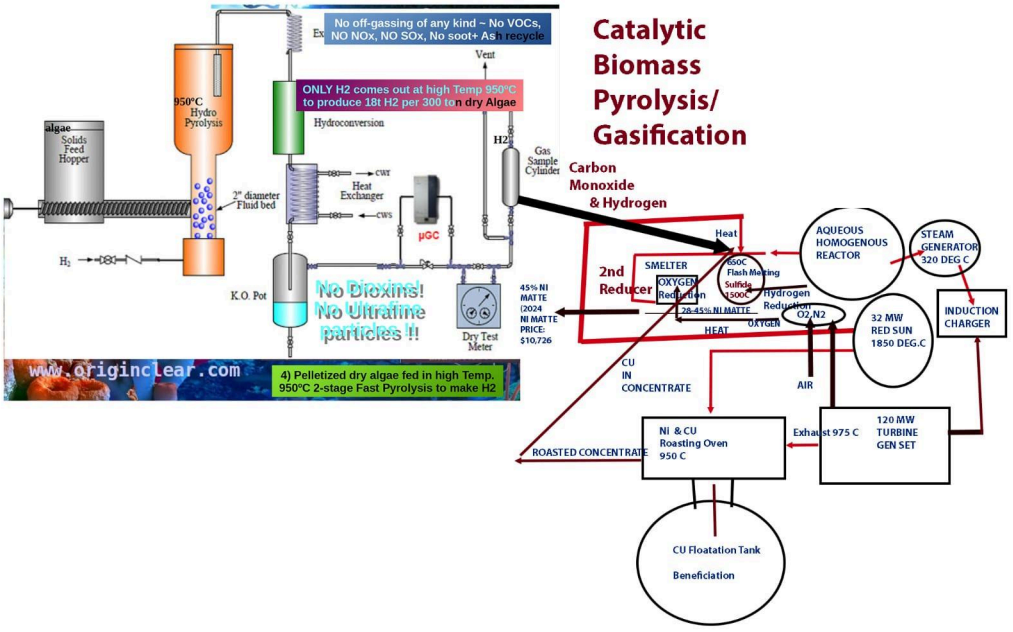
Redstar Flash Smelter

REDSUN TECHNOLOGIES



(Above)- *Redstar Flash Smelter for sulfidic ores* is transformed by marriage of Red Sun Mobile 1850°C thermal battery, providing 360 MWh/charge▪day heat and electricity to run *OutoKumpu* Green Flash Smelter (on right); plus, generating hydrogen by nuclear boiler (***AHR***, center) at 2.8 cents/kg and/or (**Above** - **left**) Redstar catalytic biomass pyrolysis (on left half) for both hydrogen and carbon monoxide to reduce concentrates turnkey production of energy, heat, and reducing hydrogen and/ or carbon monoxide and biochar to produce green Cu & Ni Matte for less than $3500/ tonne, or 30% of current price.

Intro:

The Philippines has just passed legislation banning the export of raw ores, and has yet to build smelter or refining capacity throughout the nation, despite the second largest reserves of copper and nickel in the world! Now, The Philippines can no longer send Cu and. Ni ore to China...they have to smelt it ( )see article link in ***Appendix* IV**).

Adding synergistic Redstar *Energime Green Group's 2- step Catalytic* features the trade secret cerium oxide- Iron- Manganese Metal Group catalyst - better than platinum - giving 15 tons H2 & CO/d per reactor. Thus, Red Sun thermal battery replaces fossil fuels, electricity; and, proven in 18 month JV

with *Csiro Mining*, collects and returns 30% waste heat from slag to give 200,000 MWh/year to recharge thermal batteries- completing the circuit. Moreover; only Red Sun thermal battery can provide 2000°C calcine heat to recycle red mud-cerium catalyst at $4/kg, while roasting ores at 950°C fuselessly in ducted kilns direct to 10 th generation Red Sun Battery that delivers super critical 1000°XC Steam to drive turbines and 950 to 1650 compressed air for Smelters. Calcine 2000°C catalyst production inhouse, plus matters Ni- Alloy vertically integrated manufacture enable 32 MW basalt encased 26 tonne battery to cost only 180k; at 360/ MWh / per charge gives 50c/ kWh capacity! Yet, gives double heat capacity and transmission through solid- state medium that can take. Millions of cycles like the earth, and not wear out for billions of years! Plus, 18m3 and 30tonne in containers enable transshipping everywhere wirelessly! while providing excess electricity to sell and deliver to grid or clients directly by truck, train or ship.

Redstar puts it all together and creates first affordable lower-cost green copper and nickel matte-producing clean low- cost green energy, pink and turquoise hydrogen, low-cost pure high heat, even collecting waste heat from slag; and distributing 1500°C heat for furnaces, ore roaster, heating gases and reducers, while running diesels, turbines & boilers. All without CO2 nor GHG; creating green steel, green copper and green nickel at fraction of normal cost (most of the metal cost is coke and fossil fuel energy put in)! Thus, redstar is a decade ahead as a green metal producer through key energy and hydrogen innovations and patents culminating from 30 years developing clean energy and hydrogen systems!

Thus, Redstar's marriage of Smelting with Molten Salt Reactors (and SMRs) and Transforming 1850°C Red Sun thermal batteries bring pink hydrogen into metal business for the 1st time to make green copper & green nickel matte.

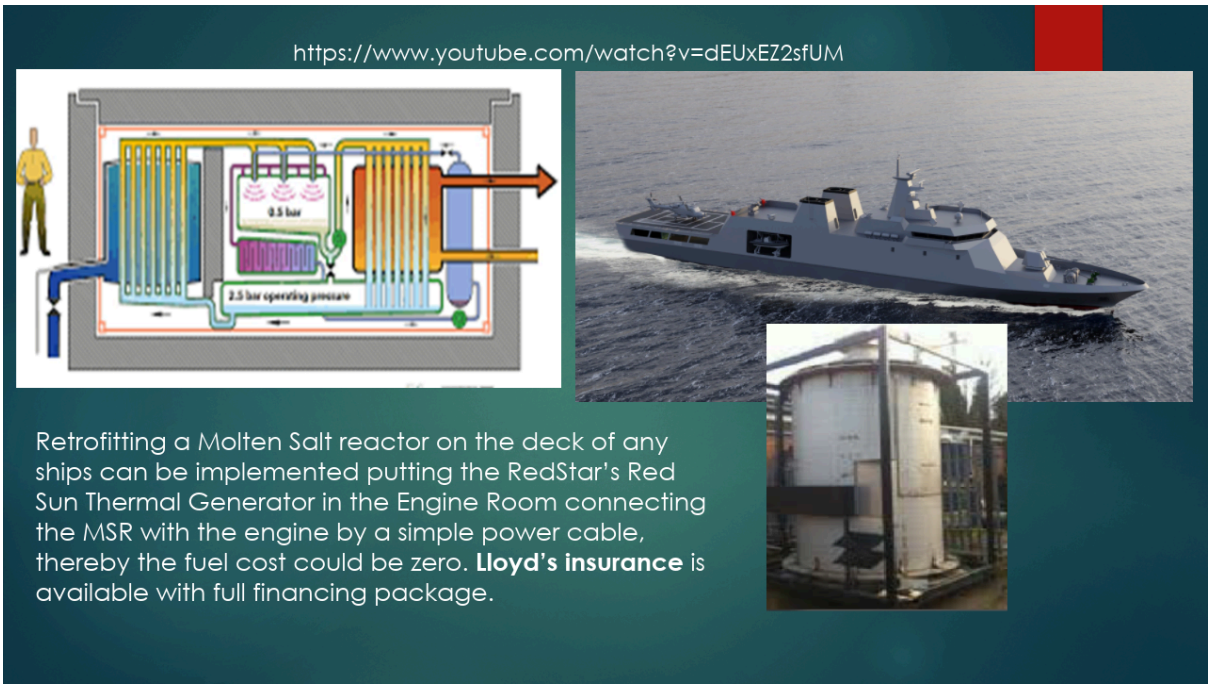
What is Nickel Matte & Red Sun Uses:

Nickel matte is an intermediate product used to make nickel sulfate, an integral product in nickel metal batteries material chain for EVs. It is also used directly to make Red Sun Mobile thermal batteries for 1/3rd the cost at $3500/ton, which is only $91k for a 32 MW Red Sun Battery, which gives 360 MWh/charge at 26 tons and 18m3. Redstar will build 400 Red Sun 32 MW batteries per year requiring 100k tons Nickel alloy and/or matte per year. This saves Redstar $182,000 per battery on main component- nickel- iron alloys, on 400 batteries this amounts to $72,800,000 per year savings on flash nickel smelter that costs less than $25M.

Intro to Smelting & Copper Industry:
Flash smelting is a metallurgical process where fine, dried sulfide concentrates are rapidly injected with oxygen or oxygen- enriched air into a hot furnace causing the materials to melt and react quickly in suspended state, primarily used to extract copper from sulfide ores. And; utilising the heat generated from oxidizing sulfides. Within the concentrate itself to sustain the smelting process. Essentially, the heat needed for smelting is largely provided by the chemical reaction of oxygen with reacting with sulfides, making an “autogenous process.”

Nine years ago, Indonesia produced just 5% of the nickel according to *Benchmark Intelligence*. By 2023, it accounted for half the global copper output, with forecasts for 65% of global output by the end of the decade. And; the Philippines is second in copper reserves globally, with a huge upside potential also, once smelters and refineries are built. What is holding the PhilippInes back are sky- high utility and gas/fuel bills, which Redstar nuclear power pllants greatly lower, with electricity and heat costs to $40/MWh. The Philippines can be major player in copper and nickel, including utilizing very low cost heat and 4c/ kWh electricity utilizing new Aqueous Homogeneous Reactors that make 220 liters of H2 per minute to reduce copper and nickel concentrates in flash smelters perfected by *Outokamku* in Finland in 1949 and reintroduced by China for green steel last year. Redstar will build Cu Smelter in

2025 for 250 kt copper matte per year featuring the AHR and Red Sun thermal battery while cutting energy costs in half and hydrogen costs by. 90%. Combining nuclear with cargo shipping now is the stated goal of ***IMO & LLOYDS REGISTRY***.



Energy Metrics & Nuclear Cost Breakthroughs:

With a complete combustion or fission, approx. 8 kWh of heat can be generated from 1 kg of coal, approx. 10 kWh from 1 kg of mineral oil and around 24,000,000 kWh from 1 kg of uranium-235. Related to one kilogram, uranium-235 contains two to three million times the energy equivalent of oil or coal. The illustration shows how much coal, oil or natural uranium is required for a certain quantity of electricity. Thus, 1 kg natural uranium– following a corresponding enrichment and used for power generation in light water reactors – corresponds to nearly 10,000 kg of mineral oil or 14,000 kg of coal and enables the generation of 45,000 kWh of electricity. One tiny fuel pellet can contain the equivalent usable energy of 3 barrels of oil! Returning to nuclear power is the only thing that makes sense for Italy (and Germany, Spain, Latvia, Thailand, Philippines, etc.), the EU and Asia with oil at $74 per

barrel and today's limited 18th Century energy technology the only other choice.

Red Sun nuclear- thermal Battery Flash Smelting & Patent:

Smelting is the process of extracting metal from its ore by heating and melting it to separate the desired metal from its impurities. Flash smelting is smelting process for sulfur containing ores including chalcopyrite. The process was invented by *Ottokumpu* in Finland. And first applied to smelting copper ore in 1949. It has also been adopted for nickel and lead production. Later the *International Nickel Company* introduced oxygen flash smelting. The *Redstar Flash Smelter* uses both types, reducing iron with 95% oxygen in secondary reduction process (see block diagram above) after primary reduction with heat oxidation of sulfidic ores, hydrogen, fluxes of silica and limestone, and carbon from carbon monoxide in some cases, although reducing with hydrogen soley is enough for Cu and Ni or lead for reduction including fluxes.

Flash smelting with oxygen- enriched air makes use of the energy contained in the concentrate (by exothermically oxidizing the sulfides) to supply most of the energy required by the furnaces. The concentrate must be dried before injected into the fuŕnace and, in the case of *Outokumpu process*, some of the furnaces use an optional heater to warm the reaction gas typically to 100°C to 450°C; which in our case will be created by the Red Sun thermal Battery blowing in hot air at about 2 cents per kWh.

The reactions in the dual metal flash smelting furnaces produce copper matte (or nickel matte), iron oxides and sulfur dioxide. The reacted particles fall in a bath at the bottom of the furnace, where iron oxides react with fluxes, such as silica and limestone to form slag.

In most cases the slag is discarded, and the matte is further treated (with pure oxygen) to produce blister copper in secondary reactor (see above diagram)

The sulfur dioxide produced by flash smelting is typically captured in a sulfur dioxide plant, removing the major environmental effect of smelting.

Redstar's new Cu & Ni Flash Smelter patent with *Aqueous Homogeneous Reactor (AHR)* provides hydrogen and Red Sun battery providing 25% of reactor heat and 100% calcine heat of 850°C for concentrates by Red Sun 1850°C thermal battery; and; provides initial primary 650°C heat for oxidizing sulfides. Sulfide oxidation in concentrates acts as fuel in Cu & Ni laterites to provide 75% of reactor heat energy necessary to smelt metals.

The Red Sun flash smelter patent encloses an *Aqueous Homogeneous Reactor* for hydrogen and base heat; and Red Sun 32 MW battery to drive smelting process for quarter million tons of nickel or copper matte per year per furnace, selling at an average of $10,726 per ton.

1. Battery makes calcine roasting heat - 950°C pre- reactor
2. Battery makes reactor start- up 650°C heat
3. Battery recharges from Nuclear steam from AHR at 2.8 cents US/ kWh
4. AHR Provides reducing hydrogen to top of Smelter
5. 2x 32 MW Red Sun Battery runs 120 MW turbines directly on *patented Non-Combustion Brayton Cycle*.
6. Waste 1500°C heat from slag blown with compressed air to run 38.5 MW LM 1500 to recharge Red Sun battery
7. Catalytic biomass pyrolysis can provide reducing hydrogen and CO + Carbon

Energy- wise- the Redstar Flash Smelting is run and heated 75% by sulfide oxidation of sulfide Nickel laterites and Copper sulfide ores.

The Brayton Cycle turbine run directly by the Red Sun Battery, tested by every major turbine maker, replacing fuel cannulas with heat exchangers to produce 626,000 MWh in patented Non- Combustion Brayton. Thus, 70 MW excess electricity is sold to grid, and the remainder electrically runs and heats various furnaces and reactors, plus power crushing and powderization for beneficiation. And AHR and/ or *EGG algae to hydrogen* (see link in Article Section Below for full description) or biomass gasification provide H2 and Carbon monoxide necessary to reduce the Cu and Ni ores containing Cu, Ni & Fe oxides in finely ground concentrates; and; turbines run nitrogen stripping for cryo nitrogen and oxygen manufacture.

60% x 120 MWh x 8700 hours/ year x $120/ MWh gives $75M of electricity per year produced; which can be insured by *Lloyd's Syndicate (see Lloyds pre- commitment for Red Sun)*, and municipal amd private PPAs financed. In our case it is used to run beneficiation and/or cold rolling plant to make steel for Redstar batteries, reactors and pyrolysis manufacturing.

30% Energy Recovery:

Thirty-eight mega watts can be recovered, blowing compressed air through 1 m3 of molten slag to run a GE LM 1500 turbine at 38.5 MW to recharge the two Red Sun Thermal Batteries through induction crucible charger www.inductotherm.com, and produce 350,000 MWh useful heat for flash smelting heat.

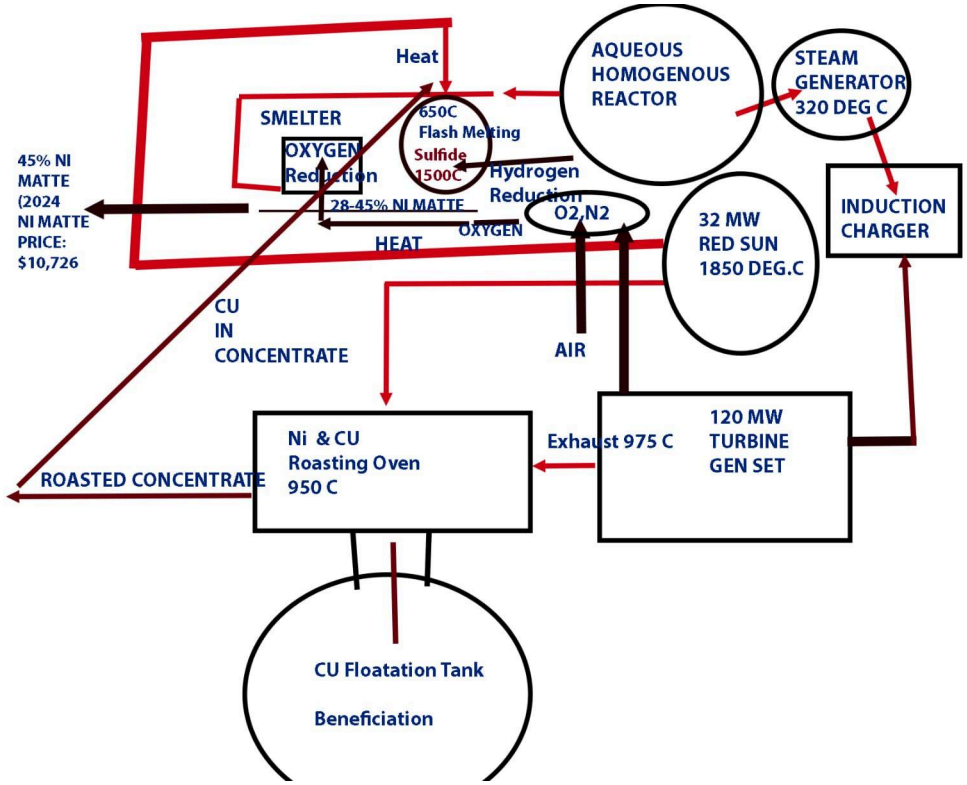
And the battery runs the refrigeration of the cryo nitrogen plant. Oxygen split off is directly injected into the secondary reduction reactor for reduction and removal of iron after primary reactor smelts and eliminates a majority of iron as slag in reduction of sulfidic laterites and finely ground concentrates of iron, copper and nickel oxides and laterites.

The collected nitrogen is cooled to cryo nitrogen in stainless steel tanks is used offsite to run other Red Sun diesel power plants combined with the heat of Red Sun thermal battery to make power fuelessly in Patented Non- Combustion Systems.

Red Sun synergy with ***Aqueous Homogeneous Reactor*** to raise 320°C heat to 650°C to ignite Ni-iron and Cu- iron fine powders at 650°C.

They go through the blast furnace twice- first to remove iron and second to separate copper and nickel

Patent extends to heating same configuration with solar thermal.



Redstar

Thermal Battery Drives Copper and Nickel flash smelter

The option to make catalytic biomass pyrolysis to use hydrogen (H2) and carbon monoxide (CO) syngas injected directly into reactor with Cu or Ni concentrates to reduce Cu oxides and sulfidic Ni laterites develops a revolutionary new patent and method to produce nickel matte in one step from fine powders in 6 seconds in flash smelting, injecting dolomites to form slag with H2 produced from AHR and/ or biomass pyrolysis; and produce 250 kt Cu Matte/ yr or Produce Steel 3,600 % more efficient and 300 x's faster and without coal.

(Above) Red Sun Mobile 32 MW retrofits and runs ships at $120/ MWh (client pays for Red Sun cryo nitrogen propulsion and power on lease and PPA for $120/ MWh)

Then heat can be pumped back from.blowing compressed air thru molten slag to run LM1500 at 9.8 MW to 38.5 MW.

So, oxygen is made inhouse from.making cryo nitrogen facility that creates cryo nitrogen at 2 cents US per liter for Red Sun diesel applications and retrofits for power. And; the Red Sun battery can run the heat and compressor directly to cool the cryo nitrogen.

Redstar's marriage of Smelting with Molten Salt Reactors (and SMRs) and accelerating and Transforming 1850°C Red Sun thermal batteriesbring pink hydrogen into metal business for 1st time to make green copper & green nickel matte.

Nine years ago, Indonesia produced just 5% of the nickel according to Benchmark Intelligence. By 2023, it accounted for half the global copper output, with forecasts for 65% of global. Output by the end of the decade. And; the Philippines is second in copper reserves, with a huge upside potential once smelters and refineries are built. What is holding the PhilippInes back are sky- high utility and gas/ fuel bills, which Redstar Nuclear Power Plants will greatly lower to $40/MWh, including the new Aqueous Homogeneous Reactors.

(Above) Red Sun 32 MW mobile thermal battery at 1850°C provides smelting and roasting heat, and moved to RE charging at night in a 20 ft shipping container transported by truck, train or ship. Also used to capture waste heat by industry; stores for 1 year; gives no emissions; 100% recyclable; and mimics Sun - Earth relationship and Earths Ni- Iron composition..

AHR Technical Data:

The 112 kW AHR is operated on 20 x 1 kg Uranium pellets of 8% U235, can be easily manufactured and current designs use 3- D printers, with novel patent- pending fluoropolymers that are neutron - proof and strong acid- proof. Easily built up to 500 MW, although current mini- AHR starting model is 112 kW, puts out 22 liters H2 per minute and produces heat of 320°C to run standard steam and ammonia engines, and is as big as a beachball. Financially, AHR is a breakthrough hit, as it makes up to 32 gm per day of Am241 and Po208- 209- and 210 per day for a total reactor cost of only $500k. The reactor and blanket have a neutron flux of 2 quadrillion neutrons per cm2 per second (@0.05) up to 5 x 10^15 neutrons per cm2▪second, which is high. A full 9 years of testing on a teen foot wide 500

MW unit by ORNL, which published and certified a glowingly positive feasibility study proving viability of AHR for radionuclide production and power, and that 347 steel for most of the reactor parts is sufficient. Thus, AHR is a super- heavy water moderated reactor of spherical design, good for Th232 blanket to transmute fertile isotopes to fissile, bringing Th232 to U233(Pa233); and, perfect for production of high demand radioisotopes Mo99, Am251 and Po 208 209 and 210 that sell at up to $2000 per gram. With LOI and next month full contract for $1500gm with *Stargen* for 1000 kg of material by 2030.

Tata Power + Nuclear steel business with SMRs:
https://www.livemint.com/companies/company-results/tata-power-keen-on-building-small-nuclear-reactors-as-india-opens-up-sector-ceo-says-11738679165844.html
REDSTAR will introduce plasma tech into flash smelting and into Hydrogen plasma reduction:
Hydrogen plasma smelting reduction is a process that uses hydrogen plasma to melt and reduce iron ire to produce liquid iron. Its a promising alternative to traditional ironmaking processes that produce large amounts of carbon dioxide (CO2).

Flash Ironmaking Process:

The novell, high intensity flash ironmaking process is a viable alternative that uses iron ore concentrates that are plentiful in the United States and China. The process uses natural gas or hydrogen (H2) to both heat the ore in the furnace and remove oxygen, converting the ore to iron metal.

What is China's New "***Explosive***" **Ironmaking Method**:

The technology triggers an explosive chemical reaction by injecting finely ground iron ore powder to generate high- purity molten iron, reducing reliance on high yield ore and coal, significantly improving energy efficiency, and achieving near zero carbon goals. This technology uses an innovative vortx lance.
https://www.scmp.com/news/china/science/article/3289441/chinas-explosive-ironmaking-breakthrough-achieves-3600-fold-productivity-boost

Philippines bans the export of all metal ores. Now we need Red Sun **Flash smelters**

https://www.philstar.com/business/stock-commentary/2025/02/12/2421026/senate-approves-bill-banning-export-raw-minerals

Redstar EGG Algae to **H2**:
Catalytic Biomass Pyrolysis:
https://drive.google.com/file/d/1Y7IqWaeKSOPSfBfl8r-08NHfyo-m21A2/view?usp=drivesdk

Terrestrial Energy:
https://youtu.be/ncKGUj6FN1E?feature=shared
PHP Must Unleash the Advanced Economy:
https://www.bworldonline.com/economy/2025/02/03/650809/phl-must-unleash-private-sector-to-become-advanced-economy-wb/

Australia's now we need Red Sun Flash smelters

https://docs.google.com/document/d/1ApISFL4ftDpj4Wy8p8HYuBlea4ryo5250xa6xC9r1yw/edit?usp=drivesdk

https://www.philstar.com/business/stock-commentary/2025/02/12/2421026/senate-approves-bill-banning-export-raw-minerals H2 Project under threat because. Local Steel company balkimg at paying for exorbitant H2 prices:

https://www.hydrogeninsight.com/policy/australias-first-green-hydrogen-production-and-power-project-at-risk-due-to-offtake-uncertainty/2-1-1775087

World's first 1600°F nuclear-powered hydrogen plant plan **revitalized** in **Japan**

https://interestingengineering.com/energy/japans-nuclear-powered-hydrogen-plant

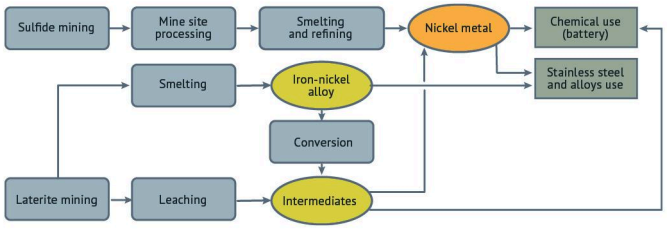
ASEAN Going for **Nuclear Power**:
https://www.csis.org/analysis/asean-going-nuclear-power

After a decade of relentless research, a team of Chinese scientists has achieved a remarkable feat: producing steel without coal and at a speed 3,600 times faster than traditional methods. This innovation, first reported by the South China Morning Post, could reshape the global steel industry while dramatically reducing its environmental footprint..

How Steel Has Traditionally Been Made ? For centuries, steel production has relied on a slow and energy-intensive process. It starts with iron ore, which is crushed, processed into pellets, and then heated to over 1,300°C before being placed in a blast furnace filled with coke, a refined form of coal. The heat and carbon extract iron from the ore, producing molten iron, which then undergoes further processing to become steel. This conventional process takes five to six hours and emits significant carbon dioxide (CO_2) due to the use of coke. Now, Chinese scientists claim to have cut that time down to mere seconds while eliminating coal from the equation altogether.

Producing Steel in Just Six Seconds According to Professor Zhang Wenhai, the lead researcher behind this breakthrough, the new technique can manufacture steel in just three to six seconds, a dramatic reduction from the standard method. The secret lies in injecting ultra-fine iron ore powder into an extremely hot furnace using a vortex lance. This process triggers a rapid chemical reaction, forming droplets of molten iron that fall to the furnace's base. The result? A steady stream of high-purity iron, ready to be transformed into steel.Well, Also, geopolitically. CHINA is the biggest supplier of all metals to Western world… Now, there are 75% tariffs...so everyone needs to find new suppliers. Here's the Philippine's opportunity to get most important trades of Ni Cu and metals directly; and for us to establish new markets in this global reset..i think the big picture is bright, But, only if we move now to fulfill these metals industries and supplies by building smelters and refineries of high volume! We say in America - "you snooze - you lose!" Of course, it has to be green also- which basically cuts off the arms and legs of our competition- because they are the biggest polluters on the planet, making 8% of global CO2. Making green metals with Redstar's eight proprietary clean energy power systems is why we will win! And, because we make our own energy onsite for 4c/kWh to 8c/ kWh- and its clean! This is the key to success in focusing now on flash smelting. . This approach works with both low-grade and high-grade iron ore, making it especially beneficial for China. The country has vast reserves of low-grade iron ore, but it has historically relied on imports from Australia, Brazil, and Africa for higher-quality raw materials. This innovation could significantly reduce China's dependence on foreign

suppliers. What This Means for Industry and the Environment:
The most significant advantage of this new method is that it eliminates coal from the steelmaking process, potentially reducing energy consumption by one-third. This aligns with China's aggressive targets for cutting CO_2 emissions, as the country seeks to achieve carbon neutrality in the coming decades. China is already the world's largest steel producer, a position that gives it significant leverage in industries like automobile manufacturing, construction, and infrastructure. If this new method is widely adopted, China could strengthen its global competitiveness while also lowering the carbon footprint of its steel exports.Im working on a new patent combining our nuclear with flash smelting system pioneered by chinese. This breakthrough isn't just about speed—it could set the stage for a more sustainable and cost-effective steel industry worldwide. If other nations follow suit, this new approach could fundamentally reshape global steel production while contributing to a cleaner planet. Incredibly, there are no smelters or refiners in Mindanao- which doesn't make sense- $$- Mindanao has the most copper and nickel and iron than any country in the world! We'll clean- up with this..plus, our Red Sun batteries directly heat the calcine and reactor processes without CO2 or GHGs, with the product - 40% nickel alloy to manufacture Red Sun thermal batteries at 20% of the cost!



Nickel flash smelting

The two commercial classes of nickel ore (sulfide ores and silicate oxides) are produced in the highest quantities in Canada and Russia which equates to approximately 20-25% of the world's production. Using nickel flash smelting technology it is possible to process sulfide nickel concentrate and produce nickel matte and slag in a relatively efficient process. Any materials resulting as smelting and converting slags are recirculated in the electric furnace and recovered where possible as nickel matte. Nickel (Ni) is a silvery-white, hard metal. Although it forms compounds in several oxidation states, the divalent ion seems to be the most important for both organic and inorganic substances, but the trivalent form may be generated by redox reactions in the cell. Nickel compounds that are practically insoluble in water include carbonate, sulfides (the main forms being amorphous or crystalline monosulfide, NiS, and subsulfide Ni3S2) and oxides (NiO, Ni2O3). Water-insoluble nickel compounds may dissolve in biological fluids. Particles of the same chemical entity (oxides and sulfides) have different biological activity depending on crystalline structure and surface properties.

There are two commercial classes of nickel ore, the sulfide ores (pentlandite and pyrrhotite) and silicate-oxide. Most nickel is produced from the sulfide ores, and the two largest producers, Canada and the Russian Federation, account for 20–25% each of total annual production, which was 784.82 thousand tonnes in 1988.

In Nickel Flash Smelting technology, sulfide nickel concentrate is processed in the Outotec® Flash Smelting Furnace to produce nickel matte and slag. The matte is transported to the Peirce-Smith converters where it is blown to high-grade matte. The metal values in the smelting and converting

slags are recovered in the electric furnace as nickel matte. The matte is then circulated to the Peirce-Smith converters.

The dried feed mixture, oxygen-enriched process air and distribution air are mixed in the concentrate burner to assure an even distribution of the feed in the reaction shaft suspension. As the dried charge flows downwards in the reaction shaft, the concentrate particles dissociate, ignite and undergo controlled partial oxidation generating a large amount of (exothermic) heat, which results in the melting of the material into fine droplets. In the settler, the immiscible slag and matte phases separate and form two layers according to their specific densities.

The process gas flows upward through the uptake shaft and then to a heat recovery boiler for cooling. Part of the flue dust is separated from the gas stream in the boiler. The gas flows onward to an electrostatic precipitator where the remaining fine dust is recovered. The dust collected under the boiler and precipitator is returned back to the furnace.

The produced slag is tapped from the Flash Furnace and directed along with the converter slag into an electric slag cleaning furnace before being granulated and discarded. Reduction is carried out batch-wise using coke as a reducing agent. During the settling period, reduced metal droplets and mechanically trapped matte droplets are settled through the slag layer to the bottom of the electric furnace to form the matte layer. Immiscible slag components with a much lower density stay at the top of the bath and form the cleaned slag layer.

The mattes obtained from the flash smelting furnace and from the electric *Outotec® Slag Cleaning Furnace* are converted in Peirce-Smith converters with oxygen-enriched air, which is blown through tuyeres into the converter. For slag forming purposes, some silica flux is added. The produced high-grade matte is granulated and further treated in the refinery. The waste slag is also granulated and transferred to the slag disposal area.

A typical flash smelting furnace is shown schematically in Figure 1. The refractory-lined furnace vessel is composed of three sections: reaction shaft, settler and uptake shaft. In the flash smelting process, a sulfidic feed mixture is distributed through the top of the reaction shaft by a concentrate burner, where the correct design is vital to furnace operation. The concentrate burner consists of several concentric ducts through which the process gas and the concentrate are blown and mixed in the furnace. The main task of the burner is to produce an optimal suspension of solid particles and oxygen-enriched process air in the reaction shaft.

Individual particles heat up as they fly about in the furnace and after ignition they start to combust with oxygen in the process gas. The combustion reactions with fine (<100µm) sulfides are very rapid and a substantial amount of heat is released, which leads to the complete melting of the combusting particles, as well as that of the other materials introduced in the feed mixture. The molten particles flow downstream and they are collected in the settler, where silicate slag and sulfidic matte layers are separated. The off-gas (mainly an SO2-N2 mixture) flows through the uptake to the waste heat boiler, where it is cooled down and its heat content is recovered as steam.

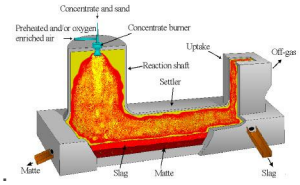


Figure 1: Flash smelting furnace with its main sections and material flows.

https://www.manilatimes.net/2025/02/04/news/southeast-asia-looks-to-nuclear-power-to-supercharge-its-energy-transition/2048608

Global shake-up of metal supplies as China adds 75% tariffs to metal goods going to US: https://www.mining.com/web/us-metal-buyers-likely-to-turn-to-mideast-chile-as-tariffs-bite/

Terrestrial Energy: https://youtu.be/ncKGUj6FN1E?feature=shared

PHL Must unleash the Advanced Economy:

https://www.bworldonline.com/economy/2025/02/03/650809/phl-must-unleash-private-sector-to-become-advanced-economy-wb/

Australia 1st Hydrogen project under threat because local steel mill refinery off- taker is baulking at paying exorbitant H2 price that triples price of steel replacing coke:

https://www.hydrogeninsight.com/policy/australias-first-green-hydrogen-production-and-power-project-at-risk-due-to-offtake-uncertainty/2-1-1775087

Nickel industry - Part 1 - Processing nickel laterites and sulfides

MAY 03 - 2024

Let's dive into this new series of articles on sustainability, treatment processes and innovations in nickel production, starting with nickel ores.

Nickel is primarily used in two areas today: stainless steel and other alloys, and chemical uses including batteries. Stainless steel is the largest part of the nickel market, while batteries are the fastest growing. To meet the global nickel demand, nickel is produced from two main sources: fresh ores and recycled materials. Recycling (whether stainless steel and nickel alloys or batteries) is an important part of the nickel value chain. The very high recylability of nickel is a critical part of its sustainability profile, but most of the nickel market is focused on the fresh material put into the supply chain, now about 3 million tonnes/year.

Two broad ore types:

Nickel occurs in two broad ore types:

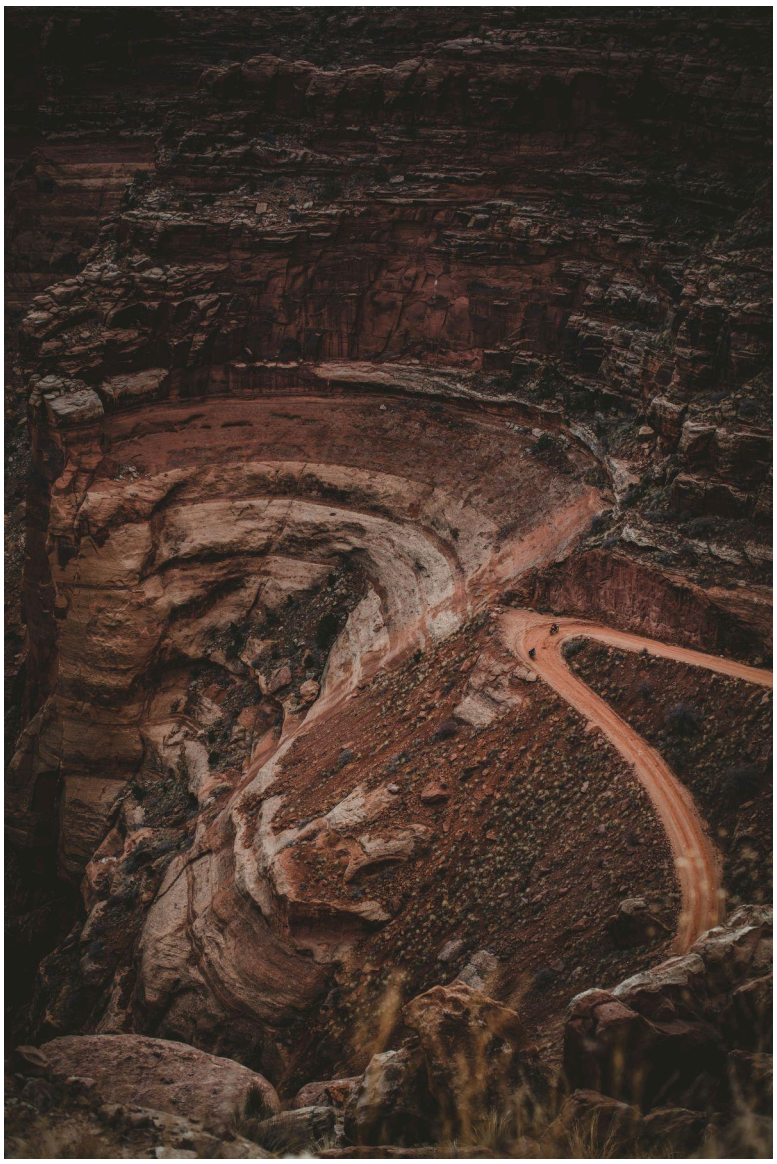
1. laterite (oxide) ores, principally located in tropical and sub-tropical areas, and
2. sulfide ores, principally located in the temperate to sub-Arctic regions.

Major nickel mining locations are depicted in the map – but some of these locations have many operations, and some only one. More than 50 % of nickel produced today is mined in Indonesia. Ore is often processed near the mine site, but there is substantial regional and global trade in nickel laterite ores, and some trade in nickel sulfide concentrates.

Laterite ores

Laterite ores occur as surface deposits and are traditionally separated into two main types: limonites (lower nickel, high iron) and saprolites (higher nickel, low iron). Limonites typically have cobalt as an additional value component, while saprolite is treated for its nickel value only.

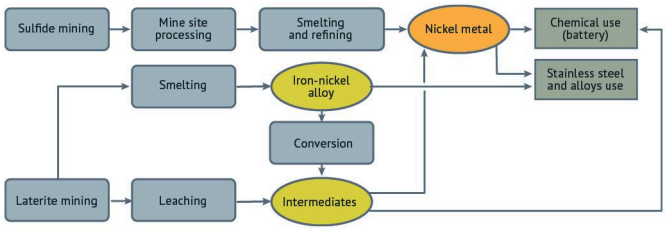
Today, limonite ores are mostly treated by leaching, where the ore is reacted with sulfuric acid and the dissolved nickel and cobalt are recovered as nickel-cobalt intermediate products. These intermediates can be refined to nickel metal or directly into the battery supply chain. This processing based on dissolution in water is called hydrometallurgy.Saprolite ores are treated by smelting, where the ore is dried and melted using energy from coal and electricity – often coal-based – to recover the nickel as an iron-nickel alloy. The iron-nickel alloy is generally used directly to make stainless steel. With growing battery demand, we have seen a resurgence of a past practice to convert the alloy into a higher-grade material (nickel matte) for refining. The processing based on melting materials at high temperatures is called pyrometallurgy.



Sulfide ores

Sulfide ores can be at (or near) the surface or deep underground, and often have additional value streams beyond cobalt such as copper, platinum, and palladium. Together, these can be worth more than the nickel.

These ores are treated differently to laterites. They can almost always be upgraded at the mine site to a shippable nickel concentrate. The concentrate can then be treated at centralised facilities. Most of these are nickel smelters, where the concentrate is melted using the energy from the contained sulfur and electricity to create nickel matte which is subjected to further refining, but there are also direct hydrometallurgical approaches in use.



General industry flowchart for fresh nickel materials

This is the first in a new series of articles on the nickel industry, written from an inside perspective to offer a deeper view of what we do, how we do it, and some of the challenges in the production of this important and versatile element.

Future articles will unpack technologies a little bit further, identifying some of the historical and ongoing improvements, some of the sustainability challenges faced by the industry, and some of the potential alternative routes which might come to fruition alongside the current commercial approaches.

AUGUST 07 - 2024

Nickel industry - Part 2 - Processing nickel laterites and smelting

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Nickel industry - Part 2 - Processing nickel laterites and smelting

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In Part 2 of this series we dig deeper into the specifics of laterites, one of the two main nickel ore types and look at smelting, the most common processing technique.

Laterite orebodies: Laterite orebodies are formed from weathering of bedrock by the passage of water, creating layers over the original rock. Other variations of these orebodies can contain aluminium (bauxite) or gold, with their composition determined by the parent bedrock and degree of weathering. Nickel laterites come from high-magnesium bedrocks with low nickel content in silicate rocks. During weathering,

elements are dissolved and mobilised, then re-crystallised. These processes can create laterite deposits in under a million years, though some exposed deposits in temperate and boreal zones are not fully altered after over a billion years. The two main processing methods for laterite ores are smelting and High-Pressure Acid Leaching (HPAL).

Smelting is used primarily on saprolite ores to obtain an iron-nickel alloy (ferronickel – FeNi, Nickel Pig Iron – NPI) while HPAL is used primarily to process limonite or for higher-purity end products.

Laterites make up over 70 % of both nickel production and known terrestrial resources today and have been the fastest growing source of nickel for some time.

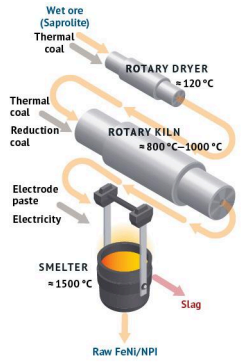
Laterite Smelting: The industry is now dominated by the Rotary Kiln Electric Furnace approach (RKEF). Blast furnaces are now used less frequently. The RKEF route consists of three main steps: dry, reduce, and smelt. Saprolite ore is the normal feed, but limonite ores can also be smelted. Most facilities follow the process outlined below, but there are exceptions.

RKEF route: The prepared ore (crushed and blended as necessary) is dried in a rotary dryer, which is generally run with coal or gas firing; but is easily replaced with Red Sun thermal battery heat blown in through heat exchanger to provide the necessary heat to remove some of the free moisture in the ore by heating it over 100 °C. The goal is to produce a material that is neither sticky nor dusty for the next processing steps.

After drying, the ore is passed to a rotary kiln for further drying and the start of the chemical processing. In the rotary kiln, more heat is added through combustion of fossil fuels to raise the temperature to around 900 °C. A high-carbon product like anthracite coal is also added as a chemical reductant – to remove the oxygen from the iron oxide and nickel oxide minerals so they can be produced as metals.

Limestone may also be added to adjust the chemistry for smelting. Both sets of hot tumbling equipment generate dust, which must be captured from the vent gases and the solids recycled, which adds complexity in both dust capture and blending dust with fresh feed.

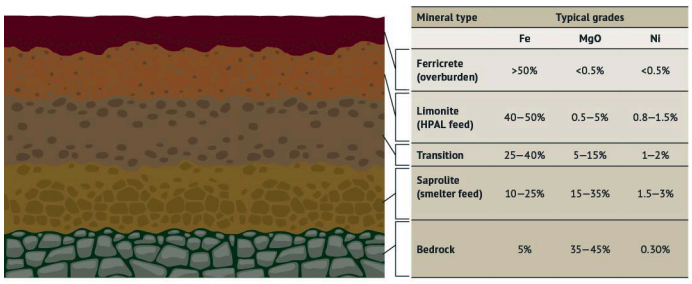
Simplified RKEF process



Rotary dryers are typically 3–5 m in diameter by 30–50 m long, while rotary kilns can be well over 100 m long.

The hot, partially-reduced ore is then passed to the electric furnace, where the chemical reduction is completed. The ore is melted at a temperature of around 1500 °C by the addition of electricity and the continued reaction of the carbon added in the kiln, as well as reaction of the carbon electrodes which are slowly consumed. The end result is a liquid ‘metallised’ iron-nickel product that sinks to thebottom of the furnace, from where it is removed, while the lighter slag materials fl oat on top. Themolten iron-nickel alloy is refined to remove materials detrimental to the later steel-making processes, and then either converted to solid forms for transport or, in some recent integrated operations, transported hot into the steel-making. The large rotary equipment has to run continuously, at high temperature, on well-maintained roller systems. Electric furnaces require a very large continuous power supply, with some facilities requiring up to 40 MWh/t Ni produced. Most furnaces require sophisticated cooling systems to ensure long life of the furnace lining.

Smelting is very energy-intensive, using fossil fuels for thermal energy and chemical reduction, as well as electrical power generation. Air pollution from coal combustion is similar to power plants, as long as metal-bearing dusts are well-controlled. The slag produced is reasonably stable and often usable as a construction material.



Mineral type	Typical grades		
	Fe	MgO	Ni
Ferricrete (overburden)	>50%	<0.5%	<0.5%
Limonite (HPAL feed)	40–50%	0.5–5%	0.8–1.5%
Transition	25–40%	5–15%	1–2%
Saprolite (smelter feed)	10–25%	15–35%	1.5–3%
Bedrock	5%	35–45%	0.30%

Typical composition of nickel laterite deposit

Full life-cycle approach

For highly-recycled metals such as nickel, the environmental impact associated with initial production can be amortised over time, depending on how oft en the nickel is recovered at the end of one product cycle (e.g. nickel batteries or nickel-containing stainless steel) and re-used in another.

The full ‘life-cycle’ of nickel is usually much longer than that of the products in which it has been incorporated.