LINKING NATURAL RESOURCES, POPULATION, ENERGY, COMMODITIES, SERVICES, ECONOMY, HEALTH, GOVERNANCE AND THE SOCIETY

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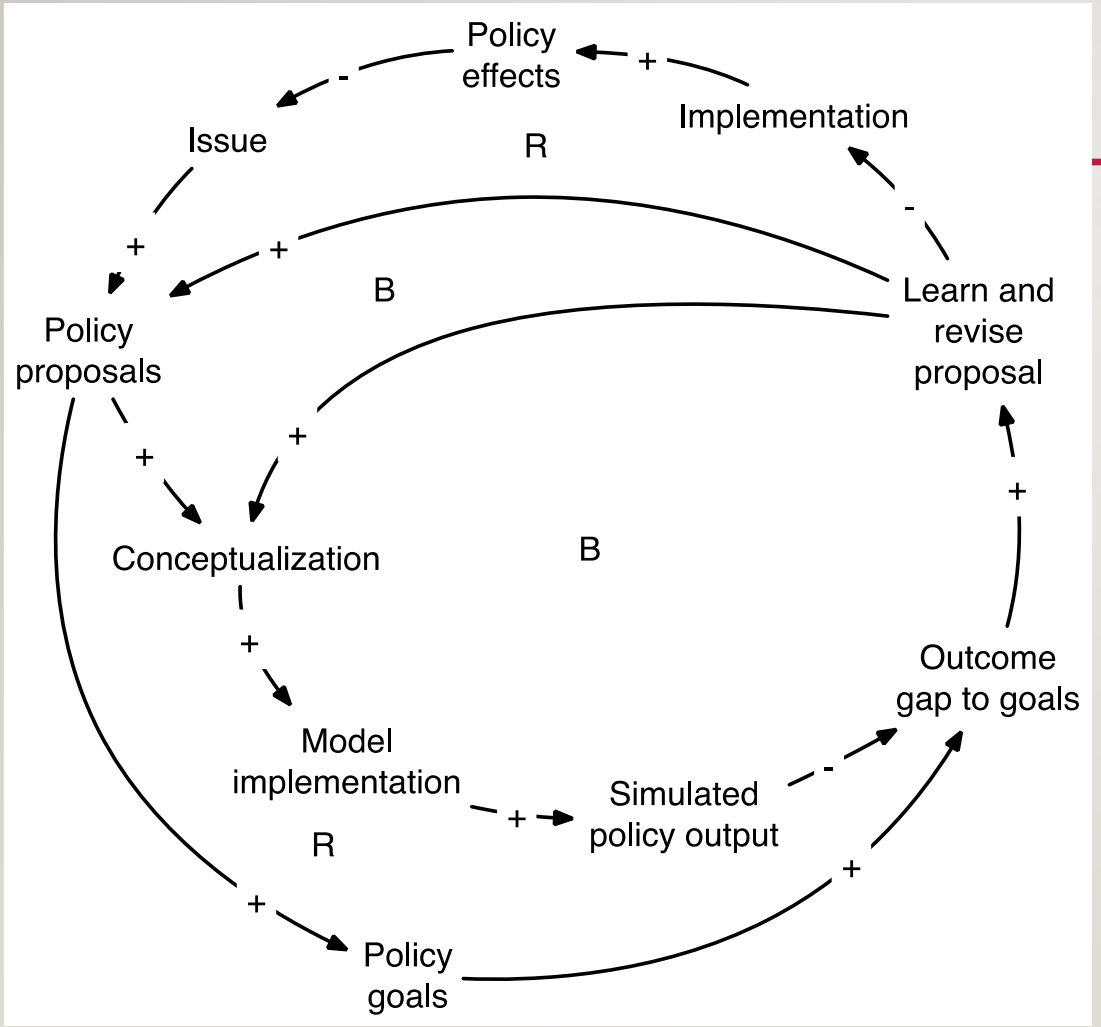
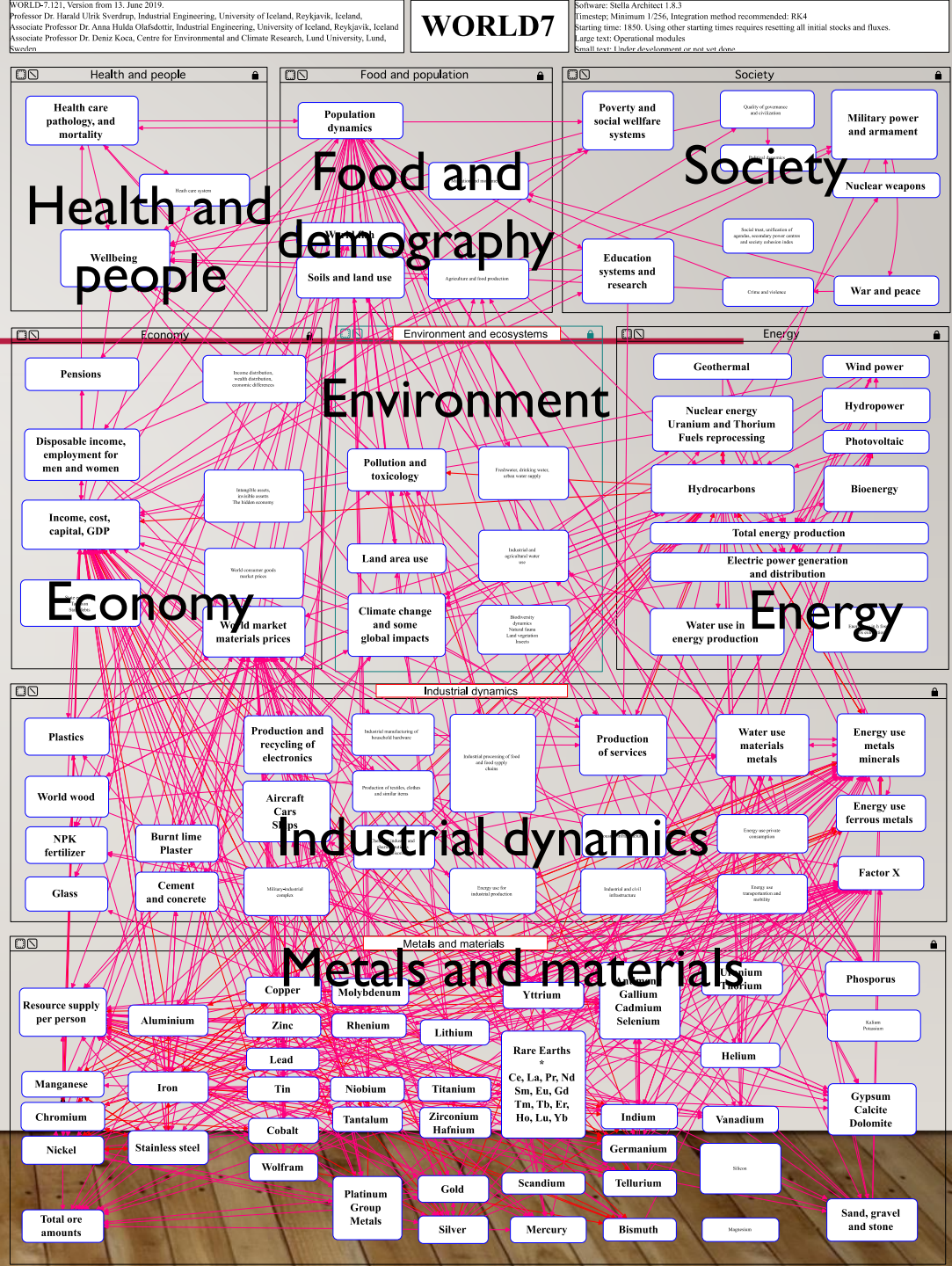
ON THE GREATEST OF CHALLENGES

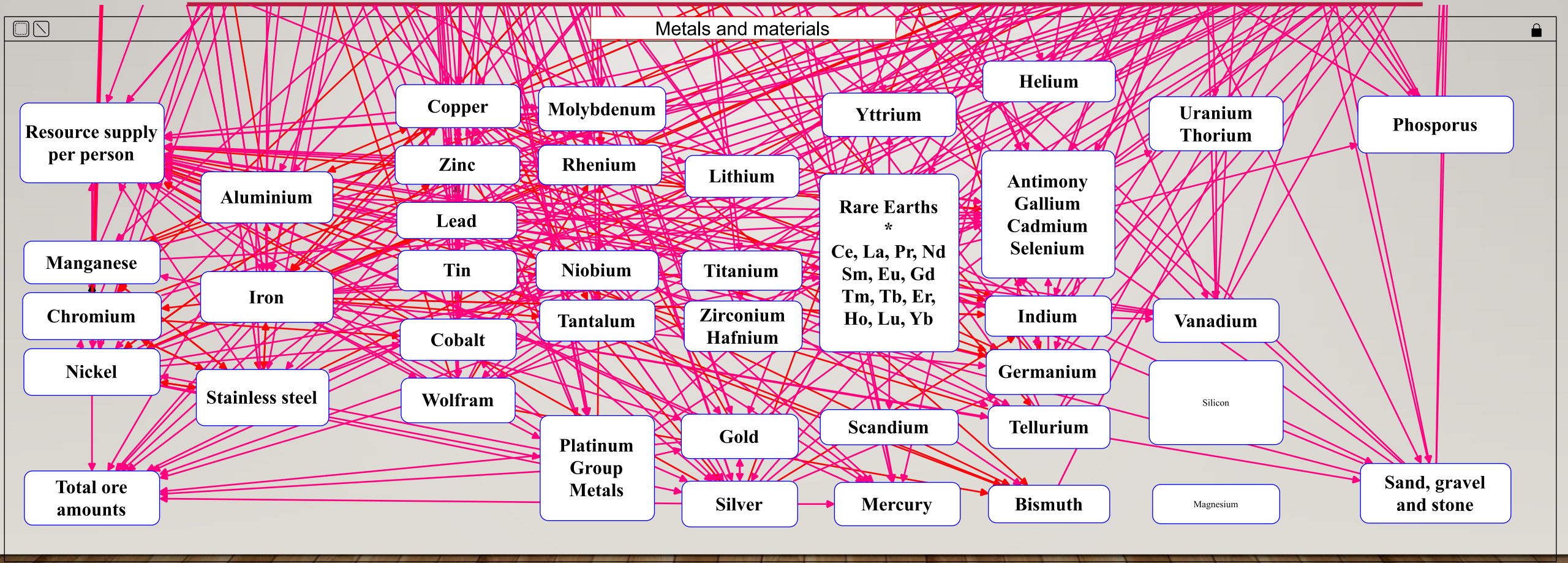
- On the future of our society; The challenges are all connected and linked
  - The ongoing energy challenge
  - The run on material resources
  - The progressing ruin of the environment for human civilization
- Assessing what is left; The final countdown for society

WORLD7 IS OUR TOOL





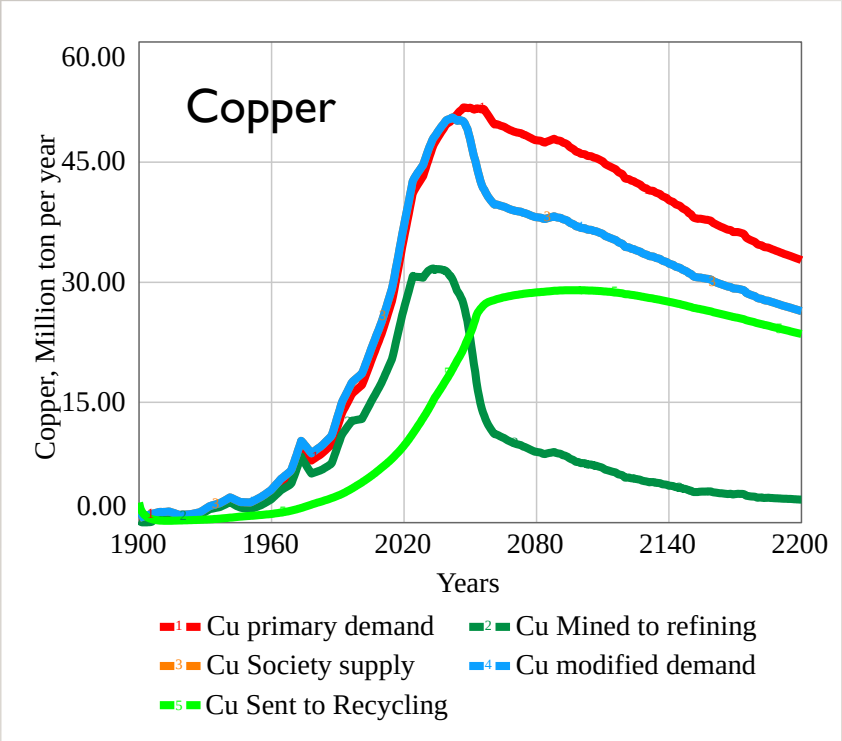
NATURAL RESOURCES, METALS AND MATERIALS

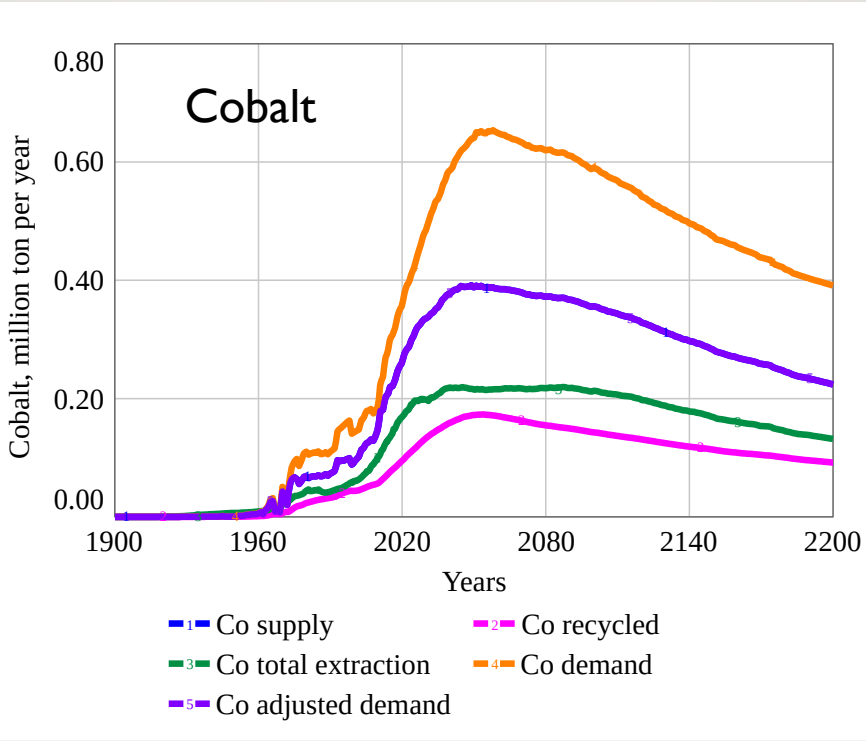


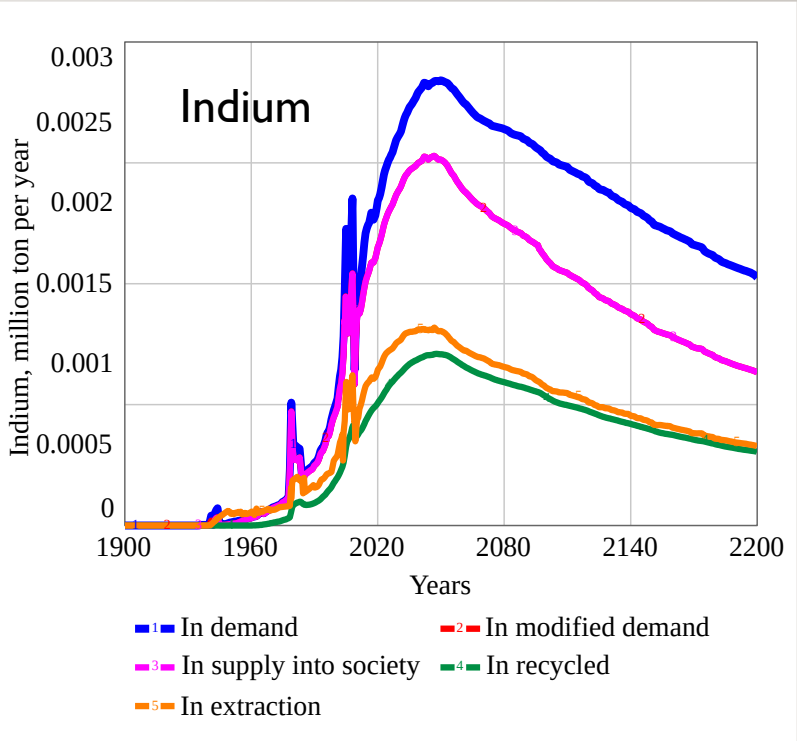
READING WORLD7 DIAGRAMS FOR LITHIUM, UNDERSTANDING «SCARCITY»

COPPER, COBALT, INDIUM

DEMAND, MODIFIED DEMAND, SUPPLY, MINING, RECYCLING

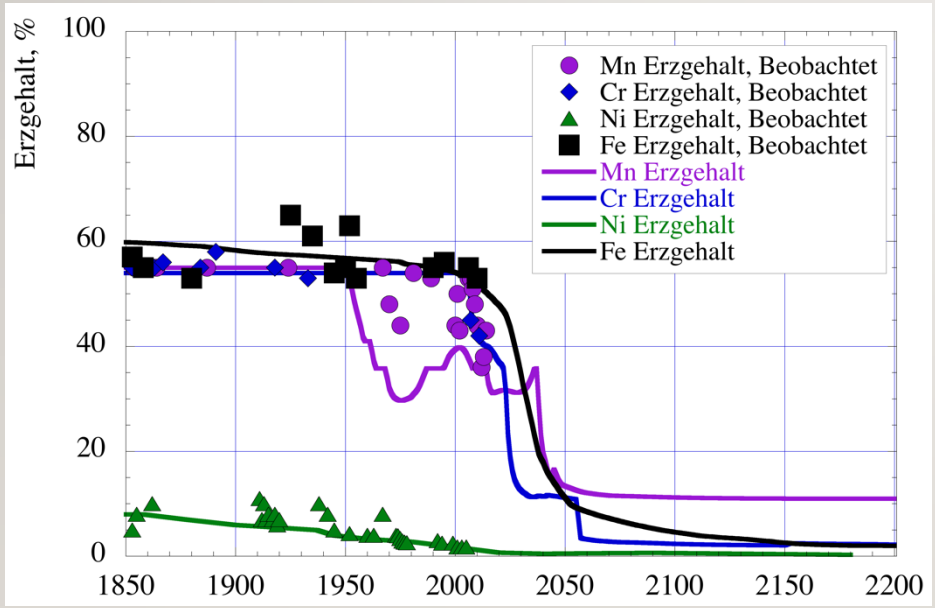




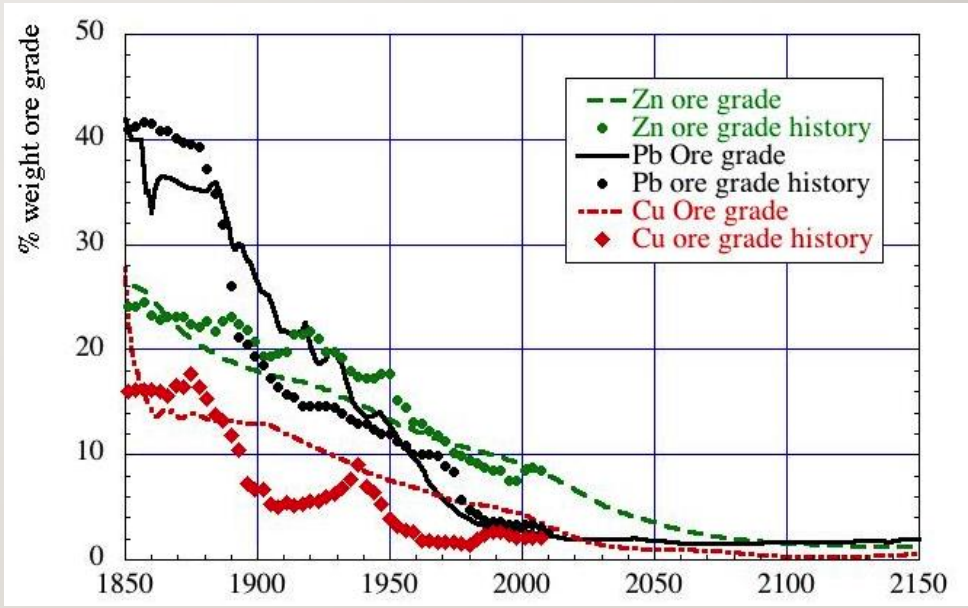


RESOURCE QUALITY IS CONSISTENTLY DECLINING FOR ALL RESOURCES

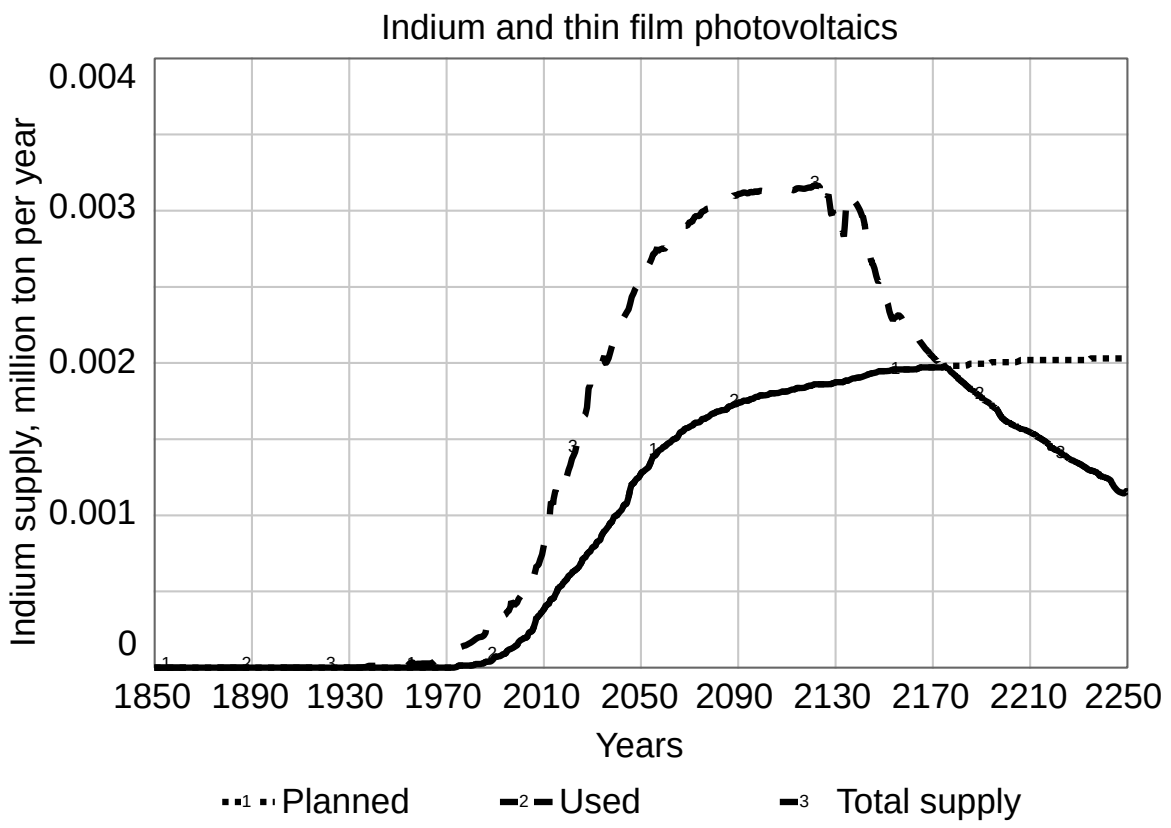
Iron, Manganese, Chromium, Nickel

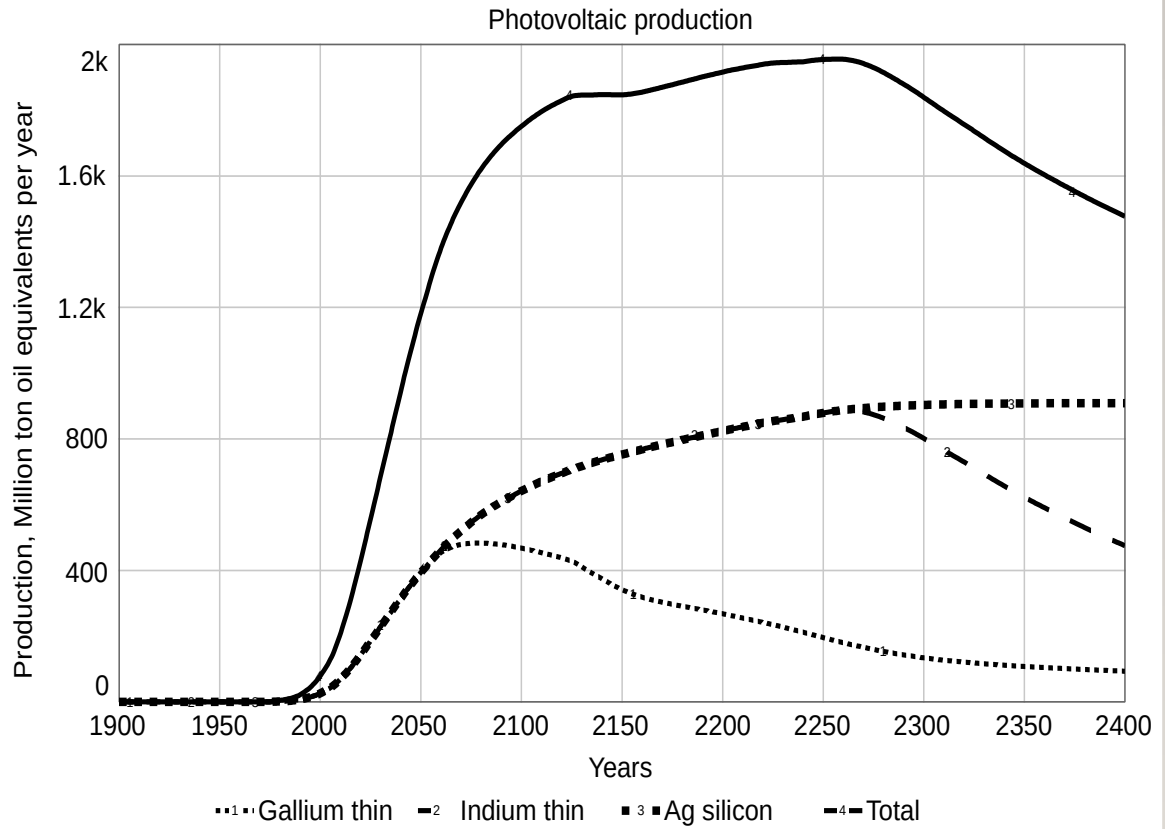


Copper, Zinc, Lead



RESOURCE SCARCITY LIMITS THE PHOTOVOLTAICS POTENTIAL, CALLING FOR SYSTEMIC OPTIMIZATIONS





THE KEY TECHNOLOGY METALS HAVE LIMITED SUPPLY

- Photovoltaic panels depend on having **Indium**, **Germanium**, **Gallium**, **Tellurium, Silver** available, potentially limiting how much solar electricity we can collect.
- Rechargeable batteries depend on **Lithium**, **Cobalt, Rare Earth Elements** for efficient function, to be chargeable, limiting how many batteries and electric vehicles we can build.
- High performance magnets, electric generators and miniature eletromotors depend on **Rare Earth Elements, Cobalt, Copper** for their function. The number of energy-efficient electric engines may be limited, the availability sets a limit for how much wind energy we can collect.
- **R&D funding for innovation:** Industrial innovation and development towards new technologies that use more abundant resources and materials than the limiting ones should be strongly promoted. Must be much stronger promoted at EU and National Research Councils than at present.

Electric vehicle potential is limitedby the extractable amount available.
We assume 100% of the resource available for cars only (Note: nothing for everything else)
(Global fleet; 1.4 billion cars, 2020 recycling: 25%)

Available resources to humans, million ton	Recycling fraction								
	Alternative 1; 25%			Alternative 1; 50%			Alternative 2; 65%		
	Lithium or cobalt (or REE) per battery unit, kg								
	5 (100)	10 (200)	30 (600)	5 (100)	10 (200)	30 (600)	5 (100)	10 (200)	30 (600)
	Millions of electric car battery units possible								
REE: 760	200	100	33	400	200	66	950	480	165
Lithium: 73	400	200	126	800	400	133	1,892	946	315
Cobalt: 44	257	128	43	514	257	86	1,140	572	191

Estimation of sustainable mine extraction of different metals in ton per year.					
Metal	Prroduction 2012, ton/year	Sustainable use in % of todays use, Time applied, years			
		10,000	5,000	1,000	500
Iron	1,400,000,000	1.6%	3.2%	16%	31%
Aluminium	44,000,000	4.3%	8.6%	43%	86%
Manganese	18,000,000	0.6%	1.1%	5.5%	11%
Chromium	16,000,000	0.3%	0.5%	2.5%	5%
Copper	16,000,000	0.4%	0.7%	3.5%	7%
Zinc	11,000,000	1.0%	2%	10%	20%
Lead	4,000,000	1.7%	3.4%	17%	34%
Nickel	1,700,000	0.6%	1.1%	5.5%	11%
Magnesium	1,000,000	surplus	surplus	surplus	surplus
Tin	300,000	2.5%	5%	25%	50%
Titanium	283,000	surplus	surplus	surplus	surplus
Molybdenum	280,000	0.8%	1.6%	8%	16%
Antimony	180,000	0.4%	0.8%	4%	8%
Rare Earths	120,000	18%	36%	surplus	surplus
Cobalt	110,000	0.1%	0.2%	1%	2%
Tungsten	80,000	0.9%	1.8%	3.6%	7.2%
Vanadium	70,000	2.7%	5.4%	27%	54%
Niobium	68,000	0.6%	1.2%	6%	12%
Lithium	37,000	9.5%	19%	95%	surplus
Silver	23,000	0.6%	1.1%	5.5%	11%
Bismuth	7,000	0.5%	72	360	720
Selenium	2,200	0.8%	1.6%	8%	16%
Gold	2,600	0.5%	1%	5%	10%
Indium	670	0.7%	1.4%	7%	14%
Tantalum	600	1%	2%	10%	20%
Gallium	280	0.2%	0.4%	2%	4%
Palladium	220	1.6%	3.2%	16%	32%
Platinum	180	2.4%	4.8%	24%	48%
Germanium	150	0.9%	1.8%	9%	18%
Tellurium	120	0.9%	1.8%	9%	18%
Rhenium	50	0.8%	1.6%	8%	16%

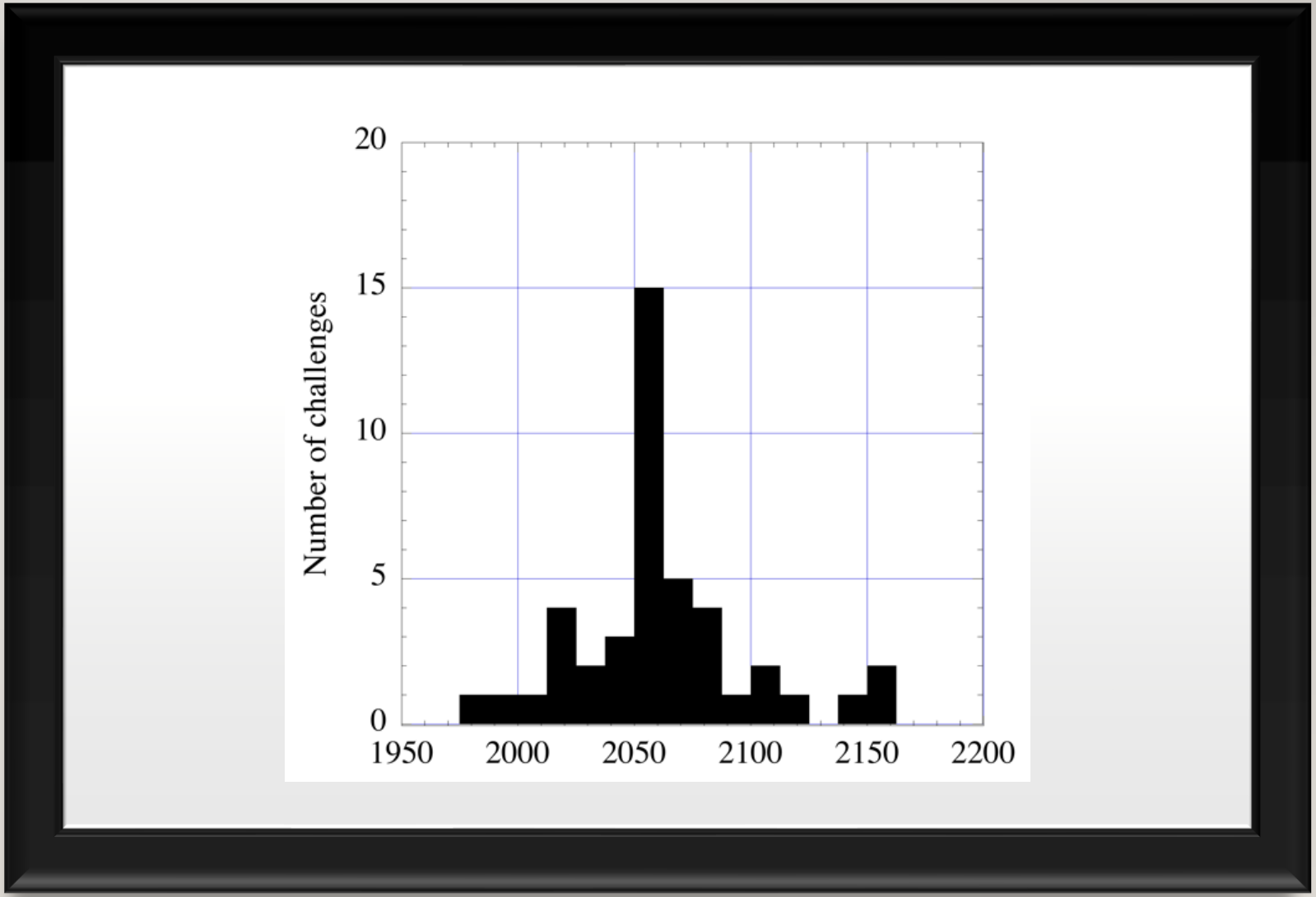
SUBSTITUTION has limitations because every amount is already booked.

Many elements have linked production, and limits in one becomes limits for many others

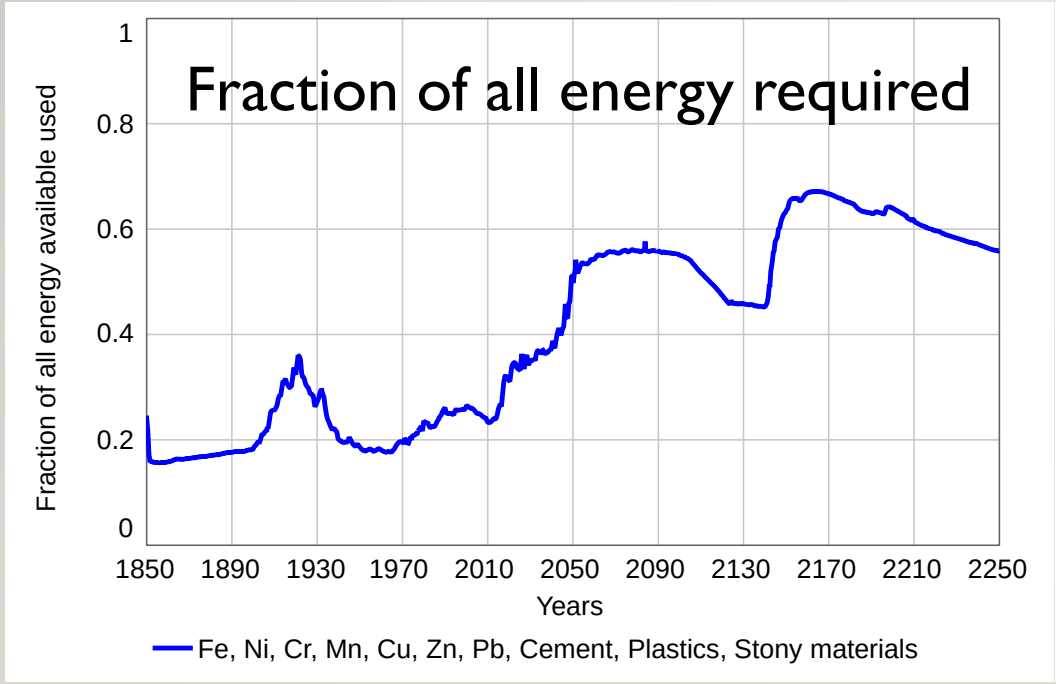
WHEN DO RESOURCE EXTRACTION, PRODUCTION AND SUPPLY REACH MAXIMUM?

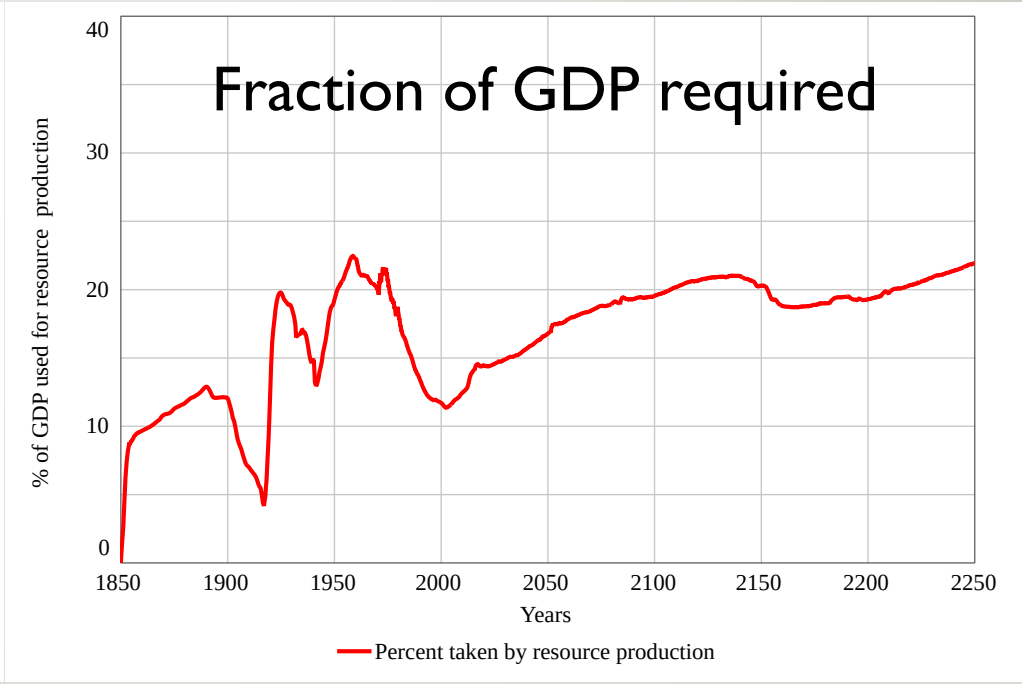
Metal	Extraction peak year	Supply peak year	Recycling degree (%)	Metal	Extraction peak year	Supply peak year	Recycling degree (%)
Oil	2012	2014	0	Titanium	2038	2060	40
Gas	2016	2016	0	Tellurium	1984	2060	0
Coal	2020	2018	0	Phosphorus	2035	2060	16-25
Cadmium	2010	2020	80	Palladium	2042	2065	60
Gold	2016	2036	85-90	Aluminium	2030	2070	75
Cobalt	2026	2040	40	Iron	2052	2072	60
Gallium	2026	2042	5-15	Stainless steel	2052	2070	65
Silver	2038	2045	70	Manganese	2053	2072	45
Selenium	2042	2050	0-5	Tantalum	2035	2078	60
Cut stone	2040	2050	20	Molybdenum	2038	2080	40
Lead	2041	2051	65	Rhenium	2042	2080	40
Niobium	2045	2052	60	Uranium	2035	2080	50
Tin	2046	2055	40	Zinc	2046	2090	20
Antimony	2048	2056	5-15	Chromium	2051	2110	22
Indium	2042	2055	20-40	Copper	2044	2120	60
Rhodium	2034	2058	60	Lithium	2060	2142	10-20
Germanium	2042	2058	20-30	Sand	2075	2150	30
Bismuth	2044	2059	5-15	Gravel	2130	2150	20
Nickel	2028	2060	50-60	Rare Earths	2045	2280	15
Platinum	2036	2060	70	Thorium	2090	2400	90

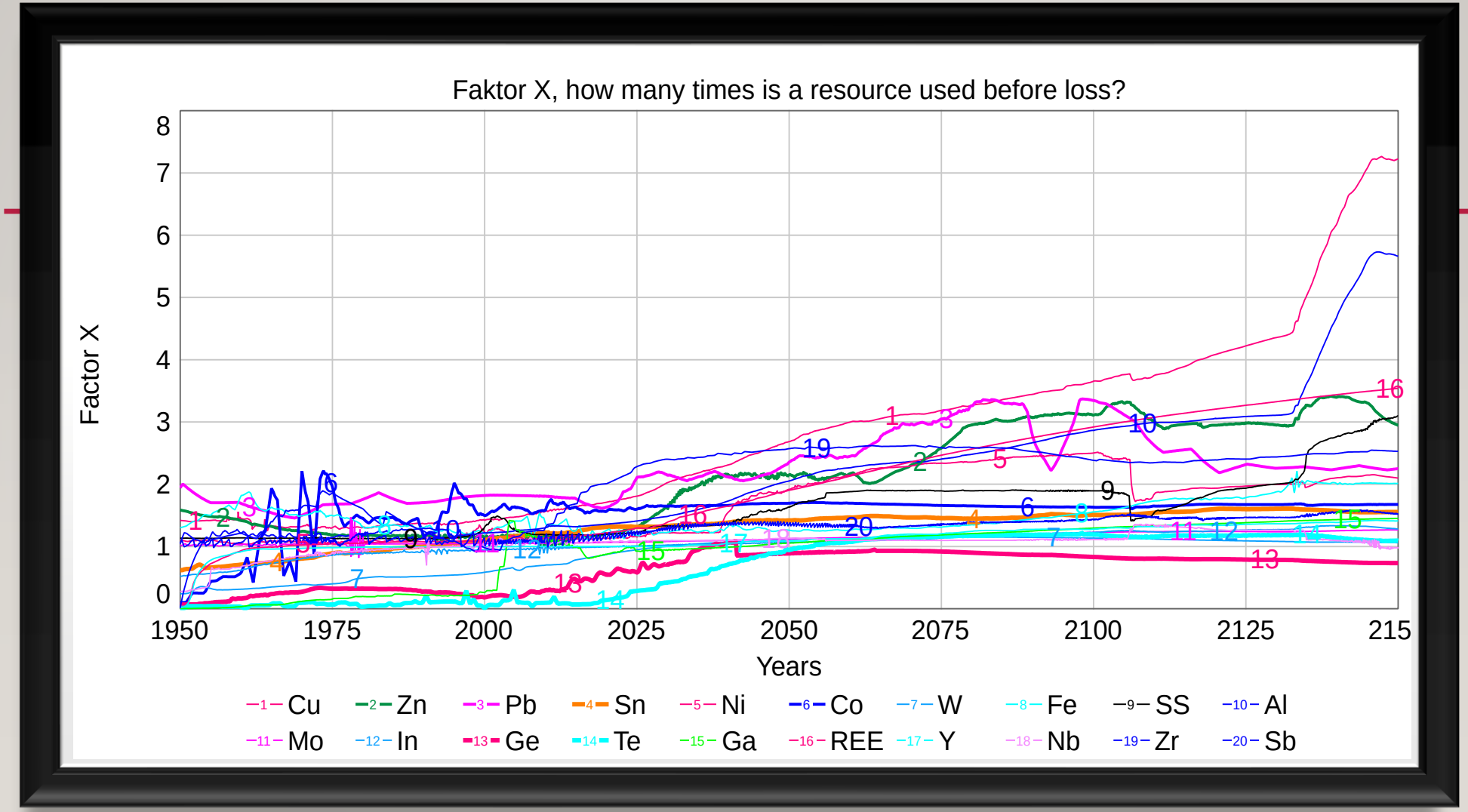
CHALLENGES PILE UP UNDER BUSINESS-AS-USUAL TOWARDS 2040 - 2070



AS RESOURCE QUALITY DECLINE, COST AND EFFORT GO UP IN ORDER TO MAINTAIN SUPPLY






Faktor X, how many times is a resource used before loss?
Factor X
0
1
2
3
4
5
6
7
8
1950
1975
2000
2025
2050
2075
2100
2125
215
Years
1 Cu
2 Zn
3 Pb
4 Sn
5 Ni
6 Co
7 W
8 Fe
9 SS
10 Al
11 Mo
12 In
13 Ge
14 Te
15 Ga
16 REE
17 Y
18 Nb
19 Zr
20 Sb

RANDERS SUGGESTED SOME SUGGESTED FUTURE POLICIES, WE RAN WORLD7 TO TEST THEM ON SUSTAINABILITY AND RESOURCE USE.

Policies suggested	Energy	Resources	Social	Works?
1. Reduce man-made greenhouse gas emissions as soon as possible – **Global Energie-wende**	Can be done with better energy efficiency	Needs a lot of specialty materials	Depends on being socially sustainable	**Yes**
2. Help poor nations grow faster – by rapid industrialisation similar to Japan, Korea and China	Challenging energy supply, challenging pollution risks	High risk for hard scarcity on key technological materials	Limited by corruption, poor governance or dictatorship	Difficult
3. Reduce unemployment and inequity through more jobs	Can be done in Energiewende	Increases demand of key supplies	Social change stresses	**Yes**
4. Further slow population growth – through positive incentives	Decline reduce consumption	Decline reduce consumption	Needs global attitude change	**Yes**
5. UN high population scenario	Energiewende becomes far more challenging	Risk that resource scarcity strikes	Economic crisis and disruptions Social stresses	Probably not

CHALLENGES TO BE ADDRESSED AT ONCE

- **Alternative energy production**
  - To avoid scarcity in critical components, and combination of different technologies will be necessary for photovoltaic solar and for wind energy collection.
  - There are limits to how much windmills we can make (magnets in generators).
- **Vehicles**
  - There are only resources for 20-30% substitution of all fossil fuels cars with electric cars with full combination and optimization of technologies (batteries, magnets, electronics).
  - There will be fuel cars in the future, and they must then use sustainable fuels (No fossil fuels).
  - There will be less cars than now in the future

SIGNIFICANT CHALLENGES TO BE SOLVED

- **Scarcity**
  - All metals, and almost all materials are fossil and finite within the next three generations.
  - All metals, materials and fuel resources will get into soft scarcity, higher price makes more material available in the intermediate term but accelerates exhaustion.
  - Important key materials are in transition to hard physical scarcity now (Pd, Pt, Rh, Ag, Li, Co).
  - All fossil fuels have a quantifiable end date (Oil, Gas, Coal, Uranium, Thorium).
- **Substitution**
  - Only works when substituting with very much larger production is available and is expandable; the production is at present fully booked
  - No substitute for phosphorus exists, limited substitution for Co and Li at the moment.
- **Resource shortages**
  - cause economic contraction. **Unequally distributed contraction** will cause painful social stresses and very serious challenges for governance and democracy.
- **Fossil fuels**
  - Stop subsidizing fossil fuels production, which will enrage those receiving the money, and potentially change power relationships

CONCLUSIONS

- A systemic approach is a condition for resolving the challenges
  - Sectorial appoaches are not sufficient, adjusting the parameters of the present system is insufficient
  - When society is materially circular, that creates a circular economy
- Systemic changes need to be multi-sectorial, causally linked and pervasive
  - **Energie-wende** is linked to **Resource-wende**, which is linked to **Social-wende**
  - Rearranging the **structure of the systems** and resetting parameters, imply **transformative changes** to existing society and existing power-structures
  - Must involve **all fundamental systems**; industrial-, economic- and social dynamics
  - Unresolvable **goal conflicts** will lead to challenging choices that the citizen must be prepared for
- Transformative changes take time,
  - Plan with at least **20 years** from start to implementation. Thus, the **start** is needed **at once**