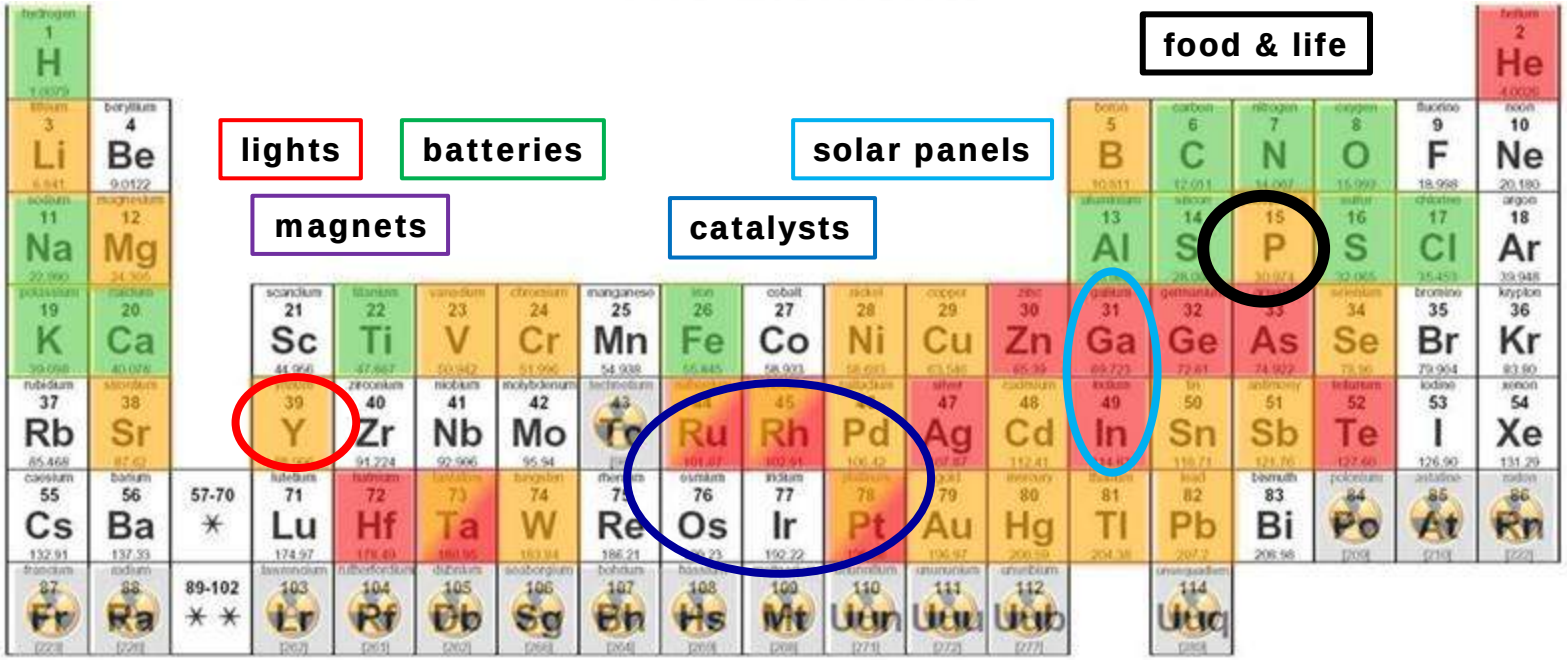
Material Scarcity

– in Search of Solutions –

Endangered Elements

- Metals and Phosphorus -

The Elements



Serious threat in next 100 years

Rising threat from increasing use

Limited availability future risk to supply

Abundant element

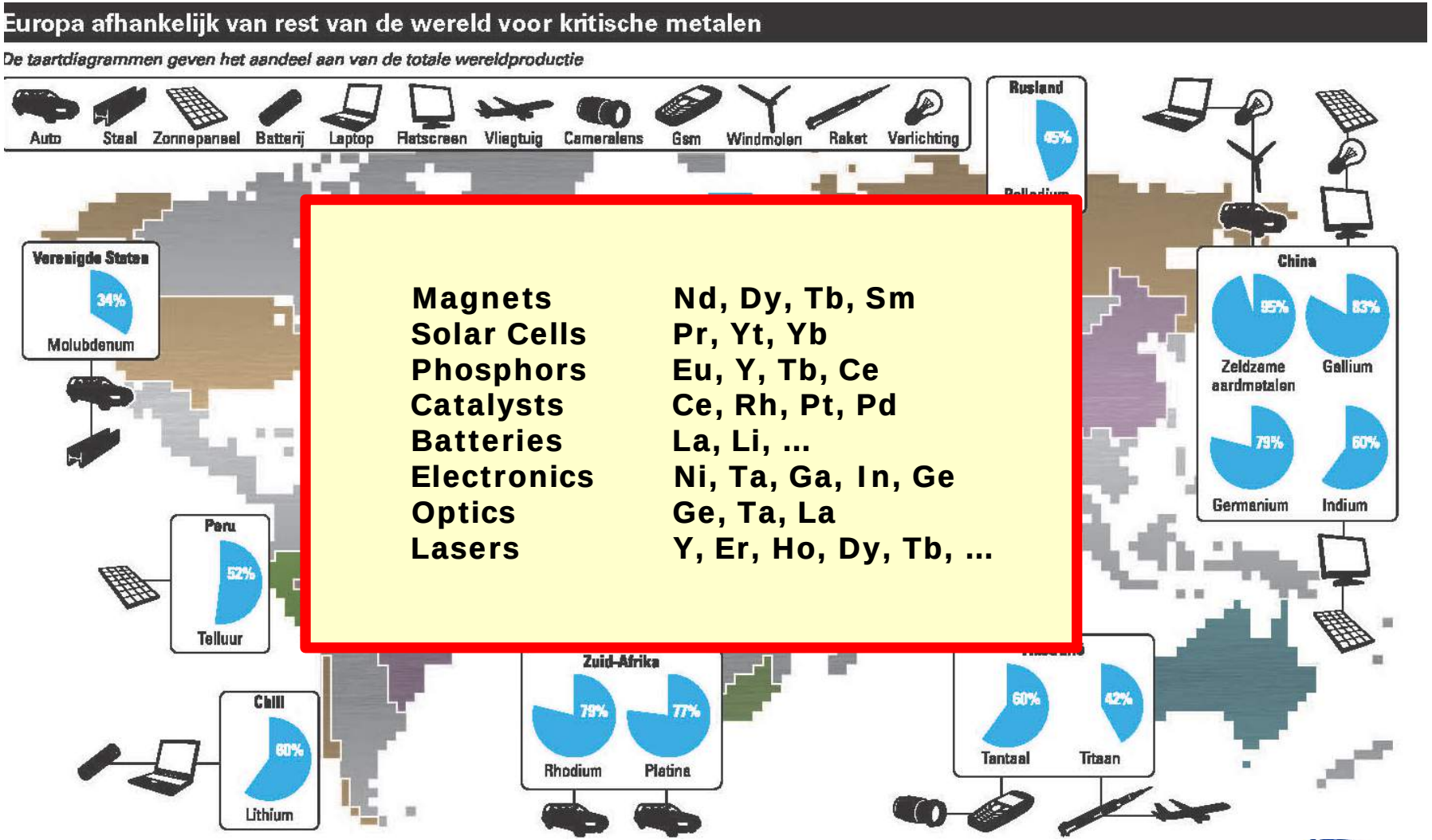
Formed by radioactive decay

Insufficient information

China dominates the rare earth metals

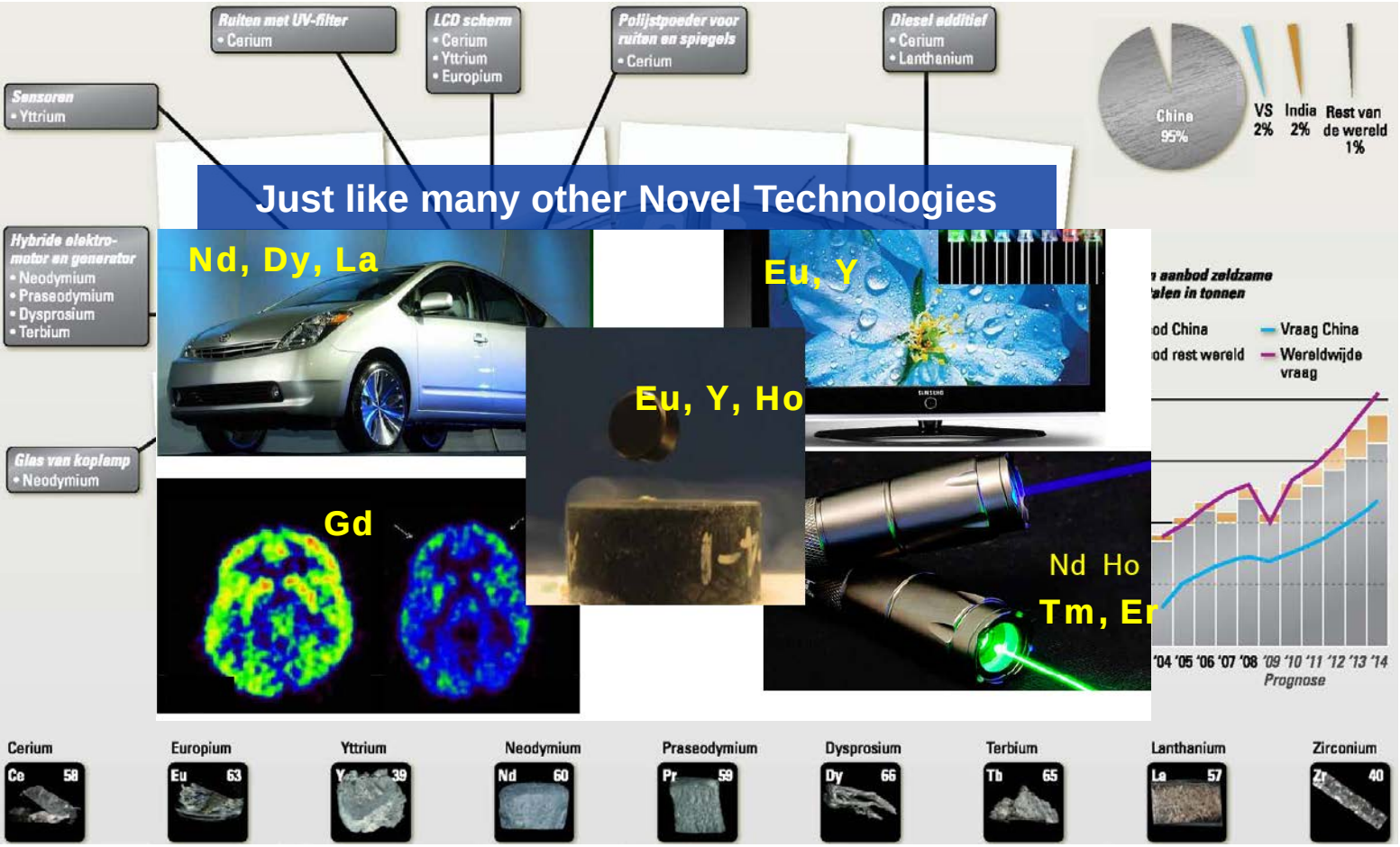
NRC-Handelsblad January 16, 2010

Hybrid cars, flat screens, and solar panels contain rare (earth) metals. Most are obtained from China and unstable regions. The Western world is vulnarable.



Without rare earth metals, no car

NRC-Handelsblad January 22, 2010



Neodymium

500 g

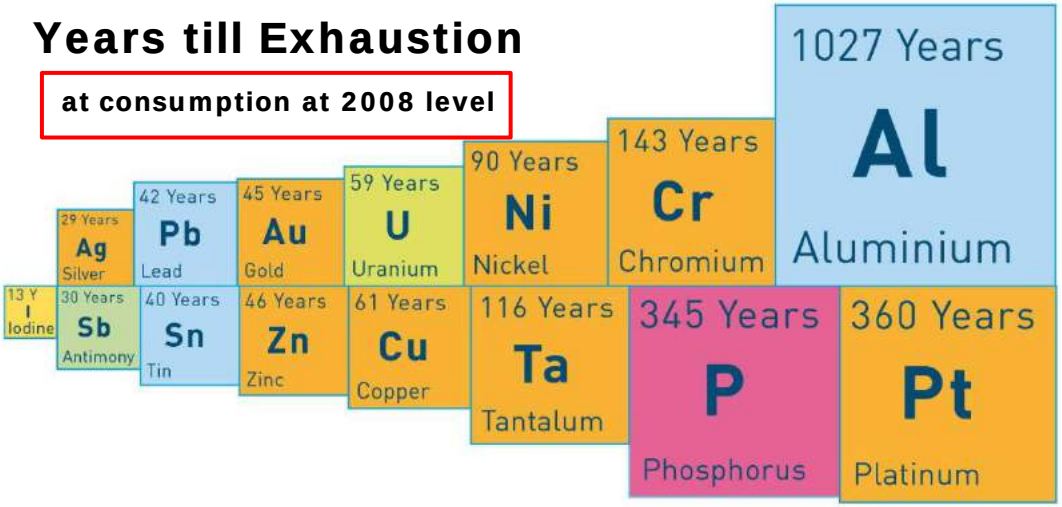
Toyota Prius
Mercedes S 400

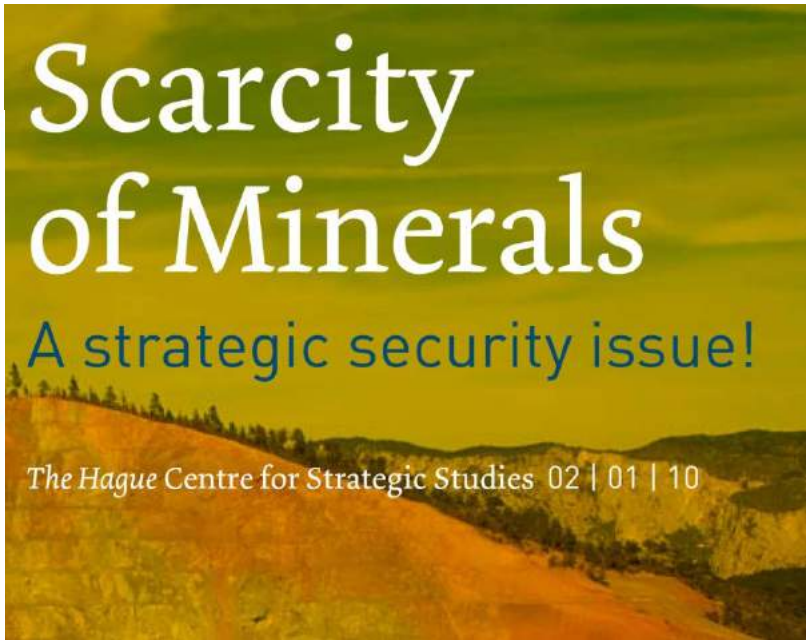
200 kg

Windturbine 16m

Years till Exhaustion

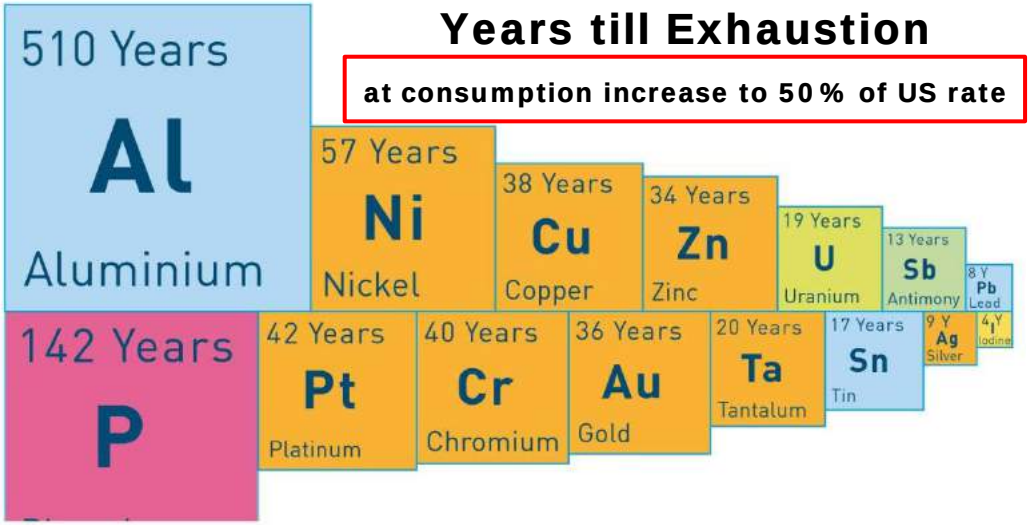
at consumption at 2008 level





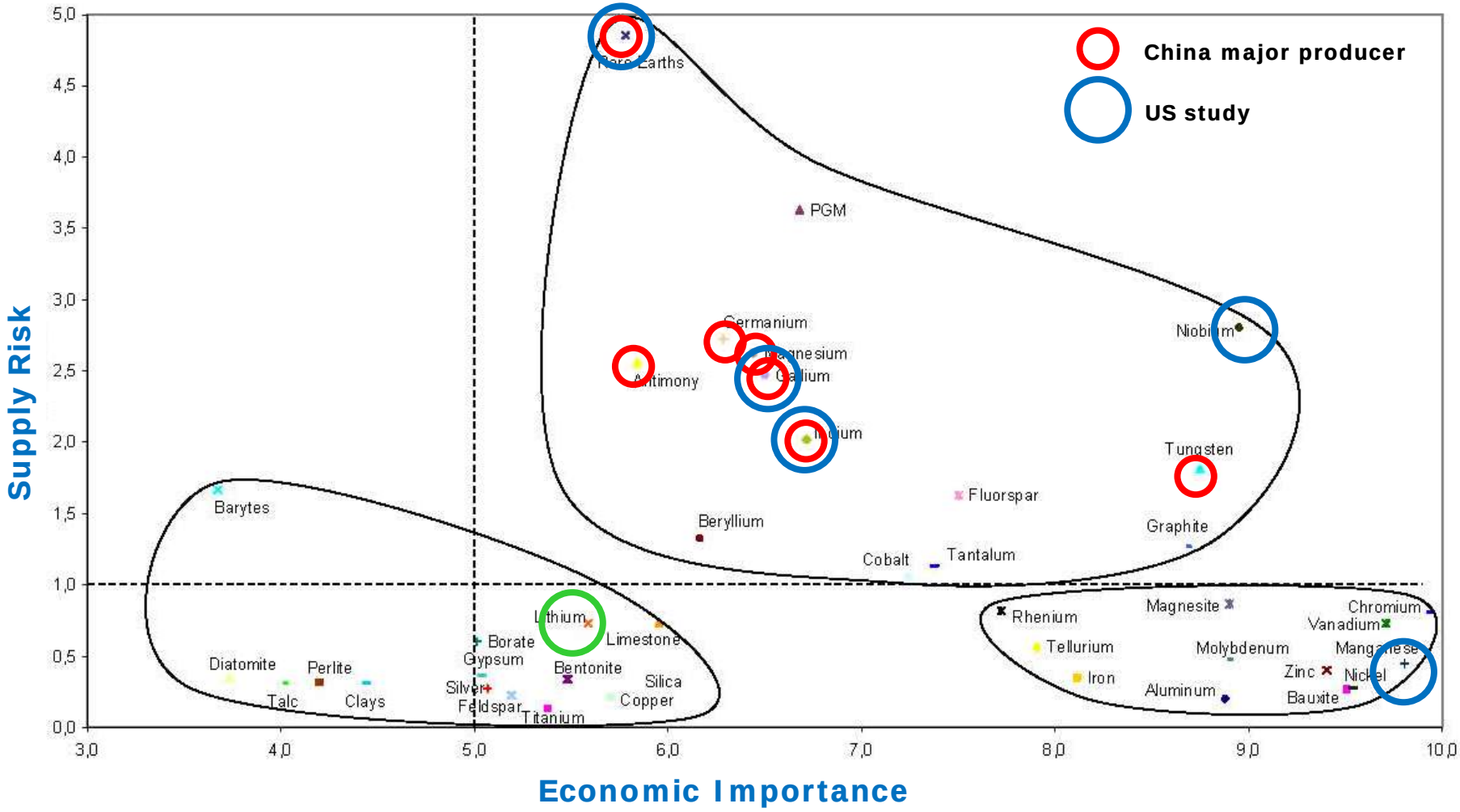
Years till Exhaustion

at consumption increase to 50% of US rate



War on Unobtanium

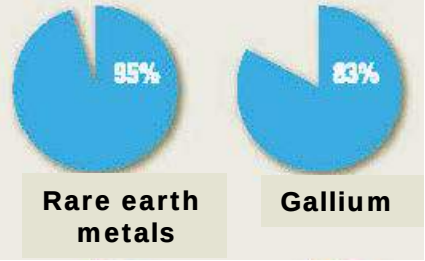
EU Critical Materials List



Scarcity of Minerals

MINERAL	SHARE[1]	EXPORT QUOTA (2010)	MAIN APPLICATIONS
DYSPROSIUM	99%	Full export ban	Permanent magnet (electrical vehicles; windturbines)
LANTHANUM	95%	ca. 9.000 tonnes[2]	NiMH battery (electrical vehicles)
NEODYMIUM	95%	ca. 5.000 tonnes[3]	Permanent magn vehicles; windtur
ANTIMONY	87%	57.500 tonnes	Semiconductors,
TUNGSTEN	84%	14.300 tonnes	High-performanc cutting tools
GALLIUM	83%	-	Semiconductor (s defense)

Chinese share of world production



China keeps rare earth metals for itself

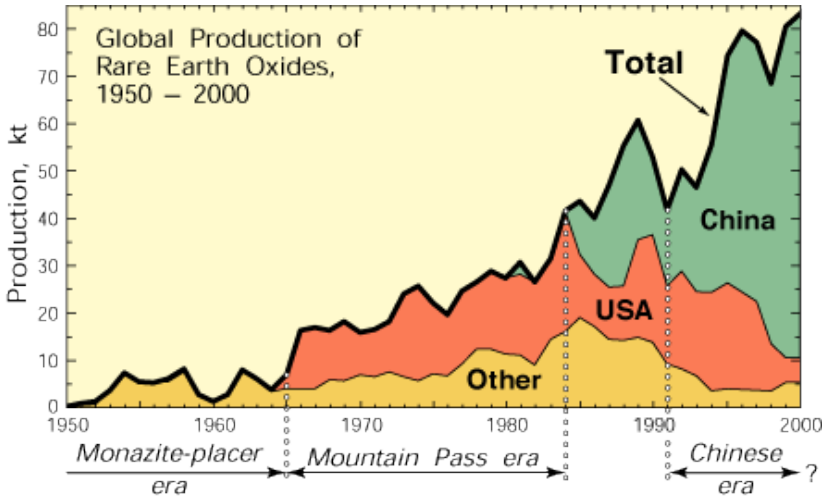
(NRC – Dutch Newspaper)

China's Rare Earth Element Export Quotas

	Export Quotas (Tonnes Rare Earth Oxides)	Annual Change
2005	65,609	-
2006	61,821	–6%
2007	59,643	–4%
2008	56,939	–5%
2009	50,145	–12%
2010	30,258	–40%
2011	30,184	–0.24%

(Source: Kingsnorth 2010 and Scott 2011)

Scarcity of Minerals - China



Bayan Obo Mine, Inner Mongolia

the largest worldwide

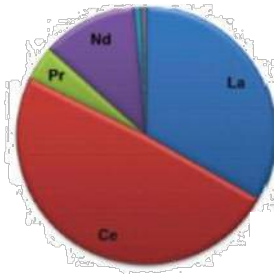
Scarcity of Minerals – non-China

Deposit	Resource (million tonnes)
Bayan Obo	1,460
Kvanefjeld Greenland	215
Mountain Pass	20
Nechalacho	65
Mt Weld	12

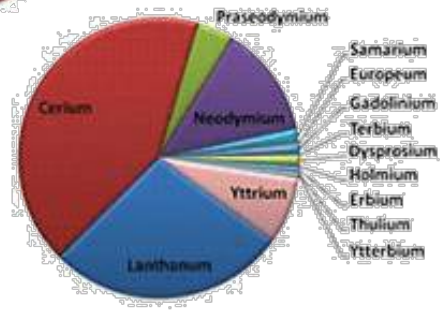
Source: IMCOA 2009

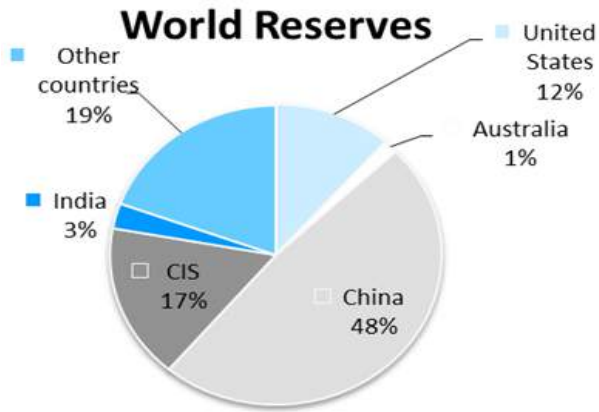
Relative Abundance of Rare Earth Elements

Mt Pass



Kvanefjeld

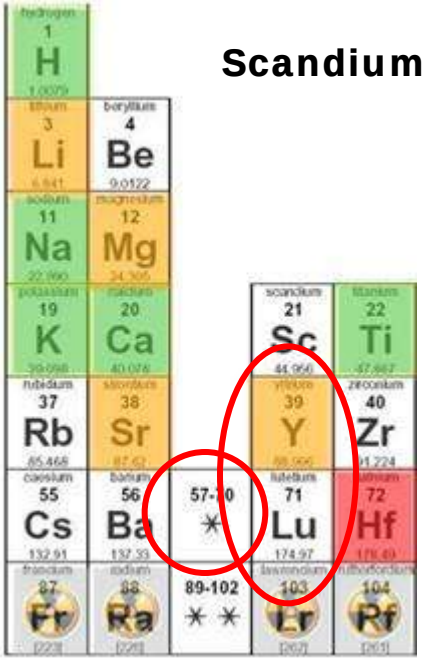




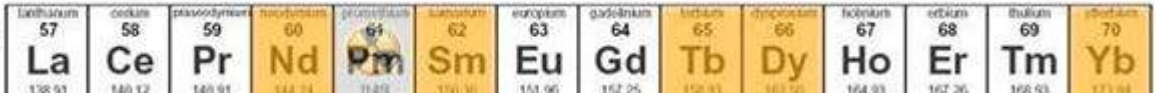
World Reserves in million tons (USGS 2012)	
United States	13
Australia	1.6
China	55
CIS	19
India	3.1
Other countries	22
Total	**114**

Rare Earths & Precious Metals

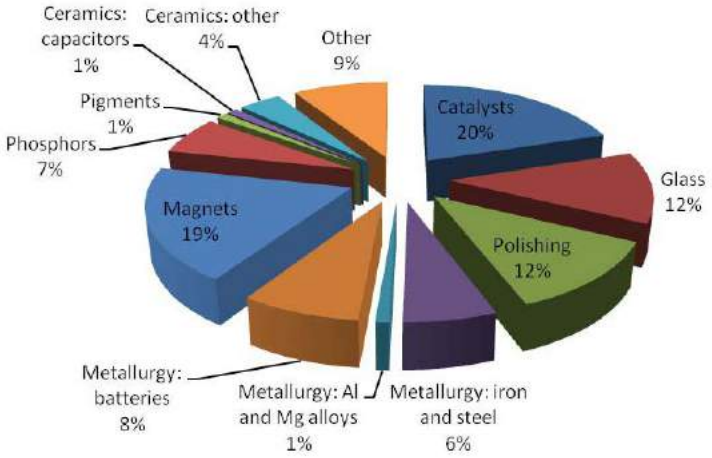
Scandium, Ytrium, and the Lanthanides



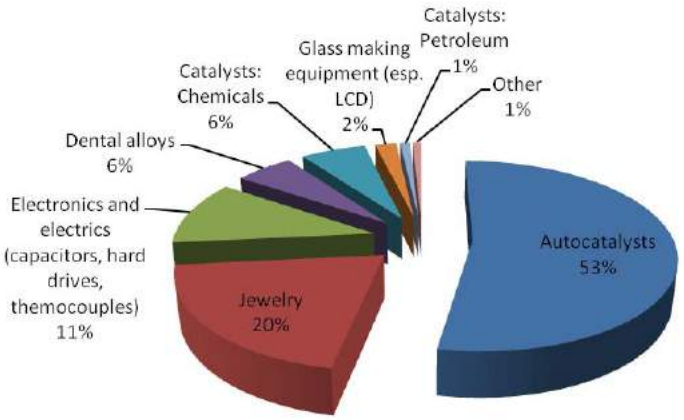
*Lanthanide series



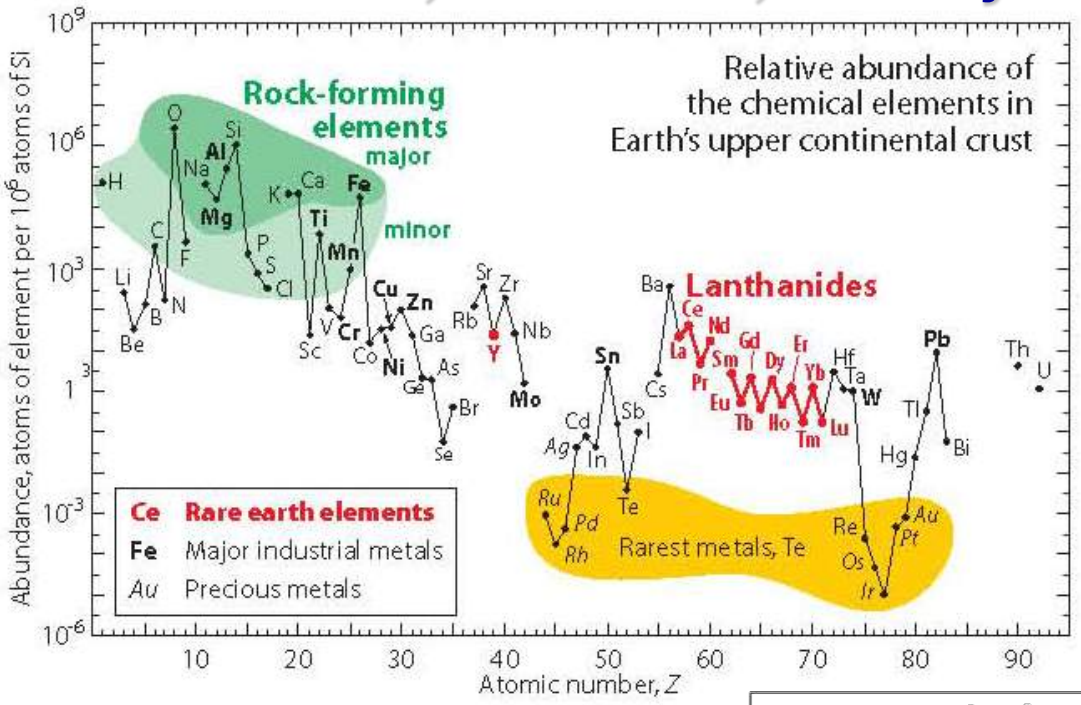
Economic Importance



Global Precious Metals Reserves



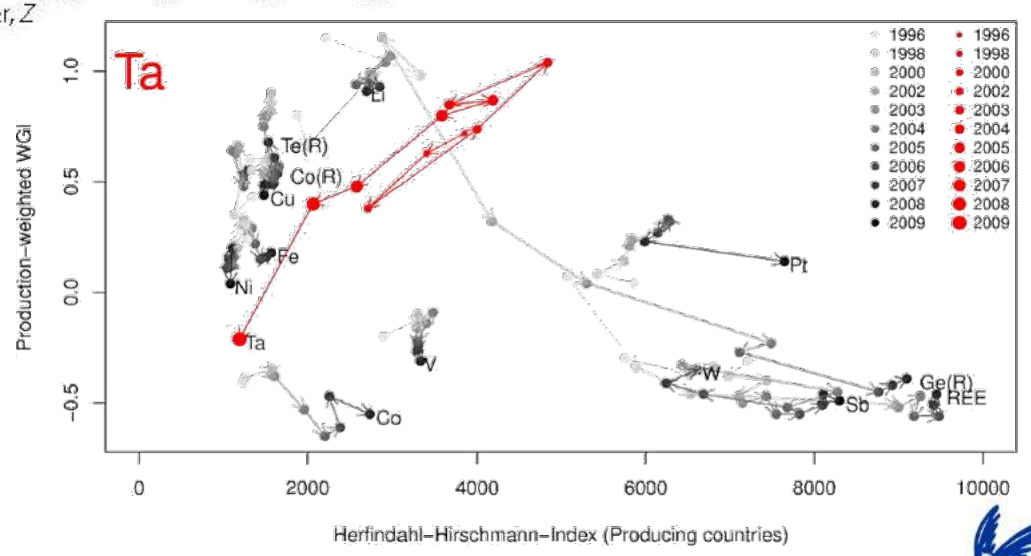
Precious, Rare Earth, and Major Industrial Metals



WGI Worldwide Governance Indicator
vs
Hersfindahl-Hirschman Index

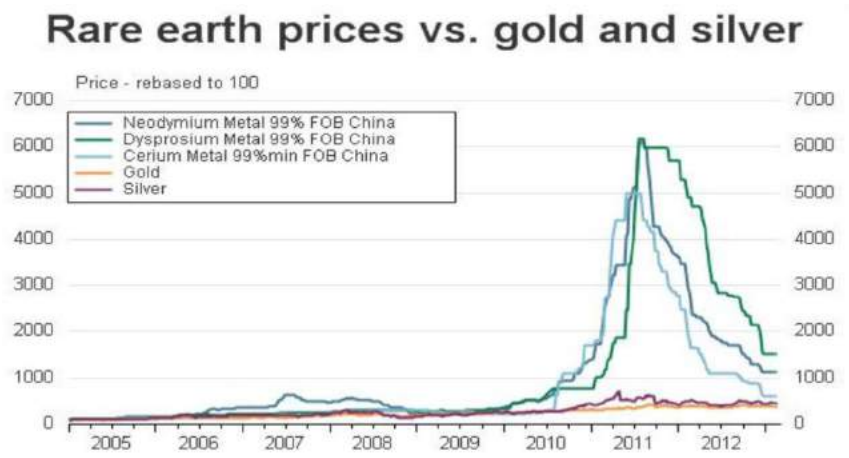
Σ (market share)^2 of 50 largest firms

Above 2500 means highly concentrated

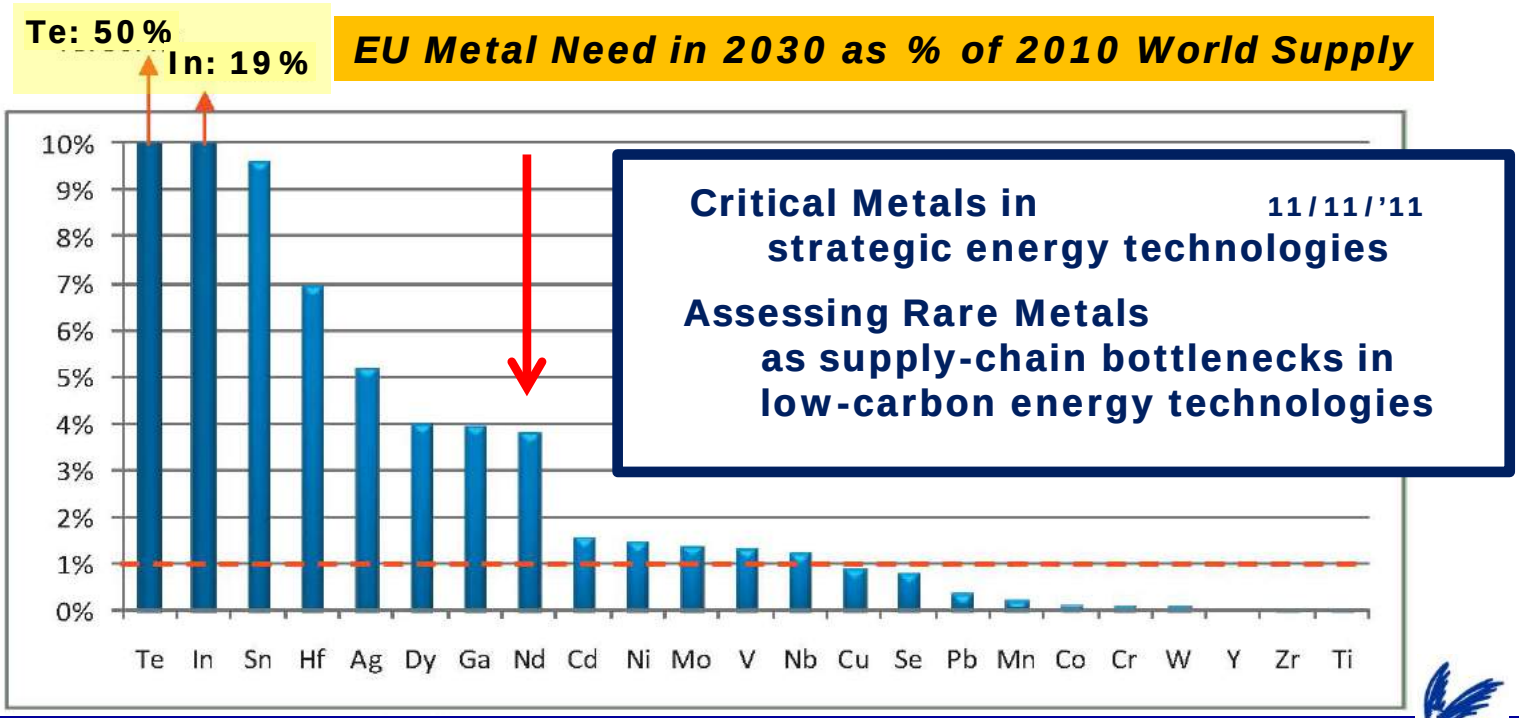


Buijs, Sievers, Terzero Espinoza *Polinares* ***2011***.

EU Critical Materials for Energy



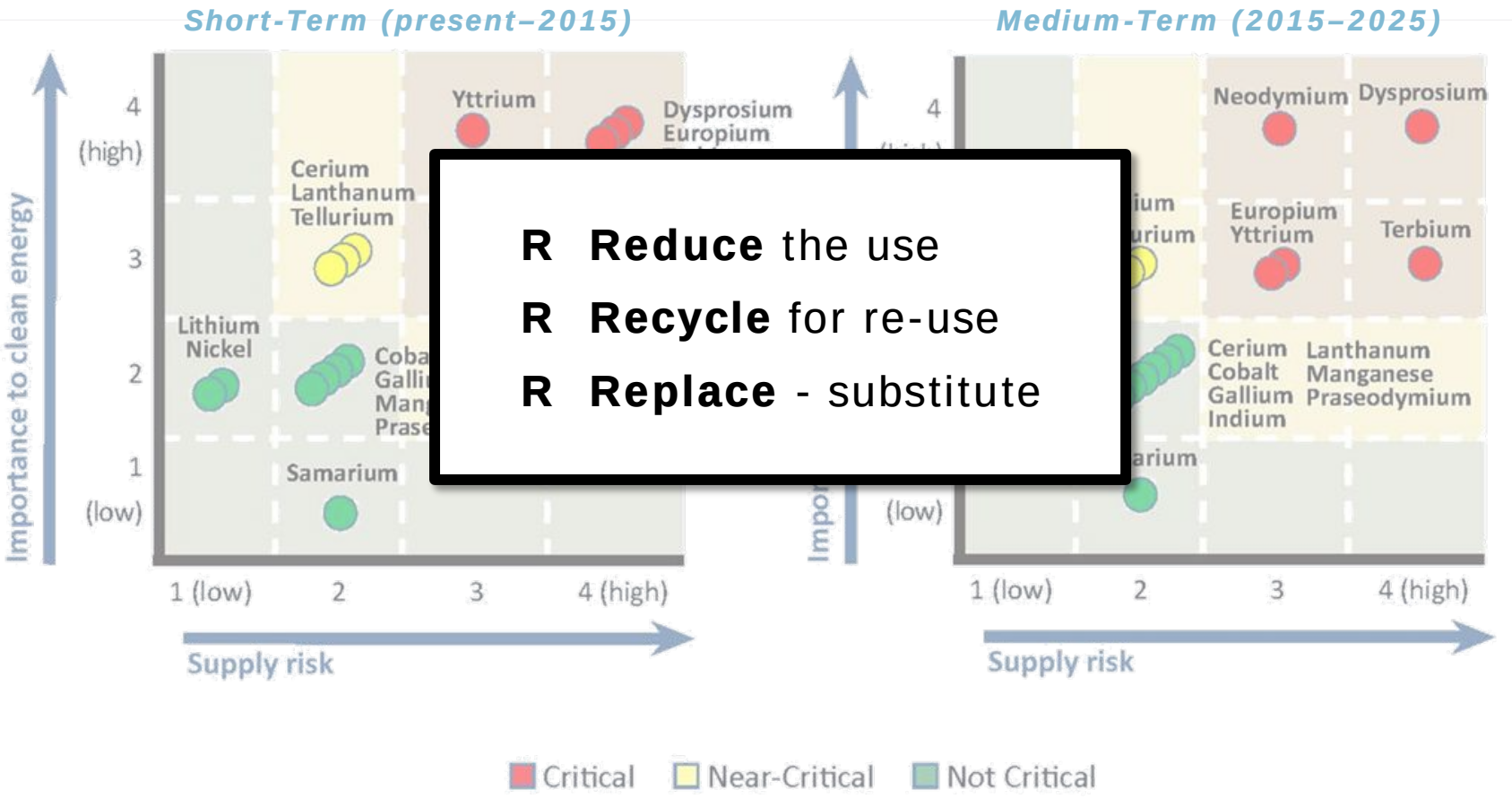
14 critical metals



Critical Metals in strategic energy technologies 11/11/'11

Assessing Rare Metals as supply-chain bottlenecks in low-carbon energy technologies

US DOE *2011* Critical Materials List (16)



All Energy Related – PV coatings, magnets, batteries, phosphors