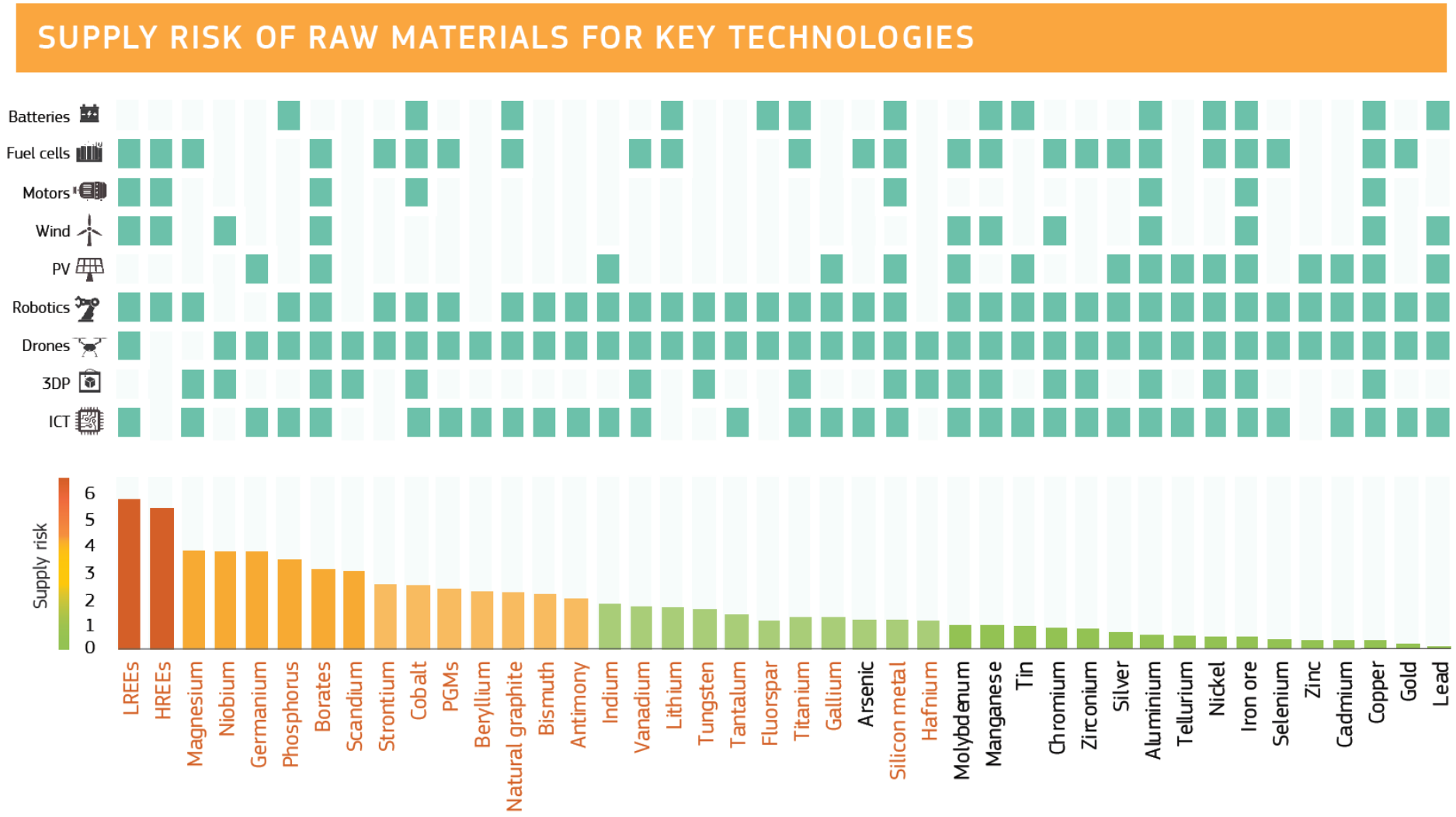
Yhteiskunnan sähköistäminen tarvitsee metalleja – mihin luonnonvaramme riittävät?

Saku Vuori
Johtaja, Tiede ja innovaatiot
Geologian tutkimuskeskus

NÄKÖKULMIA

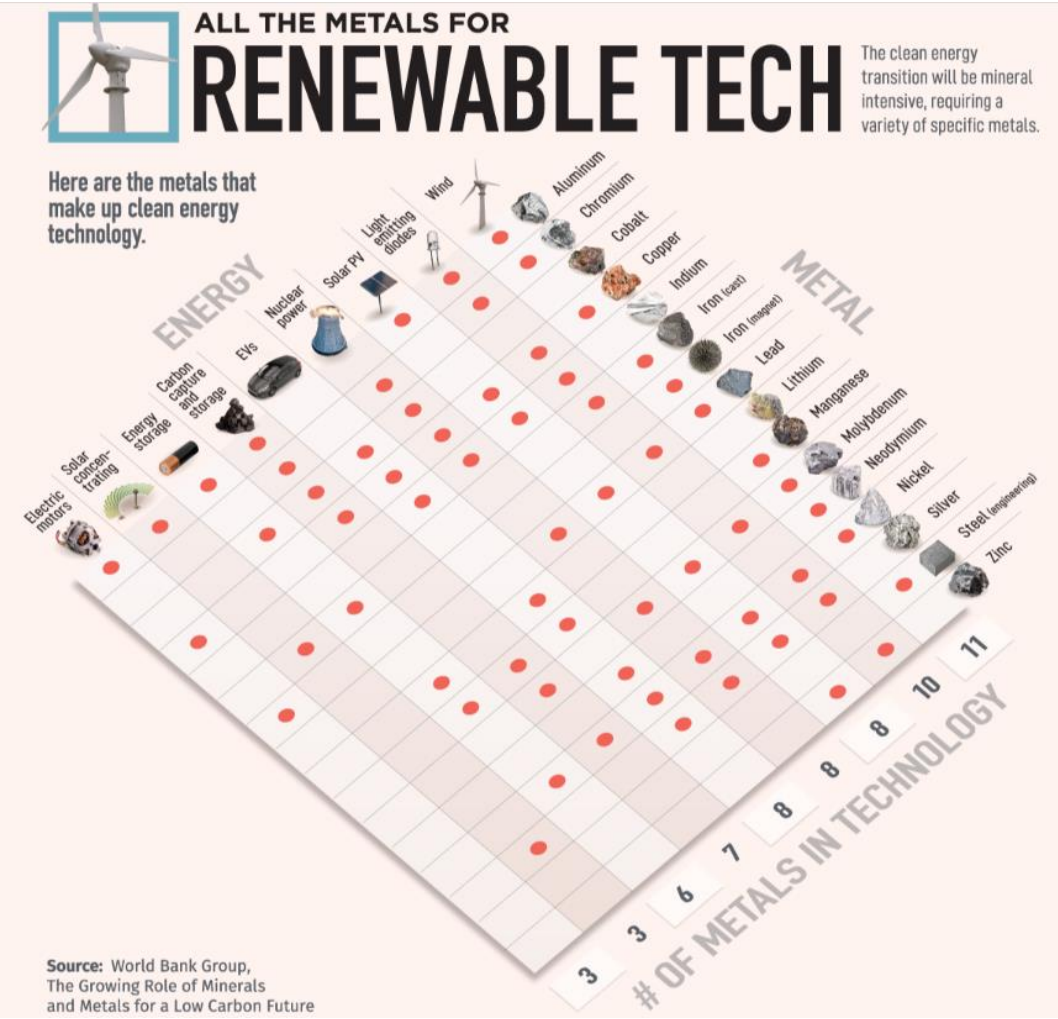
- Materiaalien käyttötavat ja tarpeet – kysyntänäkymiä
- Raaka-aineet – tarjontanäkymiä
- Näkökulmia raaka-aineiden saatavuuden turvaamiseen

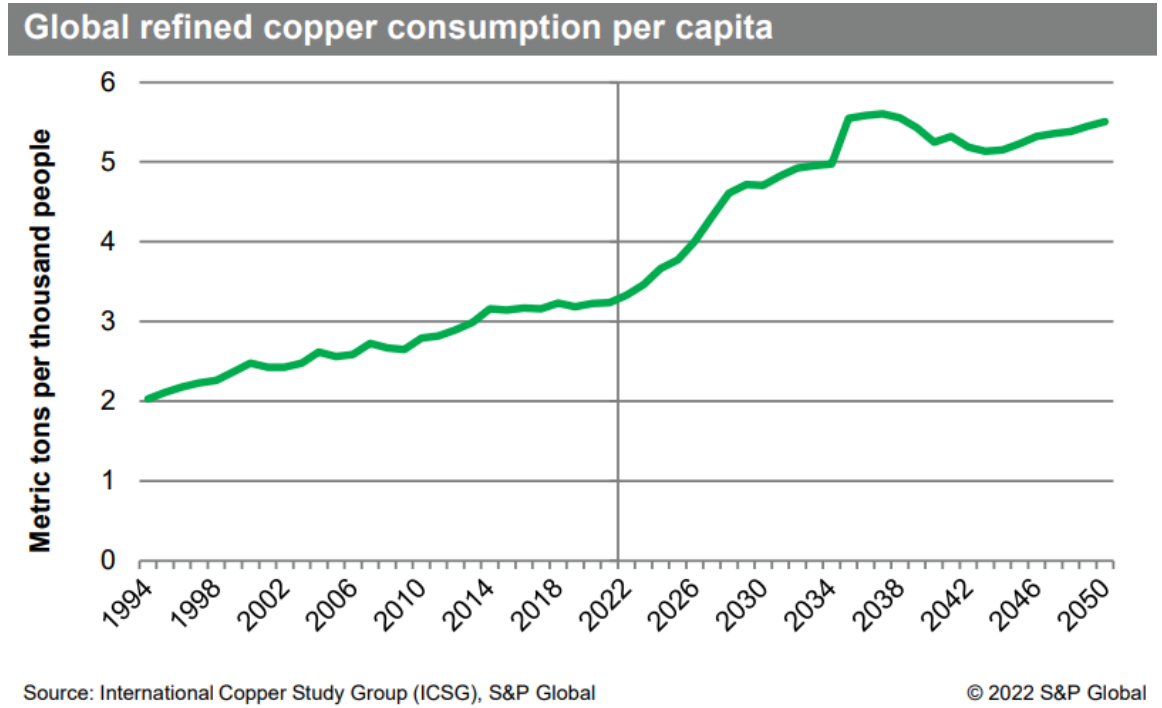
KYSYNTÄNÄKÖKULMIA



Source: European Commission, Critical materials for strategic technologies and sectors in the EU - a foresight study, 2020

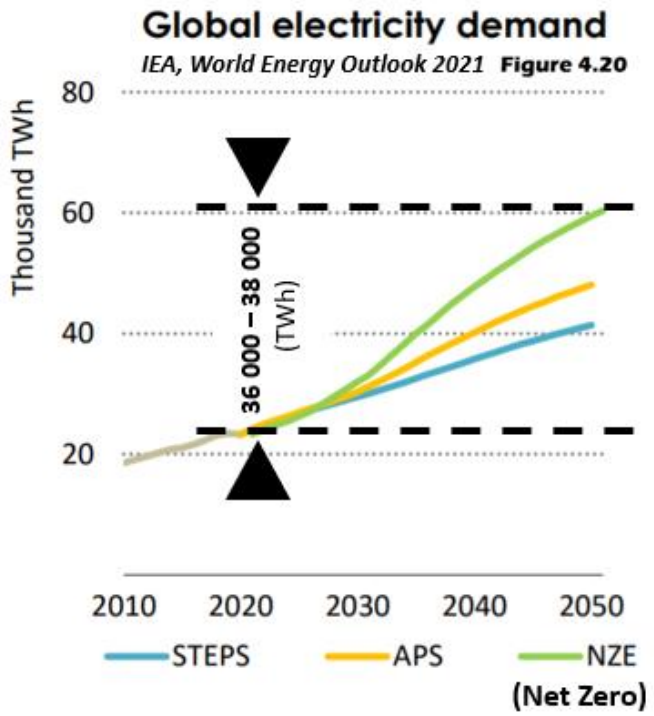
KYSYNTÄNÄKYMIÄ



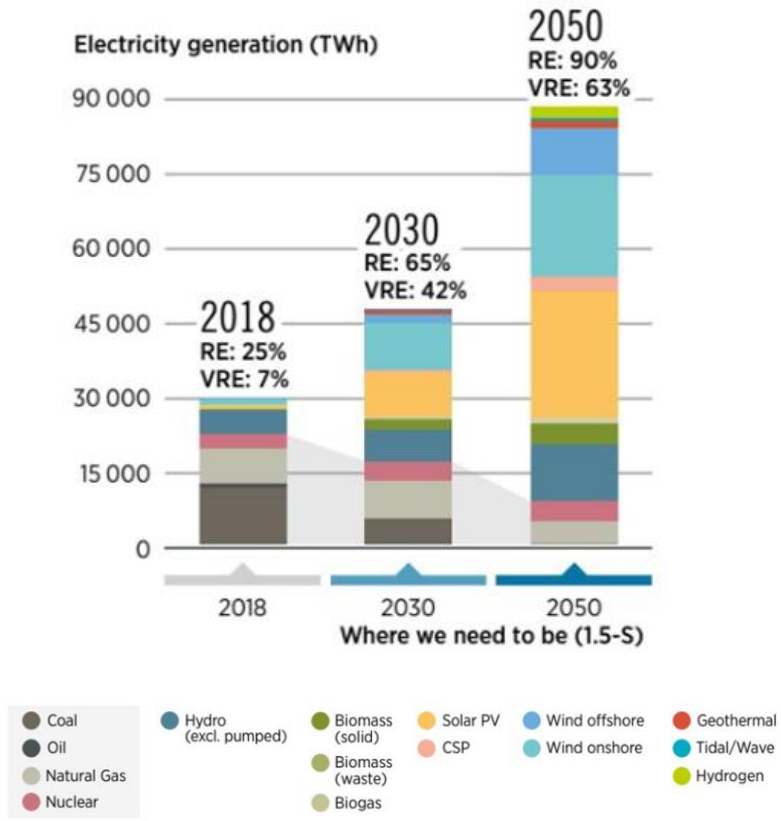


https://elements.visualcapitalist.com/all-the-metals-for-renewable-tech/

KYSYNTÄNÄKYMIÄ

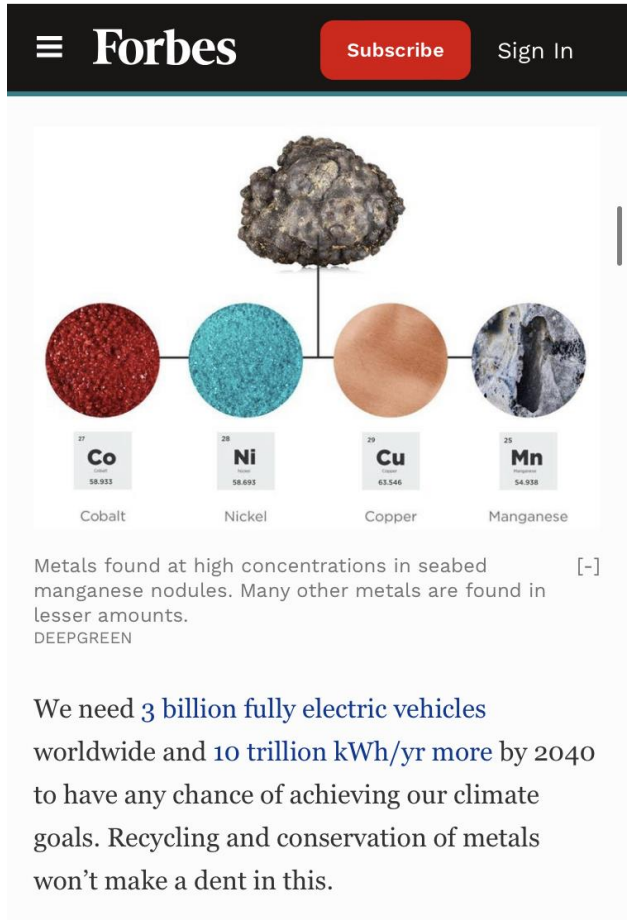


Simon Michaux ~36 000 TWh



https://www.irena.org/Digital-Report/World-Energy-Transitions-Outlook-2022#page-2

Note: 1.5-S = 1.5°C Scenario; CSP = concentrated solar power; GW = gigawatts; PV = photovoltaic; RE = renewable energy; TWh/yr = terawatt hours per year; VRE = variable renewable energy.



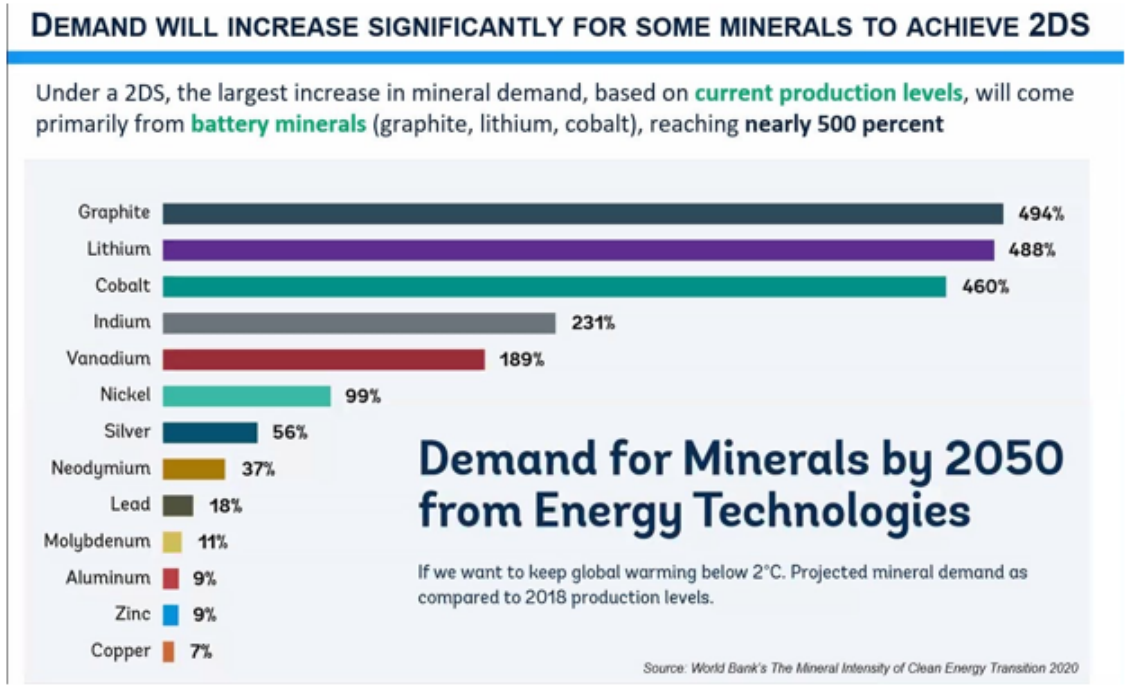
Simon Michaux ~1,4 billion
(no growth of fleet from this)

KYSYNTÄNÄKYMIÄ

% metal required in 2050 for clean energy technologies vs. 2020 overall use (Global SDS ambitious climate scenario).** †

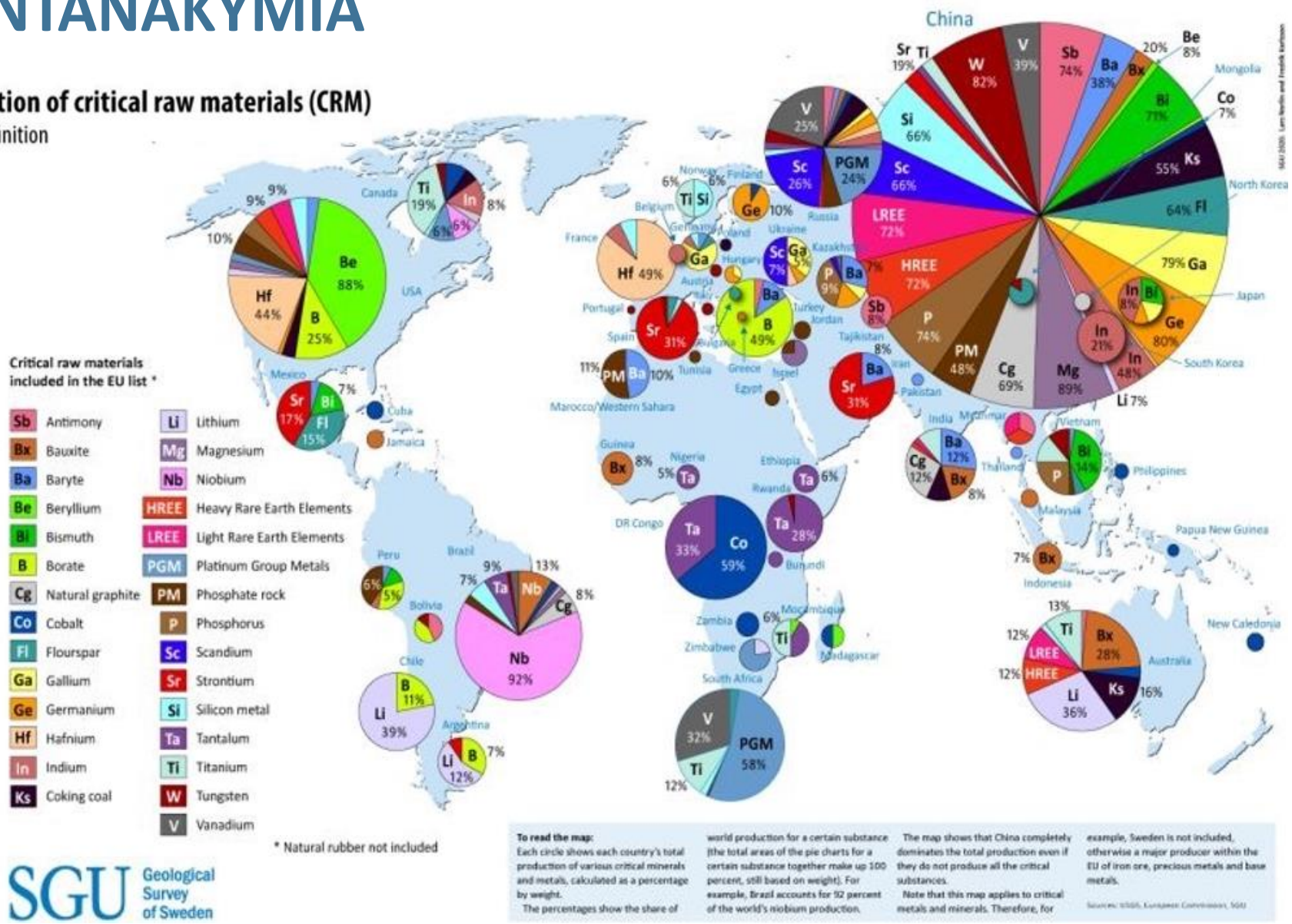
Lithium	2,109%	Silicon	62%
Dysprosium	433%	Terbium	62%
Cobalt	403%	Copper	51%
Tellurium	277%	Aluminium	43%
Scandium	204%	Tin	28%
Nickel	168%	Germanium	24%
Praseodymium	110%	Molybdenum	22%
Gallium	77%	Lead	22%
Neodymium	66%	Indium	17%
Platinum	64%	Zinc	14%
Iridium	63%	Silver	10%

VS.

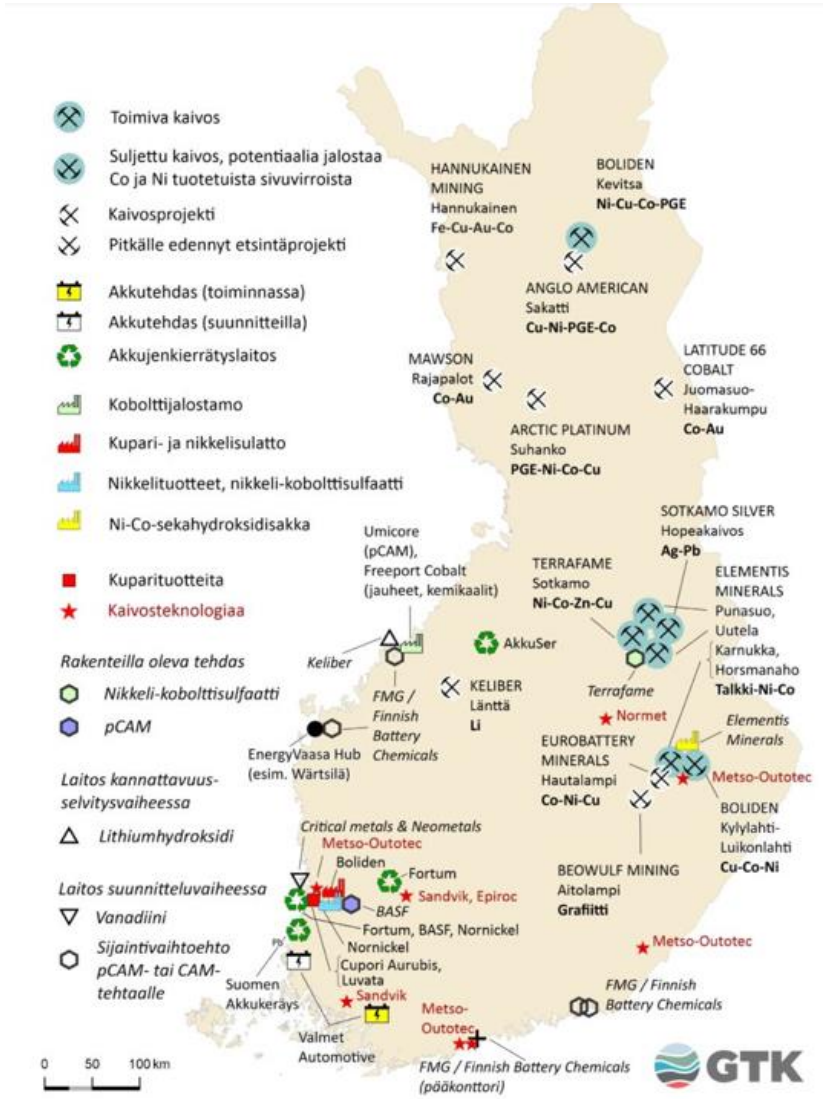


Eurometaux 2022

TARJONTANÄKYMIÄ



TARJONTANÄKYMIÄ



End-of-life recycling input rate (EOL-RIR) [%]

> 50%
> 25-50%
> 10-25%
1-10%
< 1%

H																	He 1%
Li 0%	Be 0%											B* 0.6%	C	N	O	F* 1%	Ne
Na	Mg 13%											Al 12%	Si 0%	P* 17%	S 5%	Cl	Ar
K* 0%	Ca	Sc 0%	Ti 19%	V 44%	Cr 21%	Mn 12%	Fe 31%	Co 35%	Ni 34%	Cu 17%	Zn 31%	Ga 0%	Ge 2%	As	Se 1%	Br	Kr
Rb	Sr	Y 31%	Zr	Nb 0%	Mo 30%	Tc	Ru 11%	Rh 9%	Pd 9%	Ag 55%	Cd	In 0%	Sn 32%	Sb 28%	Te 1%	I	Xe
Cs	Ba 1%	La-Lu[1]	Hf 1%	Ta 1%	W 42%	Re 50%	Os	Ir 14%	Pt 11%	Au 20%	Hg	Tl	Pb 75%	Bi 1%	Po	At	Rn
Fr	Ra	Ac-Lr[2]	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	Uut	Fl	Uup	Lv	Uus	Uuo

[1]Group of Lanthanide	La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
	1%	1%	10%	1%		1%	38%	1%	22%	0%	1%	0%	1%	1%	1%

Talens Peiro, L., Nuss, P., Mathieux, F. and Blengini, G., Towards Recycling Indicators based on EU flows and Raw Materials System Analysis data, EUR 29435 EN, Publications Office of the European Union, Luxembourg, 2018,

EV battery raw materials

Recycling could provide 45-77% of supply by 2050

Eurometaux 2022

VÄLIYHTEENVETO

KYSYNTÄÄ ON, MUTTA ON MYÖS RAAKA-AINEITA…

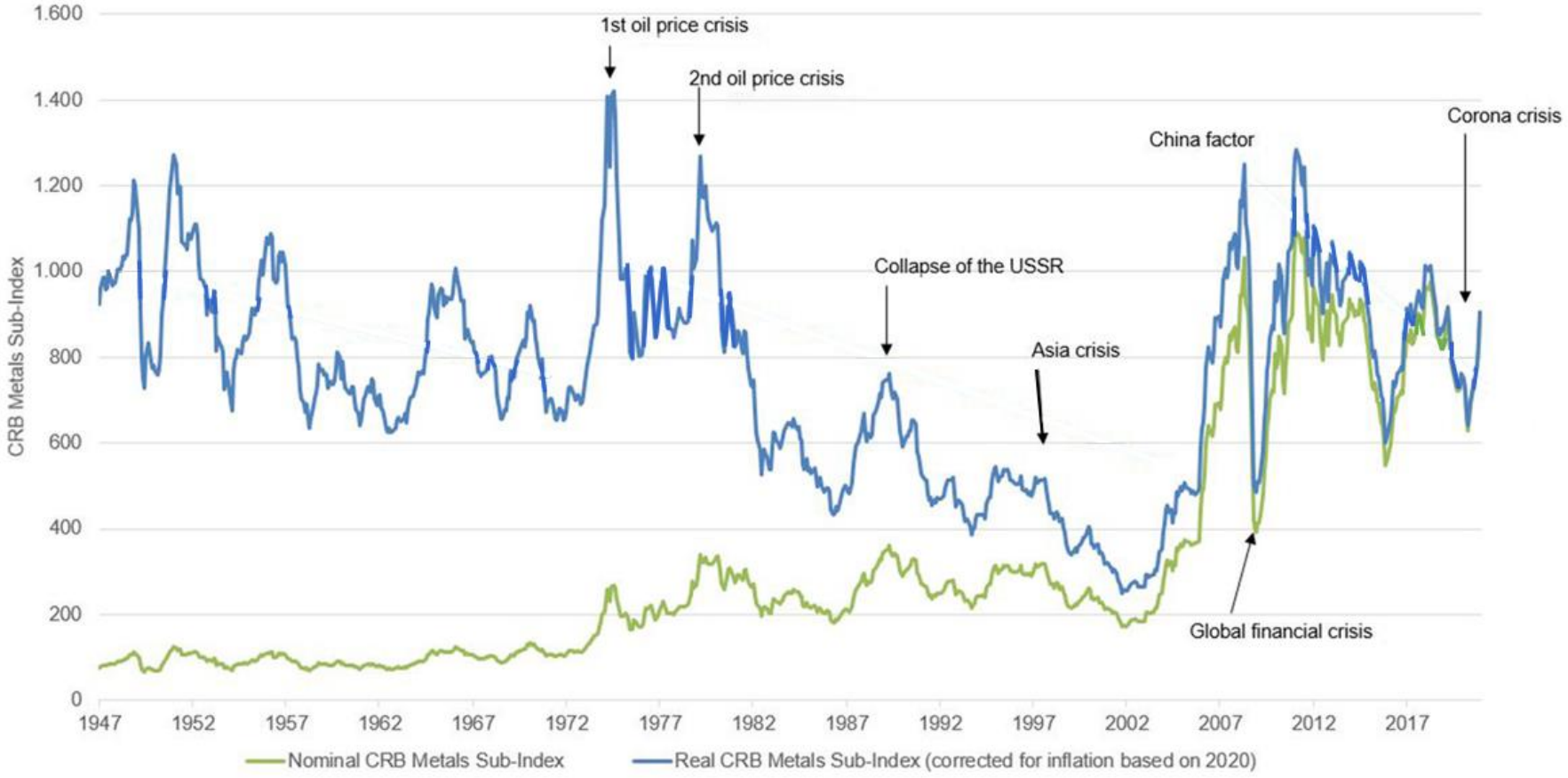
…NOUSEVAT METALLIHINNAT LISÄÄVÄT TALOUDELLISESTI HYÖDYNNETTÄVISSÄ OLEVIEN RAAKA-AINE VARAN MÄÄRÄÄ.

…HISTORIALLISESTI TUOTANNON JA KÄYTETTÄVISSSÄ OLEVIEN VARANTOJEN SUHDE PYSYNYT “SAMANA”

…SO, WHY WORRY?

RAAKA-AINEIDEN SAATAVUUDEN TURVAAMINEN

Lähtökohdat 2000-luvulle tultaessa

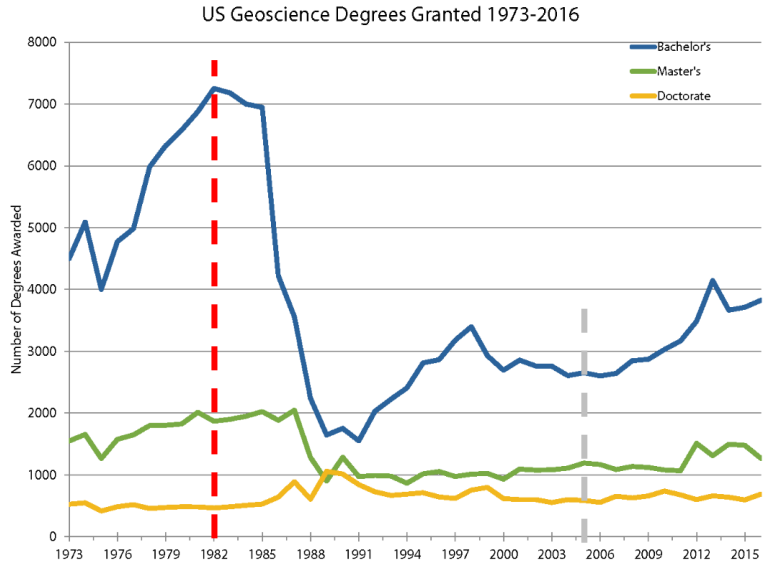


Modfied after: Development of nominal and real metal prices since the Second World War, based on the CRB Metals sub-index adjusted for inflation by the Consumer Price Index (CPI) Basis 06.2000, from Wellmer et al. 2019, p.36, updated by DERA 2021
https://link.springer.com/article/10.1007/s13563-021-00296-x

HAASTEITA – OSAAJAT

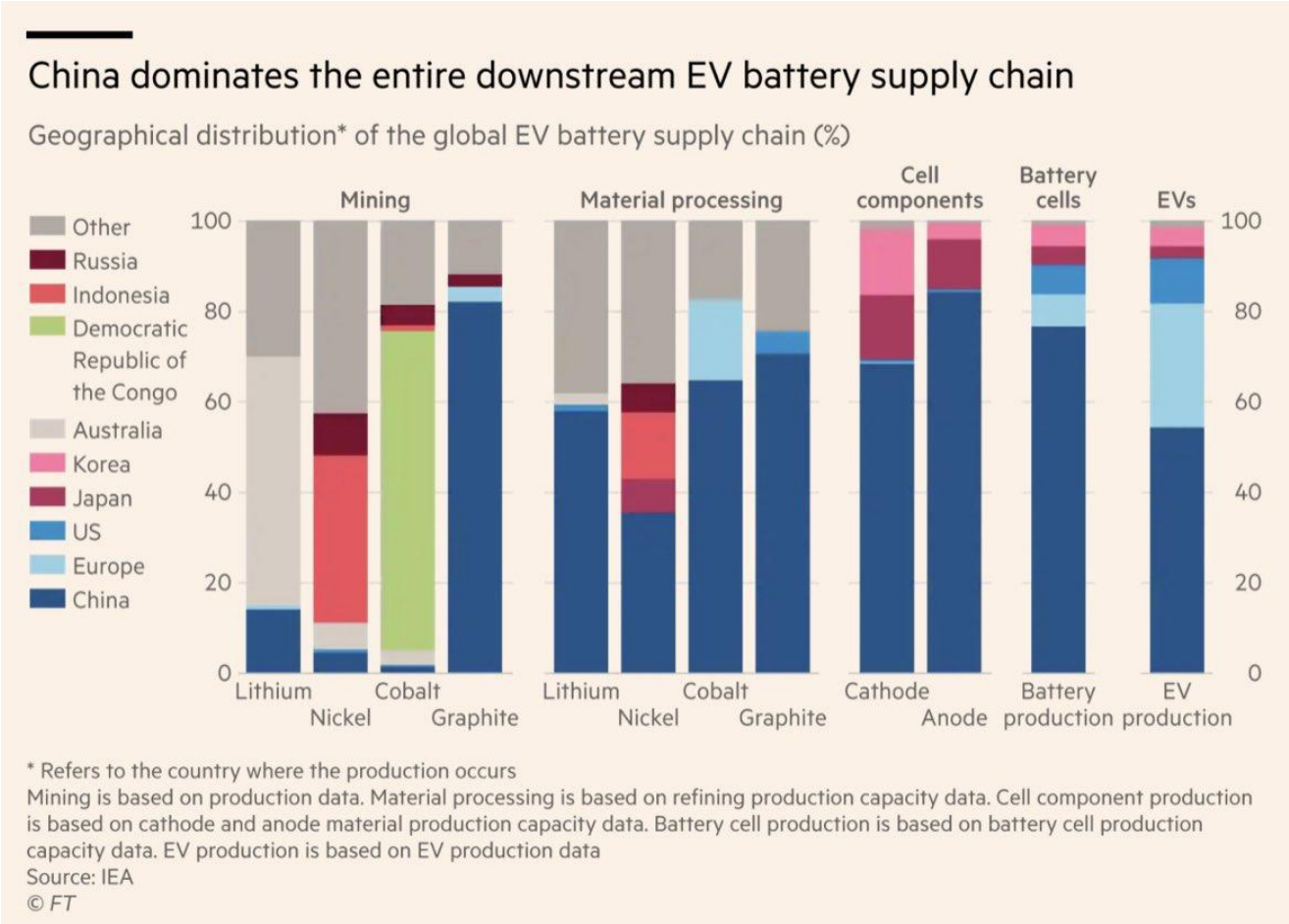
Lähtökohdat 2000-luvulle tultaessa

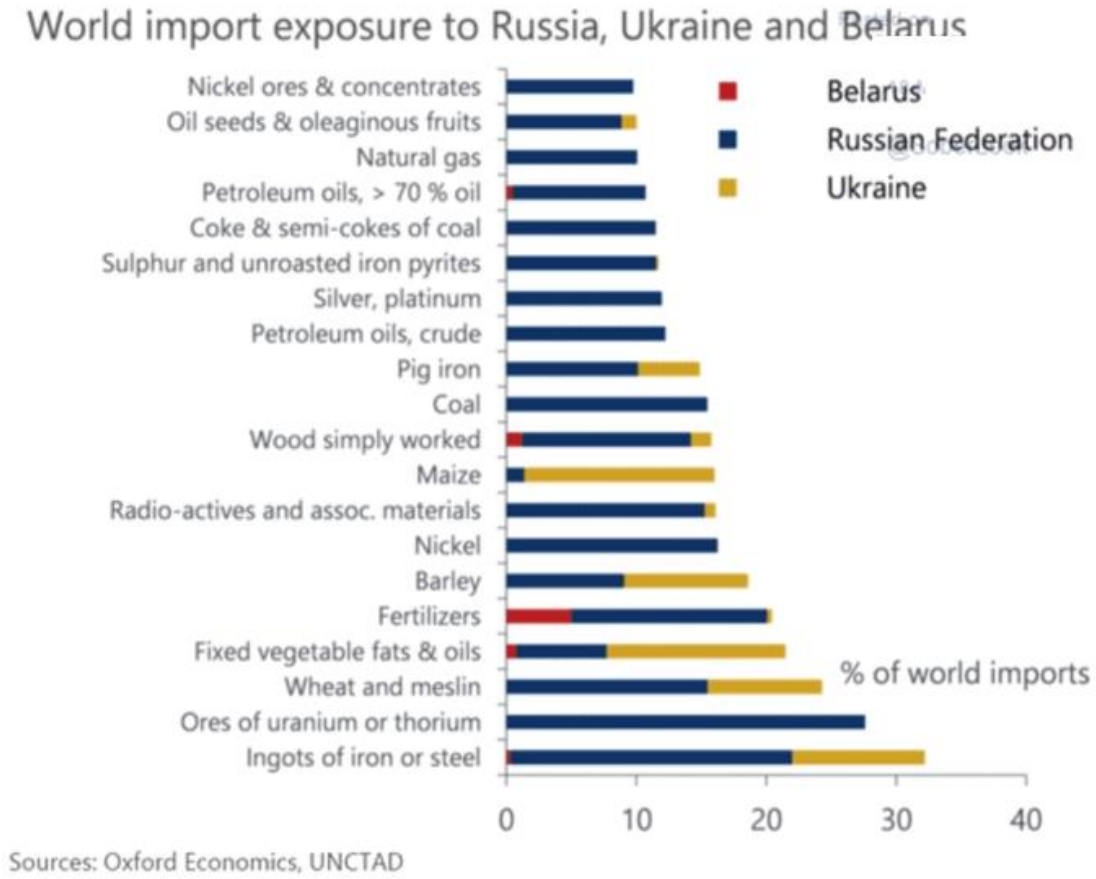
Modfied after: Development of nominal and real metal prices since the Second World War, based on the CRB Metals sub-index adjusted for inflation by the Consumer Price Index (CPI) Basis 06.2000, from Wellmer et al. 2019, p.36, updated by DERA 2021
https://link.springer.com/article/10.1007/s13563-021-00296-x



AGI american geosciences institute
connecting earth, science, and people

HAASTEITA – GEOPOLITIIKKA

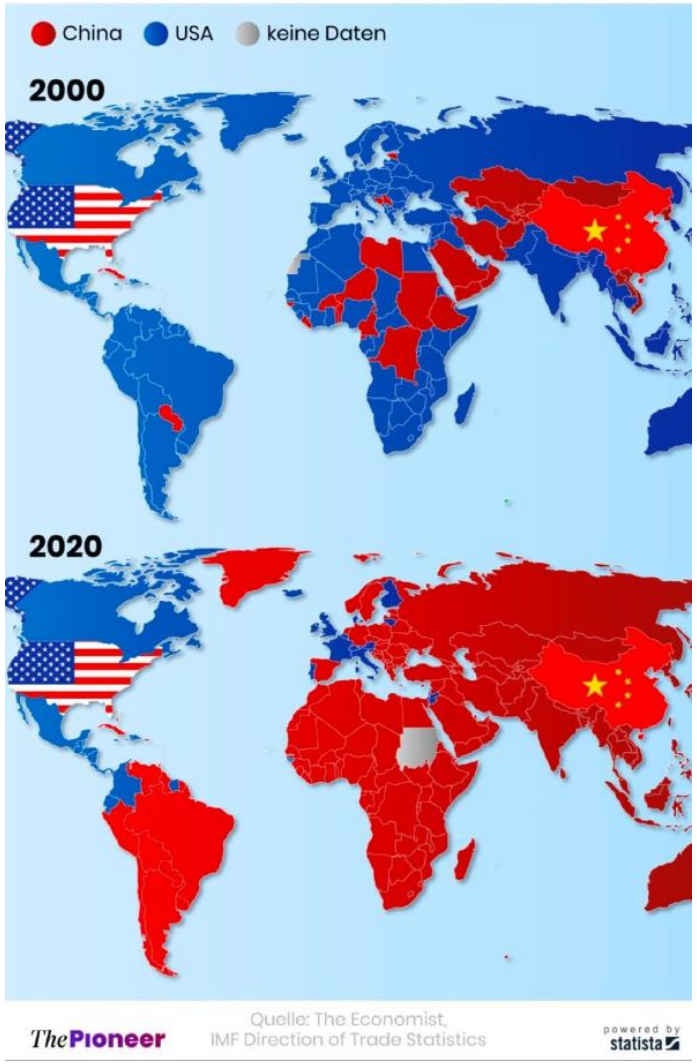




HAASTEITA – GEOPOLITIIKKA

”The European Union's dependency on metal imports is somewhere between 75% and 100% depending on the metal.”

Figure A1. China Going Global 131 countries have signed China Belt and Road Initiative by 04/2019
(Source: Economist 2019, and CCP Belt and Road Portal, , https://www.yidaiyilu.gov.cn/xwzx/bwdt/13764.htm)



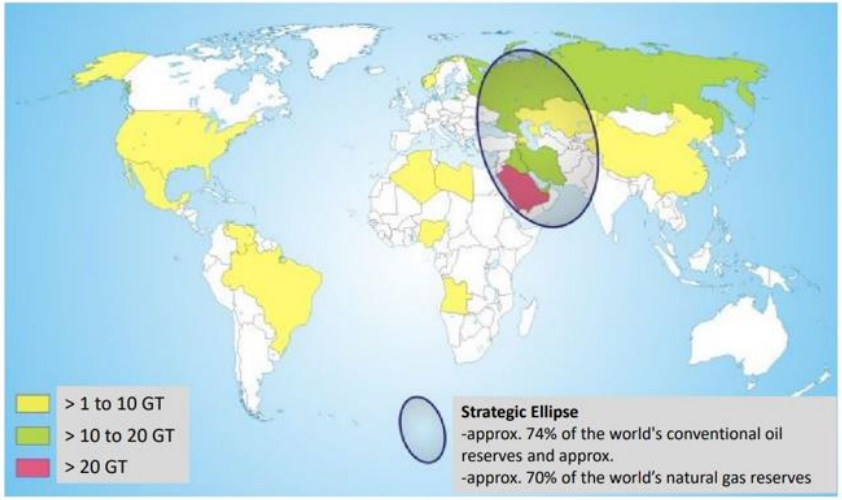


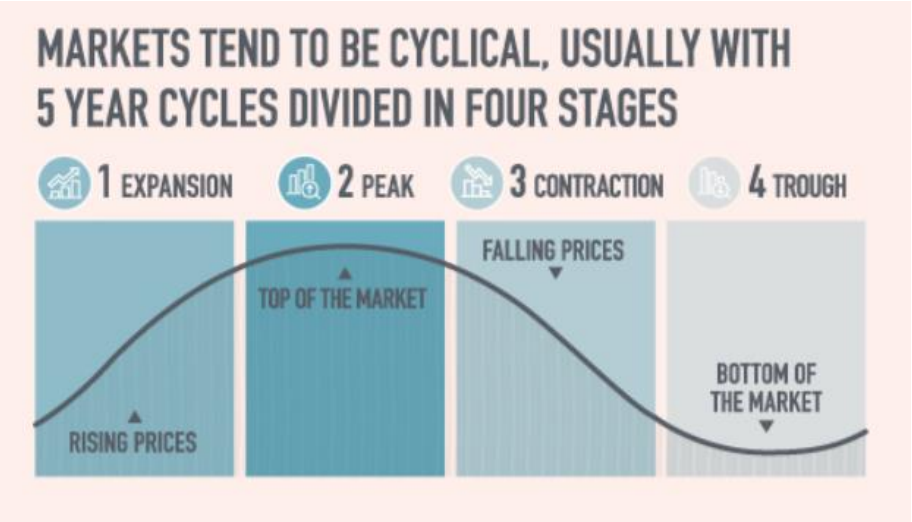
Figure 97 The strategic ellipse
(Source: BTC 2010, Federal Institute for Geosciences and Natural Resources BGR)

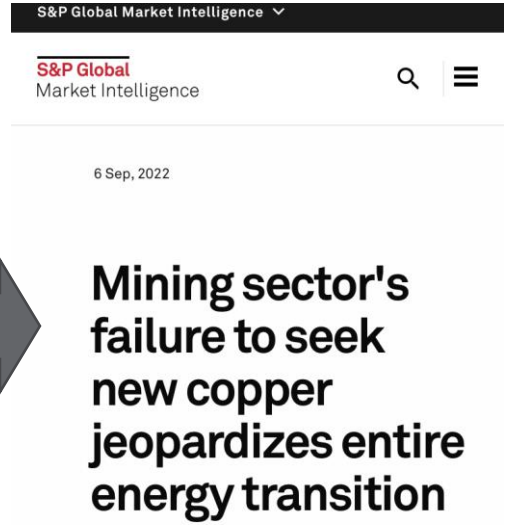
HAASTEITA – RAAKA-AINESEKTORI JA SYKLISYYS

Mining company executives' preference for safe, short-term returns has led to a massive underinvestment in new copper mines and exploration, jeopardizing the metal-intensive energy transition.

The shift toward decarbonization will require vast amounts of copper to extend transmission lines, install new wire in renewable power sources, and electrify existing appliances and cars. **Despite this nearly certain demand, the mining industry has spent the past decade moving much of its profits away from finding and developing major new copper**

S&P Global
Market Intelligence



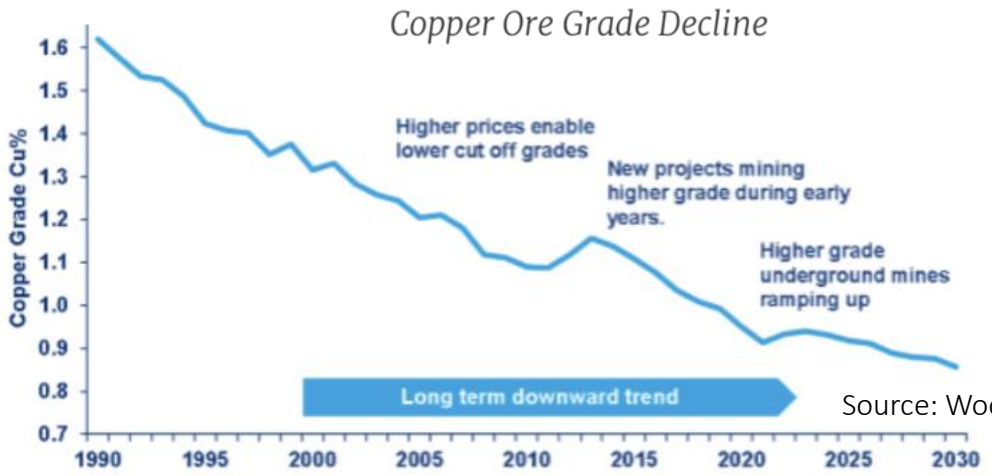

S&P Global Market Intelligence

S&P Global
Market Intelligence

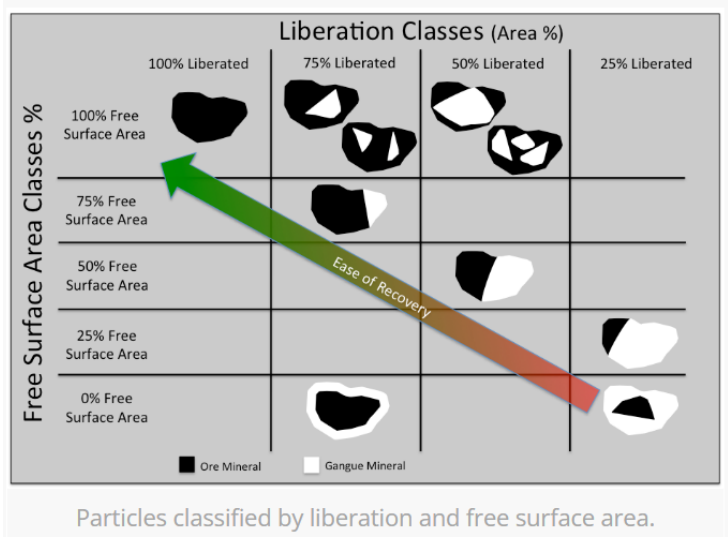
6 Sep, 2022

Mining sector's failure to seek new copper jeopardizes entire energy transition

HAASTEITA – MALMIEN LAATU

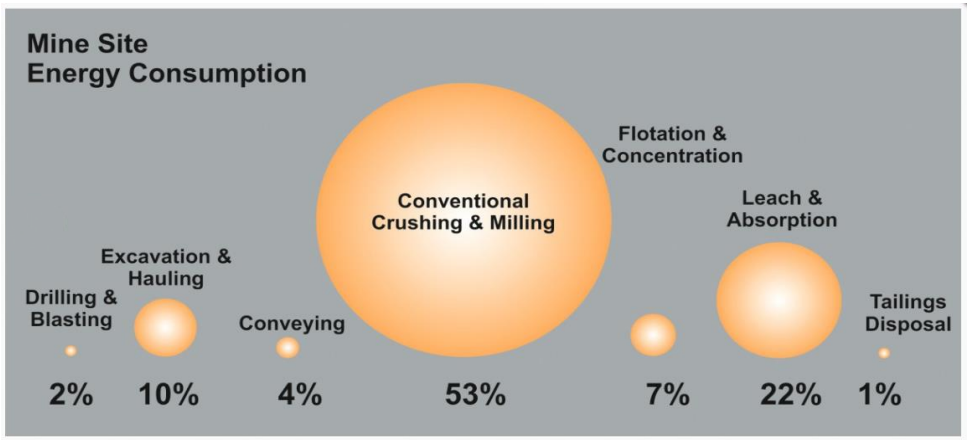


Source: Wood Mackenzie



Particles classified by liberation and free surface area.

Spencer, S and Sutherland, D 2000. Stereological correction of mineral liberation grade distributions estimated by single sectioning of particles. Image Anal Stereol 2000;19:175-182



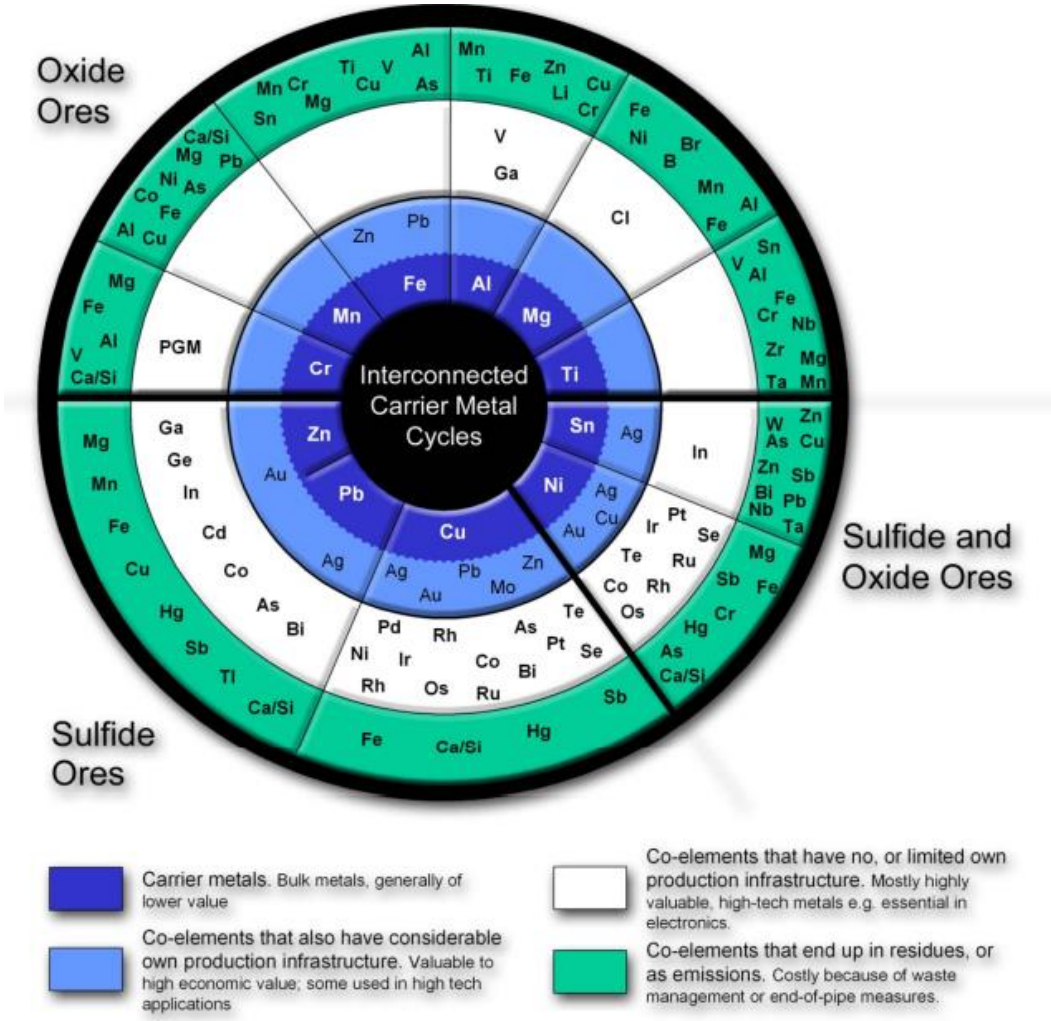
https://www.at-minerals.com/en/artikel/at_Zerkleinerung_Comminution_3154540.html

HAASTEITA – MALMIEN KOMPLEKSISUUS

Critical Raw Material´s (CRM) & Green Energy Transition Materials (GEM)

Number of CRMs and GEMs are typically by product (e.g. Co) and in many cases a processing problem

For some CRMs, albeit important/critical, the global consumption volume low and hence they are unattractive for exploration companies



The metal wheel (after Reuter et al. (2005) and Verhoef et al. (2004)

HAASTEITA – ETSINTÄ MUUTOKSESSA

At the start of the 20th century, surface prospecting accounted for about 70 % of discoveries (Fig. 3.2; Schodde, 2014a), many of which were not close to known ore deposits (thus called a greenfield setting). After World War II, geophysical technologies that had been developed for war-related purposes, followed by

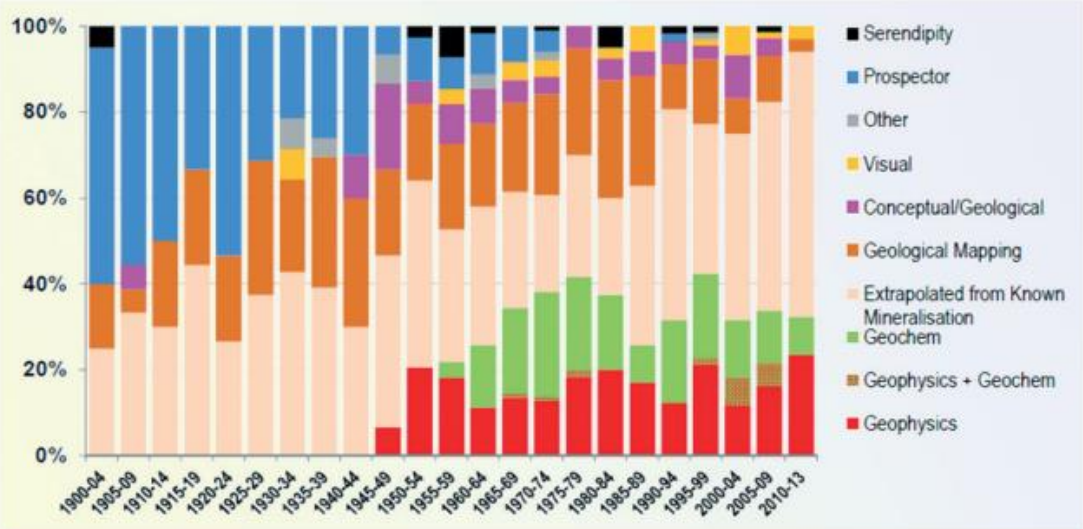
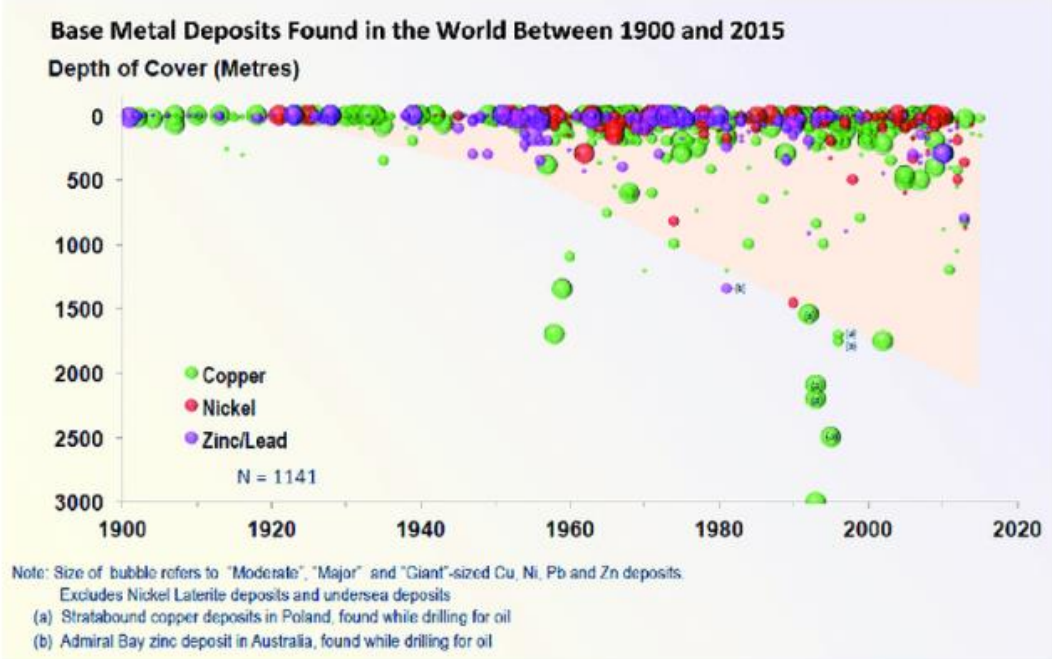


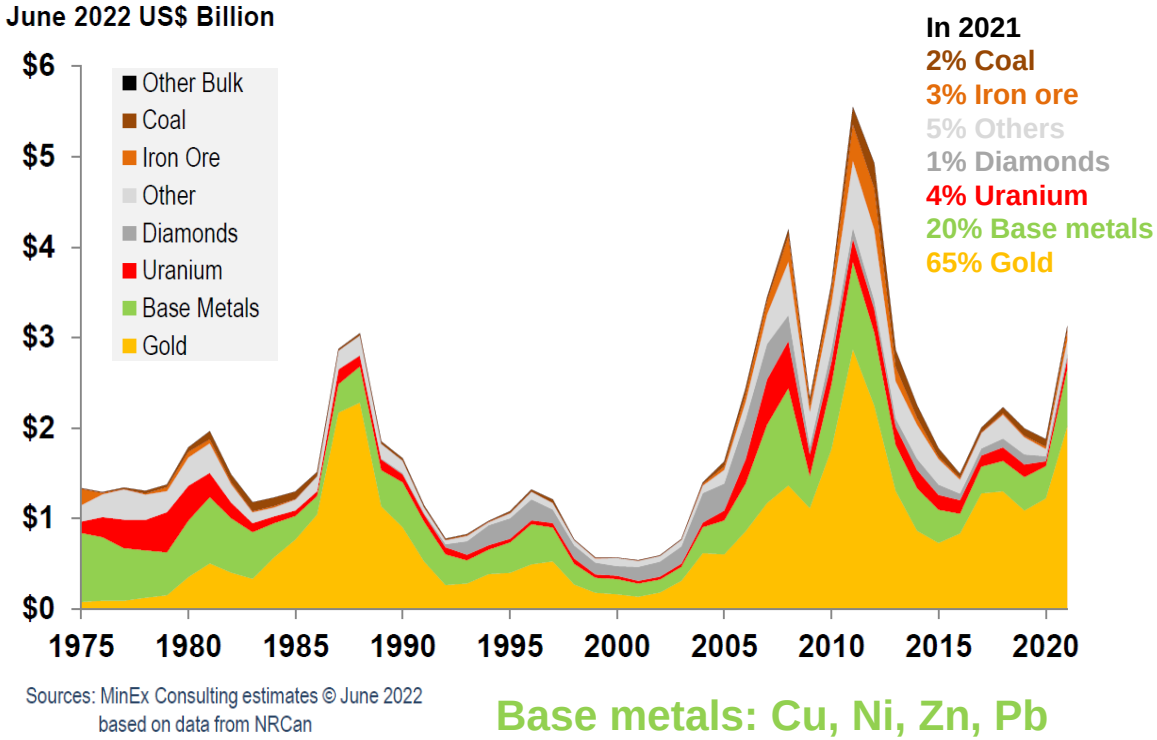
Figure 3.2 Primary search method used at the project scale for Cu, Ni, Pb and Zn deposits to decide what land to claim on which there was an eventual discovery (>0.1 Mt Cu equiv.; 930 deposits with data available out of 1568 discoveries; Schodde, 2014a).



8 Depth of Cu, Ni (except laterite deposits) and Pb-Zn deposits discovered since 1900 (modified from Schodde, 2014a and written communication, August 2016).

HAASTEITA – KUKA ETSII JA MITÄ?

In Canada (reflects the global trends)



Sources: MinEx Consulting estimates © June 2022 based on data from NRCan

Base metals: Cu, Ni, Zn, Pb

R. Schodde (2022)

"Majors are shifting risks to juniors"

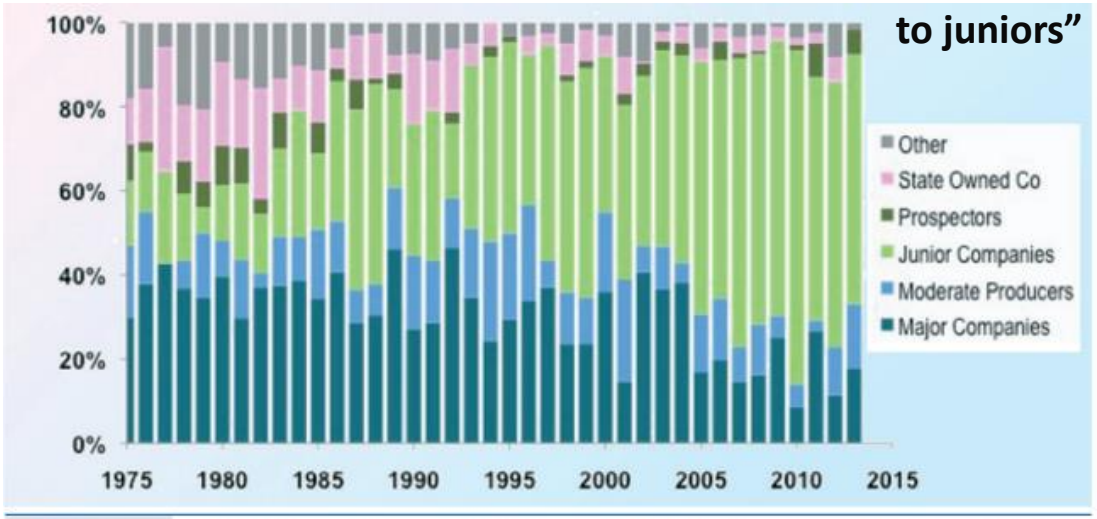


Figure 3.9 **(a)** World exploration expenditures by commodity, 1975-2015 (2015 US dollars; Schodde, 2014b; R. Schodde, personal communication, August 2016). **(b)** Group responsible for discovery (%) of giant, major and moderate deposits in the Western world (excluding bulk commodities), 1975-2013 (Schodde, 2014b).

…and juniors go for the gold?

HAASTEITA – KAIVOKSEN "INELASTISUUS"

Vaikka hinnat nousevat louhintasuunnitelman muuttaminen voi olla vaikeaa

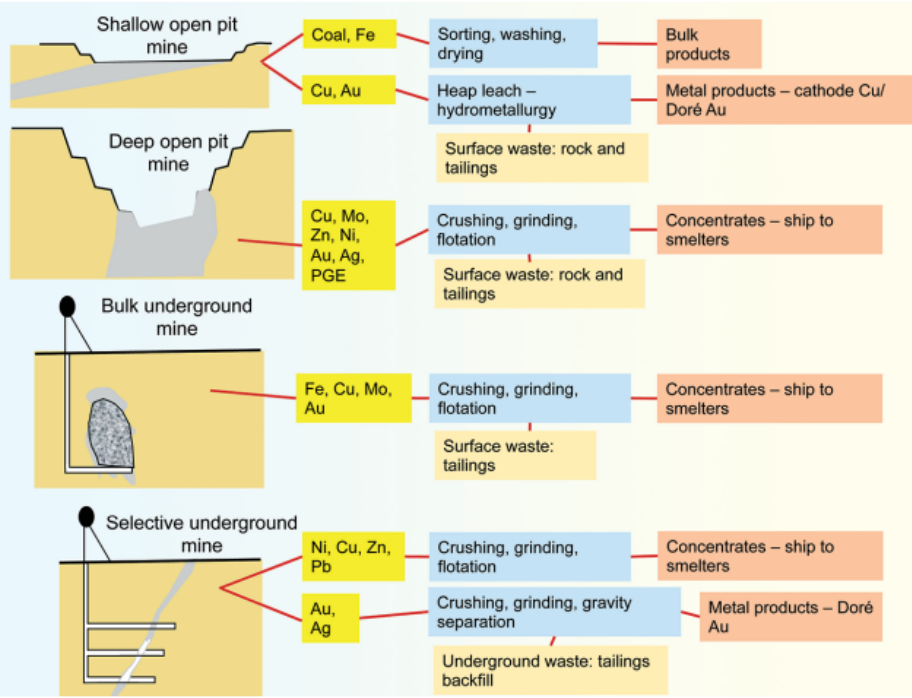
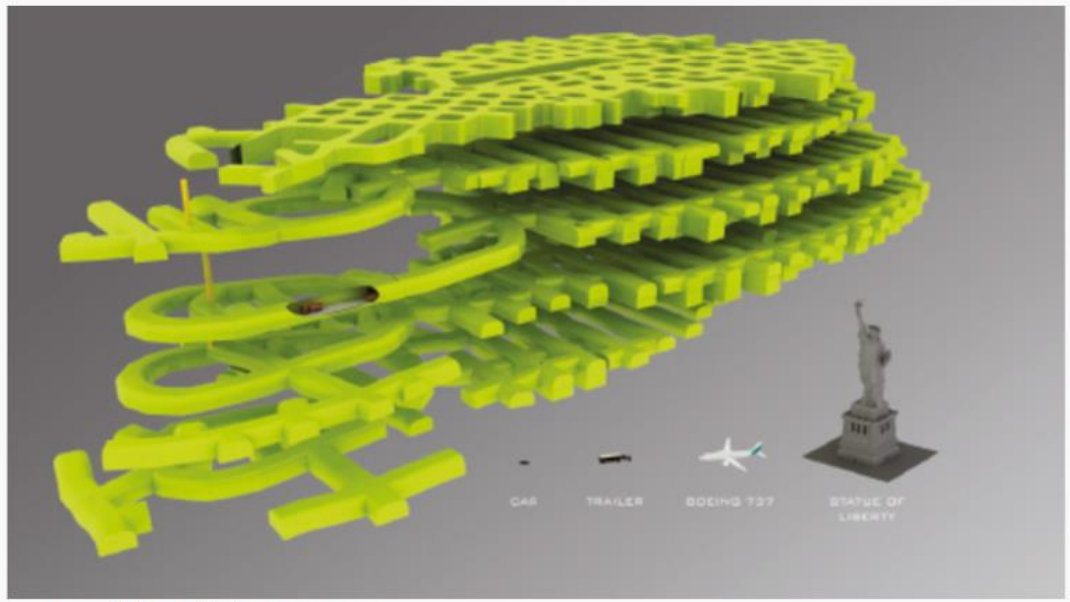


Figure 4.7 Simplified schematic examples of four deposits with different ore body geometries (in grey) and hence different mining methods. The commodities (yellow highlight), processing method (blue highlight), waste (tan highlight) and products (brown highlight) are shown.

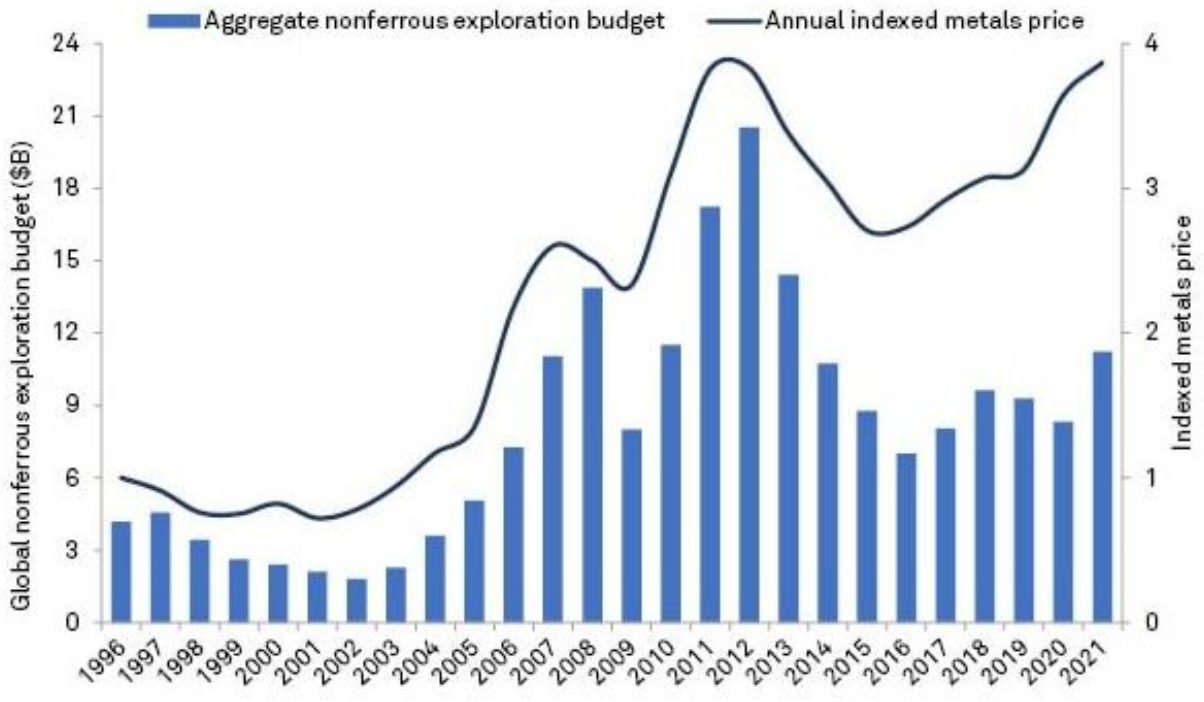


3D Map of the Lefdal Datacenter

https://baxtel.com/data-center/lefdal-underground-mine/photos

HAASTEITA – KUKA USKALTAA INVESTOIDA?

Annual nonferrous exploration budgets, 1996-2021

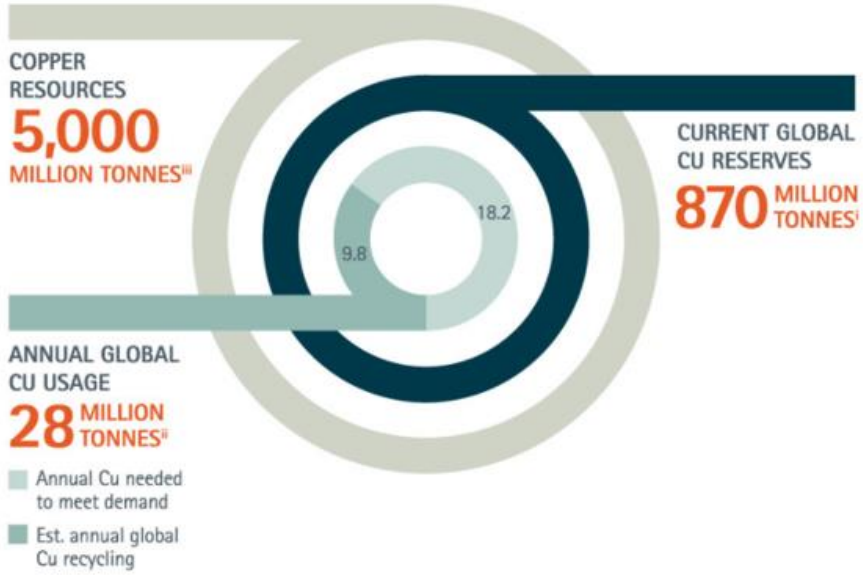


Data as of Sept. 25, 2021.
Source: S&P Global Market Intelligence

- Increasing demand (and prices) of raw materials resulting moderate increase in exploration activity during past 5 years
- W-Europe including EU 3 %
- Dramatic decline in China since 2016

"the mining industry needs to invest $1.7 trillion over the next 15 years to supply enough metals for renewable tech, according to consultancy Wood Mackenzie."

HAASTEITA – MUUTTUVATKO VARANNOT VAROIKSI?



Global copper reserves are estimated at 870 million tonnes (United States Geological Survey [USGS], 2020), and annual copper demand is 28 million tonnes. Current copper resources are estimated to exceed 5,000 million tonnes (USGS, 2014 & 2017).

KUPARIN KUMULATIIVINEN TARVE ERI KIERRÄTYSASTEILLA

Tuleva kuparin tarve (kierrätys mukana) vastaa noin 25-vuodessa sitä määrää, joka on tuotettu koko historian aikana.

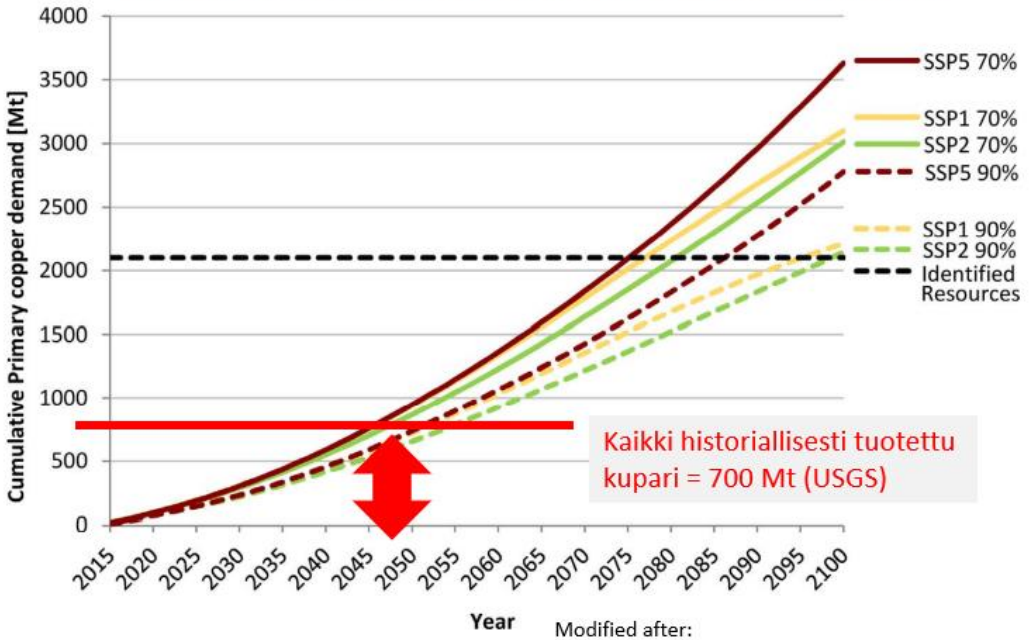


Fig. 5. Cumulative copper demand estimations using the bottom-up method with 70% and 90% recycling rates. The dashed line indicates the identified copper resources.

Modified after:

Estimating global copper demand until 2100 with regression and stock dynamics

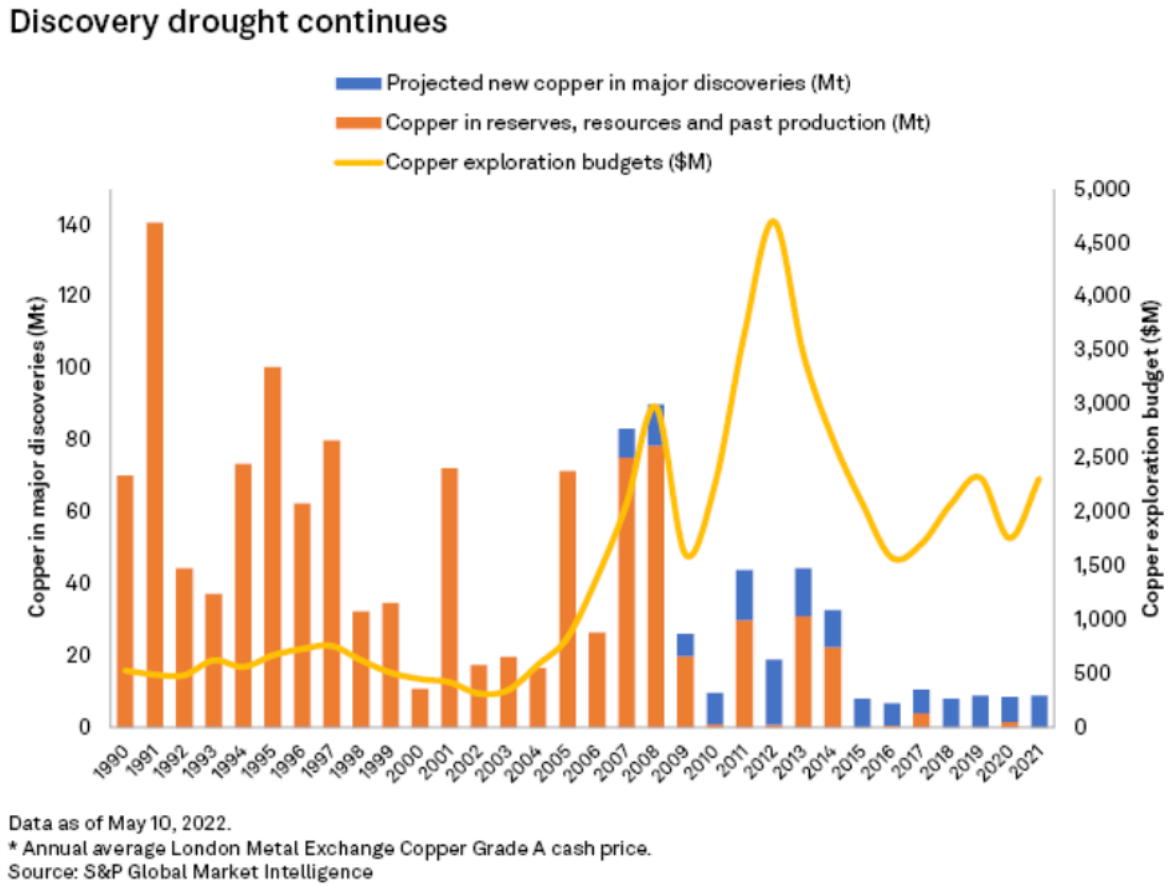
Branco W. Schipper[a,b,c,*], Hsiu-Chuan Lin[a,c], Marco A. Meloni[a,c], Kjell Wansleeben[d], Reinout Heijungs[a,b], Ester van der Voet[a]

Resources, Conservation & Recycling 132 (2018) 28–36

HAASTEITA – LÖYTÖJÄ TARVITAAN LISÄÄ

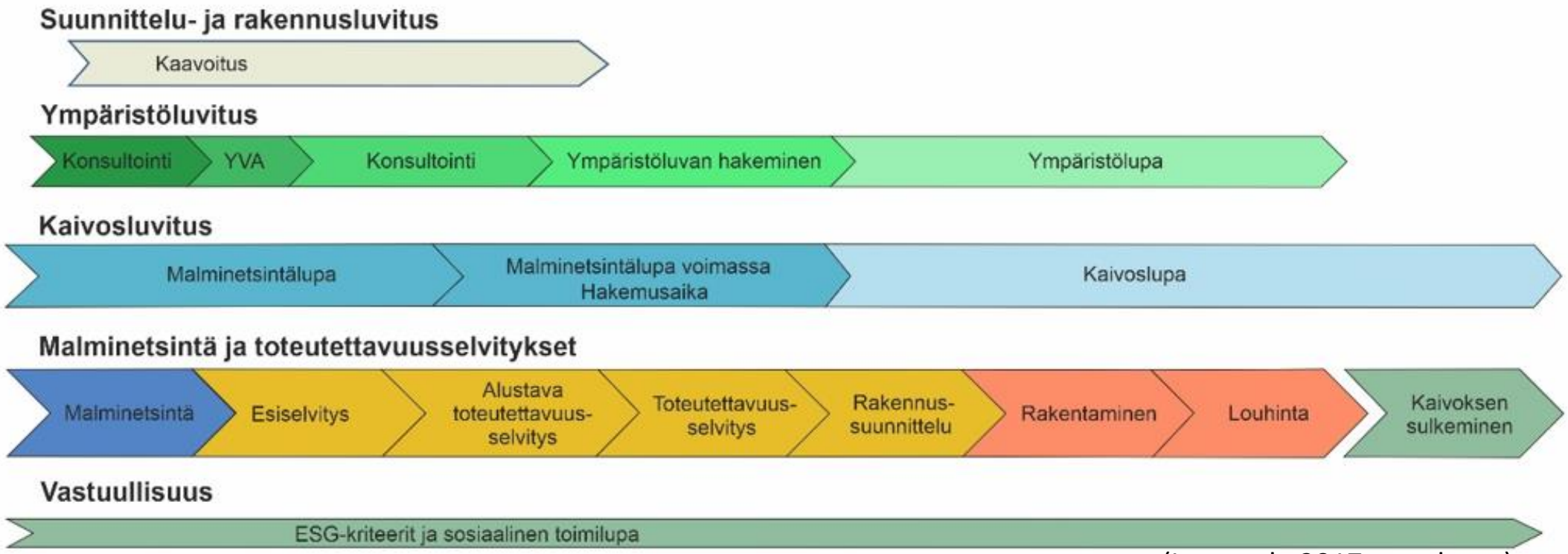
Elevated copper exploration budgets over the past several years has not led to a meaningful increase in the number of recent major discoveries. While the volume has increased by 50 million tonnes compared to our analyst last year, most of the increase came from assets that were discovered in the 1990s.
With copper demand expected to outpace refined copper production, the industry is not making enough new, high-quality discoveries to support the long-term pipeline.

Although a significant amount of copper has been added to the 1990-2021 total discovered compared with the period in our 2021 analysis, the downward trend in rate and size of major discoveries over the past decade continues**. All the new copper came from older, well-developed discoveries from the 1990s. In fact, we have only been able to identify three additional discoveries over the past five years, which added only 5.6 Mt.** This is a direct result of companies shifting more of their exploration budgets toward known deposits and existing mines — a decadelong trend identified in our annual Corporate Exploration Strategies study. Additionally, given the 50.7% increase in the London Metal Exchange average copper price year over year in 2021, it was to be expected that older, producing assets would reflect price-related adjustments to reserves and resources.



https://www.spglobal.com/marketintelligence/en/news-insights/research/copper-discoveries-declining-trend-continues

HAASTEITA – PITENEVÄ KEHITTÄMISHORISONTTI



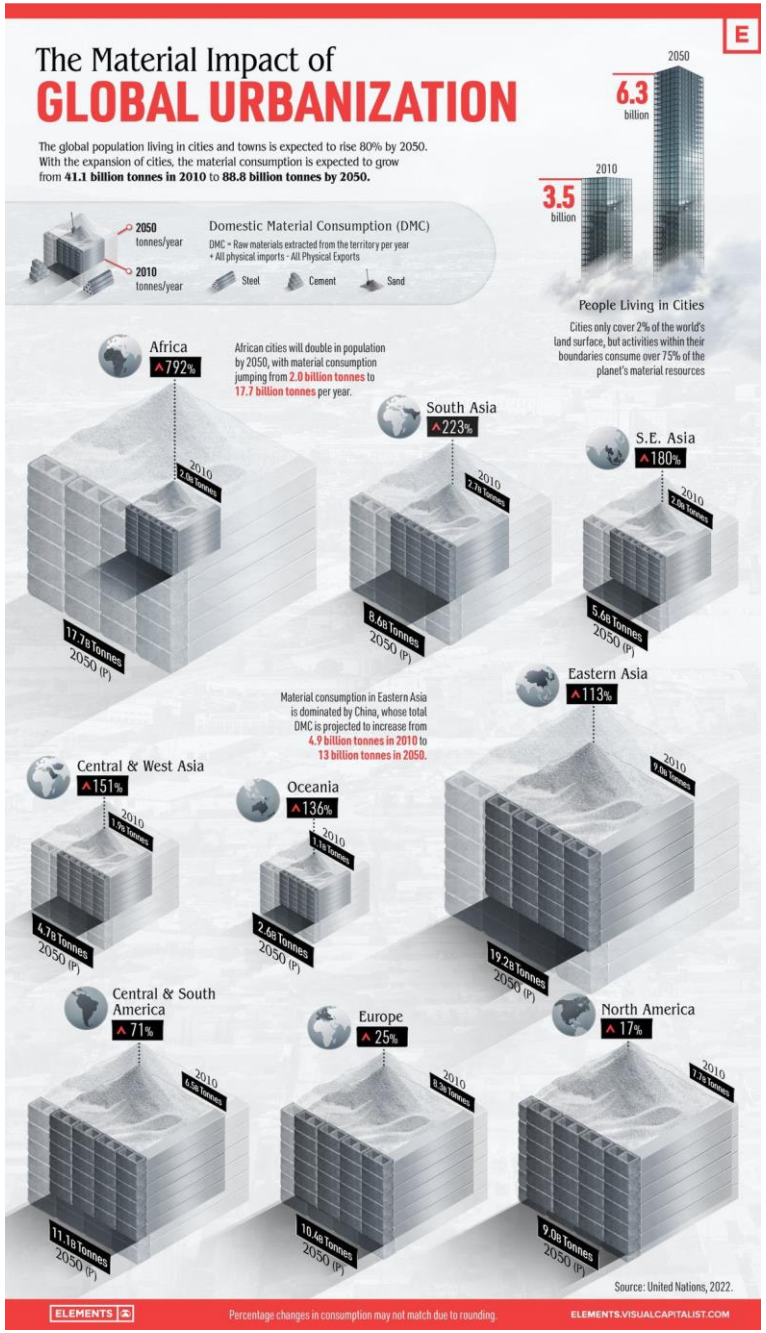
(Lax et al., 2017, muokattu)

"Major copper projects require **3 to 4 years** for completion."
US Bureau of Mines, 1956

"It has taken on average **over 16 years** to move mining projects from discovery to first production."
International Energy Agency, 2021

HAASTEITA – MUITAKIN AJUREITA EDELLEEN

”With the expansion of urban areas, the world’s material consumption is expected to grow from 41.1 billion tonnes in 2010 to about 89 billion tonnes by 2050.”



SIKSI…PERUSTELTUA

- "The shift to a clean energy system," warned the **International Energy Agency (IEA)**, "is set to drive a huge increase in the requirements for these minerals…. A rapid rise in demand for critical minerals – in most cases well above anything seen previously – poses huge questions about the availability and reliability of supply."[7]
- **International Monetary Fund (IMF)**: striving to achieve net zero by 2050 "is likely to spur unprecedented demand for some of the most crucial metals," leading to price spikes that "could derail or delay the energy transition itself."[8]
- **World Bank:** "A low-carbon future will be very mineral intensive because clean energy technologies need more materials than fossil-fuel-based electricity generation technologies.[9]
- **European Commission:** "Access to resources is a strategic security question for Europe's ambition to deliver the Green Deal…. As demand for fossil fuels decreases, increased demand for raw materials, including rare earths and metals, could lead to new supply challenges in the course of the energy transition."[10]
- **US Senate Energy Committee:** "The United States' mineral import dependency and the concentration of mineral supply from certain countries are broadly recognized as growing threats to economic growth, competitiveness, and national security. The resulting price and supply chain volatility has prompted a greater focus on policies related to mineral security and critical minerals that are important in use, susceptible to supply disruption, and for which no substitutes are readily available."[11]
- **Biden administration:** "The United States needs resilient, diverse, and secure supply chains to ensure our economic prosperity and national security…. 'Supply chain,' when used with reference to minerals, includes the exploration, mining, concentration, separation, alloying, recycling, and reprocessing of minerals."[12]

EU Critical Raw Materials Act


ELECTRIC POWER | ENERGY TRANSITION | METALS — 14 Jul 2022 | 21:12 UTC

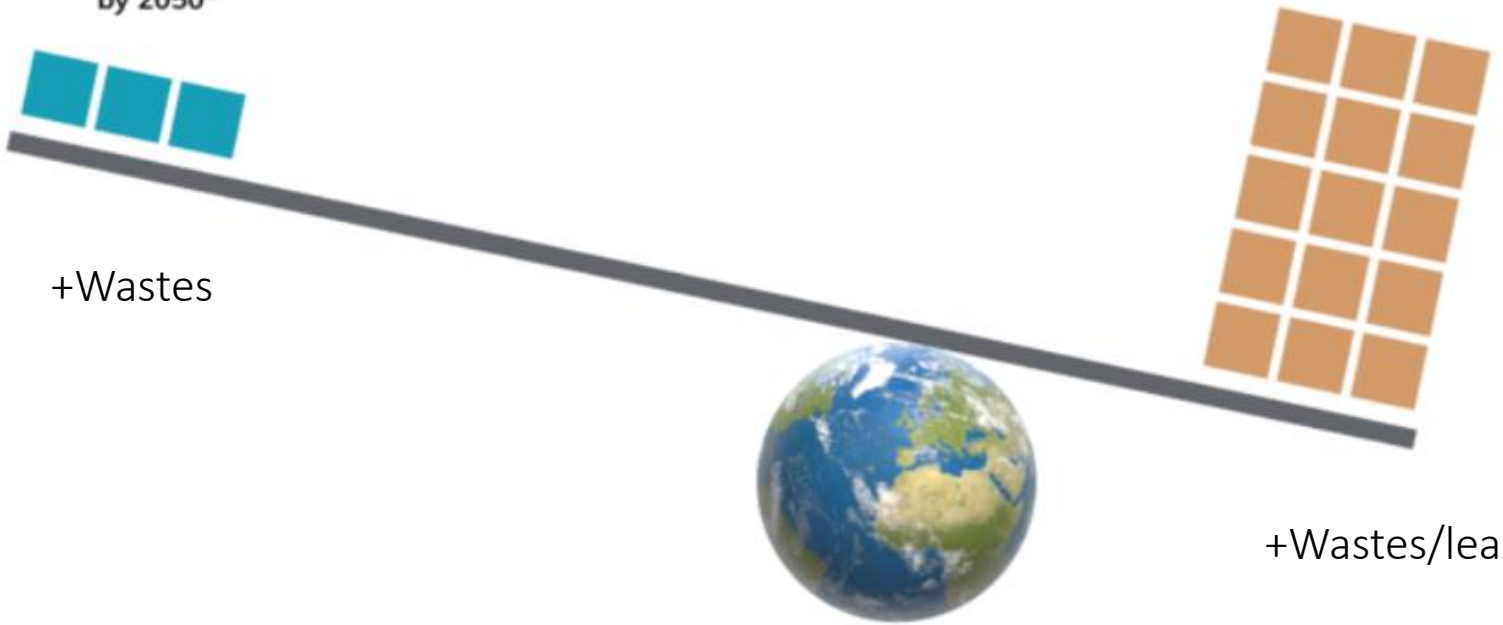
World copper deficit could hit record; demand seen doubling by 2035: S&P Global

June 2022 S&P Global | The Future of Copper: Will the looming supply gap short-circuit the energy transition?

METALLIT VIVUTTAVAT KOHTI HIILIVAPAATA TULEVAISUUTTA

~3 billion tons of metal/minerals
is needed for the transition
to low-carbon world
by 2050*

+Wastes



World uses **~15 billion tons**
coal+oil+gas** every year

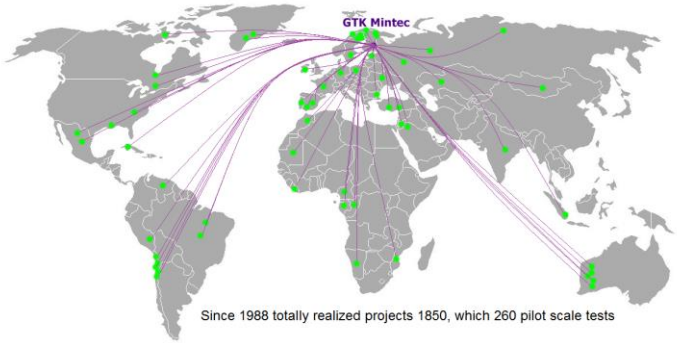
+Wastes/leaking gasses etc.

* The Beyond 2 Degrees Scenario (B2DS): Aims to limit with a 50% chance global temperature rise to 1.75°C. above pre-industrial levels. (Hund, K., La Porta, D., Fabregas, T.P., Laing, T. & Drexhage, J. 2020.)

** gas counted as tonne oil equivalent

EDISTÄMME HYVIN KONKREETTISESTI SÄHKÖISTYMISEN MAHDOLLISUUKSIA

- **GTK Mintec** on Outokummussa sijaitseva, Euroopassa ainutlaatuinen mineraali- ja kiertotalousalan tutkimusinfrastruktuuri
- Mineralogian laboratorio ja mineraaliprosessoinnin pilotti-mittakaavan koetehdas
- Erikoistunut palvelemaan globaalisti mm. kiertotalouden-, kaivos-, metalli-, ympäristö- ja kemianteollisuuden alan toimijoita
- Merkittävä toimija maailman suurimmassa mineraalialan osaamiskeskittymässä: European Institute of Innovation and Technology (EIT) – Raw Materials
- Rakentaa strategisia yhteistyökumppanuuksia alan huippuosaajien kanssa



YHTEENVETONA

Muuttuvat ja kasvavat materiaalitarpeet tulevat haastaman raaka-ainetuotantoketjun. Vaikka erityyppisiä varantoja on, ne eivät välttämättä muutu varoiksi tarpeeksi nopeasti (tai koskaan). Tämä lisää riskiä erilaisista saatavuusongelmista. Etsintää, kaivosinvestointeja, sujuvaa luvittamista, paikallista hyväksyntää, kierrätystä ja kuluttamisen hillintää, kaikkea tarvitaan - keskustelu strategisesta autonomiasta kriittisten raaka-aineiden ja energian osalta pysynee aktiivisena…

“The scarcity of mineral resources is ultimately neither physical nor geological, but rather political, economic and environmental: it mostly depends on the energy, environmental and societal price that humankind is willing to pay in order to access them.”


GTK