STRATEGIC QUESTIONS AROUND THE PRODUCTION AND USE OF PG METALS

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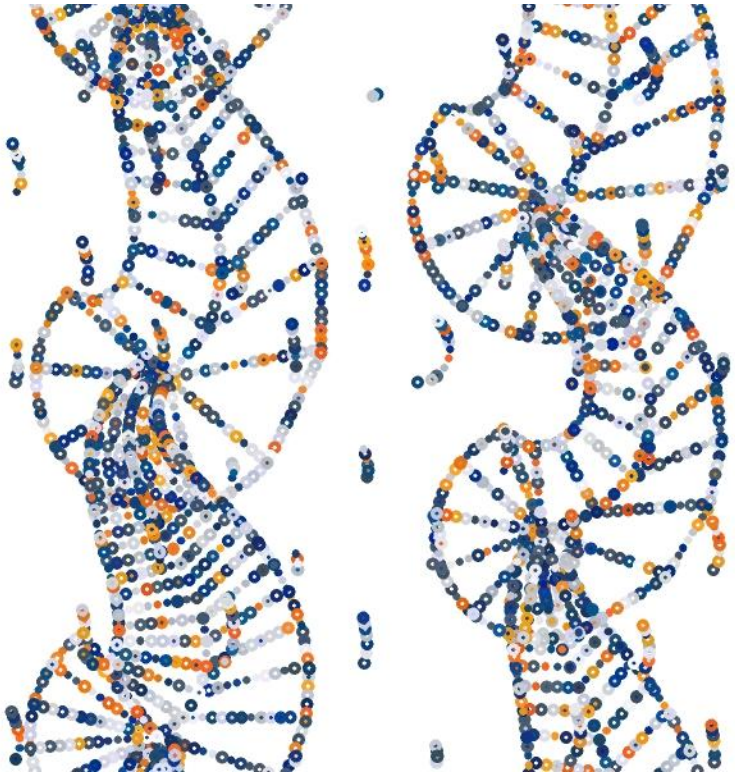
Roundtable on Sustainable Platinum Group Metals

8 April 2010
Paris

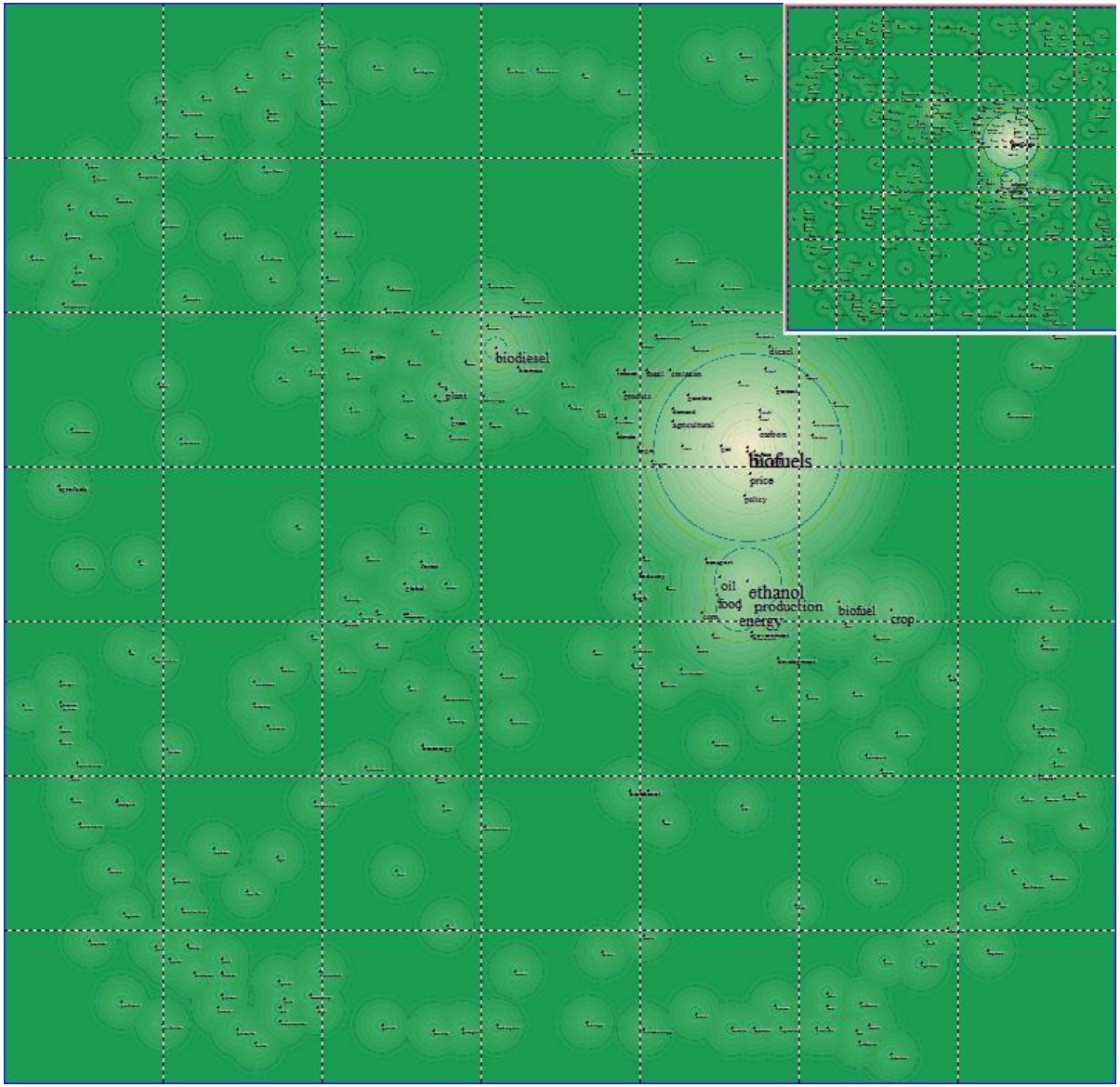


The Premise
Resource Race

Materials Are Hot and Linked: Organic and Inorganic

Trends/Opinions: BioBubbling ’08- Now, We Are There. DYNAMICS!

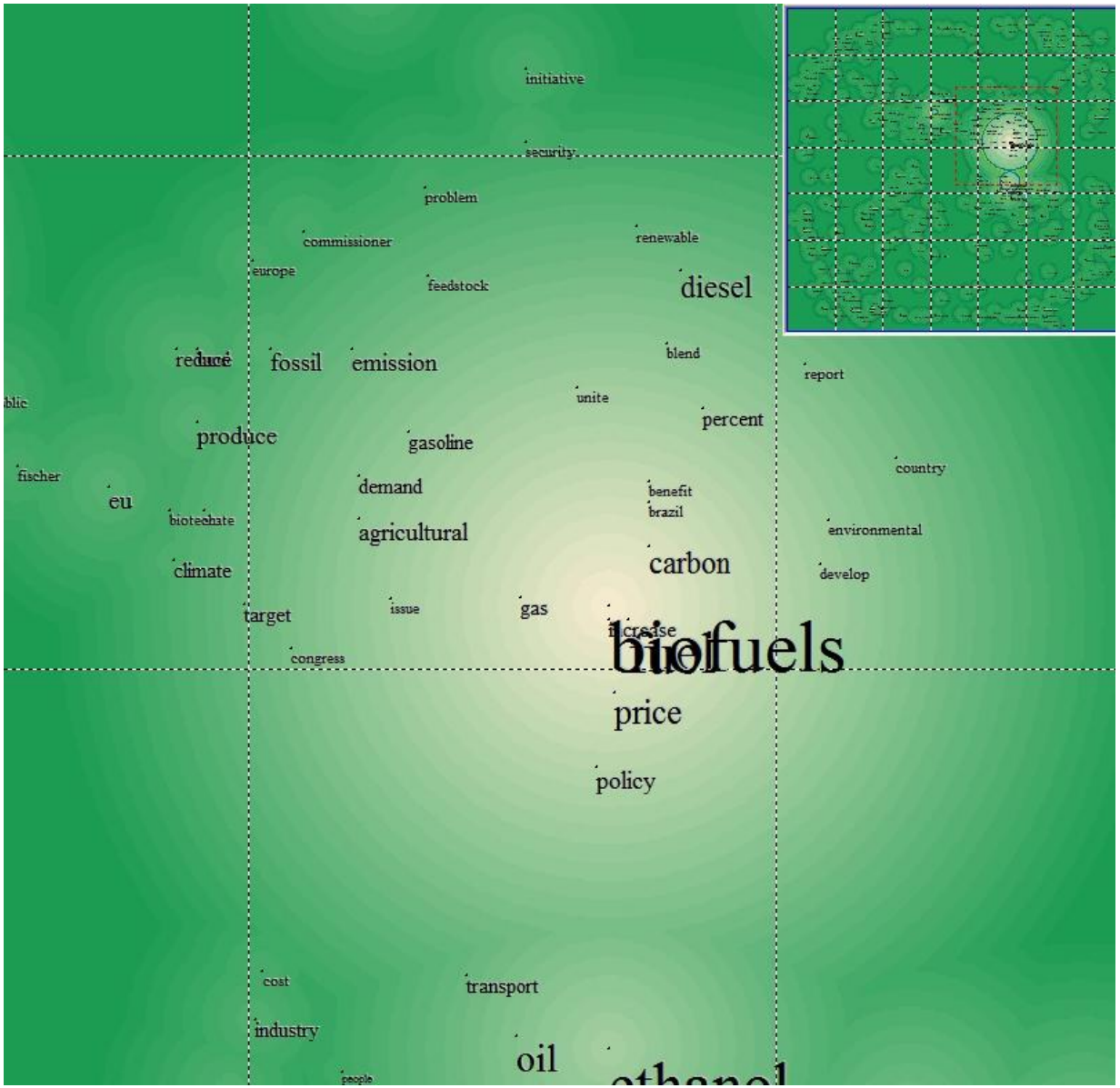
Three signals volcanoes: biofuels, ethanol, biodiesel.



Materials Are Hot and Linked: Organic and Inorganic

Heart of signals heat

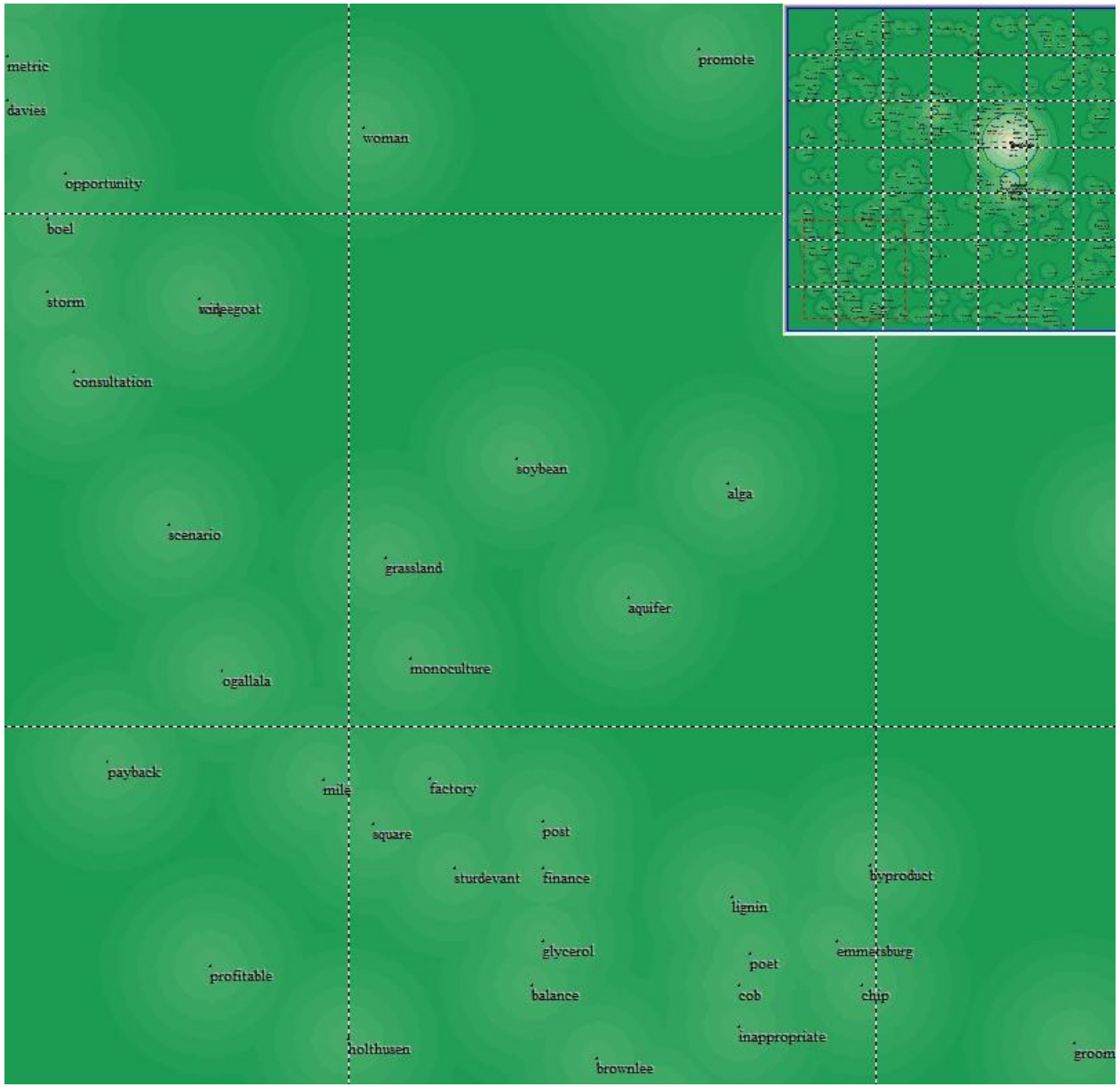
Carbon vs. Price: battle in the core. Brazil creeping up.



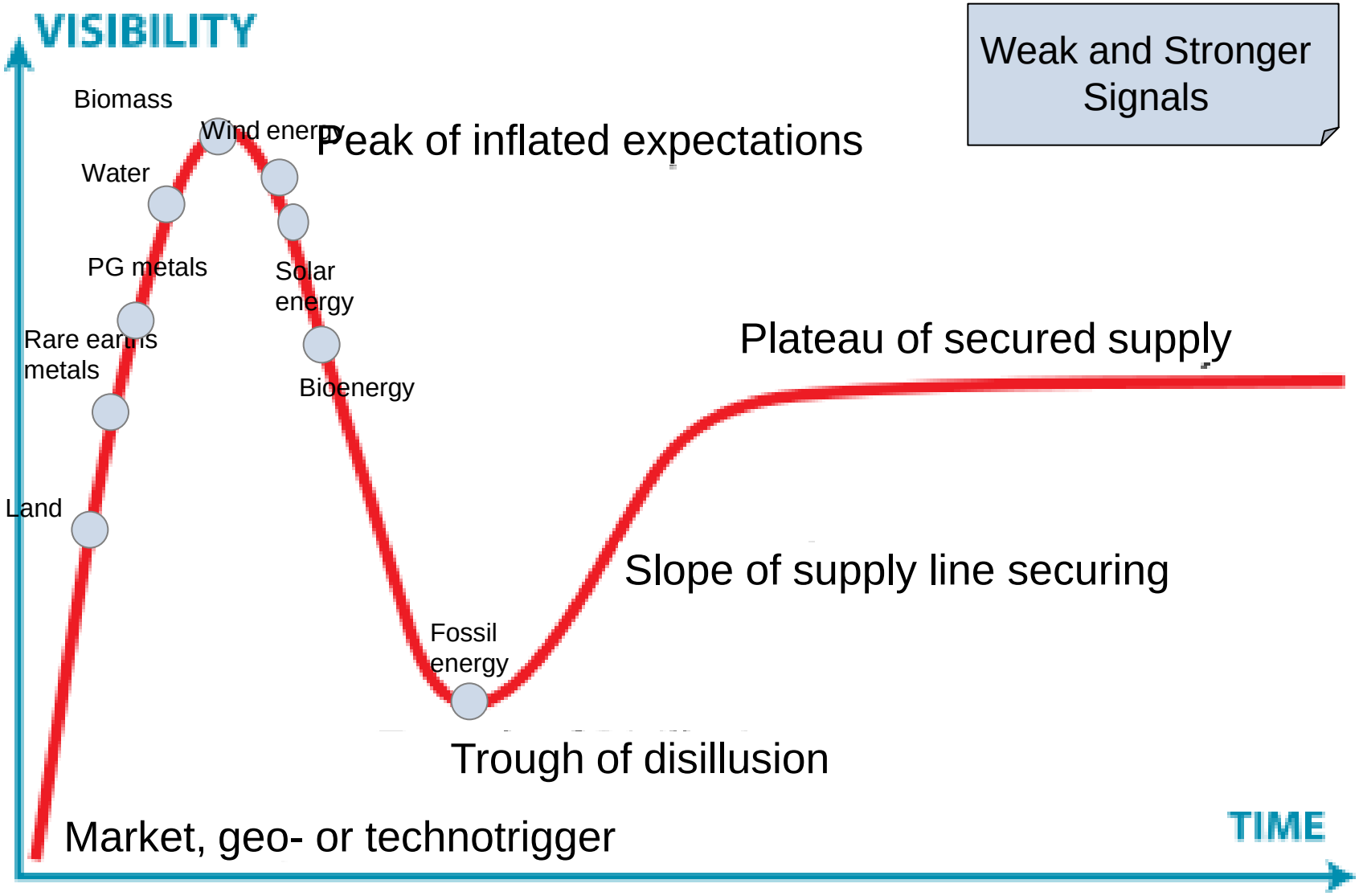
Materials Are Hot and Linked: Organic and Inorganic

In the southwest corner, a small archipelago of potential risers

Algae, soybeans, lignin. Materials brewing.



Starting Point
The Pöyry Management Consulting Resource Hype Curve



Metal's Burden
A Five-Lane Race, Where All Should Win

WHY METALS? ADAPT to prevent or move (at least) five peaks as far as possible – and influence their internal positioning.

Metals: part of all

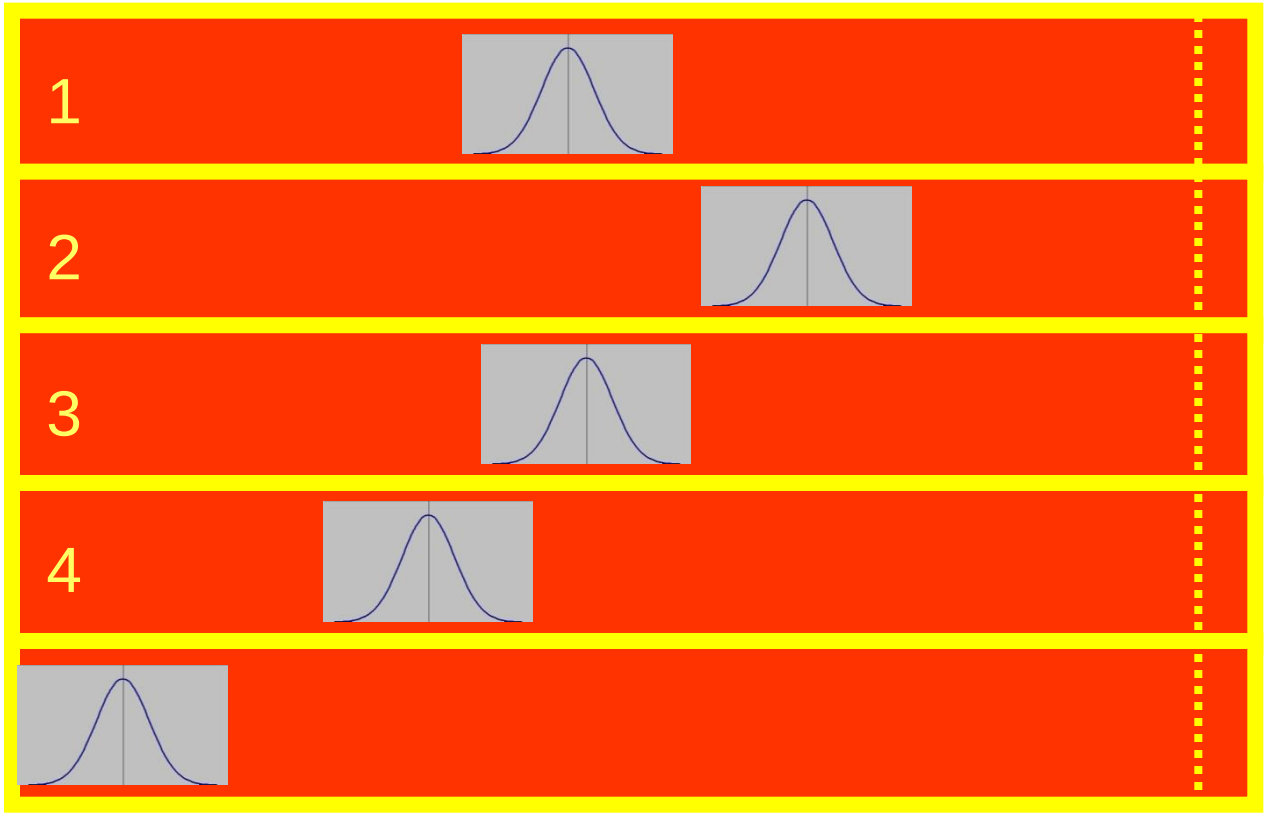
Peak oil is moved ahead, until it is no longer crucial.

Peak water is moved ahead, with more resources focused on resource efficiency as a whole.

Peak phosphorus is moved ahead, with a new and improved green revolution.

Peak land is moved ahead with increased use of space above.

Peak metals is moved beyond the event horizon.

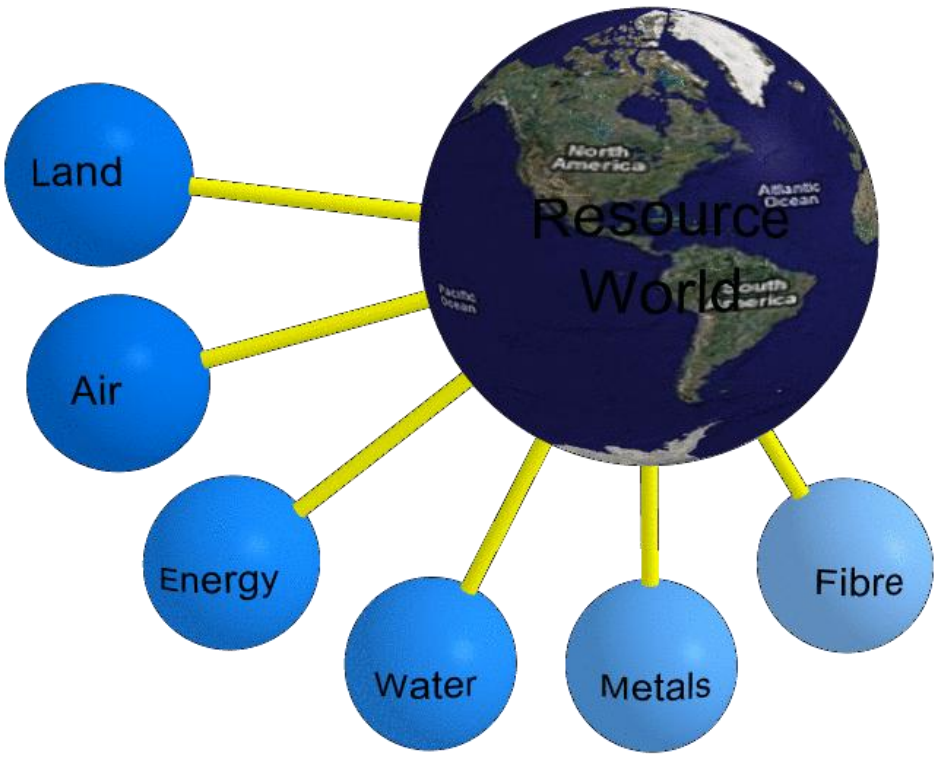


Background: A resource world

A focus on resources is emerging: a scarcity of energy, water, clean air, land, metals and fibre is in different combinations having an impact on the most varied industry sectors

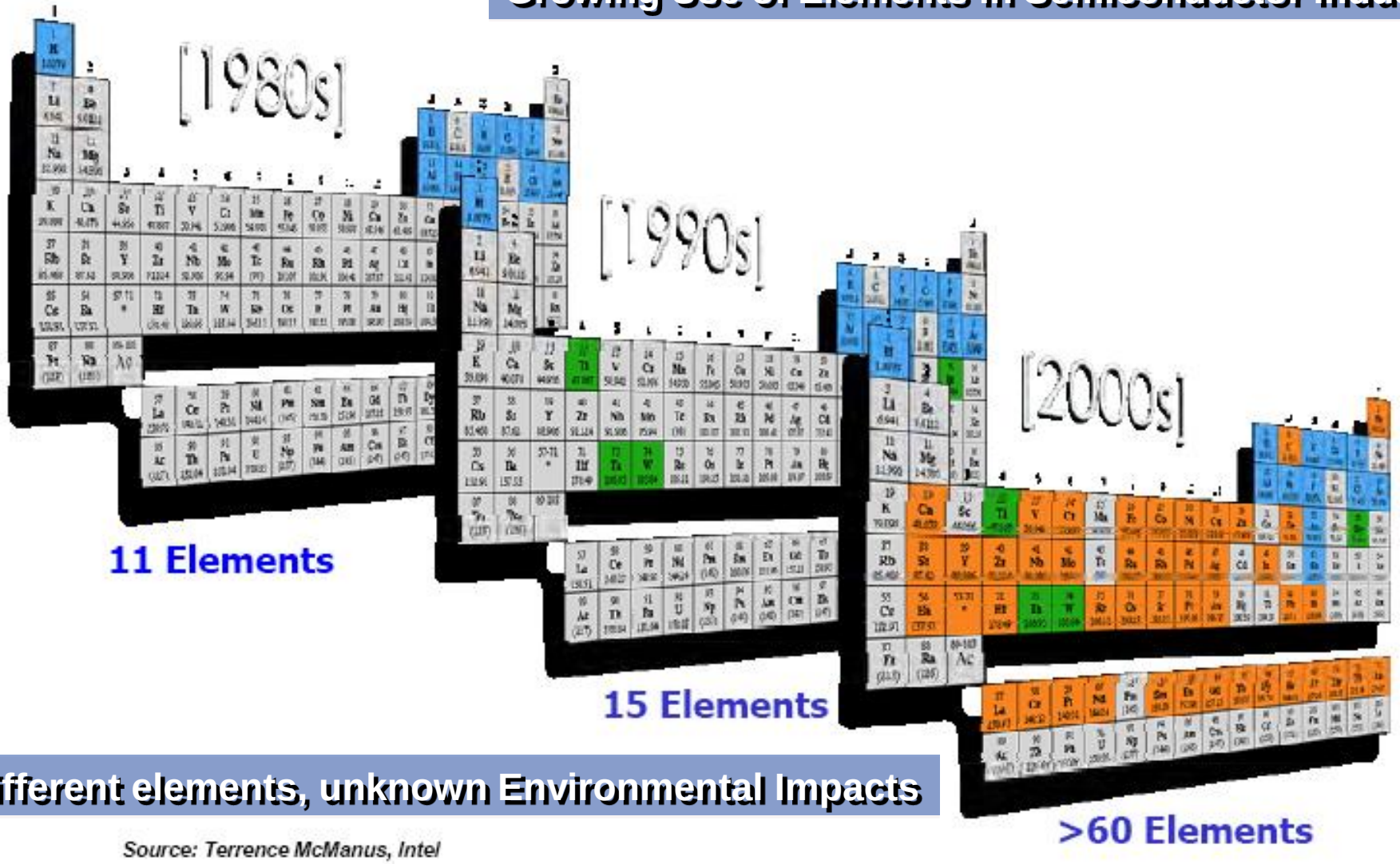
For ICT-companies, metals are a special case: the volume may be small, but so is the availability of metals such as indium, bismuth and ruthenium.

This is nothing new: there was a thorium-crisis in 1882 (with the price of thorium becoming 10-fold in a few months), and an osmium-crisis in 1897. Both times, a substituting technology saved the day.



But ruthenium is rare. "An Airbus fuselage has 60,000 pounds of composites in it. If you used the catalyst approach, a significant fraction of the world supply of ruthenium would be flying around in one plane," Moore told New Scientist.

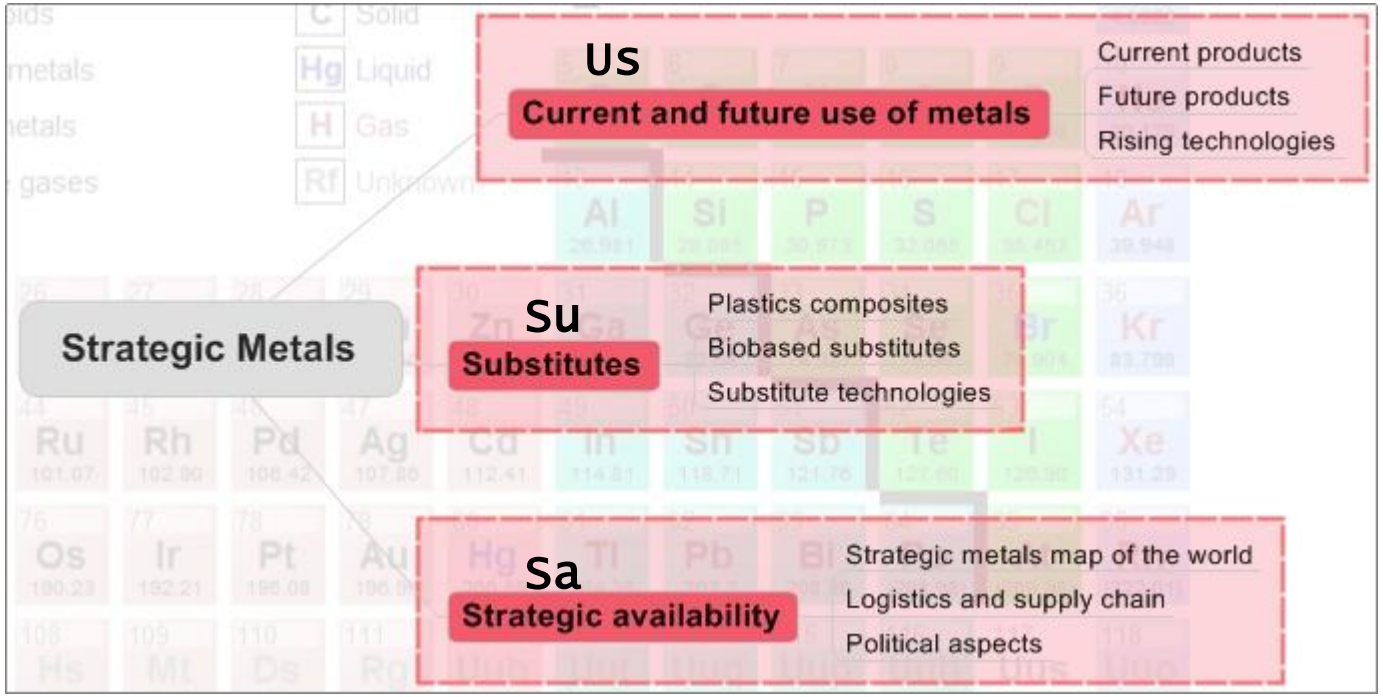
Growing Use of Elements in Semiconductor Industry



Different elements, unknown Environmental Impacts

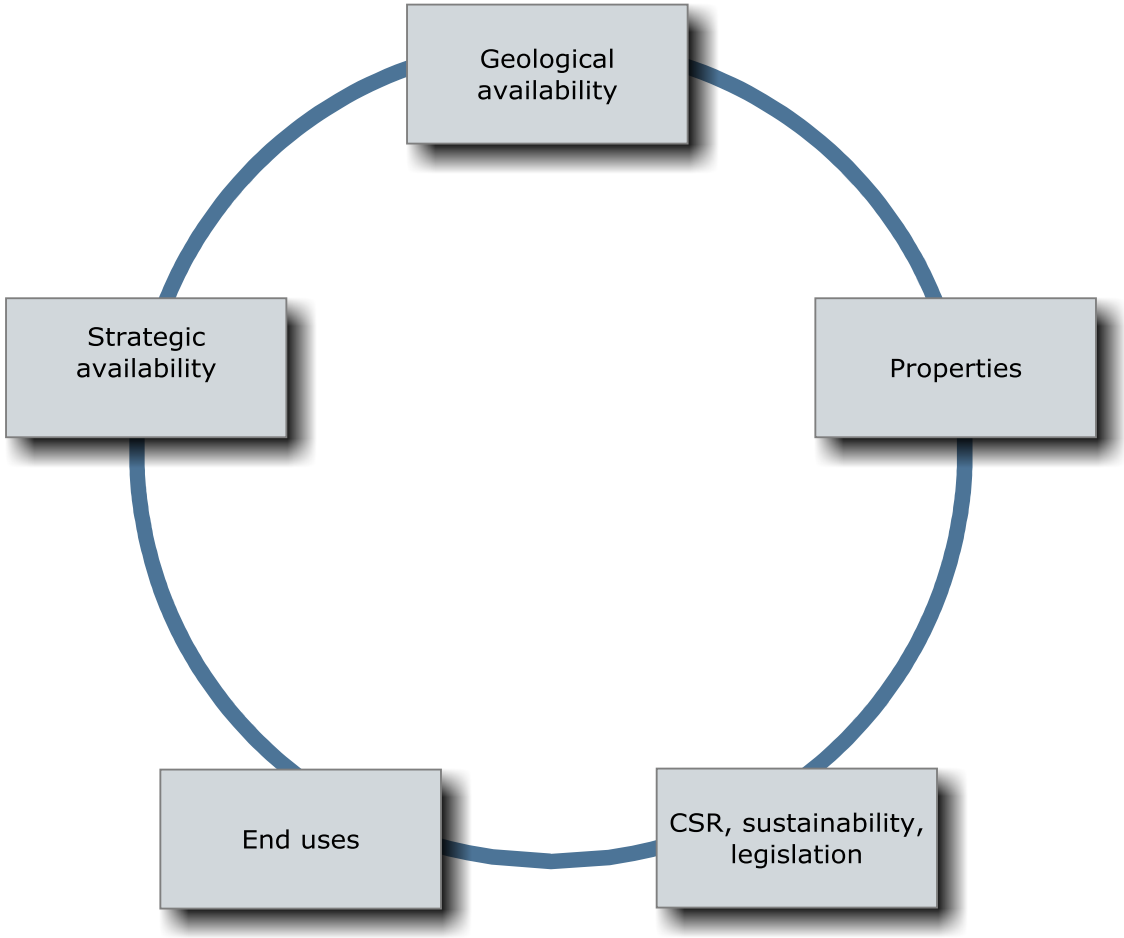
Source: Terrence McManus, Intel

The Periodic Table of Strategic Metal Issues



The *use, substitution* and *strategic availability of rare metals* are the core issues on the agenda. For *use*, we can look at current and upcoming products and technologies; for *substitutes*, plastics composites and biobased substitutes or even substituting technologies are key; for *strategic availability*, the geography, accessibility and cost of metals is the rub.

Drivers
PGM


Geological availability
Properties
CSR, sustainability, legislation
End uses
Strategic availability

Case Catalysts
Alternative, Biobased, Biomimetic…

Drying catalysts
Alkyd resins and unsaturated polyesters are being used in products such as (decorative) paints, inks, flooring materials and all types of construction materials. Alkyd resins alone are annually produced in Western Europe at approximately 500.000 tonnes scale. Production volumes of unsaturated polyesters are approximately at the same level.

Alkyd resins are air drying resins that need a catalyst to accelerate the rate of drying of the paint or ink film. Unsaturated polyesters are being cured by reacting the polyesters with a reactive component (usually stryrene) at elevated temperatures, mediated by a catalyst.

A need for alternative catalysts
Nowadays catalysts for alkyd resins and unsaturated polyesters are largely based on cobalt catalysts.
Studies ,however, indicate that cobalt aerosols are potentially mutagenic and harmful to humans. As a result there is a substantial driving force to develop cobalt free and heavy metal free drying catalysts for both alkyd resins as well as unsaturated polyester based products.

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Sustainability: Cobalt

↓

Biomimetic approach

↓

Heavy metal free biohybrid catalyst

(Heavy) metal free catalyst using a biomimetic approach
At Biobased Products we have succeeded in the development of;

- a proto type iron based catalyst for the efficient drying of alkyd resins
- a proto type metal free catalyst for the curing of unsaturated polyester resins

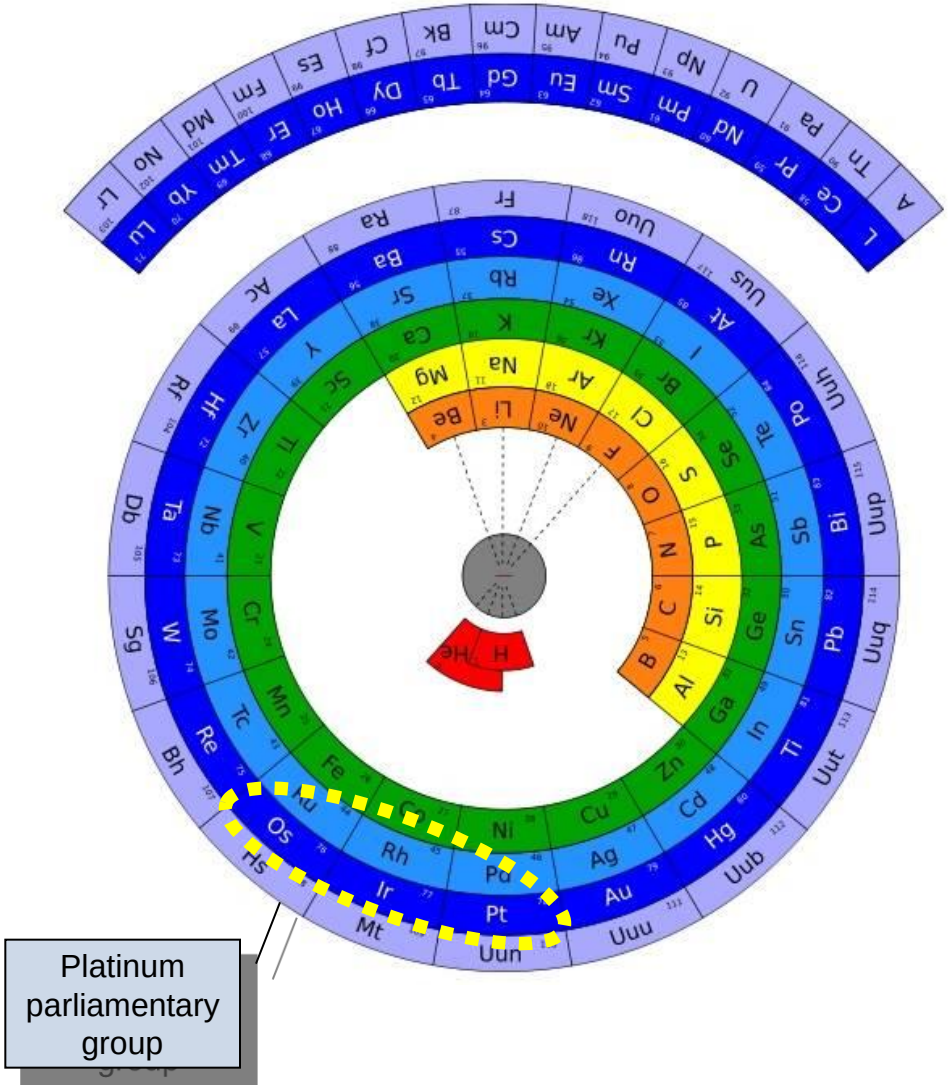
The iron based catalyst consist of an iron salt in combination with a reducing biomolecule, resulting in effective drying of alkyd resins at ambient or lower temperature. Its effectiveness has been proven in both model systems and real varnish and paint systems.

Parliament of Metals
Circular periodic table

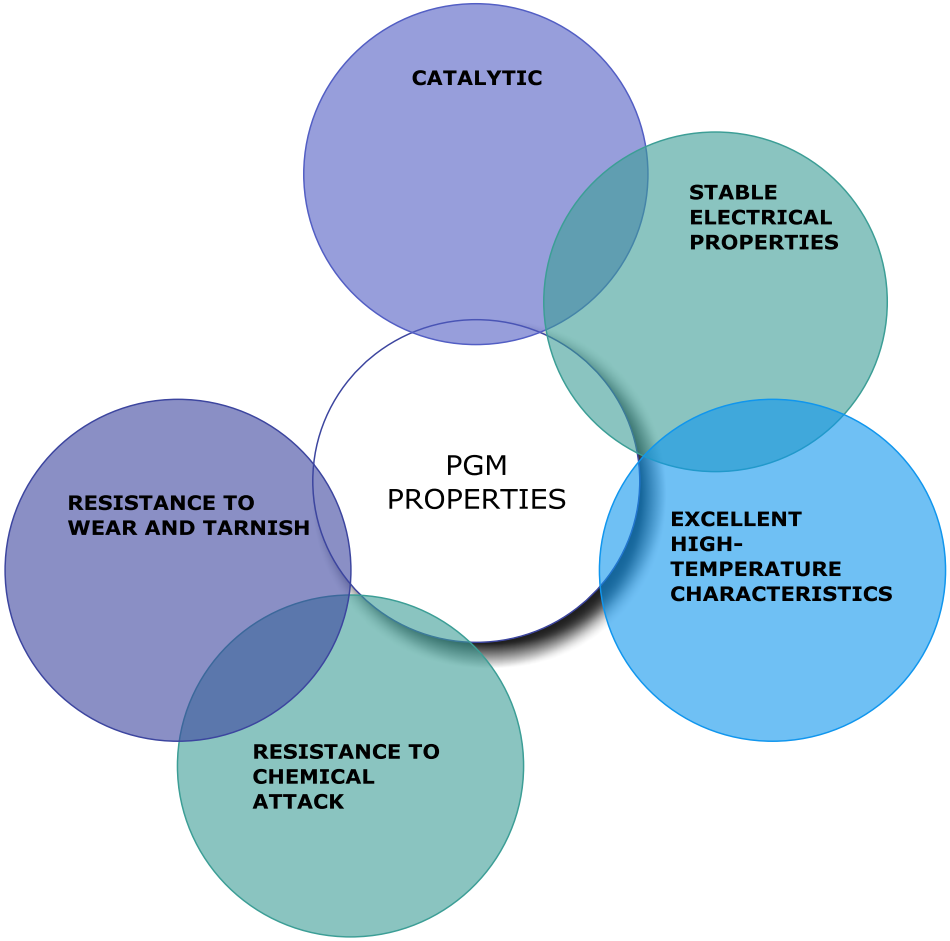
The power of the Platinum Group in the Parliament comes from their rarity and properties.

Mankind hates rarity and seeks second supplies.

Properties are key: find substitutes for properties – or technologies that do not need the properties.

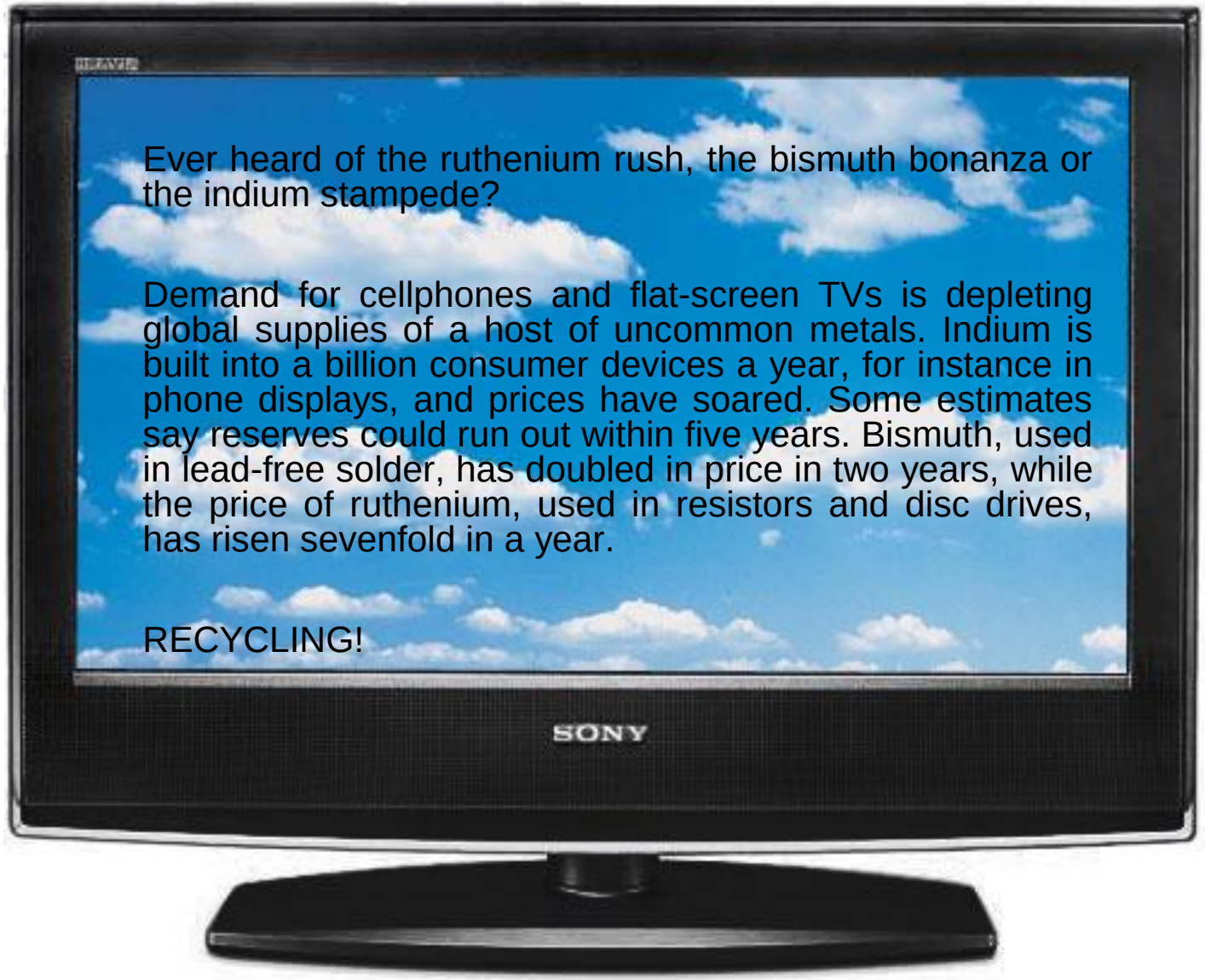


Properties
PGM



TV and Mobile Squeeze

Indium, Bismuth, Ruthenium



Platinum Exhaust
Exhausting But Rewarding

"I GET excited every time I see a street cleaner," says Hazel Prichard. It's what they collect in their sacks that gets her juices flowing, because the grime and litter they sweep up off the streets is **laced with traces of platinum,** one of the world's rarest and most expensive metals. The **catalytic converters** that keep exhaust pollutants from cars, trucks and buses down to an acceptable level all use platinum, and over the years it is **slowly but steadily lost through these vehicles' exhaust pipes**. Prichard, a geologist at the University of Cardiff in the UK, reckons that tonnes of the stuff is being sprayed out onto the world's streets and highways every year, and she is hunting for places where it is concentrated enough to be worth recovering. One of her prime targets is the waste containers in road-sweeping machines.

This could prove lucrative, but Prichard is motivated by something far more significant than the chance of a quick buck. **Platinum is a vital component not only of catalytic converters but also of fuel cells - and supplies are running out. It has been estimated that if all the 500 million vehicles in use today were re-equipped with fuel cells, operating losses would mean that all the world's sources of platinum would be exhausted within 15 years.** Unlike with oil or diamonds, there is no synthetic alternative: platinum is a chemical element, and once we have used it all there is no way on earth of getting any more. What price then pollution-free cities?

Replacing Ruthenium

Mystery material heals itself; No-one understands how it works

Self-healing composite materials that can fix small cracks in the structures of planes, bridges, and wind turbines could become more cost-effective thanks to a new bonding mechanism discovered by researchers in the US. After an impractical solution, a group set to work **looking for an alternative for ruthenium.**

Seeking to improve the approach, the group **changed to a nickel-based catalyst, but had to change the solvent as well.** The first step was to gauge the new solvent in the absence of a catalyst.

To their surprise, it worked almost as well. Moore says the solvent was probably dissolving the composite material, allowing it to mix and bond again, although he concedes the exact mechanism remains a mystery.

The group then tested **another solvent, using a chemical called chlorobenzene.** After fracture and self-healing, the composites containing chlorobenzene recovered up to 100% of their original strength – as good as new.

And, although toxic, **chlorobenzene is a hundred times cheaper than ruthenium and is much more easily available**. However, the **toxicity of chlorobenzene is likely to make the idea less industrially attractive**. The team, meanwhile, is testing a number of less toxic, **more biodegradable solvents to do the same job**.

Journal reference: Macromolecules (DOI: 10.1021/ma701992z)

The China Case

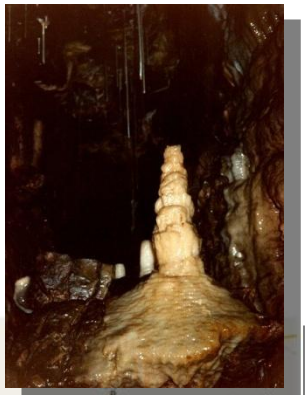
The Story of the Stone: Dynasties Rise and Fall Over 2000 Years

A single stalagmite in a cave in China tells the story of 1810 years of dynasties rising and falling across the Earth.

The Wanxiang Cave is in Gansu Province, a region where *80% of the rainfall occurs between May and September*. Gansu is located in the northwest of the People's Republic of China. It lies between Qinghai, Inner Mongolia, and the Huangtu Plateaus, and borders Mongolia to the north and Xinjiang to the west. It has a population of approximately 26 million (2004) and has a large concentration of Hui Chinese. The capital of the province is Lanzhou, located in the southeast part of Gansu.

Gansu is abbreviated Gan or Long, and is also known as *Long West or Long Right, in reference to the Long Mountain east of Gansu.*

The Yellow River passes the southern part of the province, and gets most of its water from the province. The Yellow River also flows straight through Lanzhou.

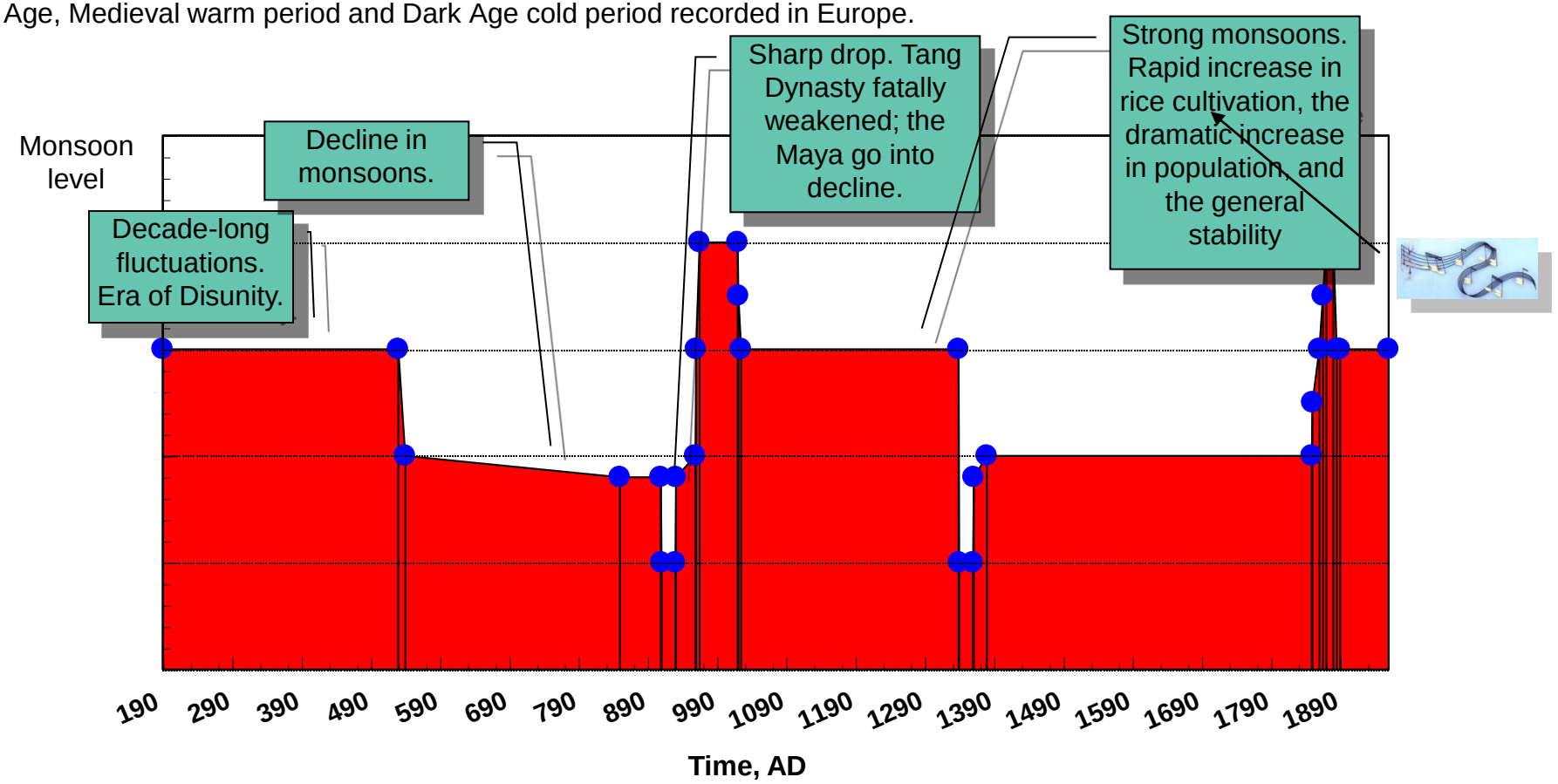


The Story of the Stone: Dynasties Rise and Fall Over 2000 Years

Slowly built from the minerals in dripping water over 1,810 years, the stalagmite is a **living story of strong and weak monsoon cycles**: the cycles that feed millions (to billions) of people.

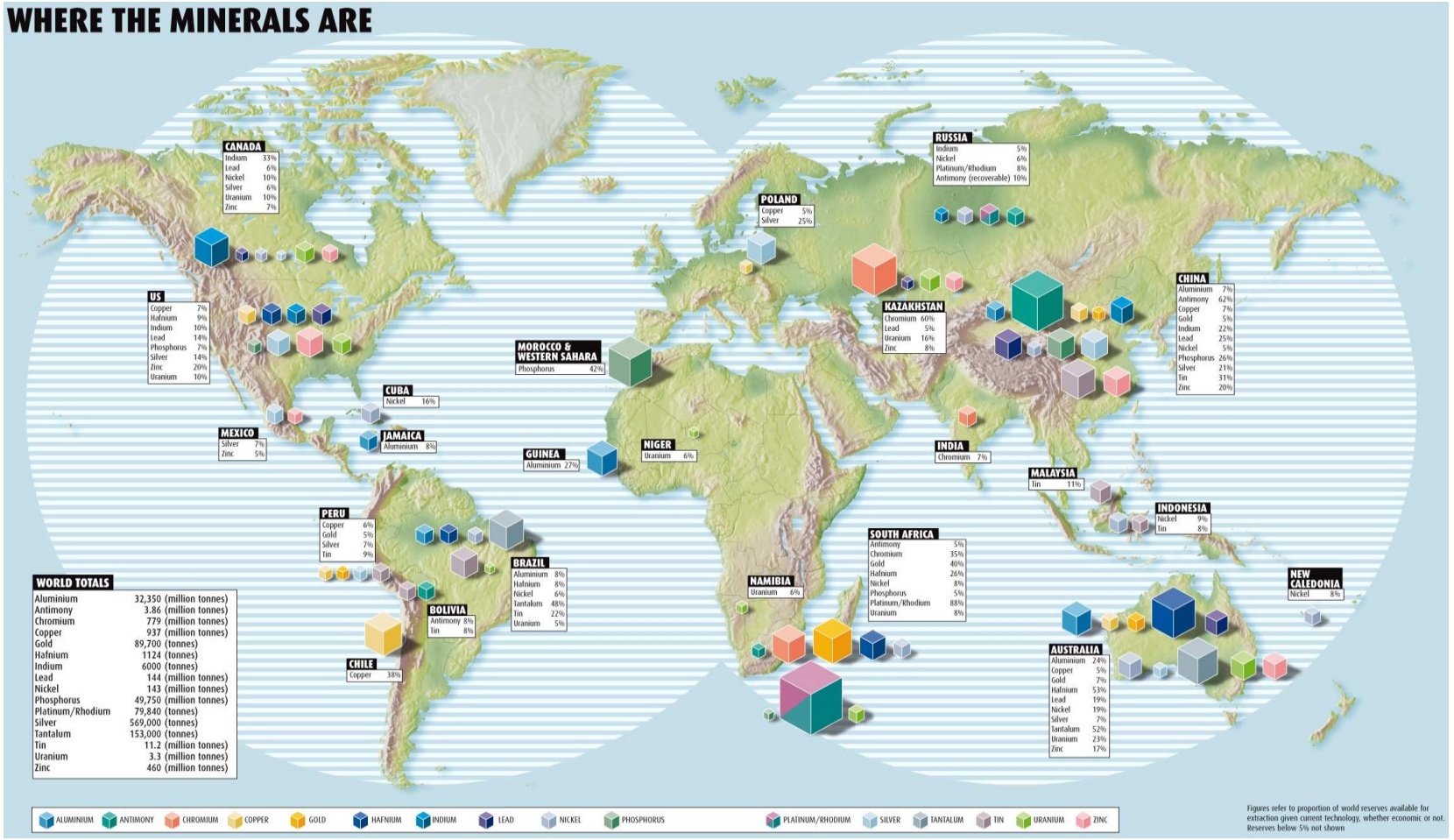
Dry periods coincided with the demise of the Tang, Yuan and Ming dynasties, it was reported in the journal Science. The research team led by Pingzhong Zhang of Lanzhou University in China also noted **a change in the cycles around 1960 which they said may indicate that greenhouse gases released by human activities have become the dominant influence on the monsoon.**

The story is one of fluctuations lasting from one to several centuries and roughly similar to records of the Little Ice Age, Medieval warm period and Dark Age cold period recorded in Europe.



METALS: THE NEXT 2000-YEAR INDICATOR FOR CHINA?

WHERE THE MINERALS ARE

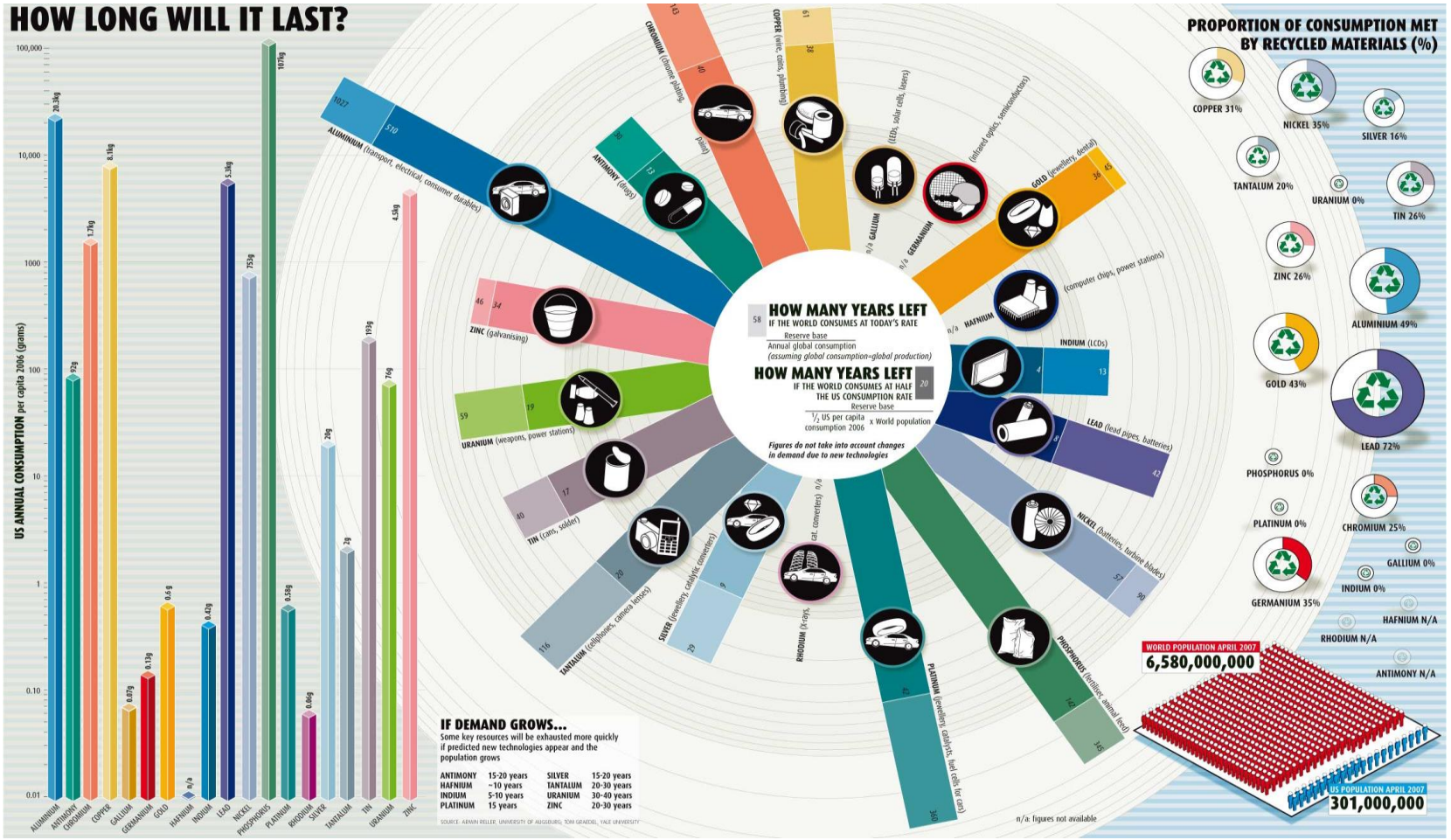


WORLD TOTALS

Aluminium	32,350 (million tonnes)
Antimony	3.86 (million tonnes)
Chromium	779 (million tonnes)
Copper	937 (million tonnes)
Gold	89,700 (tonnes)
Hafnium	1124 (tonnes)
Indium	6000 (tonnes)
Lead	144 (million tonnes)
Nickel	143 (million tonnes)
Phosphorus	49,750 (million tonnes)
Platinum/Rhodium	79,840 (tonnes)
Silver	569,000 (tonnes)
Tantalum	153,000 (tonnes)
Tin	11.2 (million tonnes)
Uranium	3.3 (million tonnes)
Zinc	460 (million tonnes)

ALUMINIUM ANTIMONY CHROMIUM COPPER GOLD HAFNIUM INDIUM LEAD NICKEL PHOSPHORUS PLATINUM/RHODIUM SILVER TANTALUM TIN URANIUM ZINC

Figures refer to proportion of world reserves available for extraction given current technology, whether economic or not. Reserves below 5% not shown


HOW LONG WILL IT LAST?
US ANNUAL CONSUMPTION per capita 2006 (grams)
100,000
10,000
1000
100
10
1
0.10
0.01
20.34g
9.3g
1.7g
8.1g
0.87g
0.13g
0.6g
n/a
0.42g
5.3g
753g
1078g
0.59g
0.06g
20g
3g
193g
76g
4.35g
ALUMINIUM
ANTIMONY
CHROMIUM
COPPER
GALLIUM
GERMANIUM
GOLD
HAFNIUM
INDIUM
LEAD
NICKEL
PHOSPHORUS
PLATINUM
RHODIUM
SILVER
TANTALUM
TIN
URANIUM
ZINC
ALUMINIUM (transport, electrical, consumer durables)
1027
510
ANTIMONY (alloys)
30
12
CHROMIUM (chrome plating, steel)
143
40
COPPER (wire, cable, plumbing)
61
36
GALLIUM (LEDs, solar cells, lasers)
n/a
GERMANIUM (infrared optics, semiconductors)
GOLD (jewellery, dentistry)
58
40
HAFNIUM (computer chips, power stations)
n/a
INDIUM (LCDs)
4
13
LEAD (lead pipes, batteries)
18
42
NICKEL (batteries, turbine blades)
57
90
PHOSPHORUS (fertilizer, animal feed)
145
345
PLATINUM (jewellery, catalysts, fuel cells for cars)
75
360
RHODIUM (X-rays, cat. converters)
n/a
SILVER (jewellery, catalytic converters)
9
25
TANTALUM (cellphones, camera lenses)
20
116
TIN (cans, solder)
40
17
URANIUM (weapons, power stations)
59
19
ZINC (galvanising)
46
34
HOW MANY YEARS LEFT
IF THE WORLD CONSUMES AT TODAY'S RATE
58
Reserve base
Annual global consumption
(assuming global consumption=global production)
HOW MANY YEARS LEFT
IF THE WORLD CONSUMES AT HALF THE US CONSUMPTION RATE
20
Reserve base
1/2 US per capita consumption 2006 x World population
Figures do not take into account changes in demand due to new technologies
IF DEMAND GROWS...
Some key resources will be exhausted more quickly if predicted new technologies appear and the population grows
ANTIMONY 15-20 years
HAFNIUM ~10 years
INDIUM 5-10 years
PLATINUM 15 years
SILVER 15-20 years
TANTALUM 20-30 years
URANIUM 30-40 years
ZINC 20-30 years
SOURCE: ARWIN REILLER, UNIVERSITY OF AUGSBURG; TOM GRADDEL, YALE UNIVERSITY
n/a: figures not available
PROPORTION OF CONSUMPTION MET BY RECYCLED MATERIALS (%)
COPPER 31%
NICKEL 35%
SILVER 16%
TANTALUM 20%
URANIUM 0%
TIN 26%
ZINC 26%
ALUMINIUM 49%
GOLD 43%
LEAD 72%
PHOSPHORUS 0%
PLATINUM 0%
CHROMIUM 25%
GALLIUM 0%
INDIUM 0%
GERMANIUM 35%
HAFNIUM N/A
RHODIUM N/A
ANTIMONY N/A
WORLD POPULATION APRIL 2007
6,580,000,000
US POPULATION APRIL 2007
301,000,000

Cross-Cluster Obstacles and Opportunities

Strategic Metals Substitution: Cross-Sector Opportunity in Biorefineries

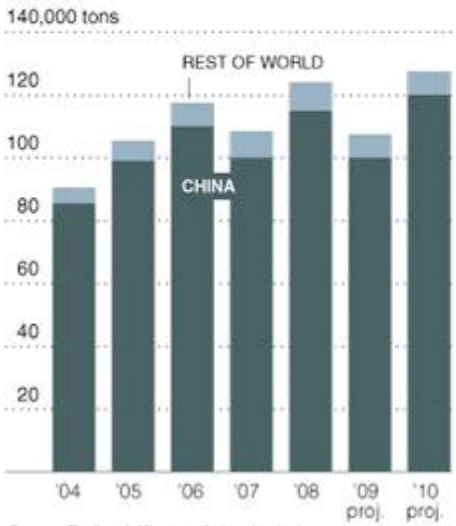
Strategic metals availability:

severely threatened

Rare Wealth

China accounts for the vast majority of the world's production of rare earths — 17 elements — which are used in a wide array of products.

RARE EARTH MINERAL PRODUCTION



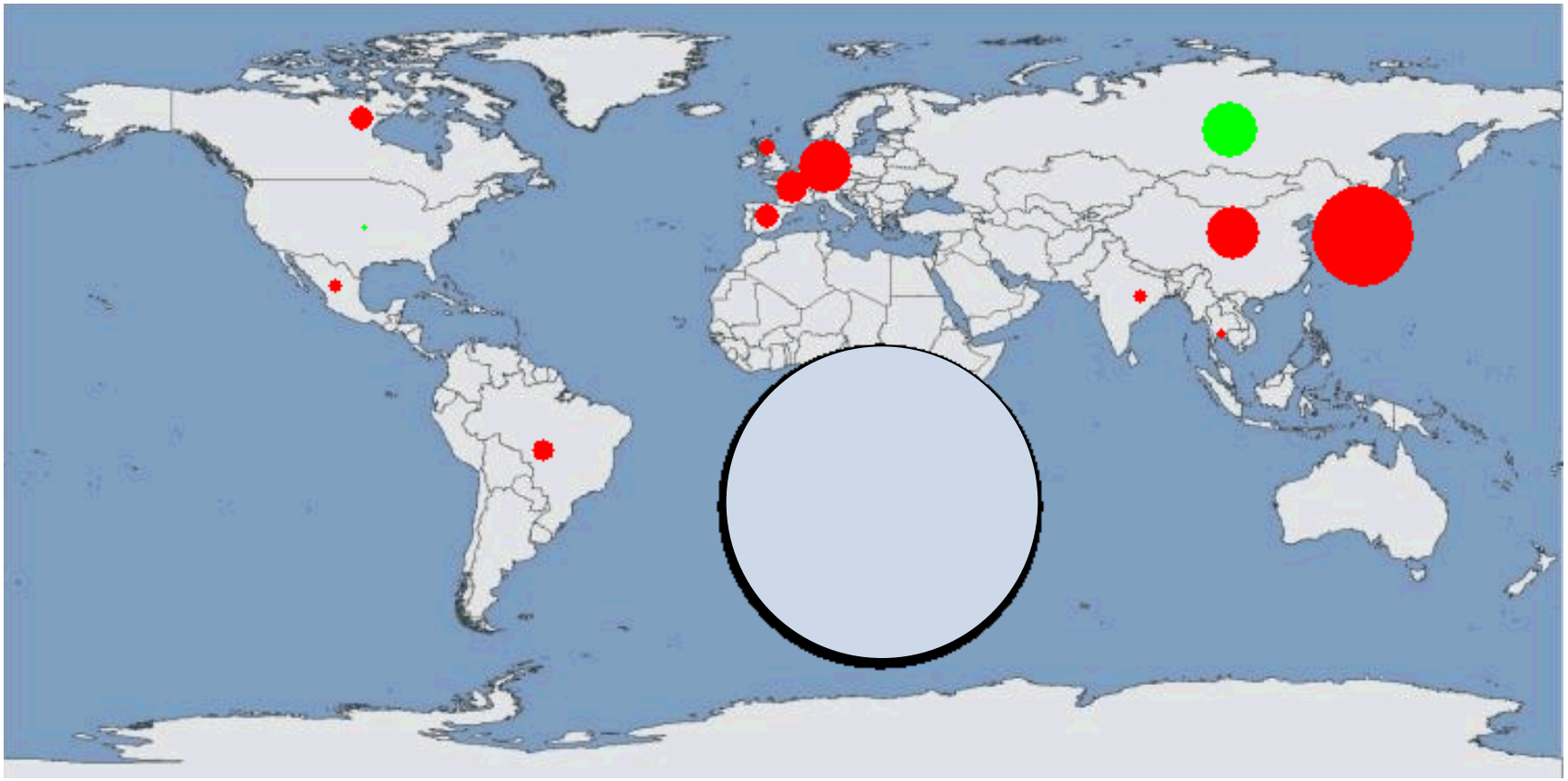
Source: Dudley J. Kingsnorth (production)

RARE EARTHS	ATOMIC NO.	COMMERICAL USE
Scandium	21	Stadium lights
Yttrium	39	Lasers
Lanthanum	57	Electric car batteries
Cerium	58	Lens polishes
Praseodymium	59	Searchlights, aircraft parts
Neodymium	60	High-strength magnets
Promethium	61	Portable X-ray units
Samarium	62	Glass
Europium	63	Compact fluorescent bulbs
Gadolinium	64	Neutron radiography
Terbium	65	High-strength magnets
Dysprosium	66	High-strength magnets
Holmium	67	Glass tint
Erbium	68	Metal alloys
Thulium	69	Lasers
Ytterbium	70	Stainless steel
Lutetium	71	None

THE NEW YORK TIMES

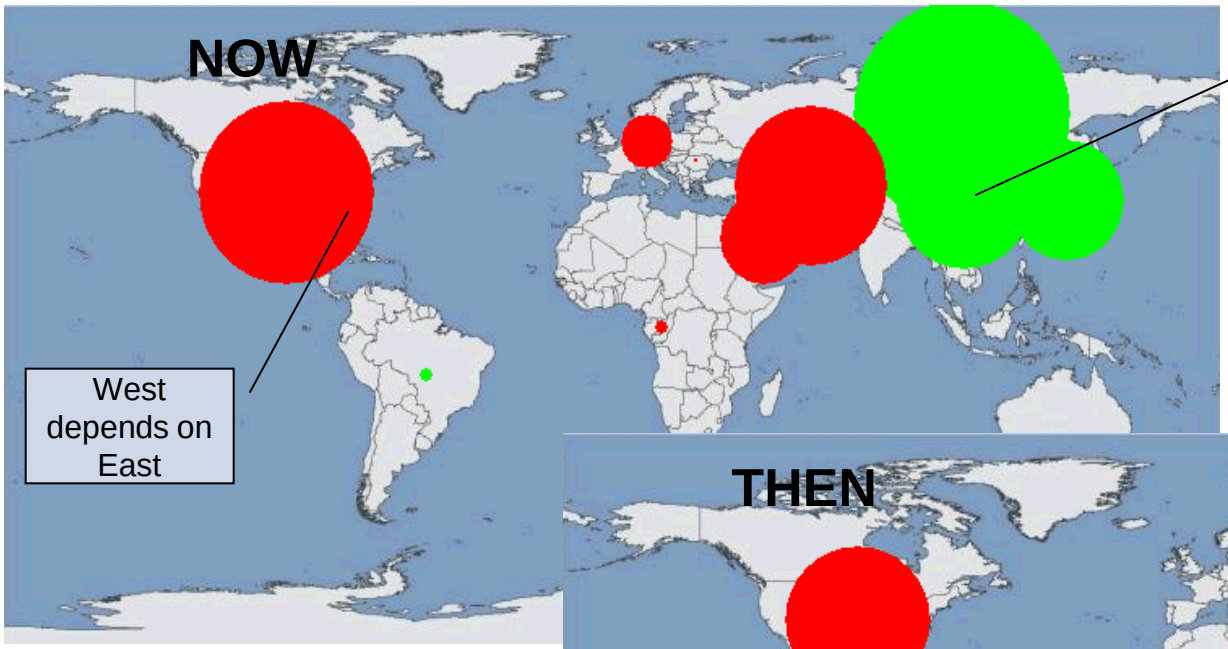
Platinum Hub

South Africa is the key. Something disrupts South African platinum, and many industrial sectors globally are in jeopardy.



Global Steel Hockey

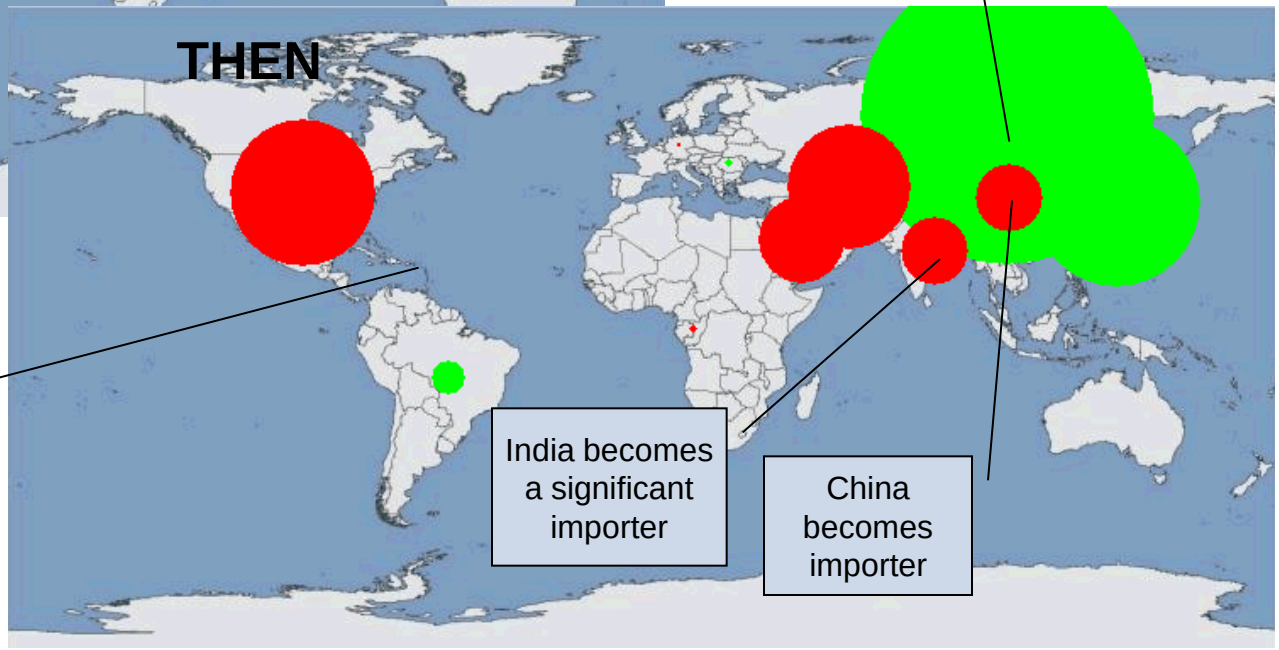
China is the world's largest producer and consumer of steel. What if China's appetite further increases, while India mass-exports cars?



China exports steel

Russia increases its dominance

West depends on East



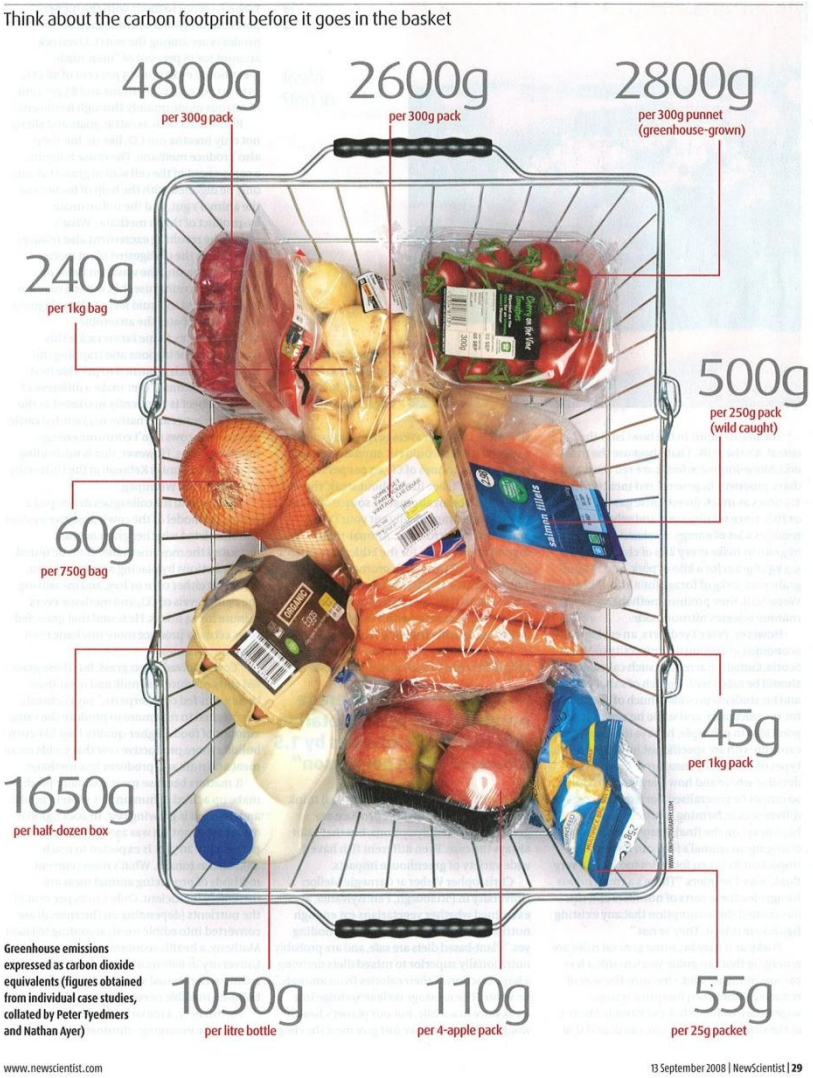
The West becomes more dependent, even if the material flow decreases the value increases. Net effect is reduction of steel based production

India becomes a significant importer

China becomes importer

Unknowns in Emissions

Case China: The Growing Middleclass can afford this basket….



If the expected Chinese middle class (520 million people by 2025) would ONLY ONCE a year purchase this food basket, the GHG emissions produced would be about 70 Mt CO2-eq. The GHG emissions of Austria or Finland in 2006 were about 80 Mt/CO2 eq.

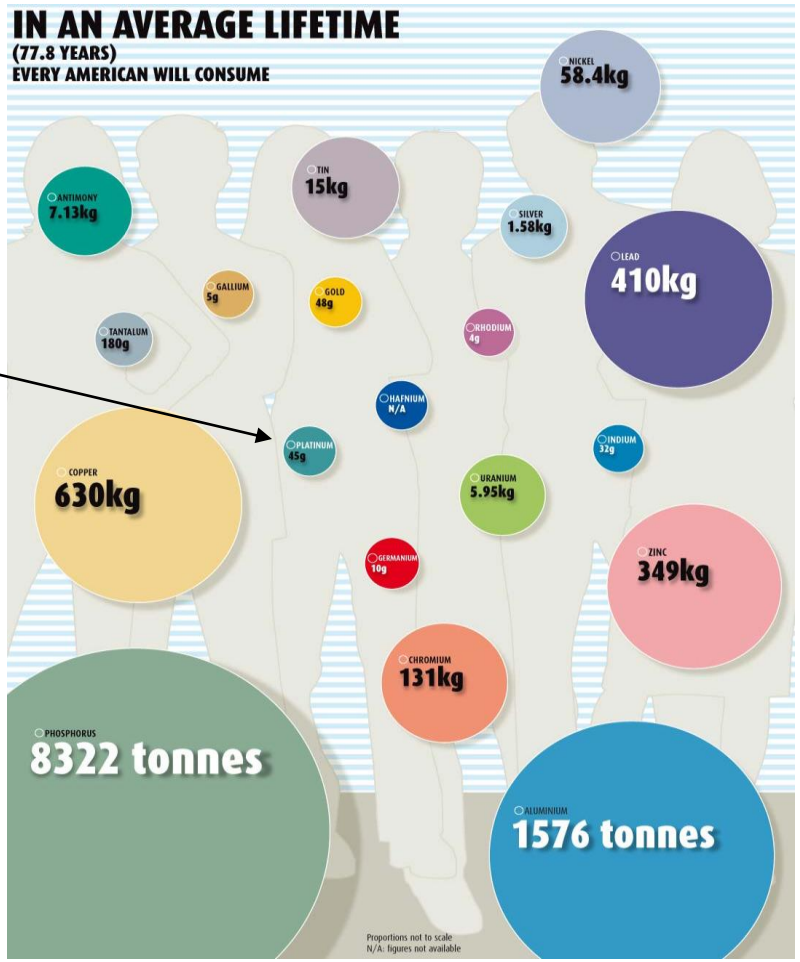
Source: New Scientist

Analogy to Food Basket
Other Platinum Case – A Labile Balance and Link Pt/CO_2

- Chinese Internet Literacy and Computers
  - 15.8% of Chinese say they are able and willing to use the internet. 68.2% of Finns say the same. (ITU)
  - A generic computer requires around 0.7 kg of Aluminum, 1 g of Silver and 5 mg of Platinum (Microelectrics and Computer Technology Corporation)
  - Some of these resources are extremely scarce. Were the Chinese to reach mere Finnish levels, which are still rising, only the Chinese computers would require around 5% of worlds silver, 2% of aluminum (ENERGY!) and 1% of platinum. Silver is seemingly very common and is used very widely because of its chemical properties. The seeming abundance fools the eye.
  - The increase would also equate burning 40 Mtons of more coal every year in China.

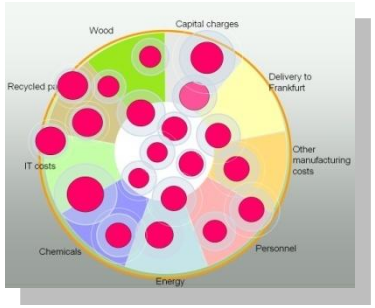
Of Course, Not Just China

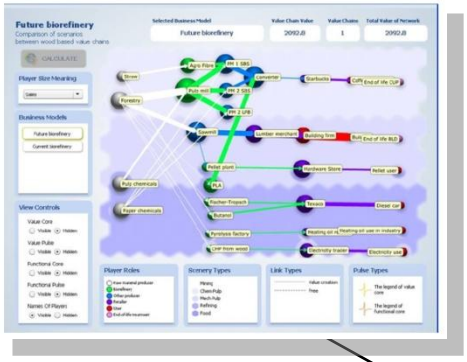
45 g Pt

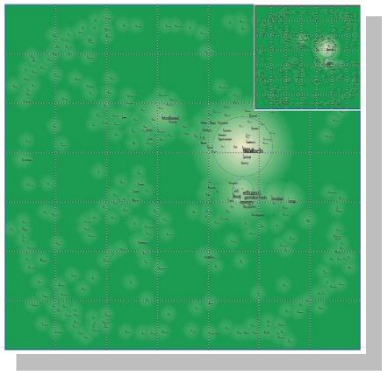


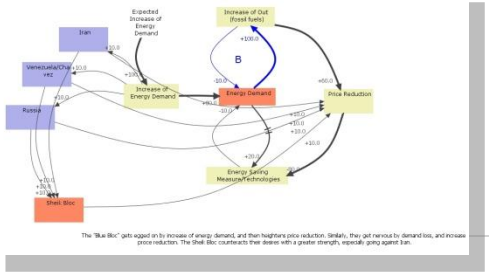
Tools For Resolution
Metals, End Uses, Substitution, Demands

A pattern of dots for the Big Picture: and examples for solution tools.







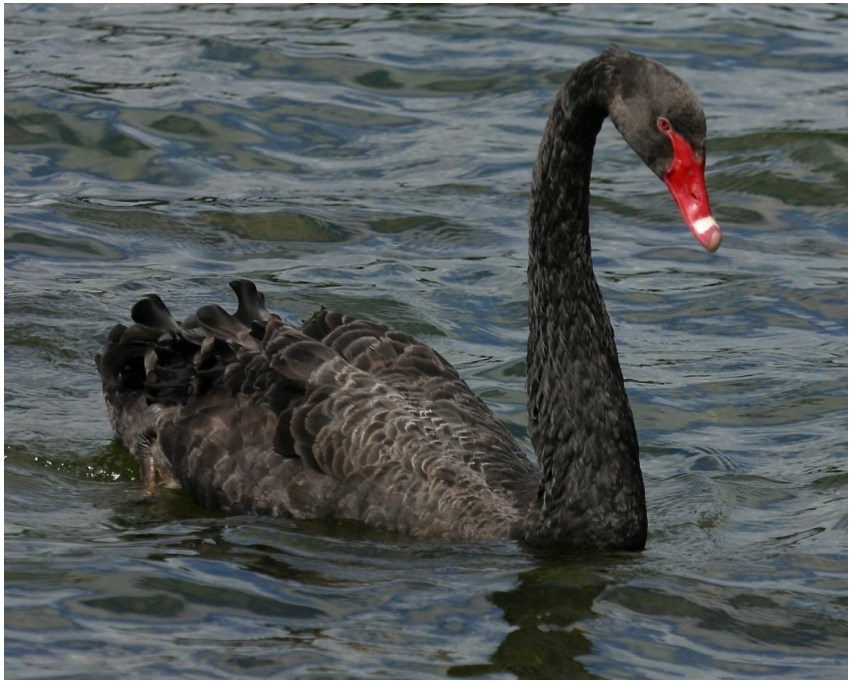


PÖYRY

The Pöyry Scenario Zoo

BLACK SWAN-class scenario

Conventional wisdom refuses to consider it: too scary, and it won't/can't happen anyway



The **black swan theory** refers to a large-impact, hard-to-predict, and rare event beyond the realm of normal expectations. The term black swan comes from the ancient Western conception that 'All swans are white'. In that context, a black swan was a metaphor for something that could not exist. The 17th Century discovery of black swans in Australia metamorphosed the term to connote that the perceived impossibility actually came to passJohn Stuart Mill first used the black swan narrative to discuss falsification.

The theory was described by Nassim Nicholas Taleb in his 2007 book The Black Swan. Taleb regards many scientific discoveries as black swans—"undirected" and unpredicted. He gives the **rise of the Internet, the personal computer, the first world war, as well as the September 11,** 2001 attacks as examples of Black Swan events.

For Taleb, a key item is a central and unique attribute: **the high impact. His claim is that almost all consequential events in history come from the unexpected—while humans convince themselves that these events are explainable in hindsight (bias).**

PLATYPUS-class scenario

Conventional wisdom acknowledges its existence, but isn't bothered: it is seemingly harmless (and/or peculiar and/or even cute)

It's toxic!

The platypus is an egg-laying poisonous mammal. Its toxin kills smaller animals, usually not humans. However, it causes people excruciating pain, paralysis, pain and muscle damage lasting weeks to months.

Even morphine has no impact on the toxin, because it seems to bypass direct routes and have a direct impact on pain receptors. As it also lowers blood pressure, it is being researched as a heart and/or pain medicine.

The value of good PR managers

Compare the platypus image to that of equally toxic snakes.

The platypus must have a truly good PR agency/spin doctor!

UNICORN

UNICORN-class

A unicorn (from Latin unus 'one' and cornu 'horn') is a mythological creature. Though the modern popular image of the unicorn is that of a horse differing only in the horn on its forehead.

LIGER

LIGER-class

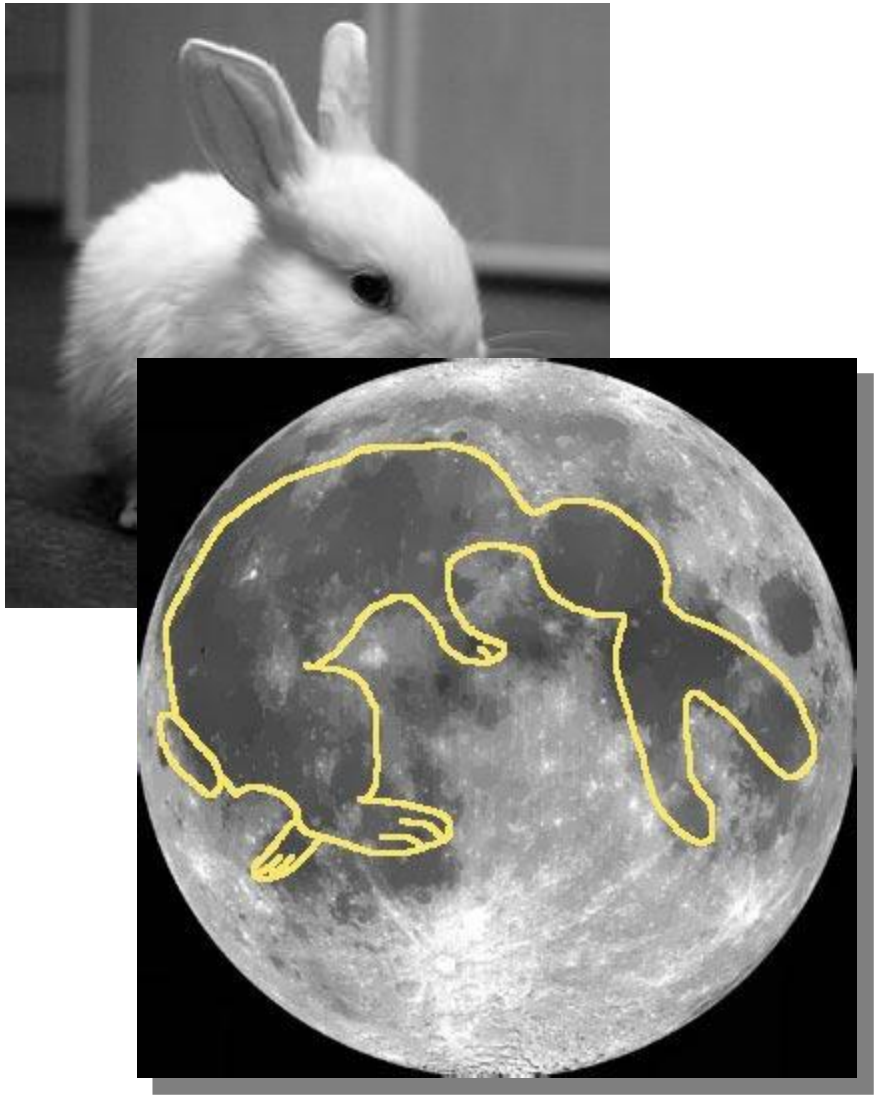
A liger is a hybrid cross between a male lion and a female tiger. It’s superior to most lions or tigers in size. This animal shows faint striping and mottling, and, in its characteristics, exhibits strong traces of both its parents as well as new features.

An absurd but plausible new combination of existing phenomena. It carries features which are absent in the parents.

RABBIT

A nice and seemingly harmless, even likeable creature but in multitudes disastrous.

Links not to the Maya (whose undoing the Gansu stalagmite tells), but to the Aztecs. For them, the rabbit was to be seen on the moon. The Aztecs had a legend to explain it. A very short version in the Florentine Codex reads: "The myth of the rabbit in the moon goes as follows: The gods, they say, were teasing the moon and flung a rabbit in its face. And the rabbit remained marked on the moon's face. That is what darkened the face of the moon, as though it had been bruised. Upon which the moon went out to light the world."



Examples

RABBIT-scenario

All reports say everybody should do the same things. Everybody does it. All starve.

PLATYPUS-scenario

Since only carbon has significance, water, metals etc. are ignored as harmless. Until water runs out.

UNICORN-scenario

Large Hadron Collider (LHC) creates a black hole that eats the. Competitiveness studies have to be remade. IMD and WEF are very irritated, if they still exist.

BLACK SWAN-scenario

Out of left field, like the subprime crisis. No, that was expected...

Pöyry Scenario Zoo

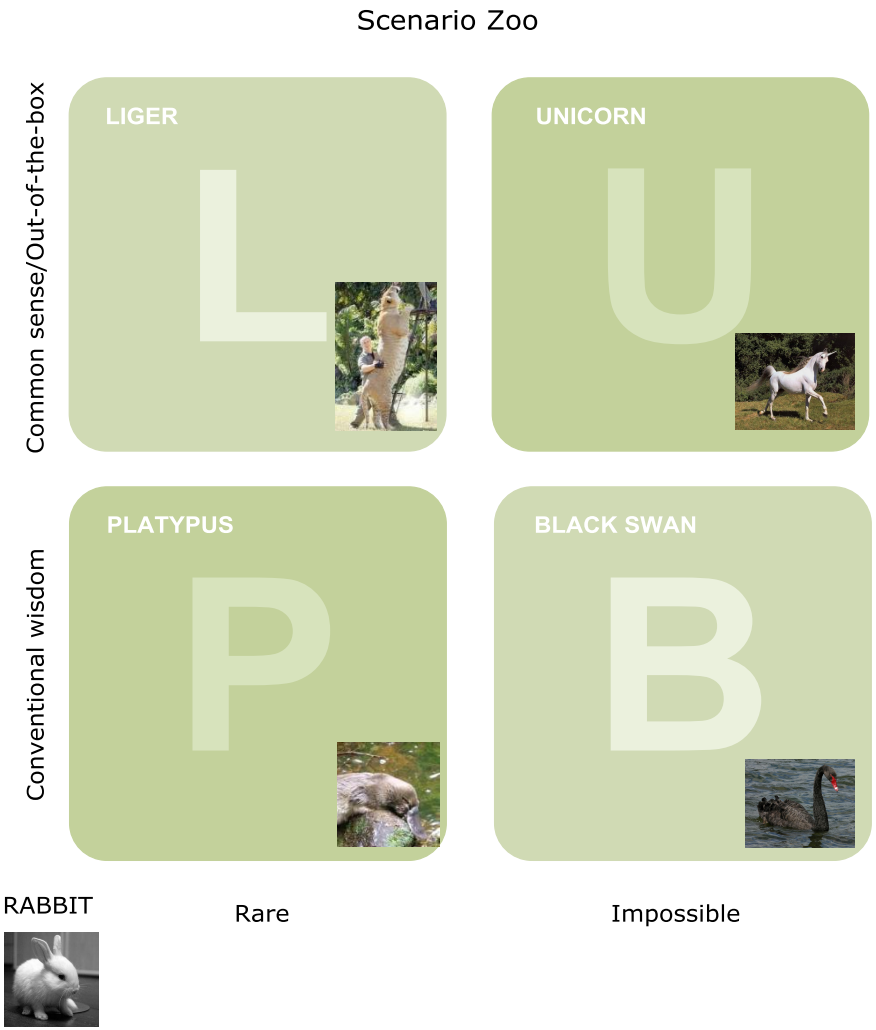
RABBIT (scenario)= everybody knows it happens. But it happens to such a degree that all restraints break.

PLATYPUS=conventional wisdom acknowledges existence, but sees as harmless. Which is untrue.

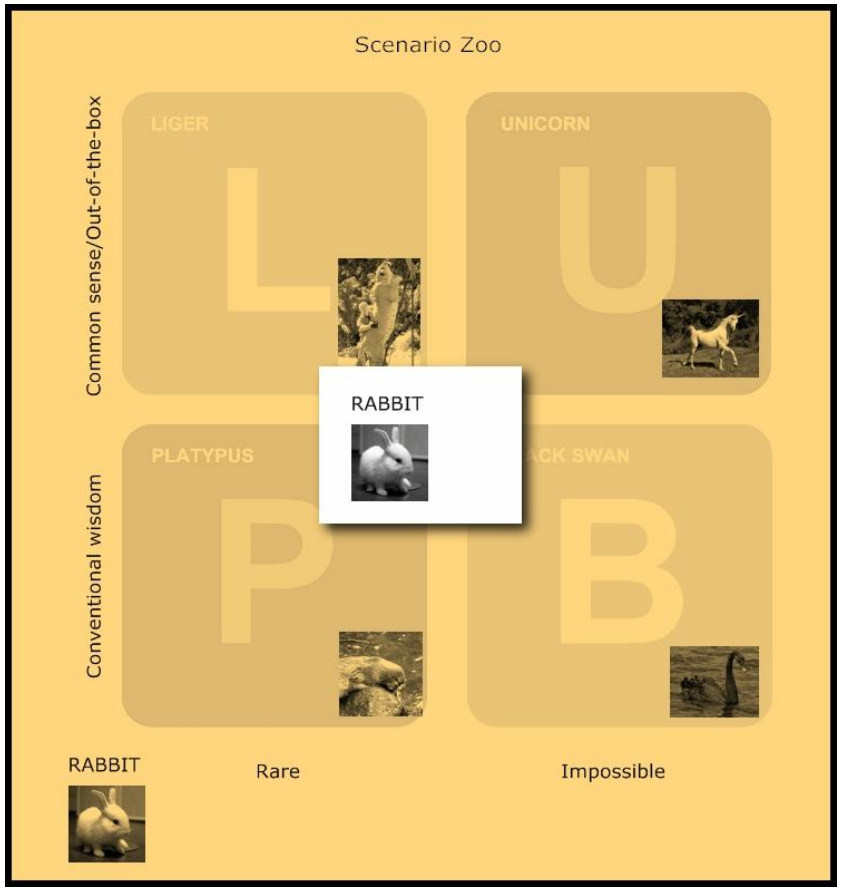
LIGER=An ”uncivilised” or NIH occurrence, although common sense realises it could happen

UNICORN=Against current scientific knowledge, impossible

BLACK SWAN=such things just don’t happen, right?



RABBIT Scenarios



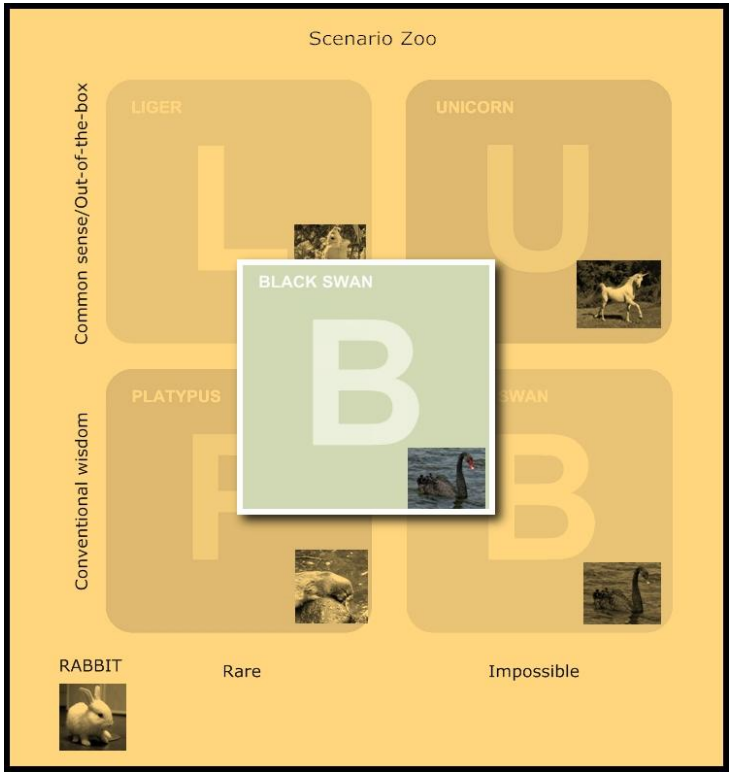
FROM 36 STRATEGIES

Take the opportunity to pilfer a goat

While carrying out your plans be flexible enough to take advantage of any opportunity that presents itself, however small, and avail yourself of any profit, however slight.

Expect a lot of short-term gaming.

BLACK SWAN Scenarios



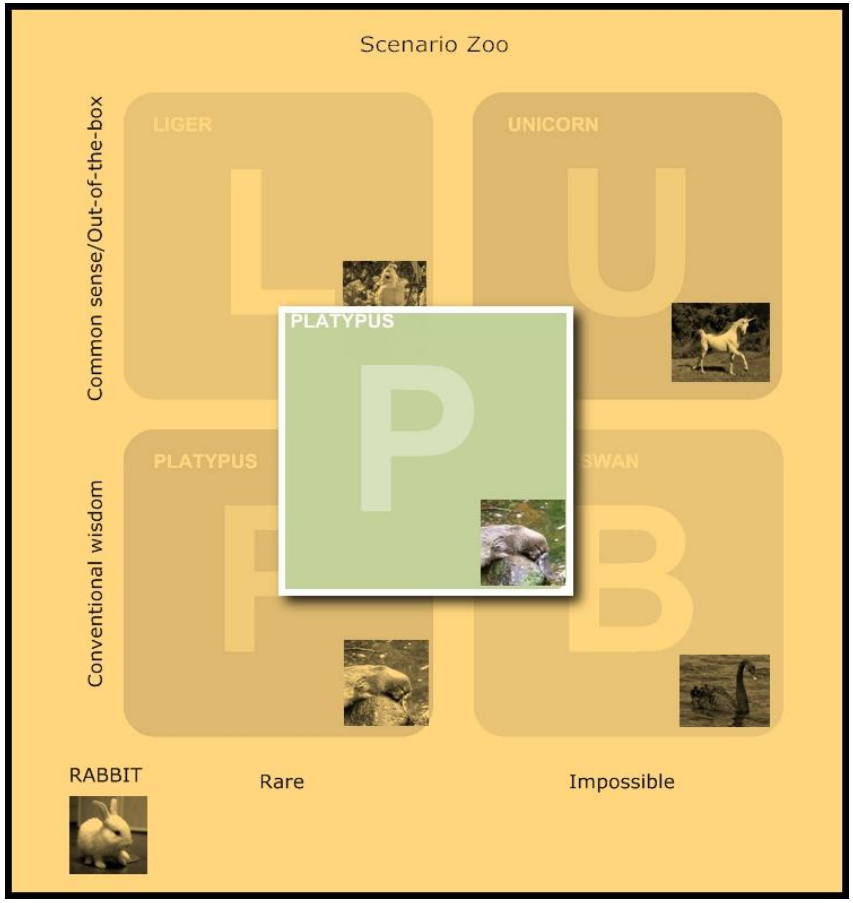
FROM 36 STRATEGIES

Remove the firewood from under the pot

Take out the leading argument or asset of someone; "steal someone's thunder".

The properties of platinum can be fully replicated using biobased substitutes

PLATYPUS Scenarios



FROM 36 STRATEGIES

Leisurely wait for the laboured

It is an advantage to choose the time and place for battle. In this way you know when and where the battle will take place, while your enemy does not. Encourage your enemy to expend his energy in futile quests while you conserve your strength. When he is exhausted and confused, you attack with energy and purpose

Those who have the metals, act very nice and cosy, until….

CONTACT

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