WMF CRITICALITY ASSESSMENT

by BRGM, CRU & McKinsey

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WMF Criticality assessment methodology

- **Objective: deriving robust and traceable KPIs for identifying critical raw materials for industry**
- **Methodology was previously based on 8 quantitative and qualitative KPIs ➔ 2 new ones to improve accuracy**
- **The combination of them allows identification of key challenges facing value chains in the 10 years ahead**

1	**Known reserves**	*Based on reserves and production by USGS 2024*
2	**Uncertainty of supply**	*Anticipated deficit based on our demand/supply scenarios*
3	**Political exposure of supply**	*Weighted WGI on main production countries (World Bank)*
4	**Recycling potential**	*Qualitative assessment of current recycling technologies**
5	**Uncertainty of demand**	*Qualitative assessment of the predictability of main demand drivers**
6	**Vulnerability on core applications**	*Qualitative assessment of the availability of alternative materials**
7	**Environmental Performance**	*Averaged measurable indicators on water & energy footprint **
8	**Social Acceptance**	*Weighted EPI on main production countries*

The 2 new KPIs

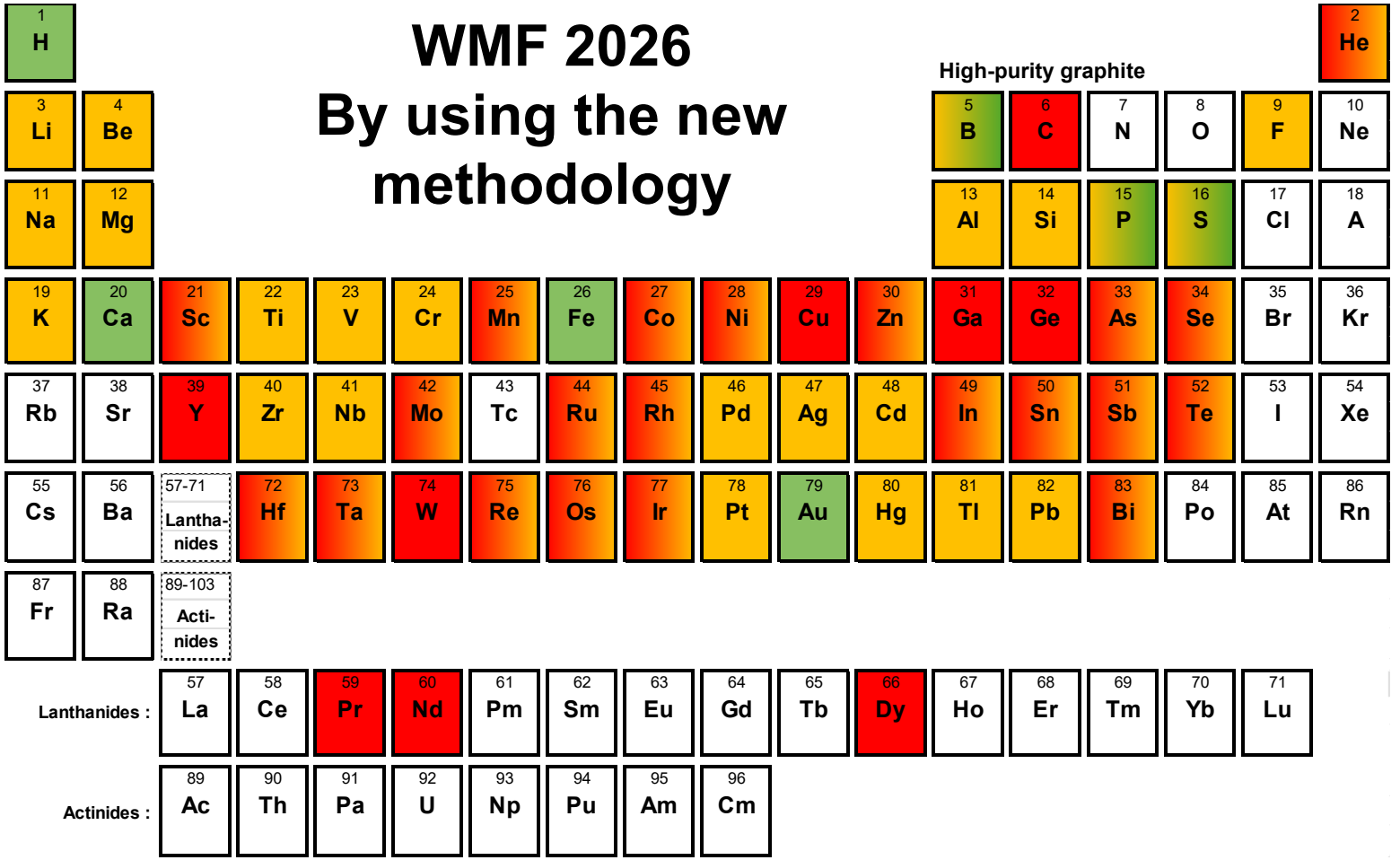
9	**Share of by-product**	*Share of the global production depending on main product*	*Based on Nassar et al., 2015*** and consortium's expertise*
10	**Downstream dependency**	*Assessment of the dependency at the refining stage (bottleneck)*	*Share of main producer at bottleneck refining stage**

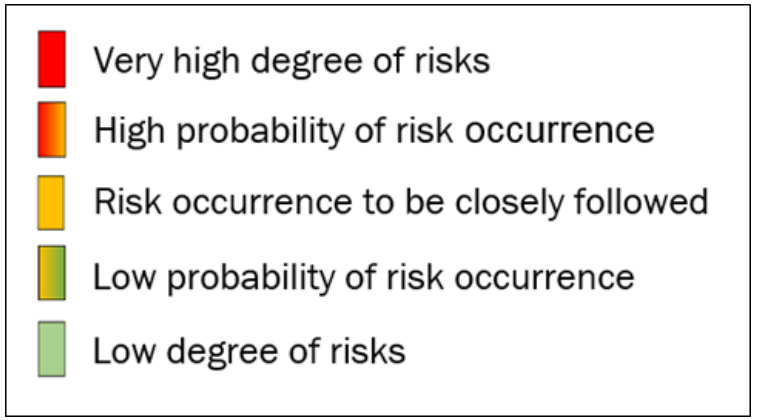
Each KPI has a score from 1 to 3 → **Composite index**

modification of the criticality threshold from 55 to 66%

*Joint expert judgment from BRGM, CRU & McKinsey
** Derived from OekoRess II project – cf. presentation 2021
***Nassar et al., 2015 in Science Advances

2026 Criticality Assessment results by BRGM, CRU & McKinsey

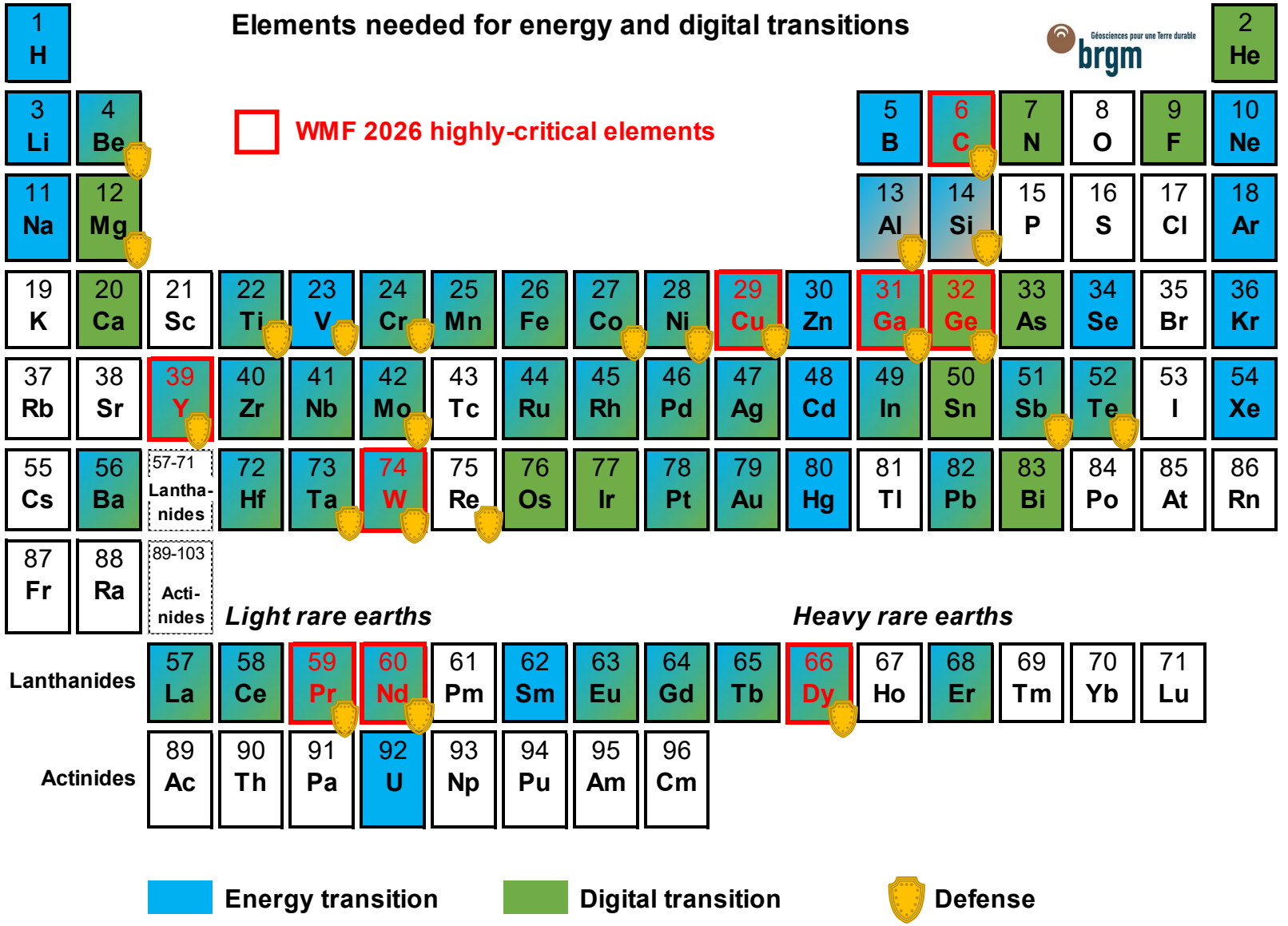




Note: Elements in white have not been assessed

- Using 2024 methodology ➔ more critical elements ➔ increase of risks since 2024
- **2026 results ➔ 9 elements qualified as highly-critical elements (in red):**
  - **3 new: Yttrium, Gallium, Germanium**
  - **Copper, Tungsten, High purity graphite, Praesodymium, Neodymium, Dysprosium**
- *Reminder: Not to forget critical elements (red/orange) which may shift in the future to highly critical*

Highly-critical elements are key for the 3 main strategic industries



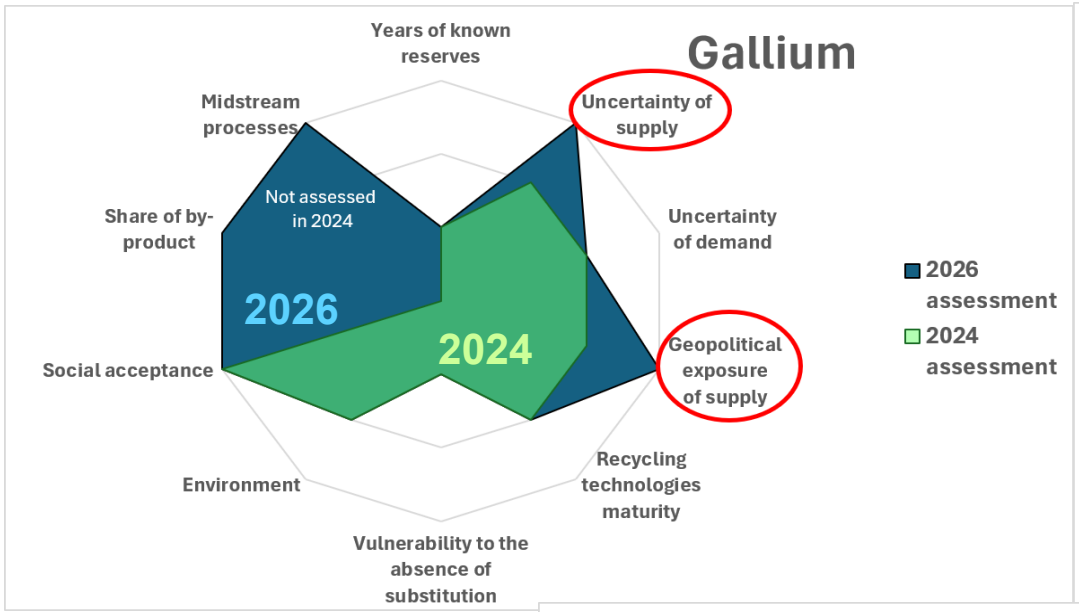
All the highly–critical elements are necessary for the 3 main strategic industries :

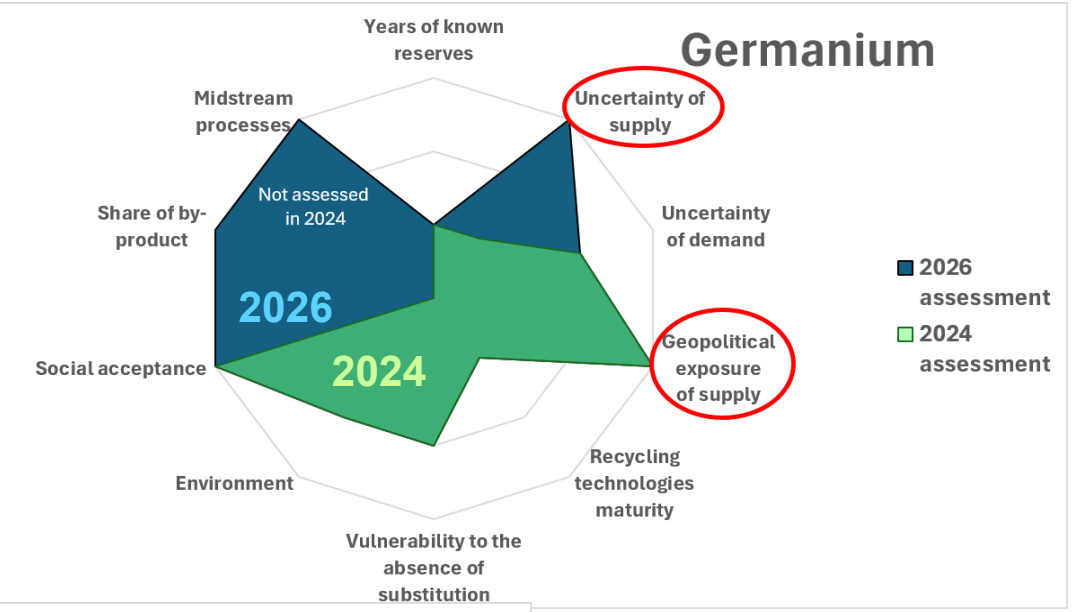
- **Low-carbon technologies** needed for the energy transition (PGMs are also to be considered)
- **Digital technologies** and semiconductors and, where many minor metals produced as byproducts are used
- **Defense technologies** which need both civilian technologies and specific needs, as for W.
  Increasing geopolitical tensions ⇔ need for increasing independence and sovereignty

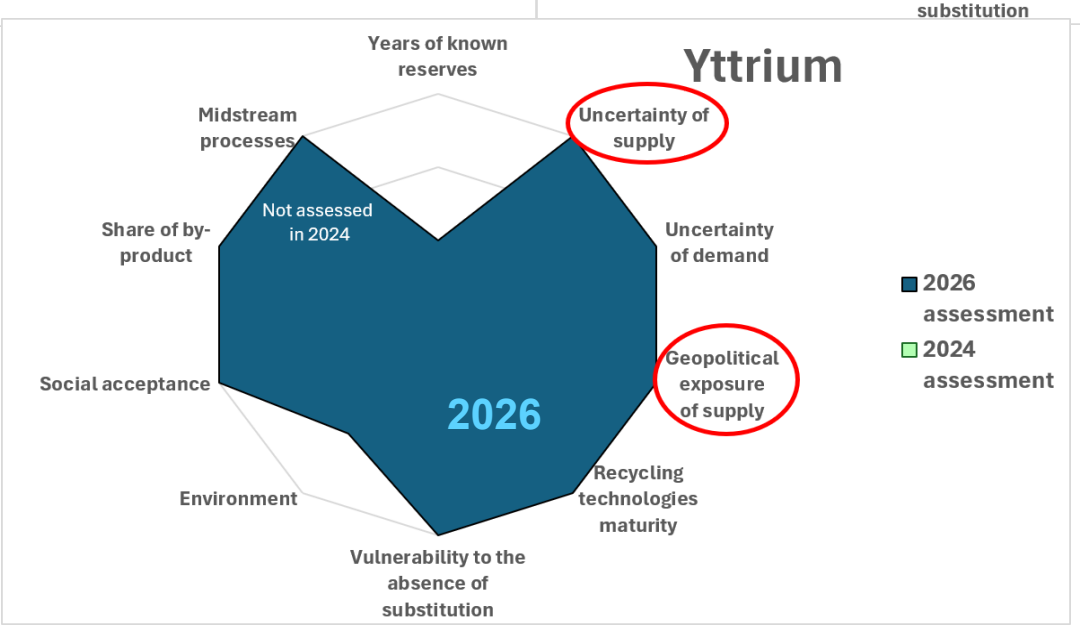
➔ Risk of concurrence and need for trade-off between the different usages

Detailed evaluation of the new highly-critical elements

Beyond the new KPIs, the evolution is mainly driven by geopolitical exposures and market uncertainties

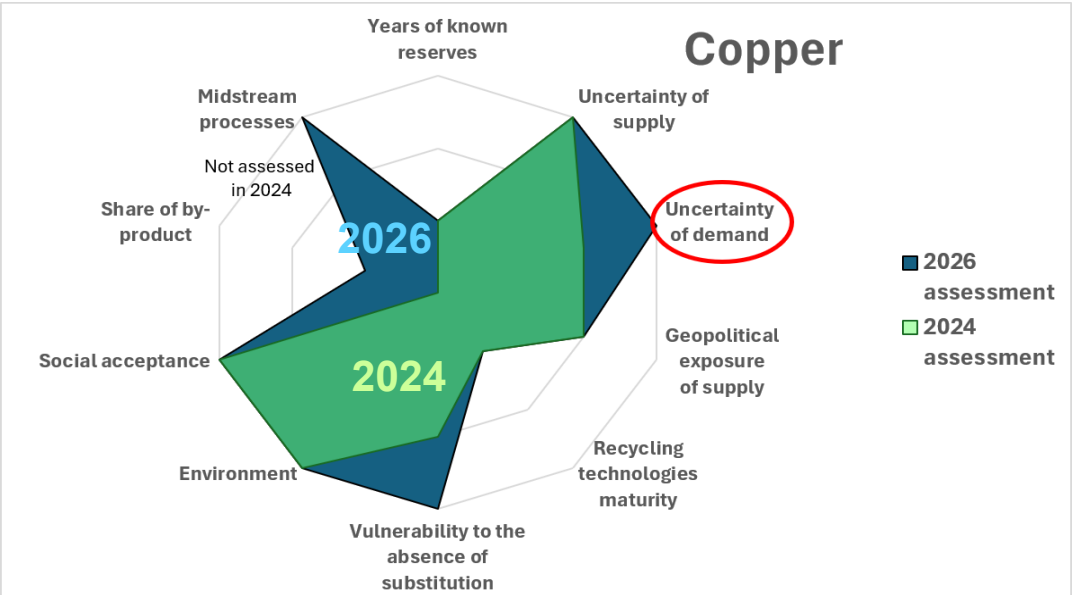


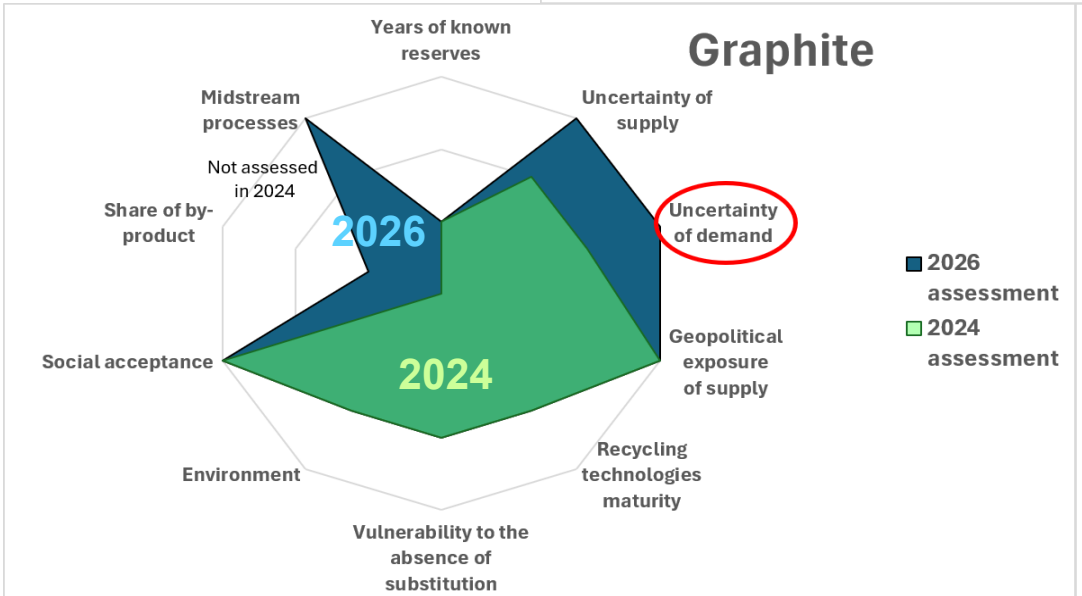


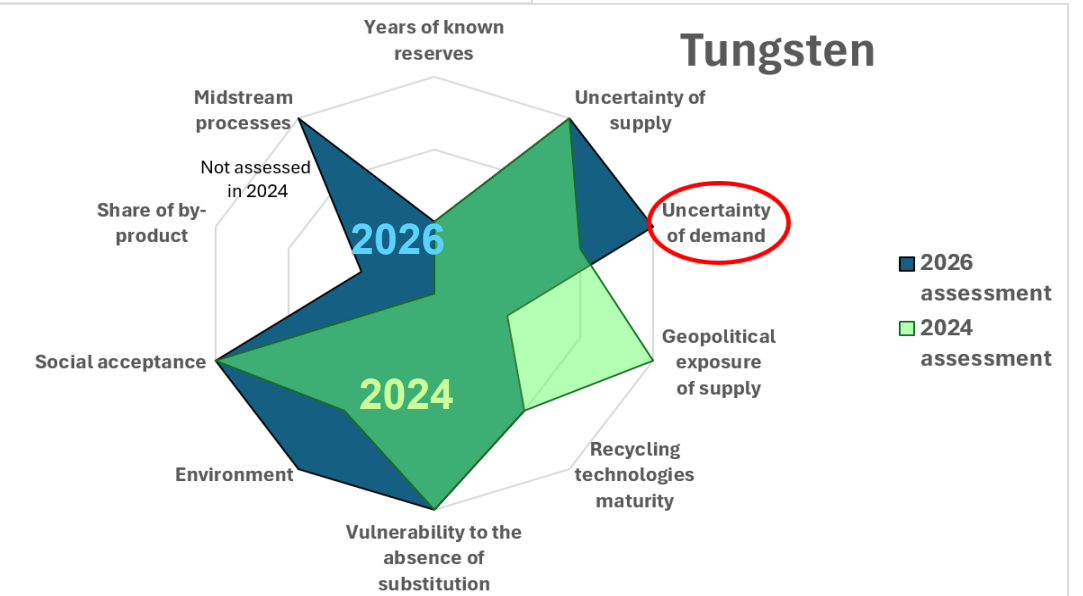


Detailed evaluation of the existing highly-critical elements

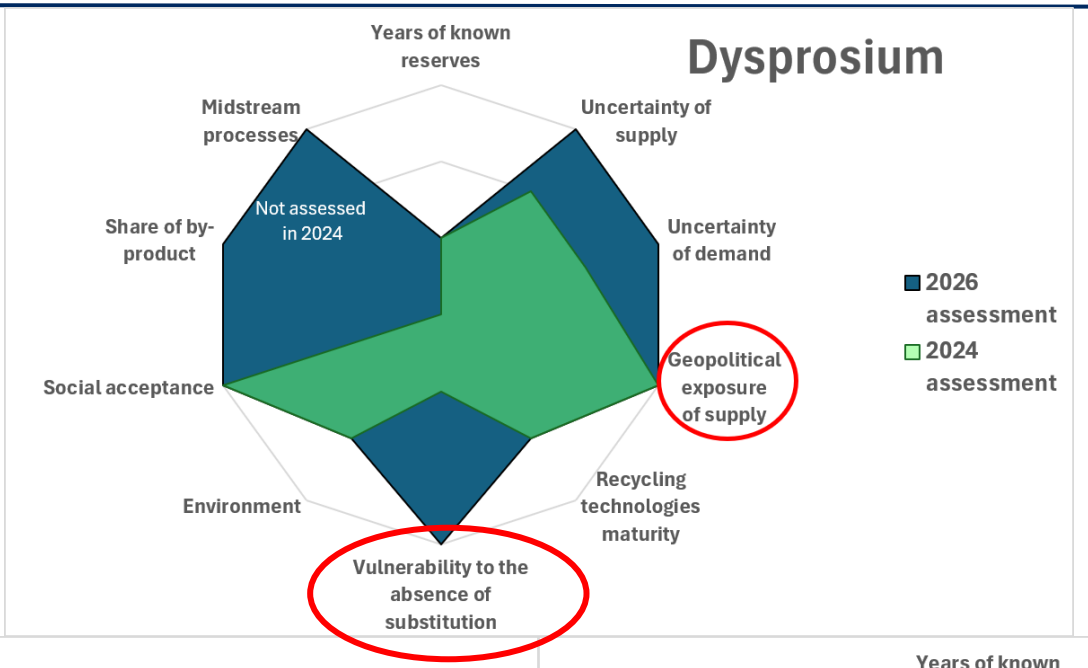
For the already existing highly-critical elements, main évolution driven by demand uncertainties

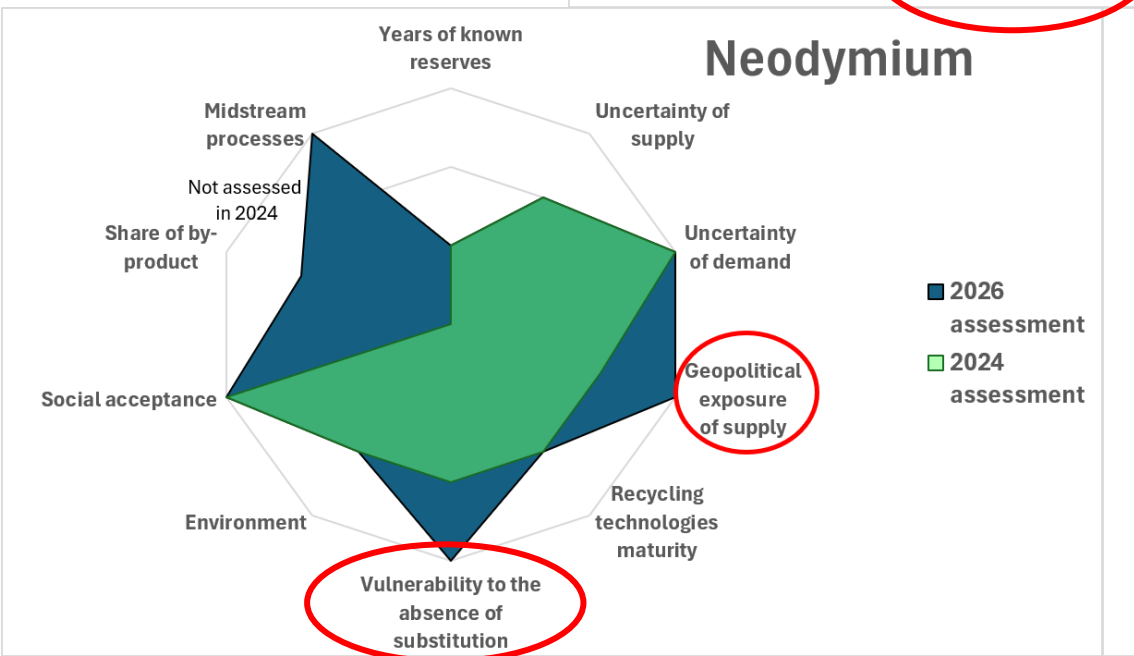


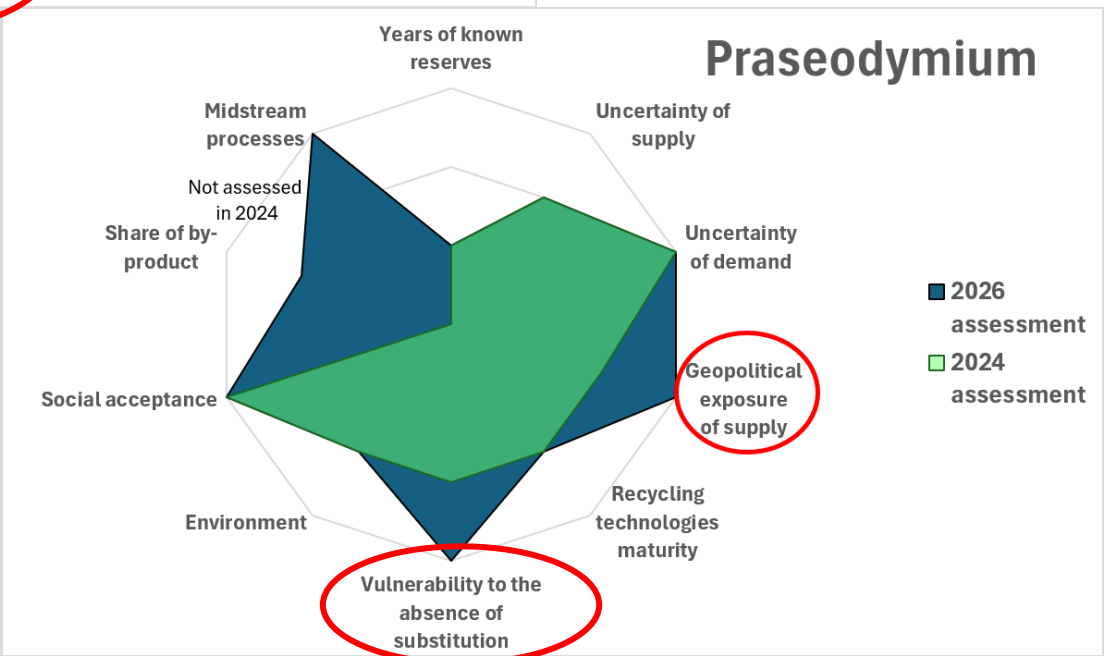




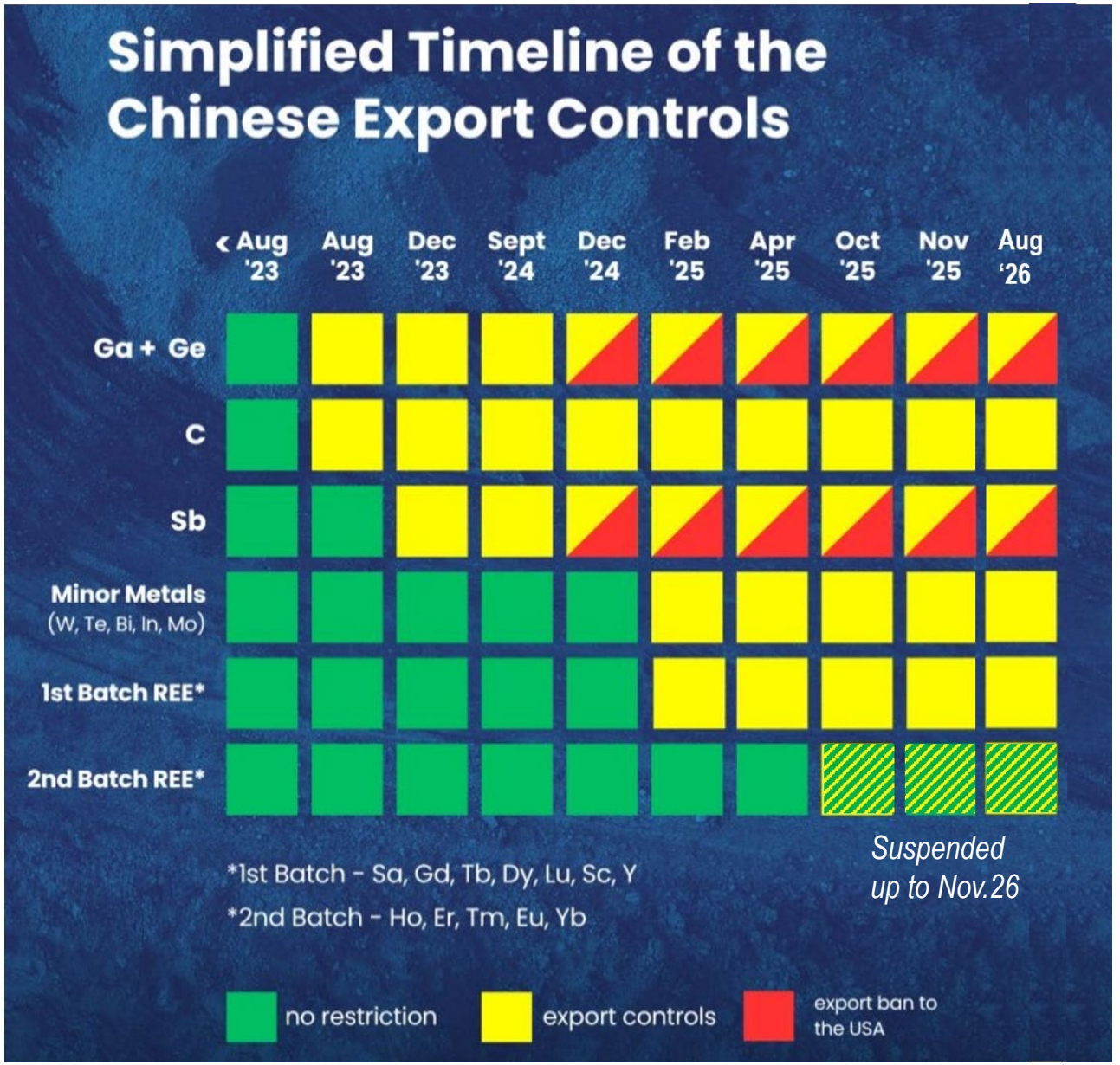
Detailed evaluation of the Rare Earths Elements





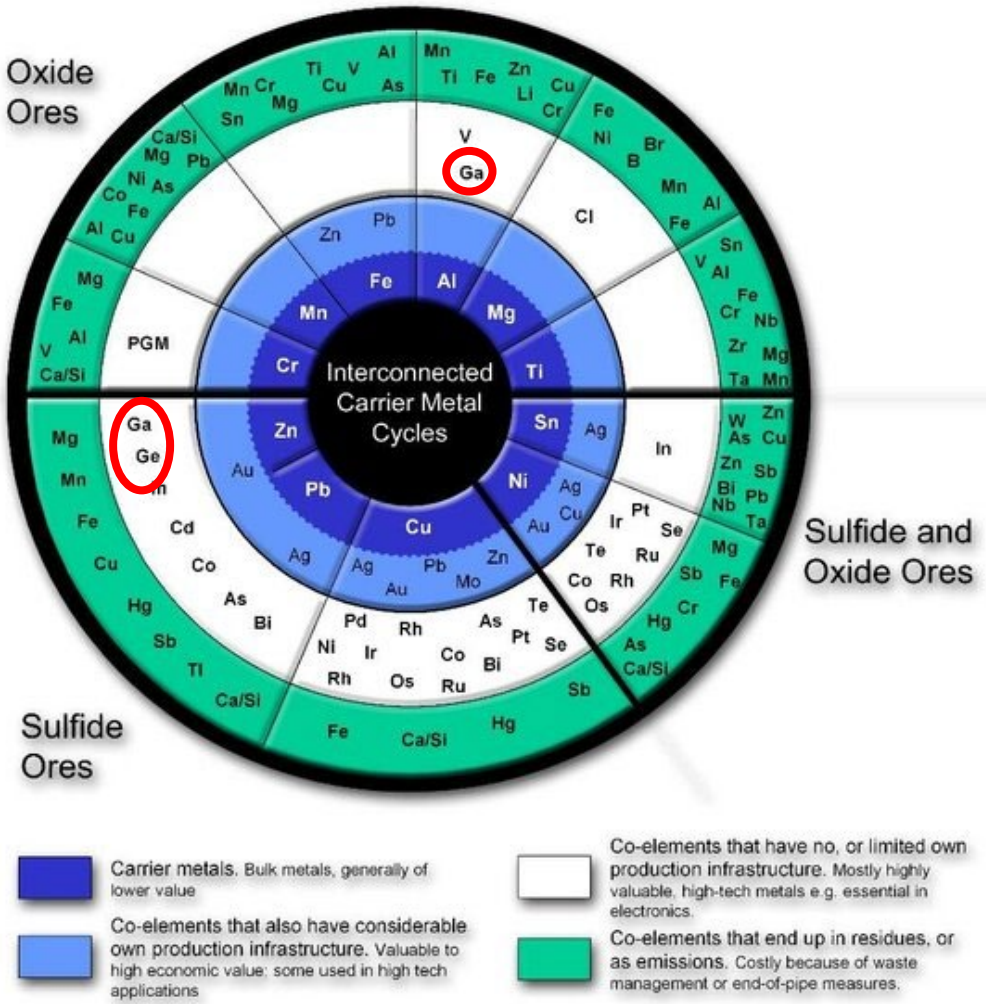


The strong impact of China export controls



- Progressive weaponisation of the critical minerals supply chains
  - From export controls to export ban (Ga, Ge, Sb)
  - Strong reduction of export volumes due to complexity and time needed to get licenses
  - Increasing data and information to provide
- Strong impact on the supply chains and the overall industry due to the lack of stockpiling
  - Civilian industries due to dual use
  - Defense industry which has growing budget (EU: +20% in 2025, +10% in 2026)
- Strong driver for developing alternative and sovereign supply sources and accelerating projets
  - Dedicated regulations : e.g. obligations of stockpiling in France for defense industry
  - EU strategic projects for which administrative steps have to be accelerated

By-products : why does it matter ?



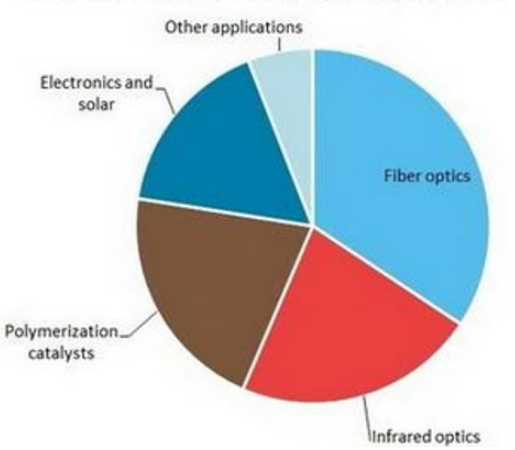
- Production of metals as by-products hinders a direct link between the production and the market needs
  - Difficulty to balance production and needs
  - Lack of visibility
  - Uncertainty on profitability ➔ reduced investment
- For the last decades, many companies went away from producing by-products for 2 reasons :
  - Overcapacity in China and low market prices
  - Challenging economics and lack of visibility
- However, minor metals are specifically critical for defense sectors, even if small amount

Ex.: Ge necessary for night vision equipments

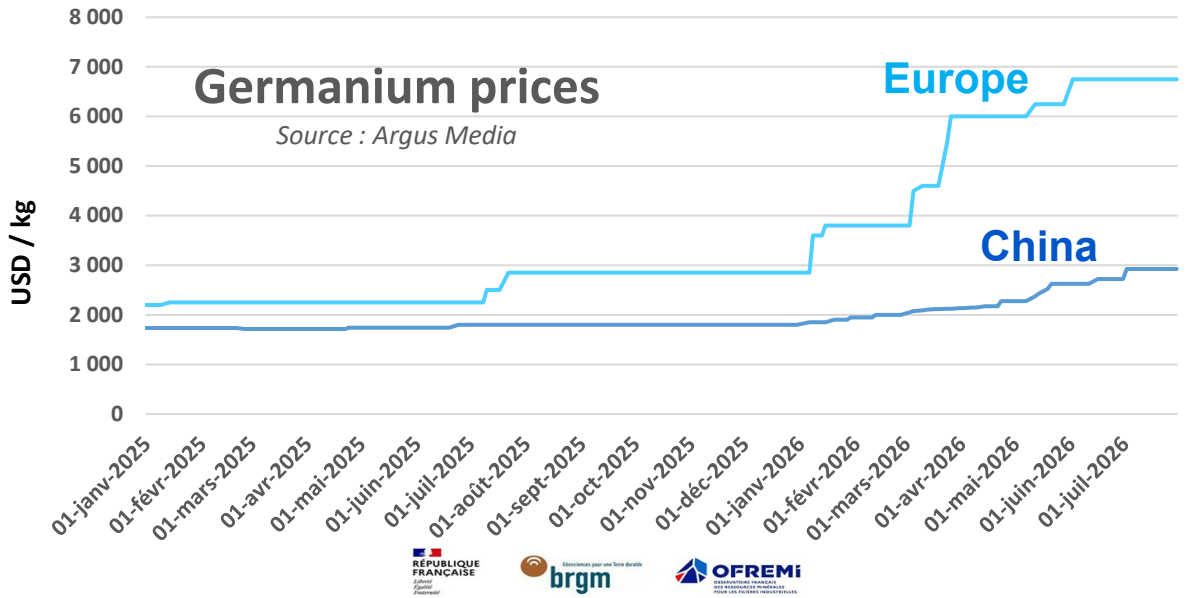
- Need for increasing industrial sovereignty ➔ new domestic projects even at a higher cost

Zoom on Germanium

World per year	% defense
150 t	30%



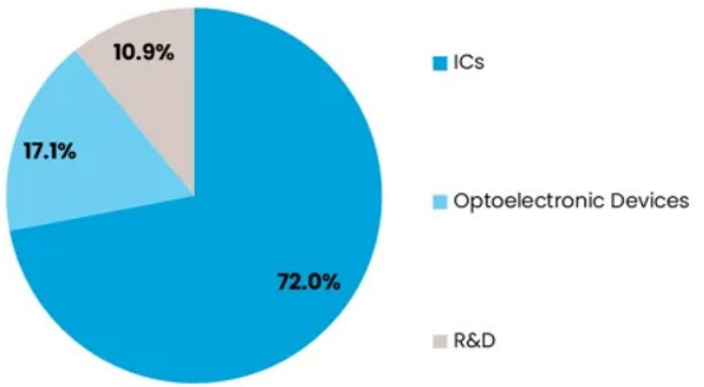
- Usage of Ge for defense: infrared (IR) optics due to its perfect transparency to thermal radiation, essential for thermal imaging & missile guidance.
- Ge produced as a byproduct of Zn refining
  - Importance of the DRC tailings and existing players (Umicore, Nyrstar)
  - In Europe, Umicore's production is the main option
- Issues = emerging opportunities to off-takes agreements but risks will remain in the future as long as China controls stockpiles and prices
- New projects are under development
  - Ex.: Korea Zinc (US), world's largest zinc refiner, is developing new production for defense
  - Rationalization of recycling streams

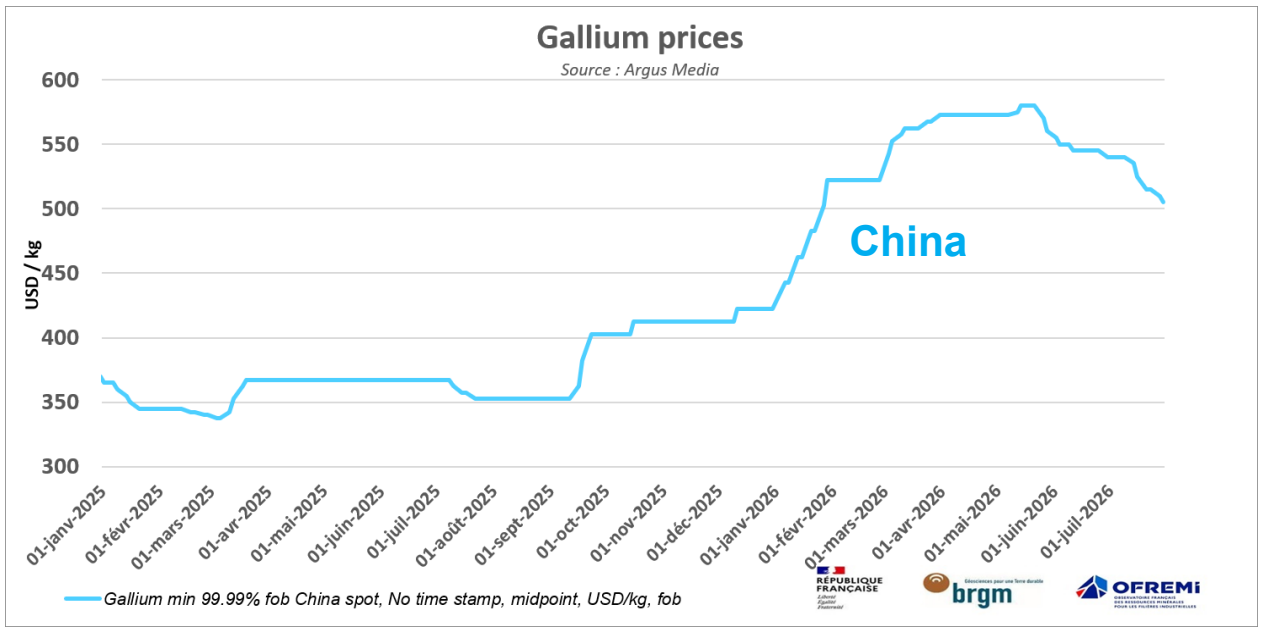


Dec.25: Korea Zinc announced the construction of a $7.4 billion refining plant at Clarksville, Tennessee. Planned to be operational by 2029

Zoom on Gallium

World per year	% defense
700 t	15%

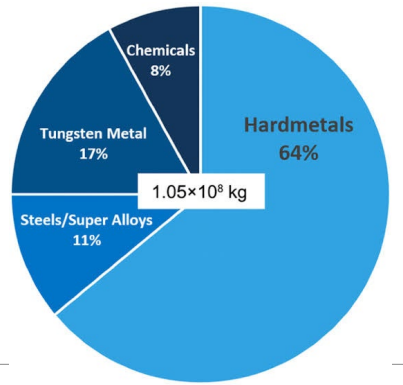




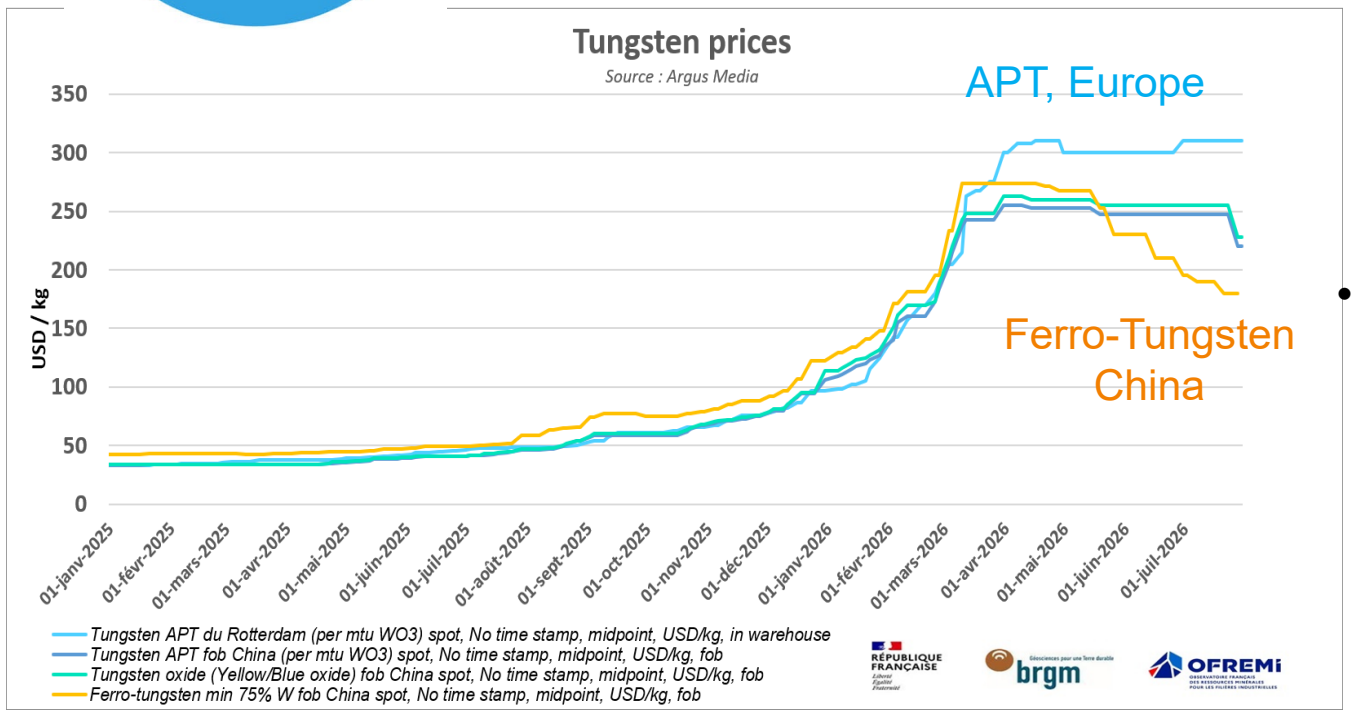
- Usage of Ga for defense: utilized in the form of GaN to power high-frequency components for the next-Gen radars & electronic warfare.
- Ga is a byproduct of Al
  - China handles ~60% of Al refining ➔ 99% of low-purity Ga production (western nations capacities dismantled for economics)
  - Difficulty to feed western high-purity refining plants due to chinese export controls
- New projects are under development
  - 2 EU strategic projects to develop an alumina / gallium refinery: Alteo project in Guinea and Metlen Energy in Greece

Zoom on Tungsten

World per year	% defense
80 kt	10%



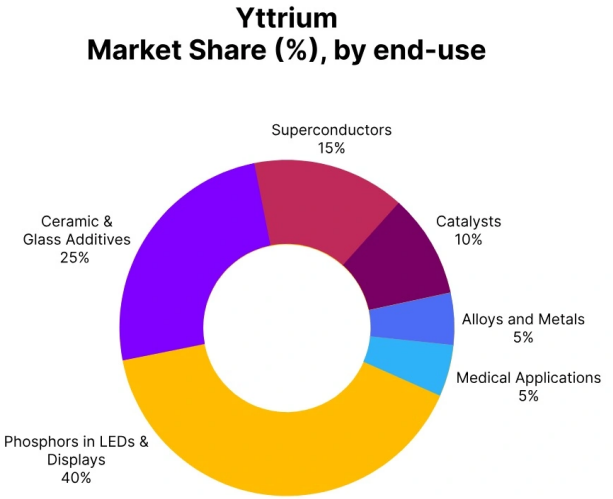
- W mainly used for its hardness and resistance to heat (fusion at 3422°C)
  - W carbide: most resistant material used for high-speed cutting tools, mining and oil drilling bits, industrial wear parts, and heavy construction equipment
  - Defense application: ammunitions, armor plating, missile and aerospace components
- China holds an absolute monopoly and a strategic chokehold on the entire tungsten value chain (52% reserves, 80% extraction, 90% refining) ➔ issue of sovereignty
  - Key roles even abroad: Nui Phao mine (Vietnam) is for sale, with intention of Chinese or Australian players.

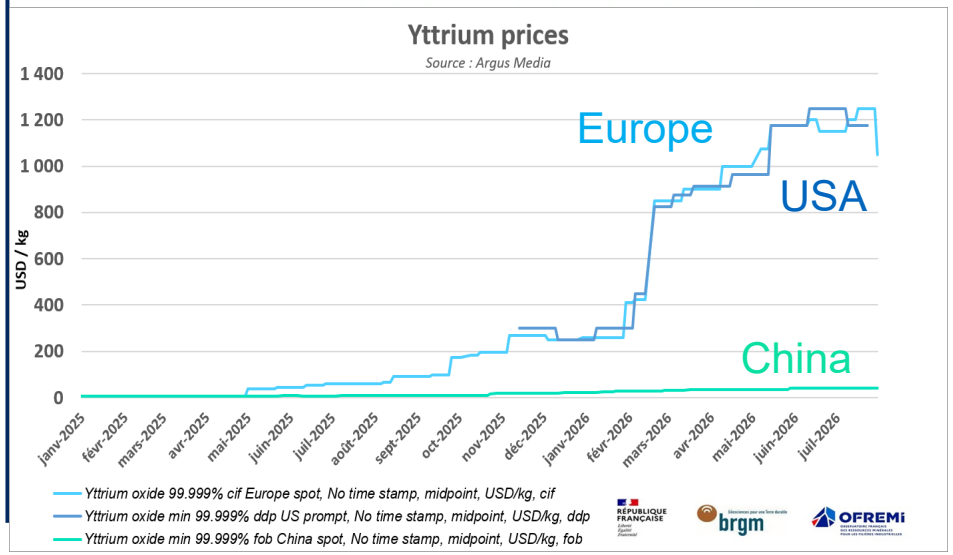


- Export control from China on dual use since February 2025 ➔ price ↗ and export volumes impacted.
  - Chinese exports of intermediate form (APT, (-98%) replaced by downstream forms (WC).
- Strong interest in developing alternative routes based on known deposits : Austria (producer + refiner), Spain, Portugal, UK, France
  - Ex. Former mine of Salau (French Pyrénées)

Zoom on Yttrium

World per year	% defense
14 kt	40%





- Y is mainly a critical performance additive in high-tech hardware, currently irreplaceable
  - Aerospace: Thermal barrier ceramic coatings for jet engines and gas turbines.
  - Components for semiconductors, YAG lasers, and LED displays.
  - Energy: High-temperature superconducting wires and fuel cells.
  - Defense: jet engine thermal barrier (Y-stabilized zirconia), laser guidance and optronics (NdYAG laser), missile windows and transparent armor, radar & communication systems (Y Iron garnets)
- Western defense industry rely heavily on refined yttrium imports ➔ issue of sovereignty
- Following tightening restrictions on "dual-use" metals, Beijing routinely denies export licenses if the end-user is a Western military contractor ⇔ almost no Y is exported from China in 2026.
- Beyond the stockpiling, several industrial projects are under discussions:
  - USA Rare Earth: commercial non-Chinese yttrium processing
  - French Caremag REE refining plant under construction in Pau plan to extend to Y refining,

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