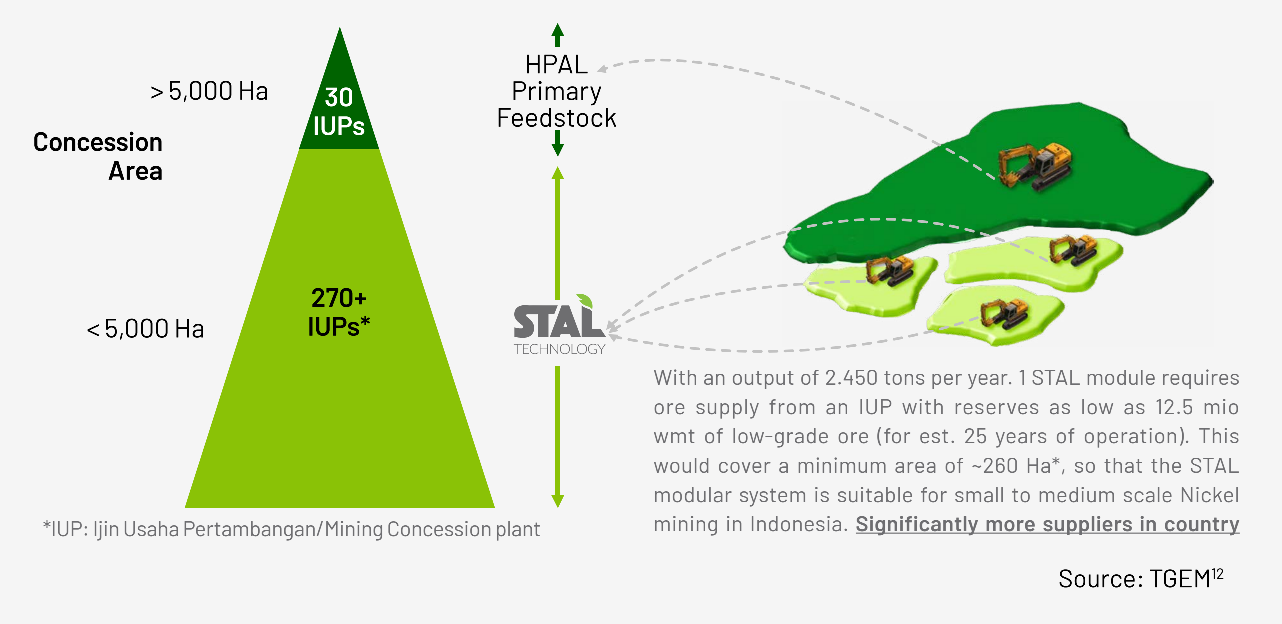
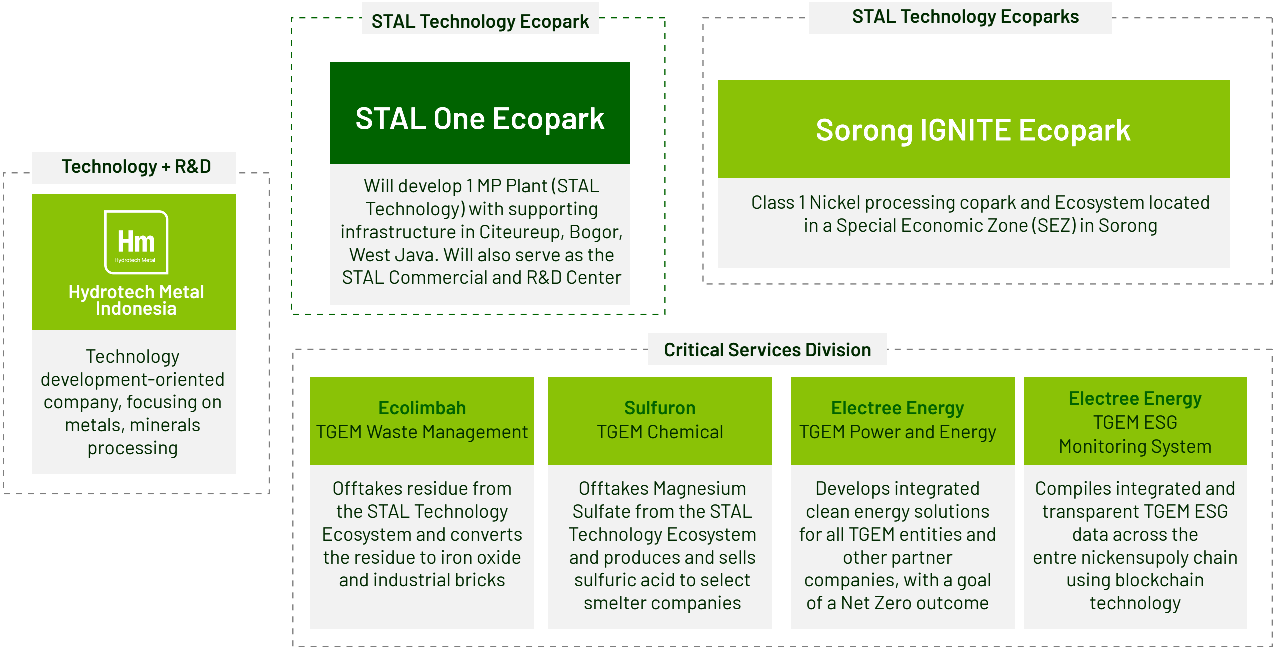


FIGURE 2: STAL technology for small and medium-sized mines

STAL One Ecopark and IGNITE will be the first of their kind in Indonesia and will serve as a model for closed-loop nickel refining ecosystems. The projects will have four support industries (Figure 3) dedicated to waste management, resource sharing, and environmental compliance. The waste management support industry will offtake residual waste from the STAL process and convert them to by-products to reduce the cost of disposal and minimize pollution of ecosystems. A chemical offtake facility will be constructed to process magnesium sulphate from the STAL process into sulphuric acid which will be sold to smelter companies within the ecosystem. While the STAL One Ecopark will be supplied with subsidized electricity from the grid, the IGNITE project will construct a power plant aimed at fulfilling the electricity needs of all partners within the ecosystem while striving to achieve net-zero emissions. TGEM will also set up an Environmental Social and Governance monitoring system that uses blockchain technology to collect and consolidate data across the nickel supply chain.

[12] TGEM no. 6



Source: TGEM[13]

FIGURE 3: Critical support industries for STAL One Ecopark and IGNITE

Key partnerships and customer segments

The IGNITE project will be built in collaboration with several partners from the USA, UK, and Japan to strengthen TGEM's strategic position in the nickel supply chain. The project will have 20 modules of which 6 will be built by TGEM while the rest will be constructed by engineering procurement and construction partners. The partnership will consist of miners and chemical suppliers responsible for providing feedstock to the STAL process, engineering procurement and construction partners tasked with module development, as well as providers of piped natural gas and biogas. The target customers are international markets in the European Union, Japan, South Korea, the UK, USA, and other Western markets. These countries have well-established battery markets and are major downstream actors in the global EV industry aside from China.

[13] TGEM no. 6

Environmental sustainability

STAL is a more environmentally friendly nickel refining technology, aligning with changing market regulations for sustainable supply chains. Through its zero-waste approach, STAL significantly reduces environmental impacts, preserves natural resources, and promotes a closed-loop system. It boasts a lower carbon footprint and consumes less energy compared to conventional methods. Furthermore, it utilizes less water and efficiently manages residues, transforming them into valuable commodities like sulphuric acid and industrial bricks, thus enhancing environmental sustainability.

TGEM is set to comply with changing global market regulations regarding the environmental sustainability of nickel supply chains through its zero-waste initiative - a closed-loop approach to nickel refining. For example, the company seeks to comply with legislative changes and requirements in foreign markets such as the European Union (EU). The EU recently published a new regulation on integrating circular economy principles into battery value chains[14] (i.e., slowing resource loops by minimizing the demand for raw materials, narrowing the loop by maximizing the useful lifetime of batteries that are in circulation and closing the loops by minimizing waste at the end-of-life). The regulations, which apply to all types of batteries that enter the EU market, address their environmental impacts from a life cycle standpoint (i.e., mining, manufacturing, use, and end-of-life) to reduce the demand for critical raw materials, minimize carbon footprint and the use of harmful substances. Nickel producers in the EU's EV battery supply chain must comply with this regulation and provide carbon footprint data for their products.

On a life cycle basis, upstream processes (i.e., raw material extraction, refining, and manufacturing) are the main hotspots of negative environmental impacts in nickel refining due to the energy-intensive metallurgical process, associated greenhouse gas emissions, emission of toxic substances into ecosystems, and resource depletion (e.g., water and metals). These impacts are expected to increase as the demand for nickel rises and ore qualities continue to degrade. STAL One Ecopark and IGNITE projects seek to reduce upstream impacts substantially and cut CO_2 emissions from the nickel supply chain. Figure 4 compares the carbon and water footprints of STAL and HPAL technologies. STAL has a carbon footprint of 15.5 tCO_2 eq per ton of nickel output which mainly comes from the combustion process and electricity consumption compared to HPAL's 21 tCO_2 eq per ton of nickel output.[15] In contrast, compared to the rotary kiln electric furnace technology, which

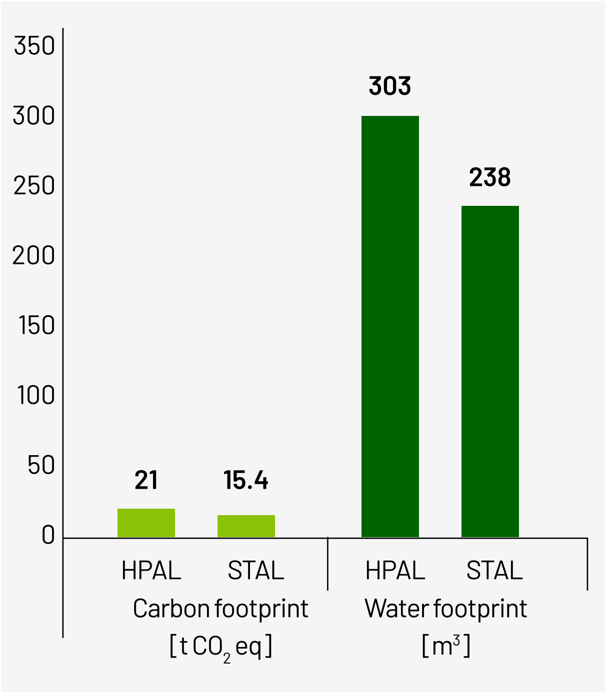


FIGURE 4: Comparison of the carbon and water footprint of HPAL and STAL technologies. The impacts are expressed per ton of nickel output (tNi-output). HPAL: High Pressure Acid Leach; STAL: Step Temperature Acid Leach

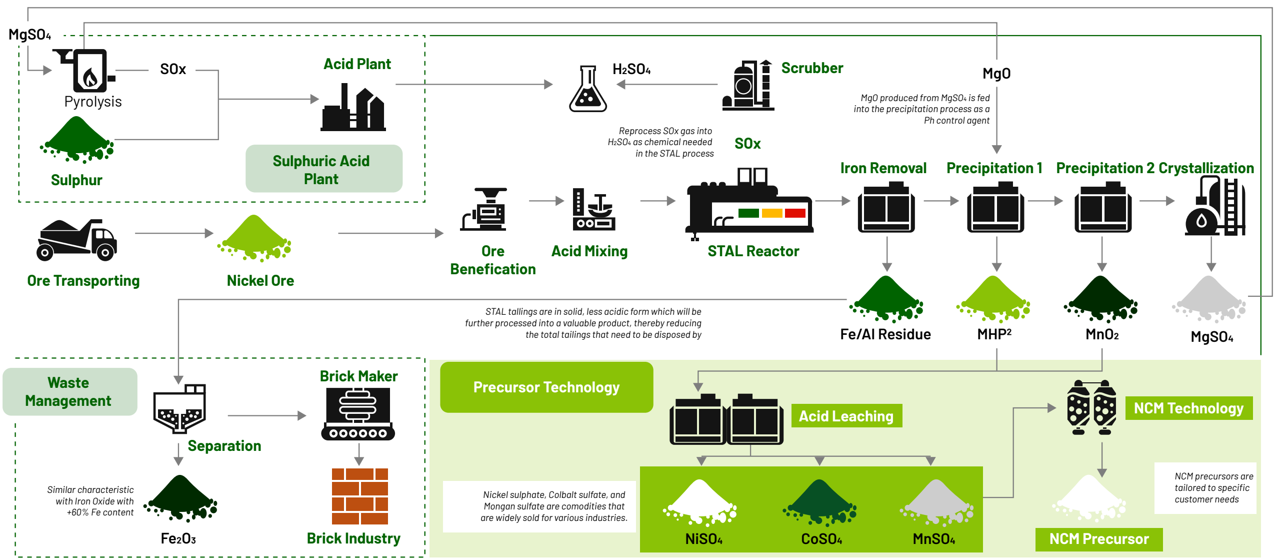
[14] Regulation (EU) 2023/1542 of the European Parliament and of the Council of 12 July 2023 concerning batteries and waste batteries, amending Directive 2008/98/EC and Regulation (EU) 2019/1020 and repealing Directive 2006/66/EC. https://eur-lex.europa.eu/eli/reg/2023/1542/oj

[15] TGEM no. 6

is commonly used to process high-grade nickel ores, STAL can reduce the overall carbon footprint of the operations by 67%. TGEM seeks to further reduce its carbon footprint by using renewable energy in the nickel refining processes to achieve net-zero CO_2 emissions by procuring renewable energy certificates.

Processes such as ore washing, chemical reactions, cooling and heat removal, waste treatment, and disposal require significant amounts of water. The HPAL process has a high water footprint of 303 m^3 per ton of nickel output while STAL is a more sustainable processing route with a footprint of 238 m^3 per ton of nickel output.[16]

STAL stands out for its reduced utilization of sulphuric acid in the leaching of laterite ores (i.e., it uses about 10 times less acid than HPAL per ton of ore processed), resulting in fewer emissions of toxic compounds per ton of nickel produced. Furthermore, managing the residues from this process is comparatively more straightforward when compared to HPAL's, which contains a high acid concentration. The STAL method achieves a closed-loop zero-waste system by repurposing residues and transforming by-products into valuable resources. For instance, the sulphur trioxide emitted from the STAL reactor is carefully treated and converted into sulphuric acid, which is then reintegrated into the STAL leaching process as shown in Figure 5. Similarly, waste materials like iron residues are less acidic and, hence, are processed into iron oxide, suitable for refining into industrial bricks. Additionally, products such as magnesium sulfate (commonly known as Epsom salt) derived from waste saline water undergo pyrolysis to produce sulphur oxide compounds, which, in turn, are used in the production of sulphuric acid. The residues from HPAL are often a mixture of various minerals, including iron, sulphur, silica, aluminum, and calcium. The HPAL residue is quite acidic and requires specialized and often more costly treatment to recover the valuable materials contained within.



Source: TGEM[17]

FIGURE 5: STAL Technology closed-loop approach

Notes: Al- aluminium; $CoSO_4$-cobalt (II) sulphate; Fe- iron; Fe_2O_3- iron (III) oxide; MgO- Magnesium oxide; $MgSO_4$ – magnesium sulphate; MHP- mixed hydroxide precipitate; MnO_2-manganese dioxide; $MnSO_4$- manganese (II) sulphate; NCM- nickel cobalt manganese; $NiSO_4$- nickel (II) sulphate; SO_x- sulphur oxides; H_2SO_4- sulphuric acid;

[16] ibid

[17] TGEM no. 6

Conclusions

FIGURE 6: Automated car factory with 3D-rendered robot assembly line and electric car battery module on platform.[18]

This company profile serves the purpose of highlighting best practices and innovations from local manufacturers in Indonesia as a part of our broader effort to catalyze partnerships and support the growth of the renewable energy manufacturing industry in Southeast Asia. In this context, we presented Trinitan Green Energy Metals (TGEM), a company exemplifying innovative solutions and practices in nickel refining and processing, which is pivotal for the electric vehicle (EV) battery industry. TGEM's adoption of Step Temperature Acid Leach (STAL) technology sets them apart by minimizing environmental impact and promoting sustainability. This profile aims to inspire collaboration, support local manufacturing growth, and bring attention to the financial considerations essential for successful projects like these. As the demand for cleaner transport rises with the EV market's exponential growth, highlighting the innovative efforts and sustainable practices of companies like TGEM becomes paramount for a greener future.

[18]Phonlamai Photo/Shutterstock.com

TRINITAN
GREEN ENERGY
METALS

DEVELOPED BY

SUSTAINABLE
ENERGY
FOR ALL