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WMF CRITICALITY ASSESSMENT

by BRGM, CRU & McKINSEY

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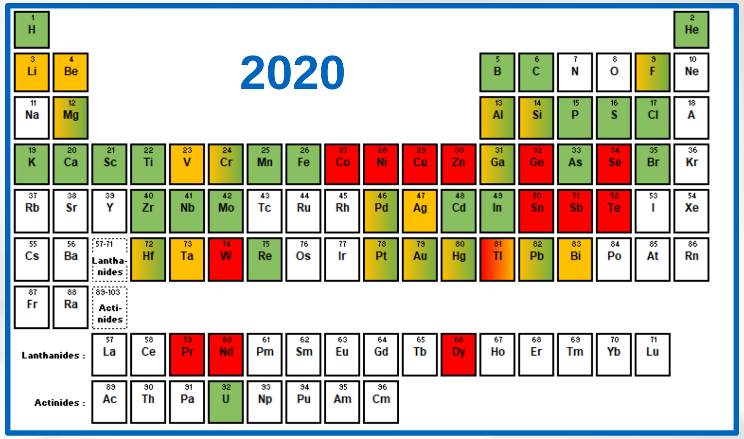
WMF Criticality assessment methodology

- **Objective: derive robust and traceable KPI for identifying critical raw materials for industry**
- **Current methodology is based on 6 quantitative and qualitative KPIs**
- **In 2021, we are introducing a 7th KPI focused on environmental footprint**

Already present in the previous assessment

1	**Lifespan of known reserves**	*based on reserves and production by USGS*
2	**Uncertainty of supply**	*anticipated 2030 deficit based on demand/supply*
3	**Political exposure of supply**	*Weighted Policy Perception Index of main production countries*
4	**Supply chain recycling**	*Qualitative assessment of current recycling technologies*
5	**Uncertainty of demand**	*Qualitative assessment of the predictability of main demand drivers*
6	**Vulnerability to the absence of substitution**	*Qualitative assessment of the availability of alternative materials*
7	**Environmental Performance**	→ *New KPI integrated in 2021*

Each KPI has a score from 1 to 3 → **Composite index**



In 2021, we are introducing a 7th criterion focused on environmental evaluation

- As our previous approach, **this new KPI is a combination of quantitative and qualitative indicators**, mostly extracted from OekoRess II Research Project (see appendix)

Definition of the WMF Environmental Performance KPI				
				Score
1	**Pre-conditions for Acid Mine Drainage (AMD)**	Qualitative Assessment	▪ Geochemical preconditions for AMD do not exist ▪ Geochemical preconditions for AMD exist in part ▪ Geochemical preconditions for AMD exist	1 2 3
2	**Mining method**	Qualitative Assessment	▪ Mostly extracted in underground mines and/or low energy intensity ▪ Mostly extracted from open pit mines and/or medium energy intensity ▪ Mostly extracted from alluvial or unconsolidated sediments/high energy	1 2 3
3	**Use of auxiliary substances**	Qualitative Assessment	▪ Extraction & processing methods with low use of auxiliary chemicals ▪ Extraction & processing methods using auxiliary chemicals ▪ Extraction & processing methods using toxic reagents	1 2 3
4	**Environmental Governance***	Quantitative Assessment	▪ < 25% quantile of EPI for 180 countries ▪ > 25% and 75% quantile of EPI for 180 countries ▪ >75% quantile of EPI for 180 countries	1 2 3
5	**Size of Energy Flow***	Quantitative Assessment	▪ < 25% quantile of 52 raw materials with available data ▪ > 25% and 75% quantile of 52 raw materials with available data ▪ >75% quantile of 52 raw materials with available data	1 2 3
6	**Water Stress Index***	Quantitative Assessment	▪ < 25% quantile of 42 raw materials with available data ▪ > 25% and 75% % quantile of 42 raw materials with available data ▪ >75% quantile of 42 raw materials with available data	1 2 3

** Detailed description and references added in the appendix*

In 2021, we are introducing a 7th criterion focused on environmental evaluation

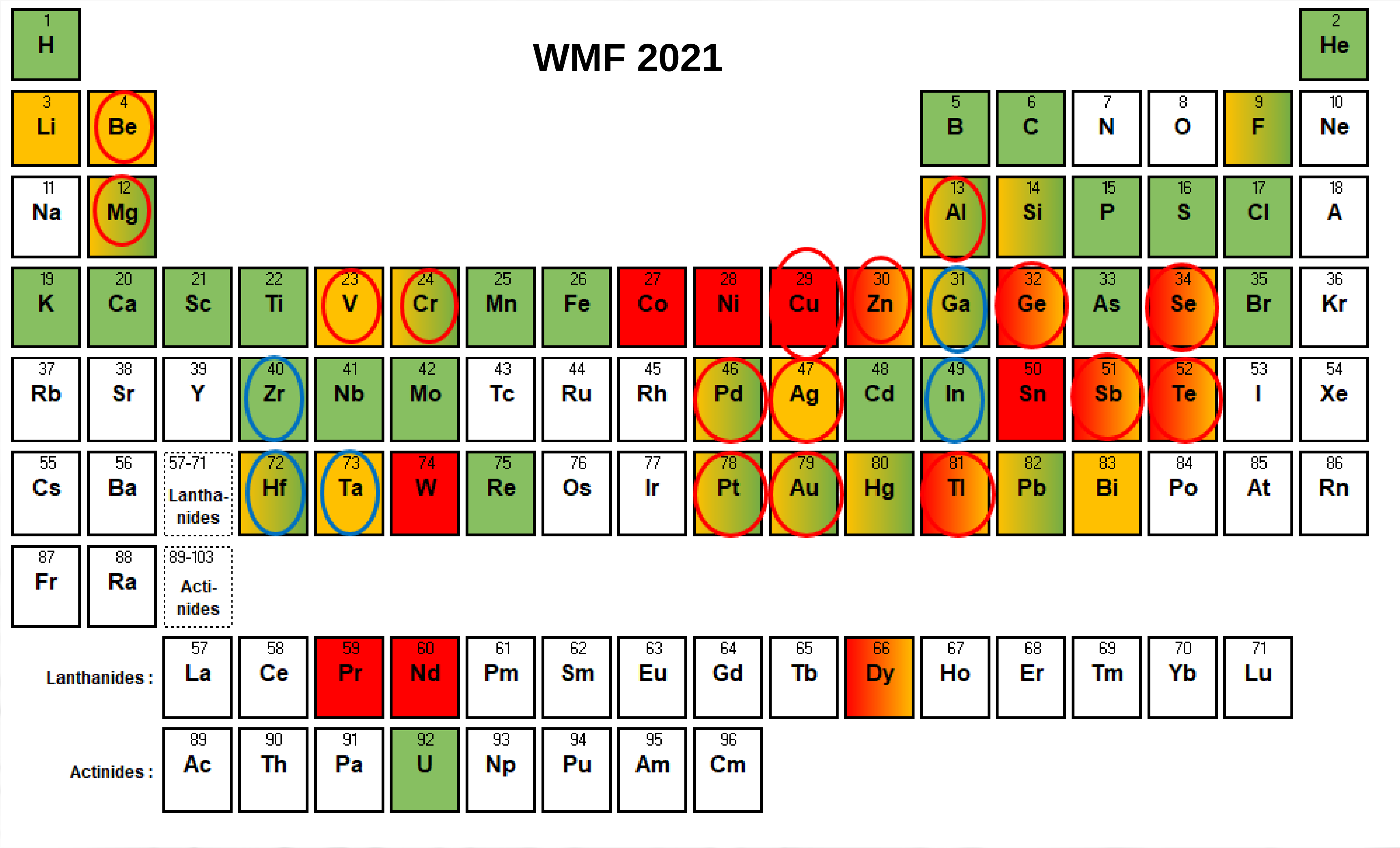
- The same weight is given to each indicator. The final environmental score is obtained by averaging scores
- Selected examples :

	Pre-conditions for AMD	Mine type	Toxic substances	Environmental governance	Water Stress Index	Size of energy flow	**TOTAL SCORE**
Cobalt (Co)	3	2	3	3	1	2	***2***
Nickel (Ni)	3	2	2	1	1	3	***2***
Copper (Cu)	3	2	3	2	3	3	***3***

- The main effect is that total scores boundaries for the aggregated indicators are lifted from previous assessments :

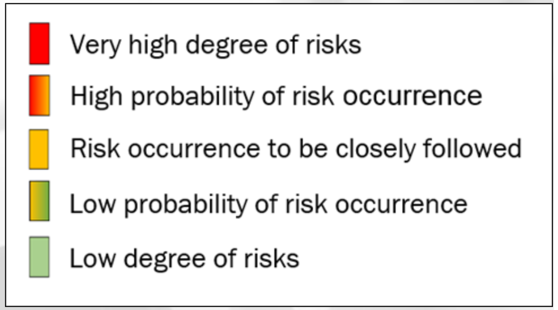
Original color coding (6 KPIs)	≤8	9	10	11	>11
New color coding (7 KPIs)	≤10	11	12	13	>13

2021 Criticality Assessment



Elements for which the environmental KPI has a strong influence :

- Mg, Al, V, Cr, Cu, Zn, Ge, Se, Pd, Ag, Sb, Te, Pt, Au,Tl



Less critical in 2021 with new criteria: 5 elements

More critical in 2021 with new criteria: 16 elements

Note: Elements in white have not been assessed

Key observations from the 2021 WMF criticality assessment

- **Our analysis prioritizes the focus on long term effects. The pandemic has accelerated structural trends for red elements:**

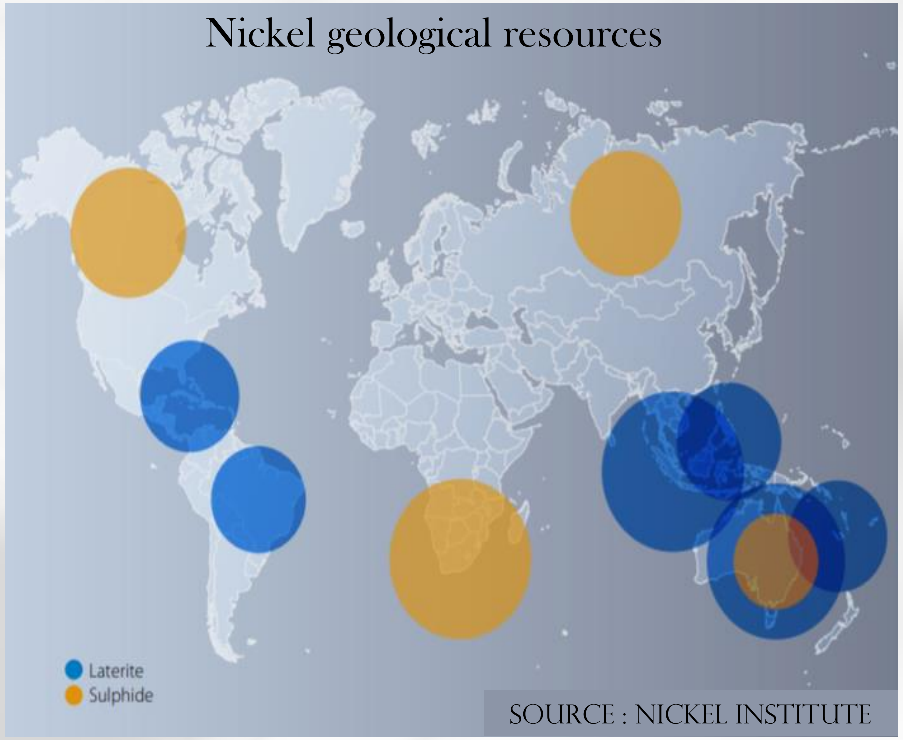
  - ***Copper:*** 1 Mt to 3 Mt additional Cu/year could be needed up to 2030 only for electrification (+ grid expansion & infrastructure). Key long-term issues on water and energy consumption at the mine sites.
  - ***"Battery materials" = Co & Ni*** : supply remains at risk in the coming decade. A necessary regionalization of supply chains and/or responsible sourcing. Substitution and recycling efforts to be increased (*but will never totally cover the demand*).
  - ***REEs :*** Chinese strategy to preserve at the short-term its own resource and increase the importation ➔ increases pressure on primary supply despite efforts on substitution and recycling.
  - ***Tin and tungsten*** : same trends as previous years, no fundamental changes: deficit of exploration weighs on price volatility (Sn) and strong dependency on China supply (W).

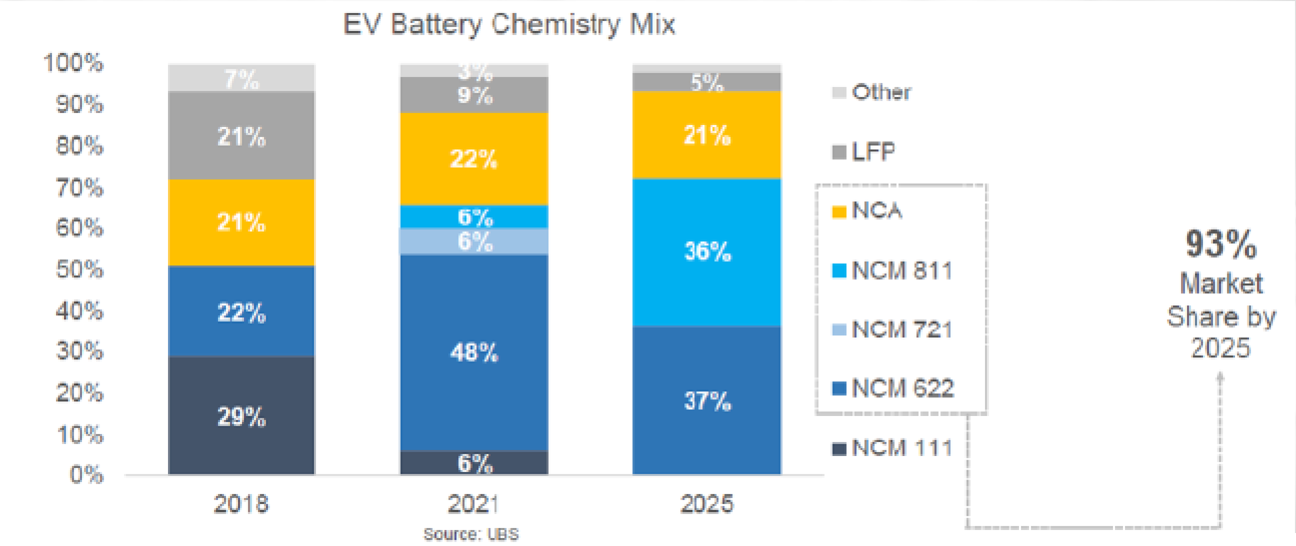
- **Adding upstream indicators to measure environmental performance highlights 6 new Red-orange elements**

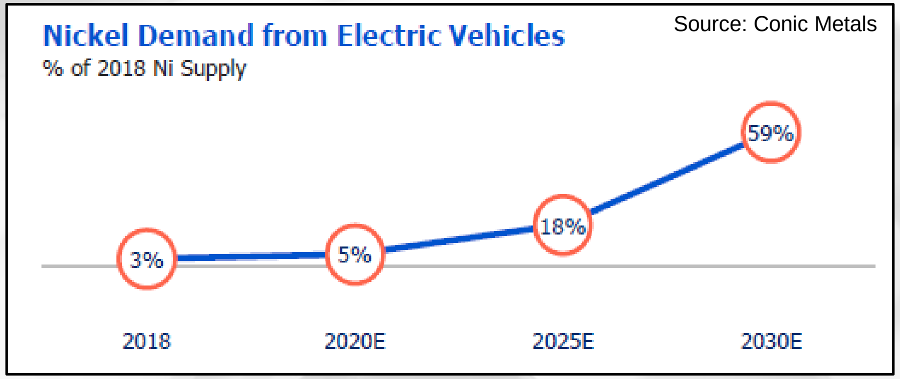
  - Zinc, germanium, selenium, antimony, tellurium, thallium

Nickel market context

- **Global Ni identified resources ~300 Mt Ni of 2 main types : laterite (60%) and sulphide ores (40%)**
- **Tensions emerging from Ni demand in batteries growing at annual rate of 10%**
- **Nickel-rich batteries will dominate EV technologies by 2025** (NCM: Nickel Manganese Cobalt)
- **Indonesia and Philippines have become World's top mining producers since mid-2010's**
- **Available high quality feedstock for Ni sulphate is the bottleneck**

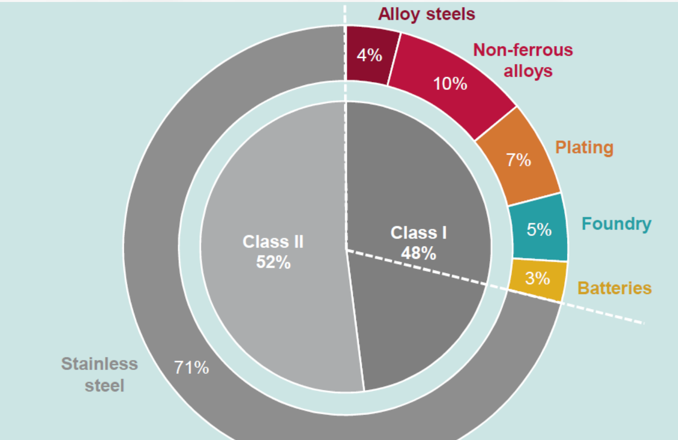




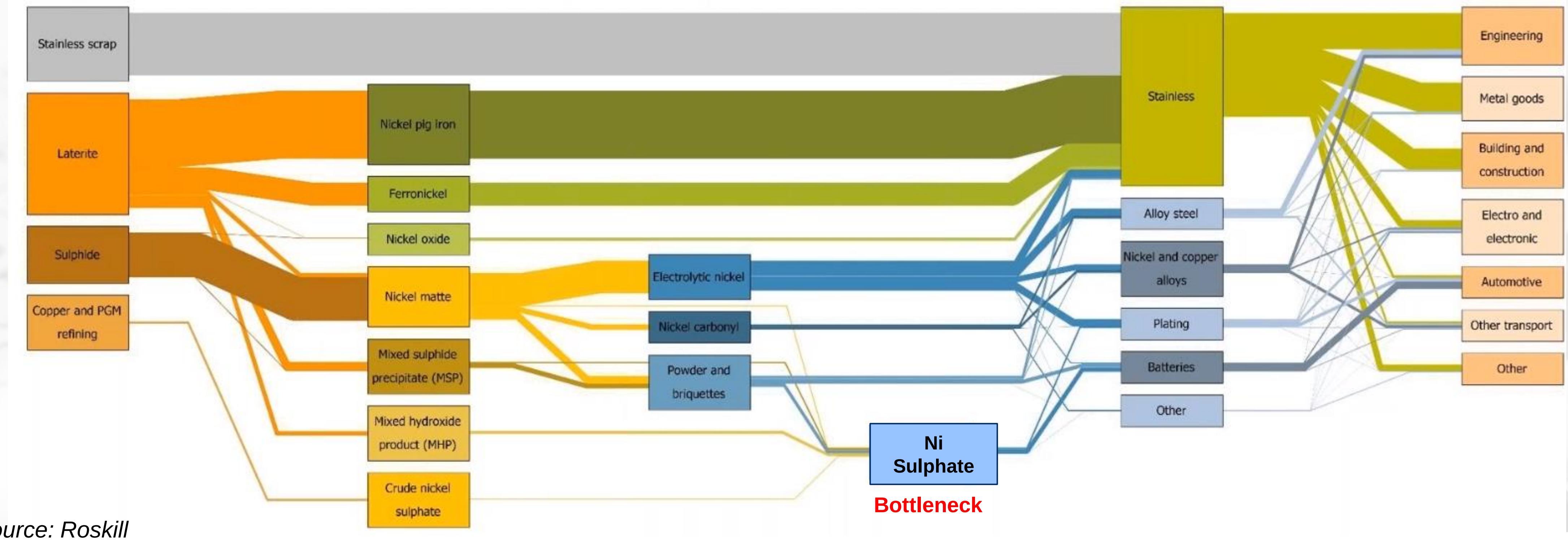


Demand for nickel in batteries calls for market changes

- **Current Ni production is destined to:**
  - 70% stainless steel applications (> 1,500 kt Ni)
  - 3% for batteries (~200 kt Ni)
- **Only a few industrial sources currently suitable for Ni sulphates production**
  - Ni sulphate is the best material for battery precursors
  - Class 1 nickel (premium products) is a preferred but costly option



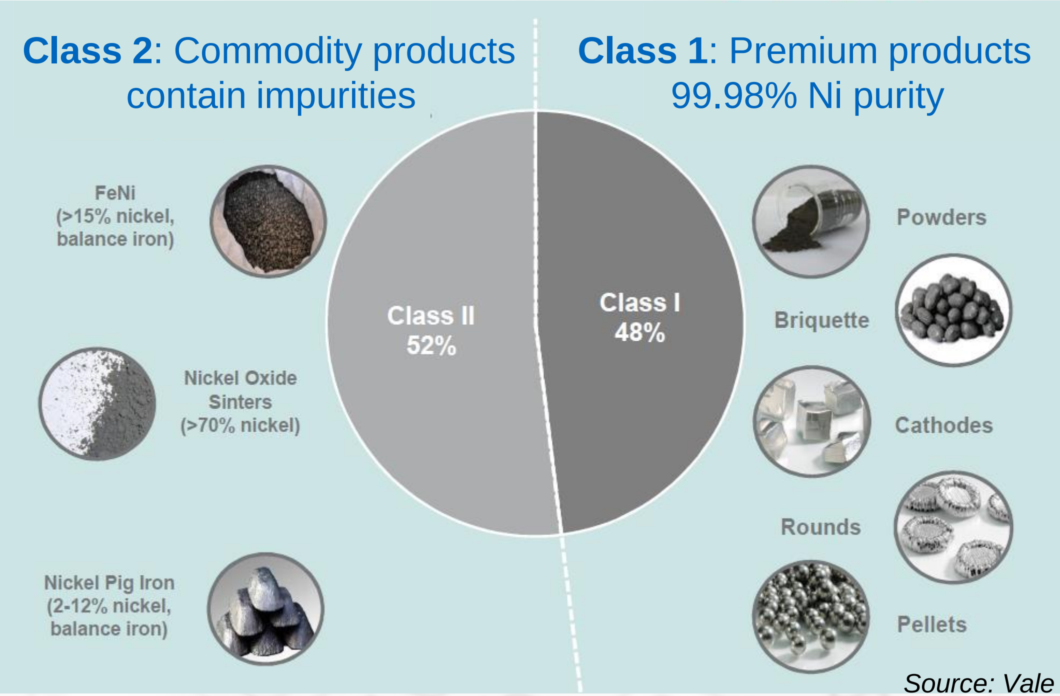
Source: Vale



Source: Roskill

A complex supply chain

- Use of NPI (Nickel Pig Iron) for stainless steel in the 2000s under the China incentives (Tsingshan) led to the reduction of attractiveness of class 1 feedstock in recent years ➔ decreased availability on Class1 supply



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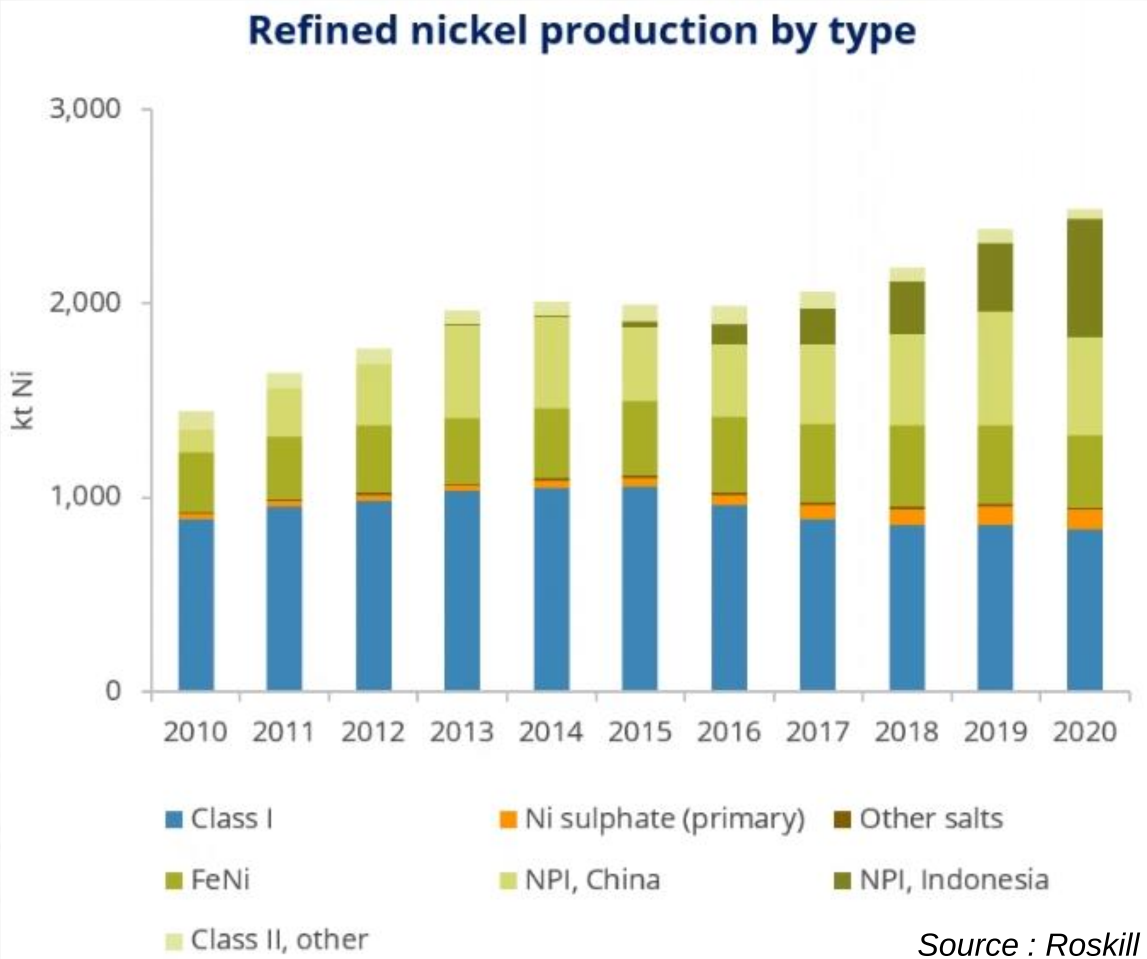
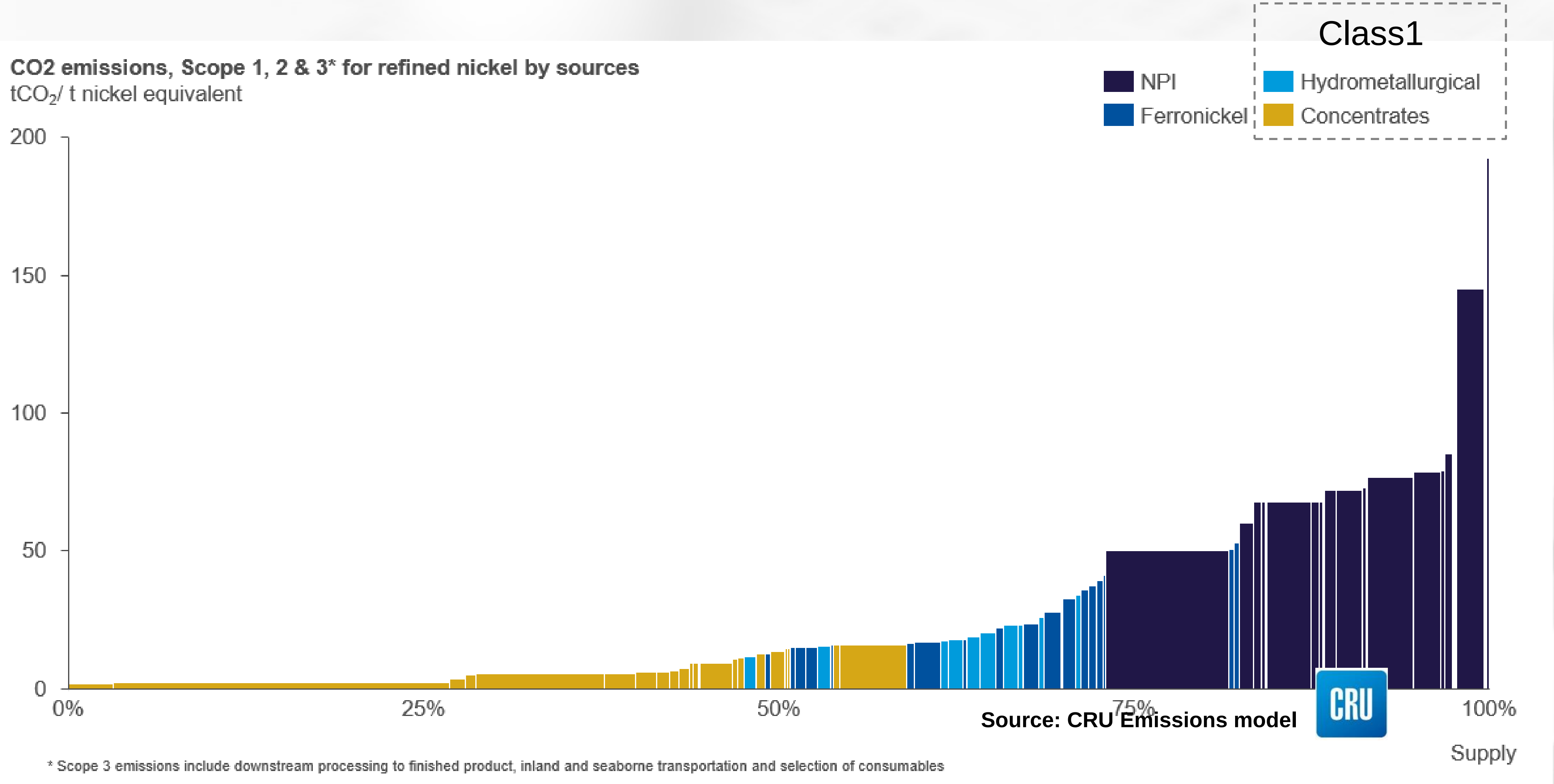


Source : Roskill

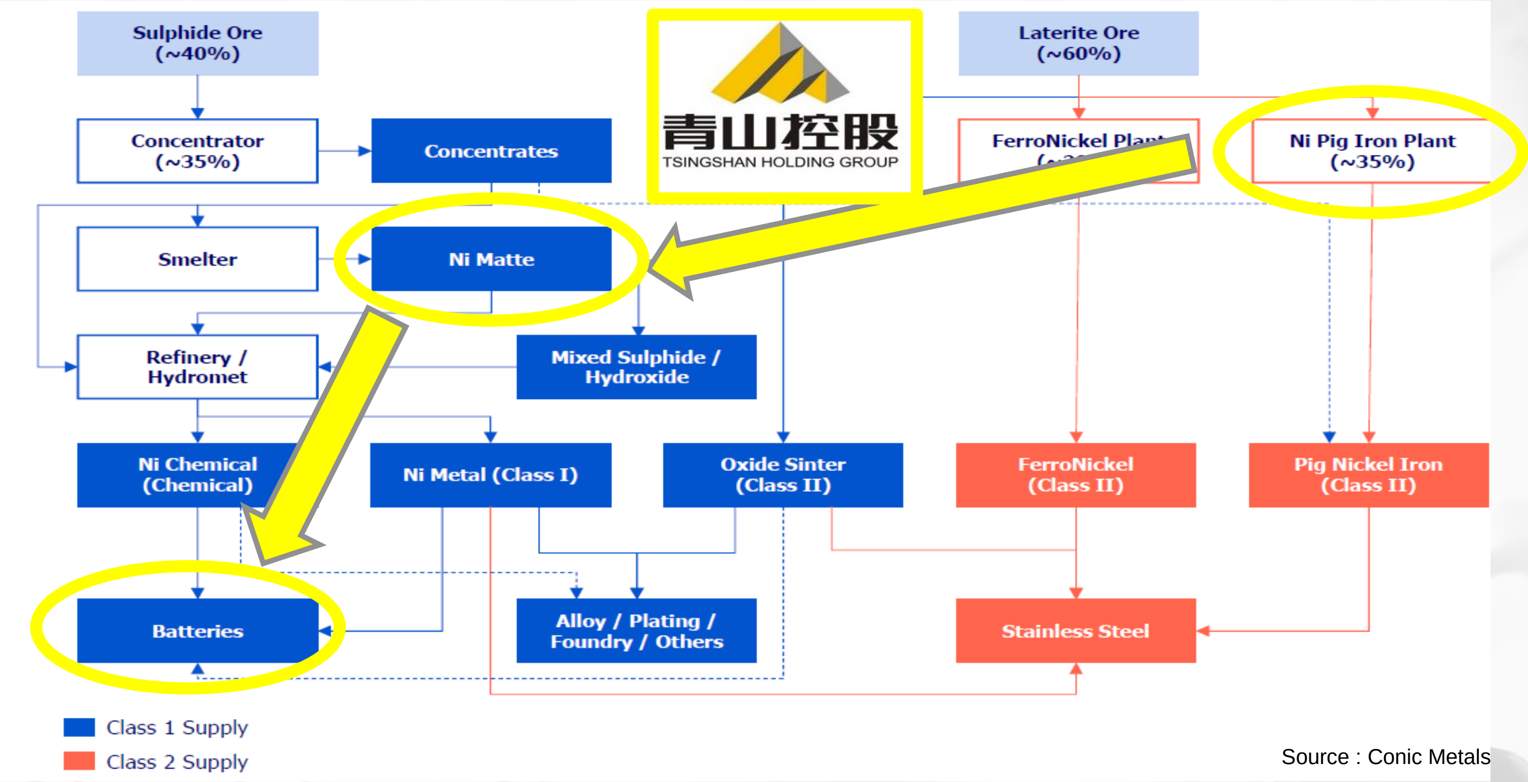
A complex supply chain

- Low-grade NPI (Nickel Pig Iron) traditionally not suitable for high-grade Ni sulphate production
- NPI has the worst environmental footprint (due in particular to transportation from Indonesia)



Disruption to come from Tsingshan Holding Group in Indonesia?

- On March 3, 2021, China's Tsingshan Holding Group announced it will use **technology transforming NPI to nickel matte** suitable for battery precursors and signed a one-year contract to supply nickel matte to Huayou Cobalt Co and CNGR Advanced Material Co ➔ decreased market Ni price
- The conversion of NPI into mattes is expected to induce further SO_2 and CO_2 emissions, which brings carbon footprint in the order of **80 to 100 t CO_2 eq. / t Ni** for this metallurgical route, much higher than Class1 supply.



Source : Conic Metals

A supply chain paradox?

- Processing **Indonesian NPI into matte** may answer to short term pressure on Ni sulphates but at a **high environmental cost**. Trade-off appearing on the Ni market between environmental and financial costs:
  - *Nickel sulphide development projects are environmentally-attractive (Canada & Western Australia) with straightforward metallurgy and low carbon intensity per tonne nickel produced but at higher cost.*
- The **"Tsingshan deal"** could reflect that China is willing to put off Western investment in new nickel production by trading the HPAL responsible for environmentally problematic deep sea tailings with NPI conversion into matte responsible for GHG emissions in order to significantly drop the Ni prices
- Will it be acceptable to Western end-users? What will be the strongest driver (price or environmental footprint)?
- The paradox is illustrated by Tesla : asking the market for ESG-friendly nickel up to investing in specific mining operations (e.g. technical and industrial partner at Goro - New Caledonia) but at the same time in discussions to construct facilities in Indonesia in order to access this cheap source of nickel.

"Please mine more nickel. Tesla will give you a giant contract for a long period of time if you mine nickel efficiently and in an environmentally sensitive way."
- Elon Musk, July 2020

NEWS & UPDATES

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April 14, 2021 | 4 Min Read | Marek Grzegorczyk

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Appendix: The OekoRess II project

- The OekoRess II Project main objective was to assess the environmental hazard potential of mining and processing for more than 50 raw materials. This project consolidated the evaluation method developed OekoRess I Project by applying it to selected raw materials. It was financed by the German Federal Ministry for Environment and ended in June 2020. More information on : www.umweltbundesamt.de/en/publikationen/environmental-criticality-of-raw-materials

- The evaluation system consists of 8 indicators on geological, technical and site-related environmental hazard potentials of mining, 2 supplementary indicators on the magnitude of global energy and material flows and 1 indicator on environmental governance in the producing countries.

- The description of the main 3 quantitative criteria selected for WMF assessment can be summarized as follows :

  - ***Environmental Governance:*** *The assessment was calculated for all raw materials based on the Environmental Performance Index (EPI) of the mining countries and their share of the global mine production. EPI is an index developed by Yale university for 180 countries (More information on: https://epi.yale.edu/epi-results/2020/component/epi)*

  - ***Size of Energy Flow:*** *For this inventory data for the indicators Cumulative Energy Demand (CED) are used (from there reference work of Nuss and Eckelman 2014; Giegrich et al. 2012). The specific values per ton of refined material are multiplied by the world production data from USGS and BGS and depict the size of energy flows (SEF) on a global level for 52 raw materials (However, data are relative to 2008-2014 reference period).*

  - ***Water Stress Index:*** *based on a GIS database with references for 42 raw materials*