WMF CRITICALITY ASSESSMENT

by BRGM, CRU & McKINSEY

World Materials Forum

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WMF Criticality assessment by BRGM, CRU & McKinsey

We applied a 3-step approach to assess criticality for the majority of the elements of Mendeleev's Periodic Table

1. Definition of 6 criticality assessment criteria
2. Definition of scoring methodology per assessment criteria
3. Definition of a composite criticality index

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Definition of 6 criticality assessment criteria → Definition of scoring methodology per assessment criteria → Definition of a composite criticality index

1 Years of known reserves	Calculation based on reserves published by USGS and actual production 2017
2 Uncertainty of supply	Calculation of anticipated deficit based on demand/supply scenarios in 2027 (negative % indicate a surplus)
3 Political exposure of supply	Calculation as weighted average of shares of top producing countries (>80% world supply) times Policy Perception Index
4 Supply chain recycling	Qualitative assessment of current recycling technologies and recycling routes
5 Uncertainty of demand	Qualitative assessment of the predictability of main demand drivers in 4 core industries (regulations & technologies changes)
6 Vulnerability to the absence of substitution	Qualitative assessment of the availability of alternative materials for key applications

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Definition of 6 criticality assessment criteria → **Definition of scoring methodology per assessment criteria** → Definition of a composite criticality index

	Sub - Criteria	Score
1 Years of known reserves	▪ Known reserves >40 years	1
	▪ Known reserves 20-40 years	2
	▪ Known reserves < 20 years	3
2 Uncertainty of supply	▪ Negative or <10%	1
	▪ 10-30%	2
	▪ >30%	3
3 Political exposure of supply	▪ >60	1
	▪ 50-60	2
	▪ <50	3

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Definition of 6 criticality assessment criteria → **Definition of scoring methodology per assessment criteria** → Definition of a composite criticality index

	Sub - Criteria	Score
4 Supply chain recycling	▪ Technologies and recycling routes exist; recycling rate medium to high	1
	▪ Technologies and recycling routes exist but recycling rate is low due to cost or quality constraint	2
	▪ Immature recycling technologies, poor collecting schemes, and/or low recycling rate	3
5 Uncertainty of demand	▪ Demand drivers, key end-uses and regulations stable and predictable	1
	▪ One of the sub-criteria expected to change in short/medium term	2
	▪ Two of the three sub-criteria expected to change in short/medium term	3
6 Vulnerability to absence of substitution	▪ Alternative materials exist, are qualified for core industries and have comparable economic viability	1
	▪ Alternative materials exist, are qualified for core industries and have lower economic viability	2
	▪ Alternative materials do not exist or are not qualified for core industries	3

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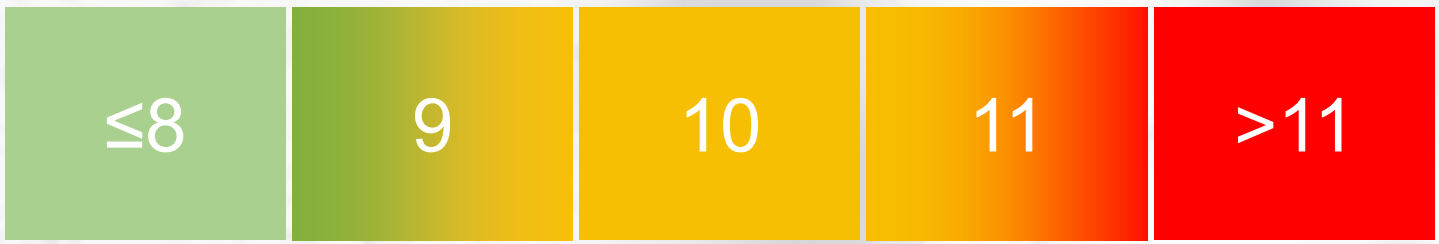
We applied a 3-step approach to assess the criticality for the majority of the elements of Mendeleev's Periodic Table

Definition of 6 criticality assessment criteria → Definition of scoring methodology per assessment criteria → **Definition of a composite criticality index**

Sum of scores and color coding



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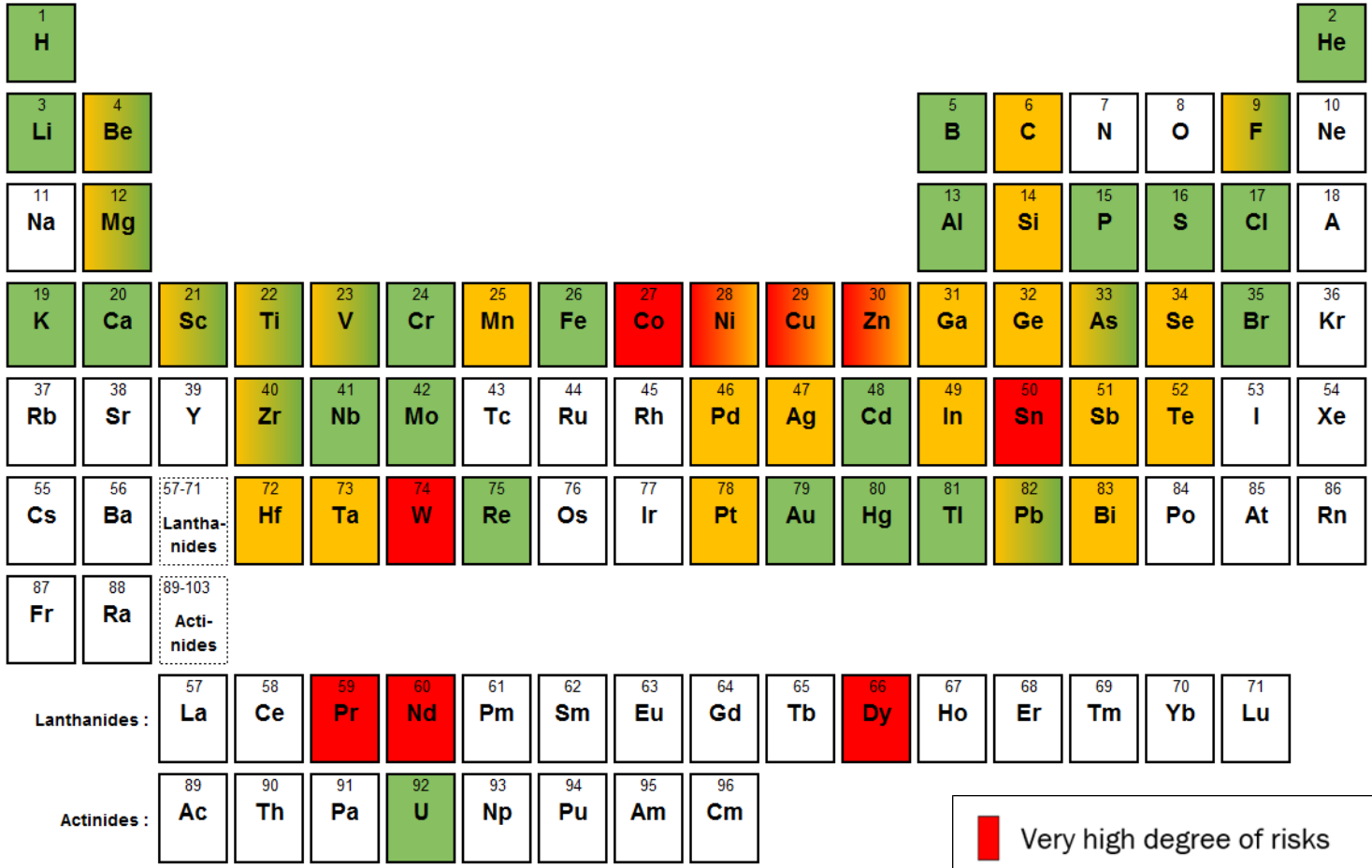


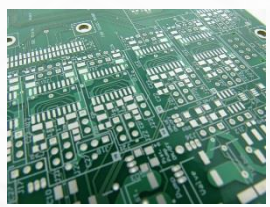
Note: Elements in white have not been assessed

Key messages from the criticality assessment

- Up to 2027, 2 core industry segments will play a huge role in the uncertainty of demand for raw materials :
  - Automotive body & power trains
  - Energy generation & storage
- Criticality can arise from the vulnerability of core industry segments to the lack of substitution of one particular metal (e.g. W, Hf)
- Criticality of some materials usually seen as “non sexy” is increasing due in part to under investment (e.g. Sn, Zn, Cu)
- Criticality of “usual suspects” involved in the development of renewable energies remains high (e.g. Co, Nd, Pr, Dy)

Selected examples and associated core industries

74	50	78	72	3
W	Sn	Pt	Hf	Li
Tungsten	Tin	Platinum	Hafnium	Lithium



Defence Aeronautics	Electronics Automotive	Automotive Energy	Aeronautics Energy	Energy Automotive

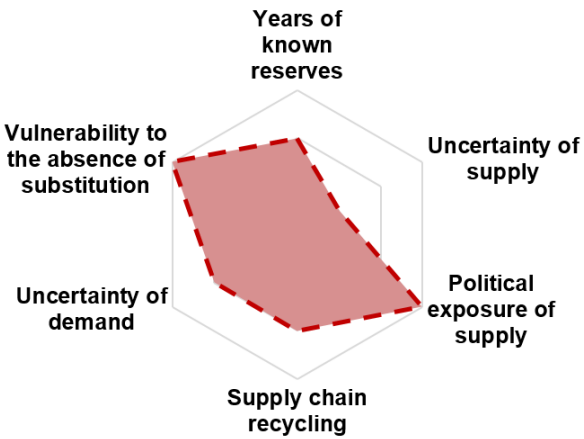
Tungsten - A vulnerable supply chain

74

W

Tungsten

Criticality Score



Years of known reserves

37 years of tungsten reserves at current production volumes (0.86 Mtpa)

Uncertainty of supply

Sufficient mine capacity to meet future demand overall (0.7 Mtpa in China & new capacity in Vietnam, EU, Australia)

Political exposure of supply

High political exposure (Chinese control on spot prices)

Supply chain recycling

Recycling routes exist but global recycling rate remains low (<25%). Some sectors achieve >50% recovery (W carbides)

Uncertainty of demand

Demand drivers in core industries might change quickly (additive manufacturing)

Vulnerability to the absence of substitution

No substitute in core industries and strategic applications

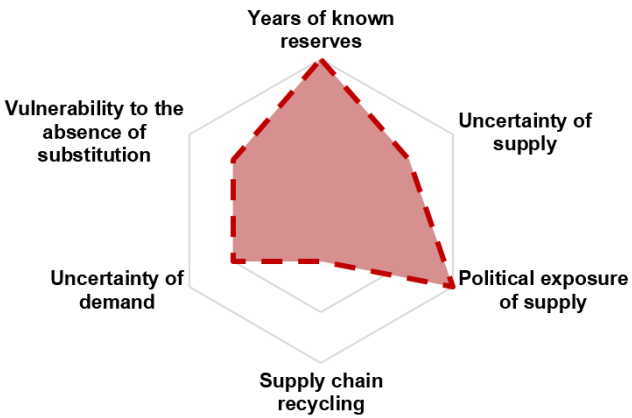
Tin - Deficit of investment in exploration

50

Sn

Tin

Criticality Score



Years of known reserves

17 years of tin reserves (4.8 Mt) due to under investment in exploration in developed countries for many years

Uncertainty of supply

Reduction of criticality could be achieved if new mines start-up on schedule (Australia, Spain, etc.)

Political exposure of supply

High political exposure (Indonesia, Myanmar, China) and increasing share of artisanal mining (Myanmar, DRC)

Supply chain recycling

Efficient recycling routes (>50%)

Uncertainty of demand

Potential role in microelectronics and automotive power trains

Vulnerability to the absence of substitution

Substitutes in core industries exist with lower performance

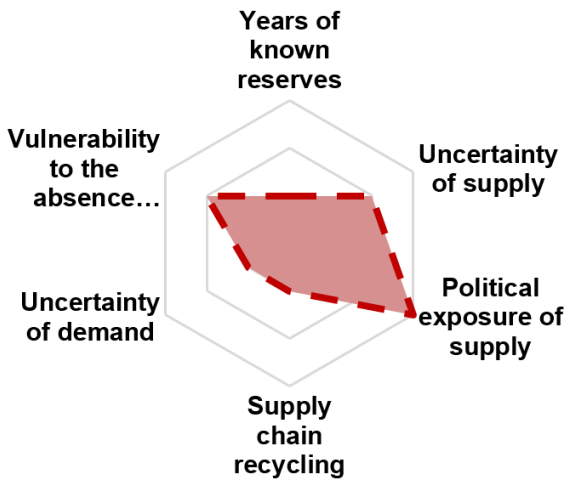
Platinum – Sensitivity to geopolitical risks

78

Pt

Platinum

Criticality Score



Years of known reserves

173 years of known platinum reserves at current levels (190 tpa)

Uncertainty of supply

Sufficient mine capacity to meet demand although concentrated in only a few specific geological settings

Political exposure of supply

Russia and South Africa together control 75% of the market with associated geopolitical and social constraints

Supply chain recycling

Efficient and well-established recycling routes and technologies

Uncertainty of demand

Low disruption potential from new demand drivers (fuel cells)

Vulnerability to the absence of substitution

Substitutes in core industries exist with lower performance

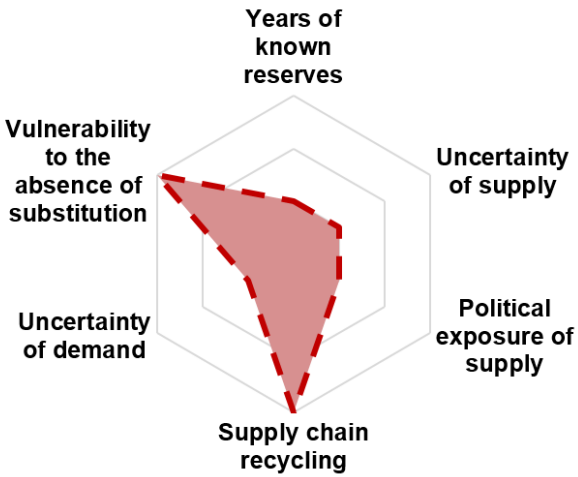
Hafnium – Vulnerability of substitution in core industries

72

Hf

Hafnium

Criticality Score



Years of known reserves

Theoretically 21,000 years of hafnium reserves at current levels (70 tpa)

Uncertainty of supply

Sufficient production capacity overall (by-product of pure zirconium for the nuclear industry)

Political exposure of supply

Low political exposure (>80% of supply from France & USA)

Supply chain recycling

Low to none recycling due to dispersive usages in specialty alloys

Uncertainty of demand

Niche market with stable demand (high purity alloys, extreme-temperature superalloys, plasma cutters)

Vulnerability to the absence of substitution

No substitutes with comparable properties and performance in core industries (nuclear reactors and aeronautics)

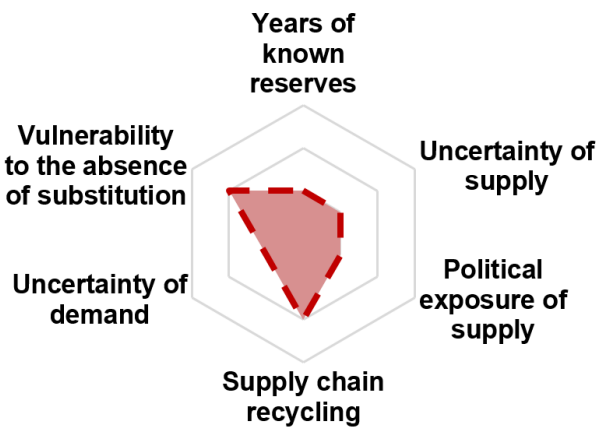
Lithium – Towards equilibrium of the market

3

Li

Lithium

Criticality Score



Years of known reserves

372 years of lithium reserves at current levels (43,000 tpa) with diversified resources

Uncertainty of supply

Oversupply expected around 2025 although technical constraints may weigh on new projects (start-up delays)

Political exposure of supply

Low political exposure although potential risk of oligopoly (4 companies control 80% of current mine production)

Supply chain recycling

Recycling routes and technologies are steadily increasing

Uncertainty of demand

Li-ion technologies to remain dominant in the medium term

Vulnerability to the absence of substitution

Substitutes in core industries exist with lower performance

THANK YOU

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