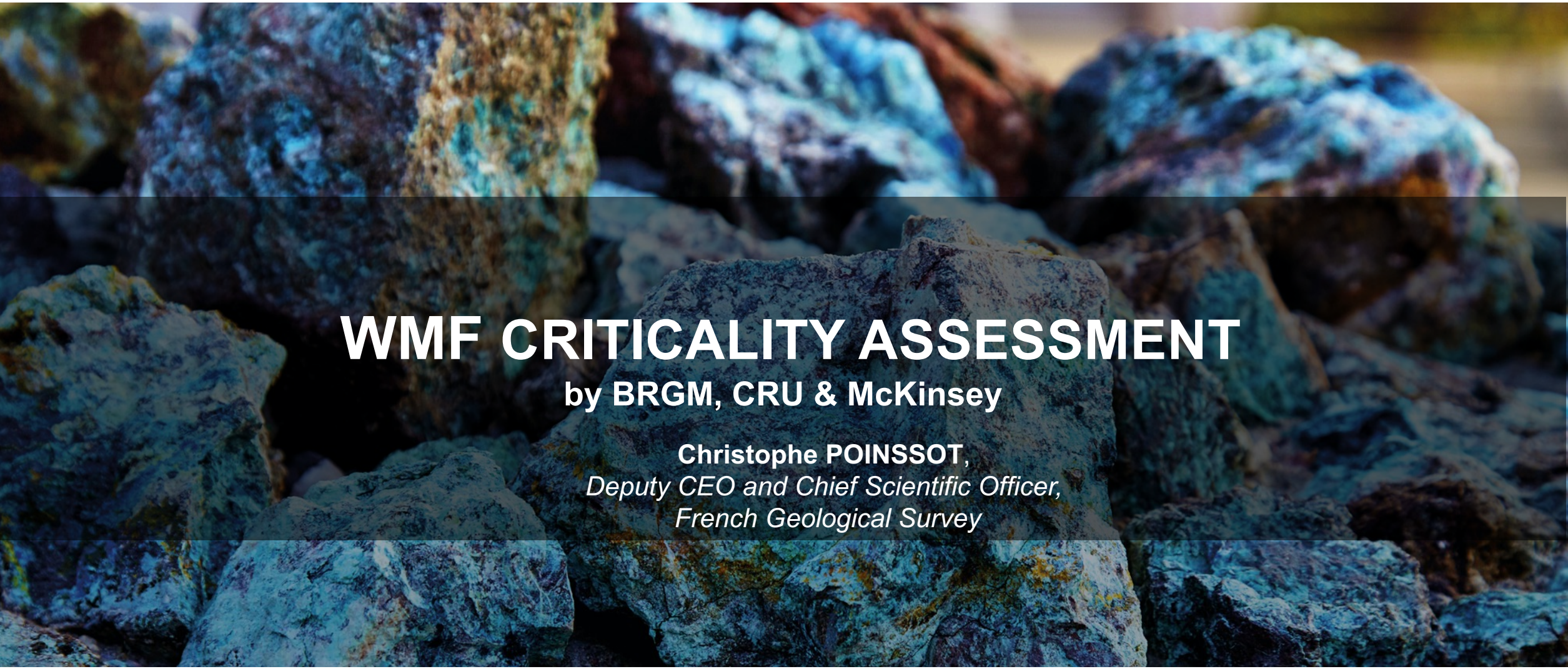


WMF CRITICALITY ASSESSMENT

by BRGM, CRU & McKinsey

Christophe POINSSOT,
Deputy CEO and Chief Scientific Officer,
French Geological Survey

6th July 2023

WORLD MATERIALS FORUM

Géosciences pour une Terre durable
brgm

WMF Criticality assessment methodology

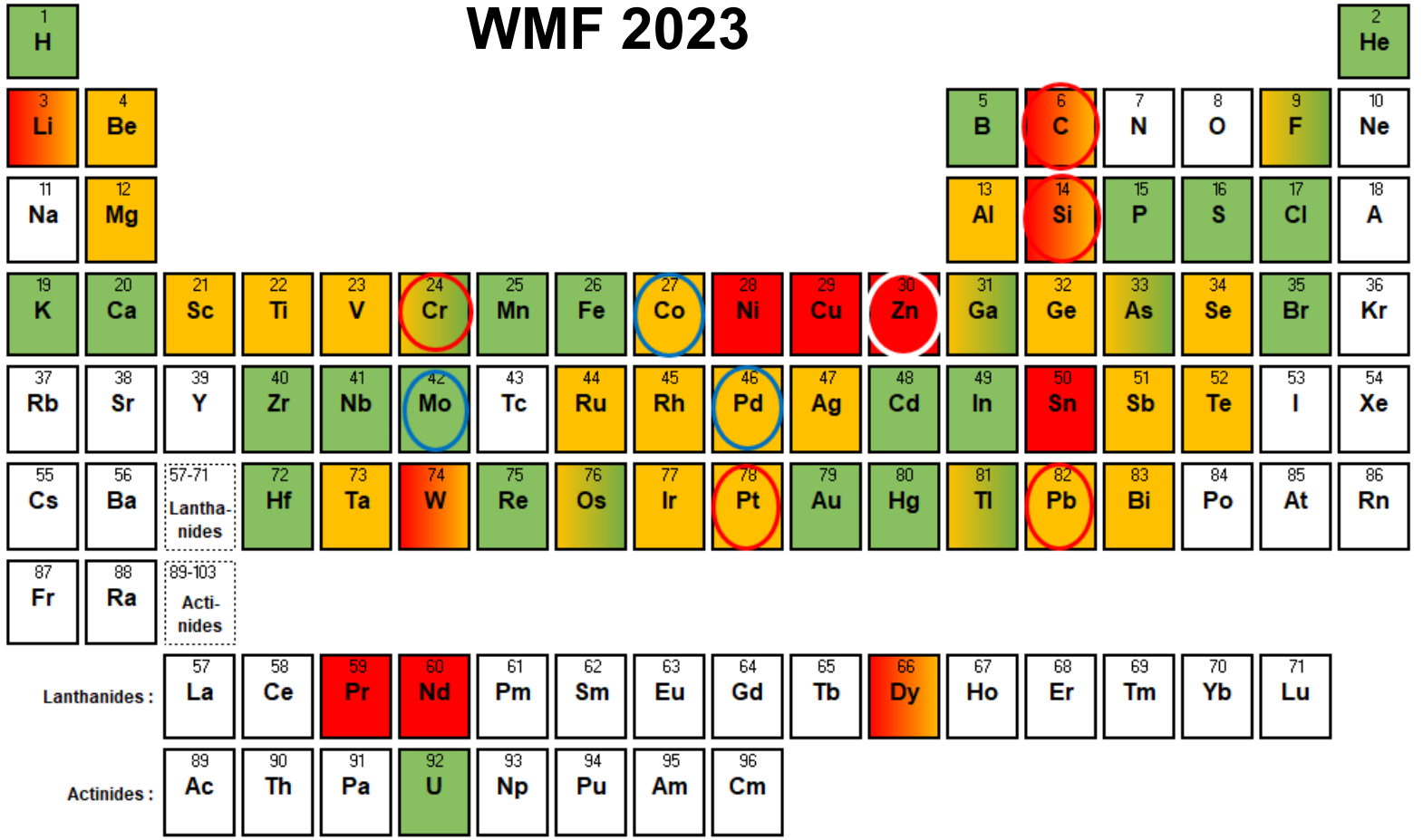
- **Methodology is based on 7 quantitative and qualitative KPIs, with Environmental Performance introduced in 2021**
- **The combination of them allows for a thorough understanding of key challenges facing value chains in the years ahead**

1	**Known reserves**	*Based on reserves and production by USGS*
2	**Uncertainty of supply**	*Anticipated deficit based on demand/supply scenarios*
3	**Political exposure of supply**	*Weighted WGI on main production countries*
4	**Recycling potential**	*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**	*Averaged measurable indicators on water & energy footprint*

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

No changes in 2023 by comparison to previous years

2023 Criticality Assessment results by BRGM, CRU & McKinsey



2023:

- **6 Red elements :**
  - **1 new: Zinc**
  - **Ni, Cu, Sn, Pr, Nd**

More critical in 2023: 5 elements – **Zn, Si, Graphite (C),** Cr, Pt, Pb

Less critical in 2023: 4 elements – **Co, W**, Pd, Mo

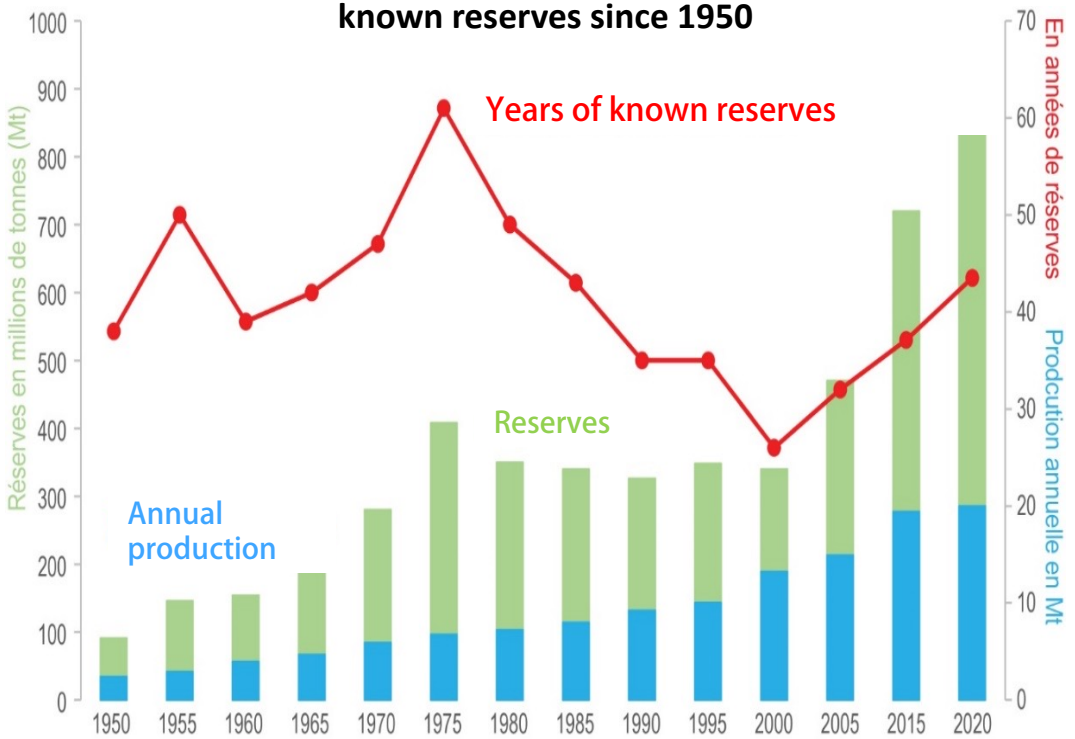
- Very high degree of risks
- High probability of risk occurrence
- Risk occurrence to be closely followed
- Low probability of risk occurrence
- Low degree of risks

Note: Elements in white have not been assessed

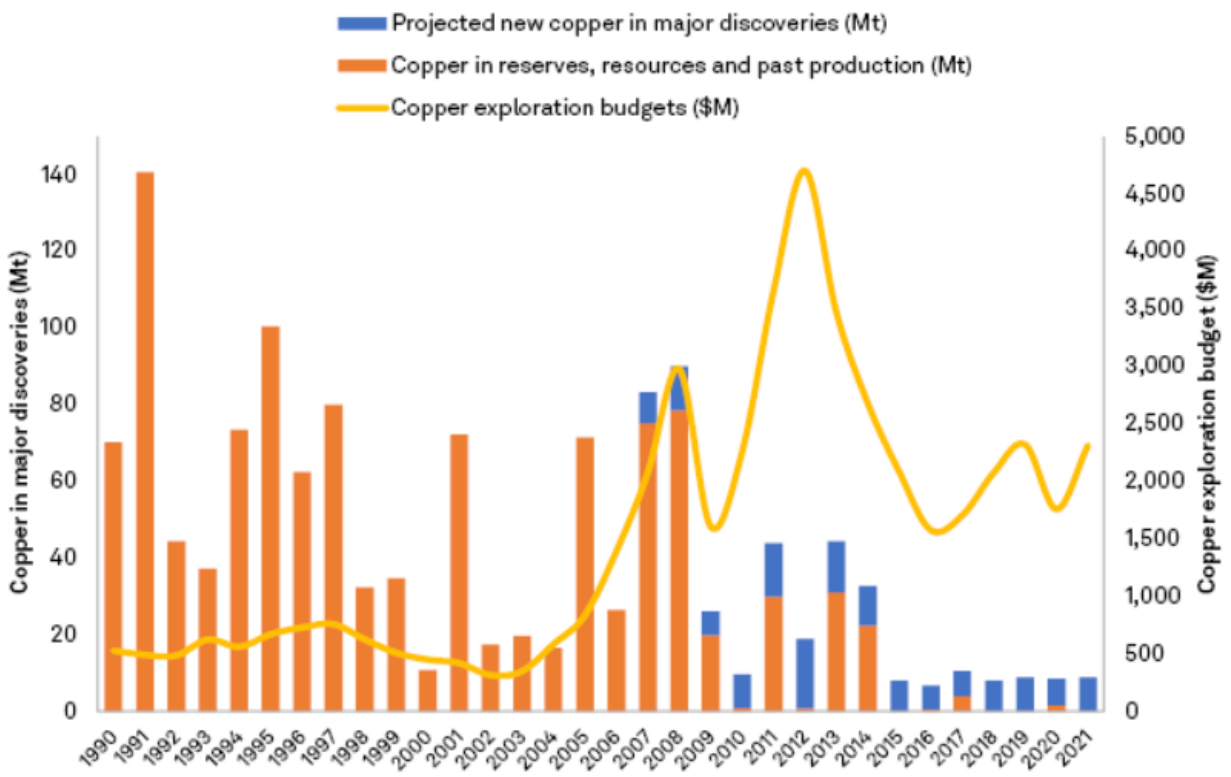
KPI 1 : Known reserves

- Useful KPI to spot underinvestment cycles.
- **Copper = key example**. Very cyclical movements. Direct correlation with exploration budgets. Difficult years to come in terms of pipeline for new discoveries.
- Crucial to continue updating geological knowledge worldwide

Evolution of copper production, reserves and years of known reserves since 1950



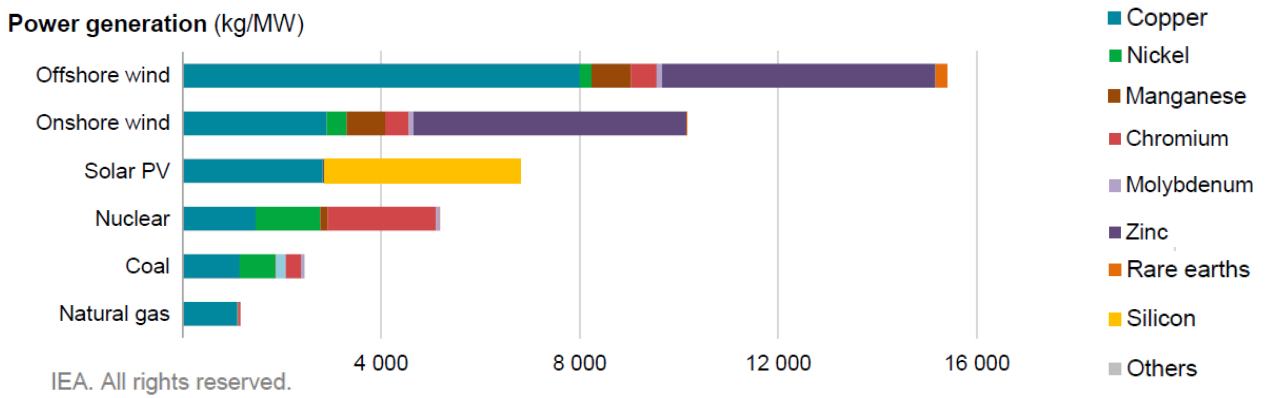
Source : USGS, BRGM



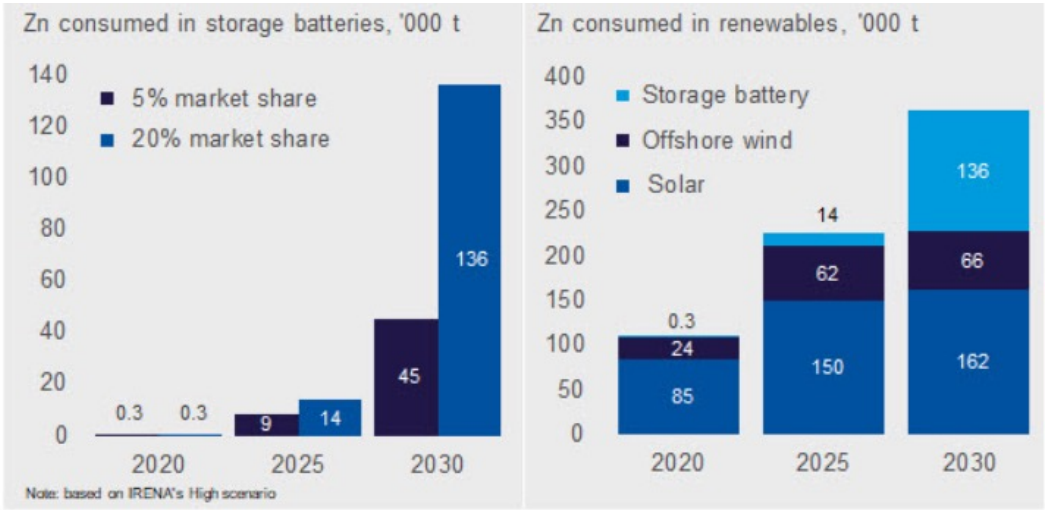
Data as of May 10, 2022.
* Annual average London Metal Exchange Copper Grade A cash price.
Source: S&P Global Market Intelligence

KPI 2 and 5: Uncertainty of supply and demand

- WMF is the **only criticality assessment** which takes into account the pipeline of new mining projects to quantify structural deficit 10-year ahead
- Energy transition means higher intensity of metals per unit of power supplied.

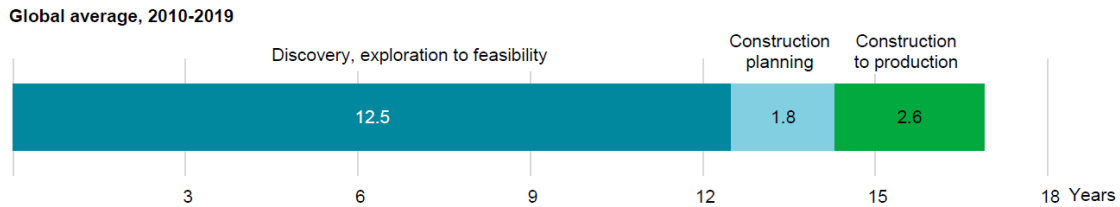


Total Zn demand in renewables could reach 360 kt by 2030



- Fast permitting and financing of new projects is crucial
  - **Average time to market of 17 years for mining projects from exploration to mine construction**
  - **As of now, only 50% of necessary mining and refining projects necessary for the energy transition are financed (3.3 trillion USD in CAPEX investment needed until 2030**)

Global average lead times from discovery to production, 2010-2019



Including 2 to 5 years permitting

KPI 3: Political exposure

- Relative annual changes of World Governance Index values have potential high impacts on materials' criticality scores
- Specific attention to this KPI allows to highlight potential future key risk-countries
- Critical change in 2022 was the Russian invasion of Ukraine, 2023 is on South Africa

Electricity crisis in South Africa : Eskom failures and consequences

Minerals council of SA estimated a loss of mining volumes of 6% in 2022 ($1,8 billion) largely due to power cuts (over 200 days last year)

Uncertainty on ports : Richard Bays issues and consequences on logistics : entire value chains are slowing down

China very reliant on South Africa imports - important share of key metals (PGMs, V, Cr, Ni, Cu)

Diplomacy : role as host of the BRICS summit in August ? Increased proximity to China and Russia

KPI 4: Recycling potential

- Monitoring progress of recycling technologies and capacities worldwide
- In the context of demand growth, recycling cannot meet the increasing demand
- Still, several value chains advancing fast, in particular :

Permanent magnets (Dy, Nd, Pr)

MagREEsource

Nominee WMF Scale Up Challenge 2023

Electric and electronic wastes (Li, Ni, Cu, precious metals)

MOMENTUM TECHNOLOGIES

« Coup de cœur » Start Up Challenge 2019

Rare-earths facilities and projects (2022)

WEEECycling

KPI 6: Substitution

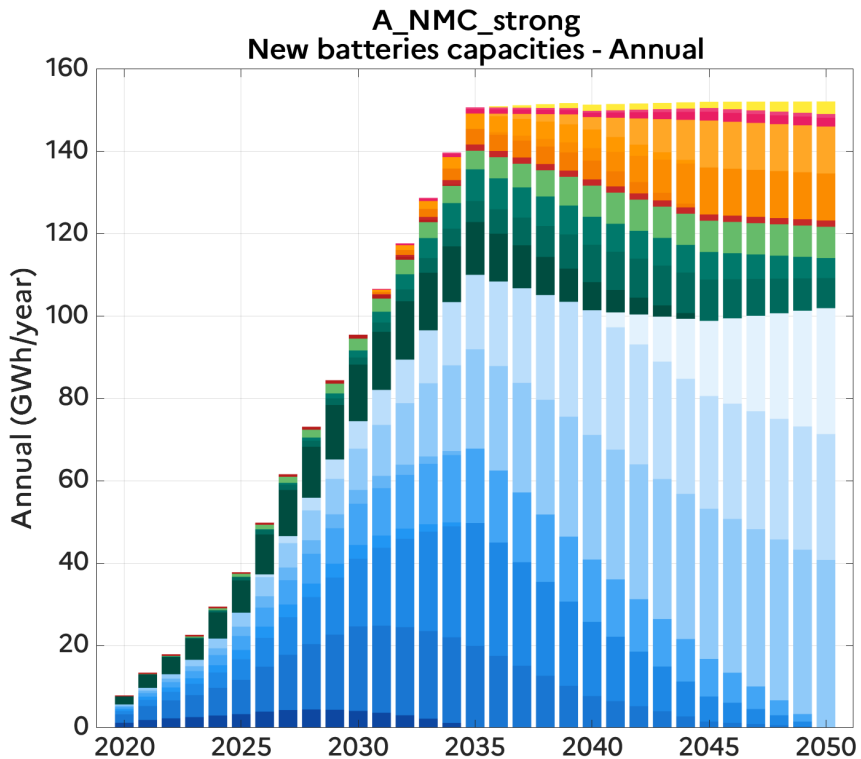
- Assessing supply chains vulnerabilities to materials which cannot be substituted (e.g. aerospace, defence)
- Example of OFREMI study on battery chemistries (**technological substitution**):

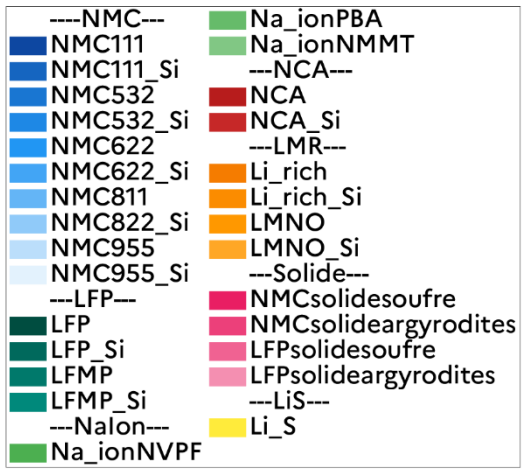
High NMC Scenario

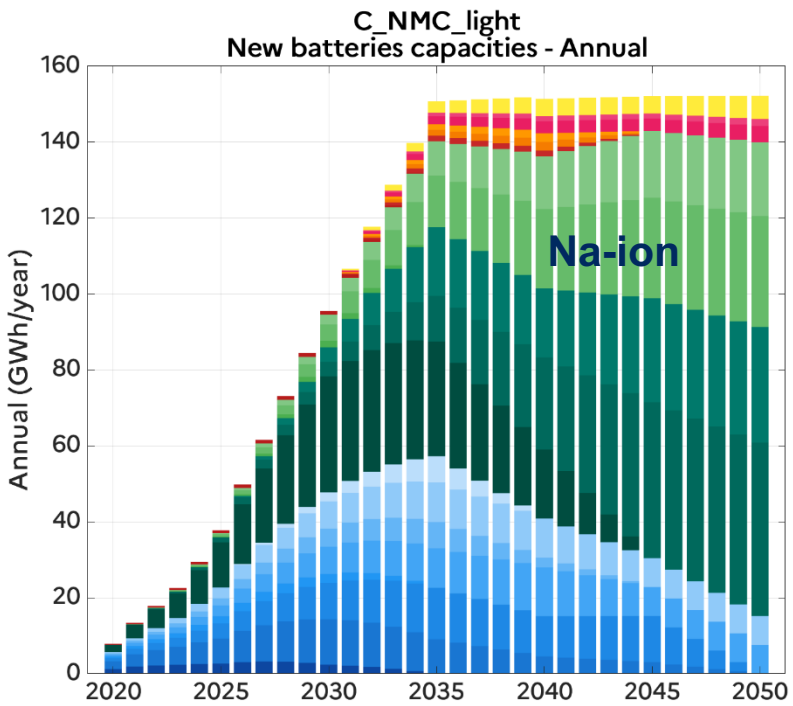
Low NMC Scenario

- Fast development of LFP and Na-ion (*in green*)
- Huge consequences on supply scenarios

Zeta ENERGY *2020* WORLD MATERIALS FORUM *2022* TIAMAT







FRANCE 2030

OFREMI OBSERVATOIRE FRANÇAIS DES RESSOURCES MINÉRALES POUR LES FILIÈRES INDUSTRIELLES

Key hypothesis : French « SNBC » scenario – fixed automotive fleet 2035-2050

KPI 7: Environmental performance

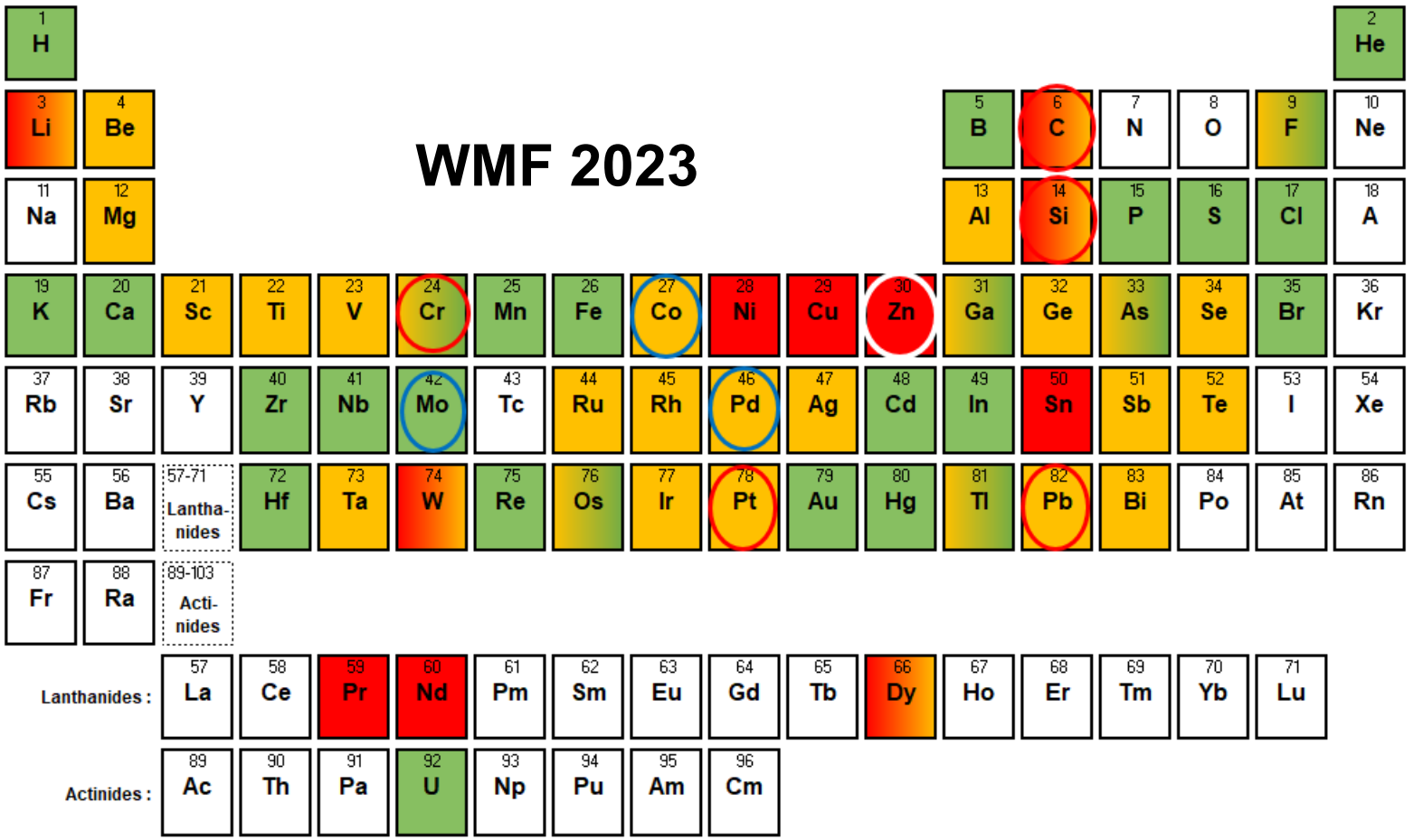
- This KPI is a combination of quantitative and qualitative indicators, mostly extracted from OekoRess II Research Project (cf. 2021 Program)
- Focusing on upstream indicators (some being root causes for CO_2 emissions) water, energy and waste footprint.
- WMF Closing session on Technologies for sustainable mining

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

Water availability in the context of climate change will become a key challenge of the mining industry

Conclusions

- **WMF Criticality assessment remains dynamic**
- **Key risks appear to be more and more region-dependent**
- **New solutions are required**



Christophe POINSSOT
Deputy Chief Executive Officer, Chief Scientific Officer,
c.poinssot@brgm.fr

Gaétan LEFEBVRE Expert in Mineral intelligence