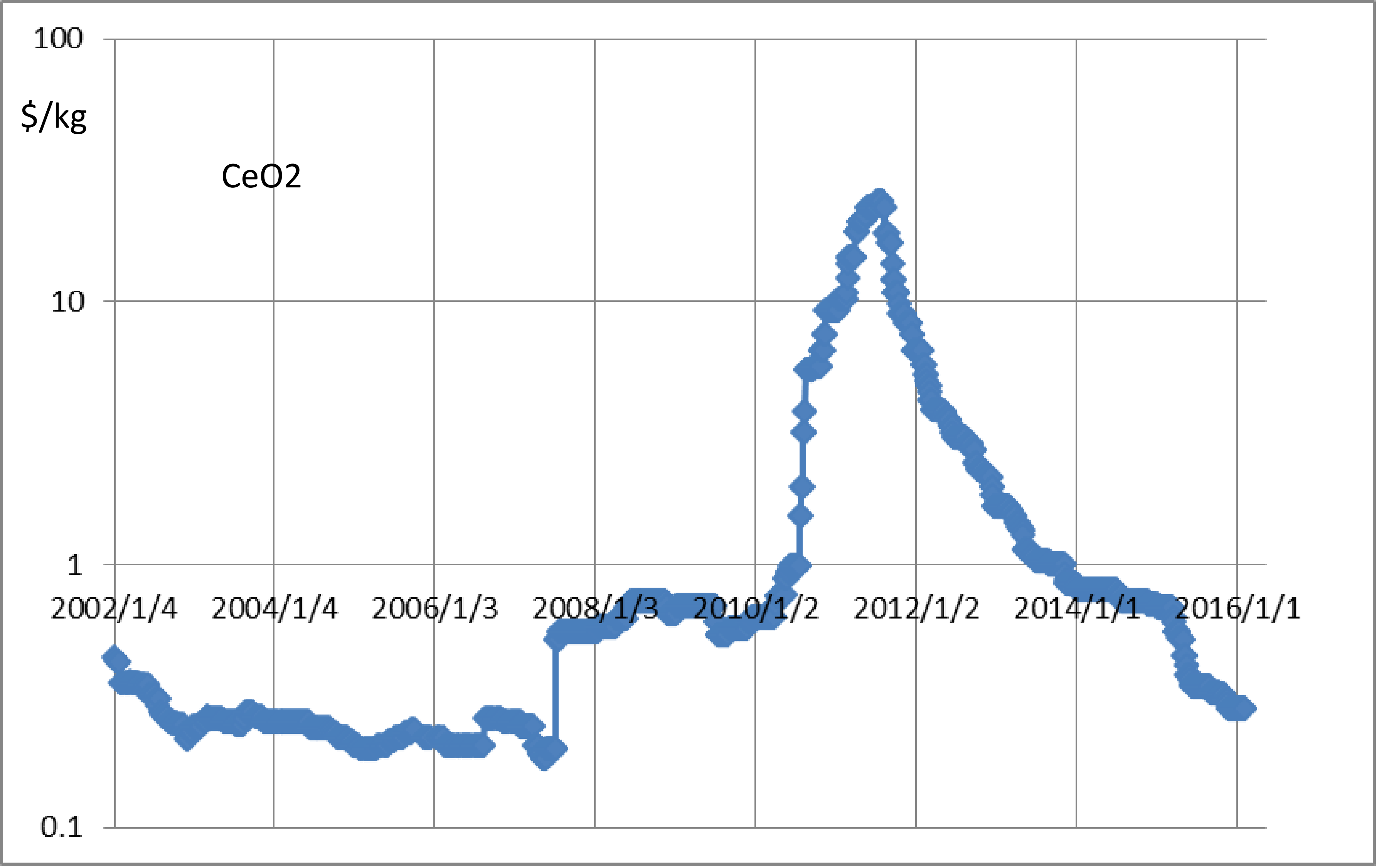
Life-cycle Analysis and Criticality of Ceramics and Elements

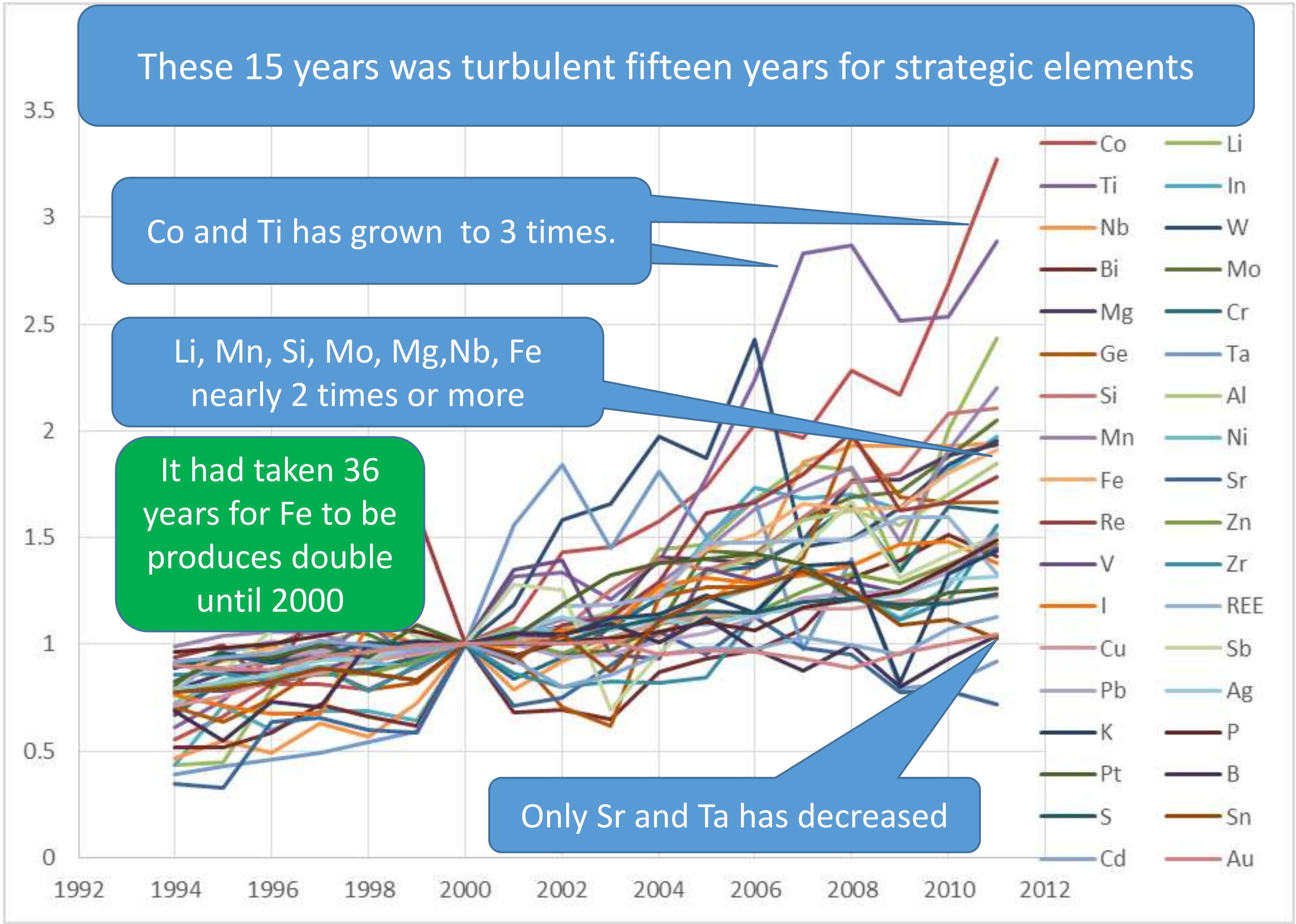
Kohmei HALADA

National Institute for Materials Science

World Academy of Ceramics Forum 2016


100
$/kg
CeO2
10
1
0.1
2002/1/4
2004/1/4
2006/1/3
2008/1/3
2010/1/2
2012/1/2
2014/1/1
2016/1/1

These 15 years was turbulent fifteen years for strategic elements



Co and Ti has grown to 3 times.

Li, Mn, Si, Mo, Mg,Nb, Fe nearly 2 times or more

It had taken 36 years for Fe to be produces double until 2000

Only Sr and Ta has decreased

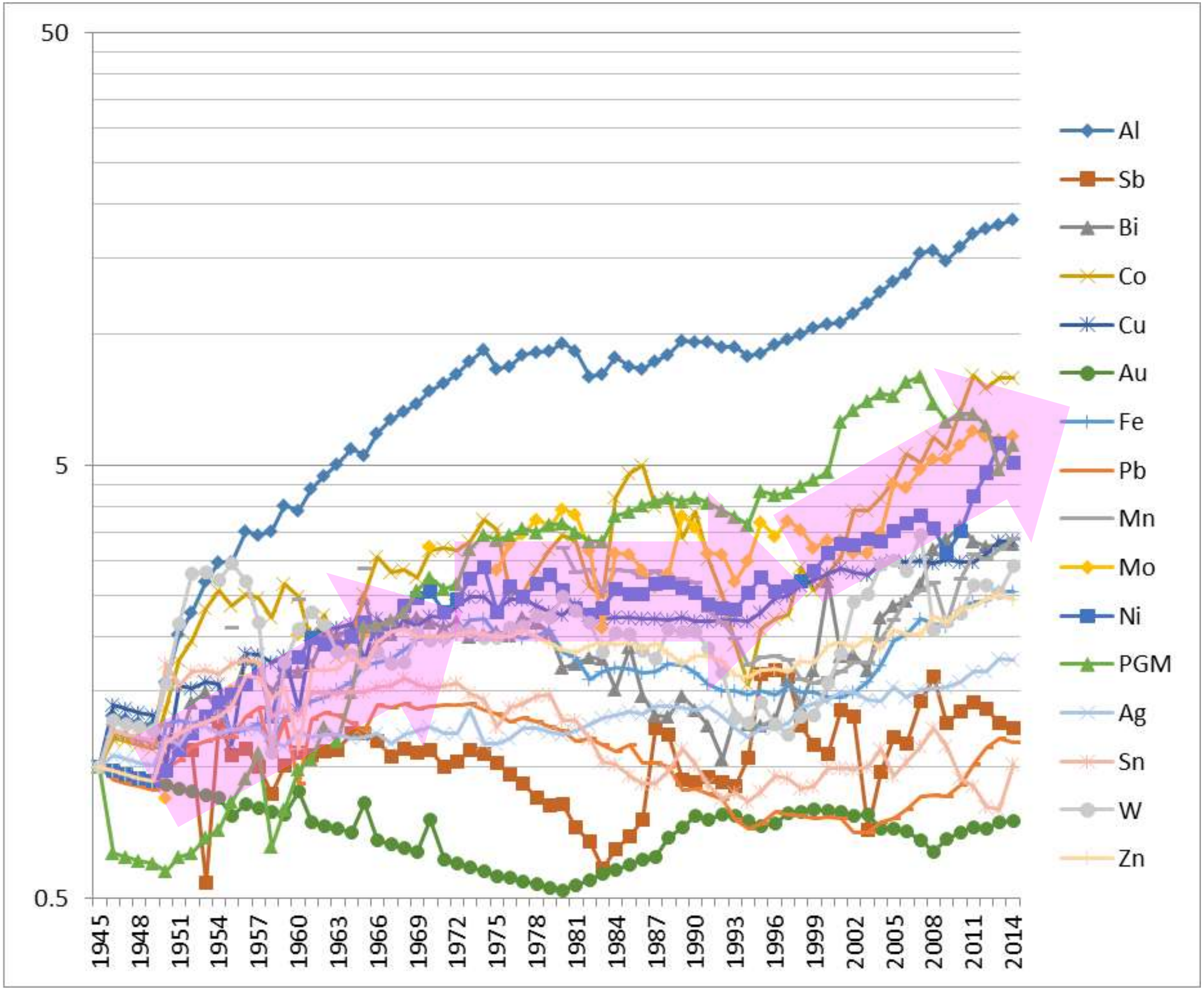
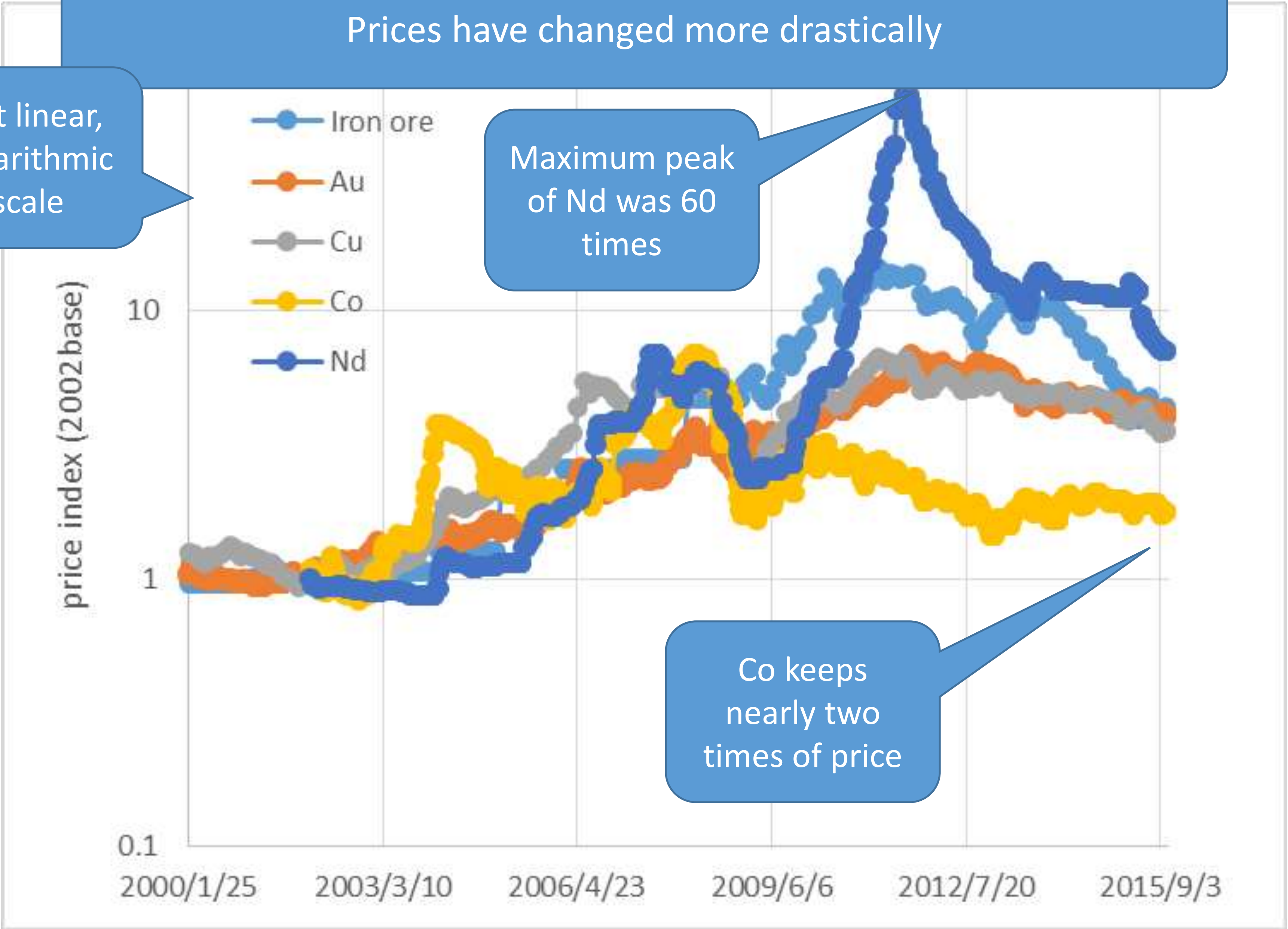


Fig.1 meta production index (1945base)

Prices have changed more drastically

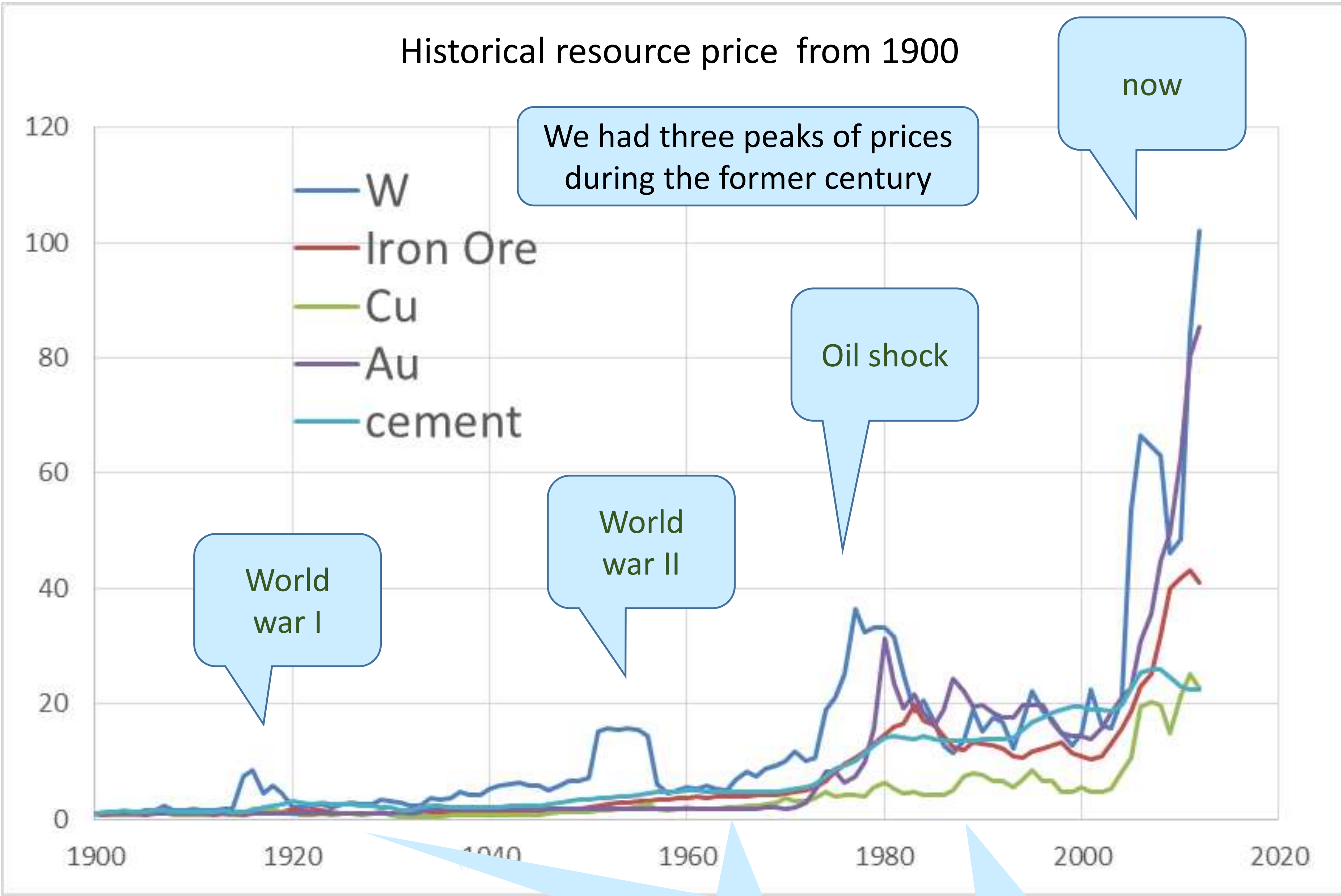


Not linear, Logarithmic scale

Maximum peak of Nd was 60 times

Co keeps nearly two times of price

Historical resource price from 1900



We had three peaks of prices during the former century

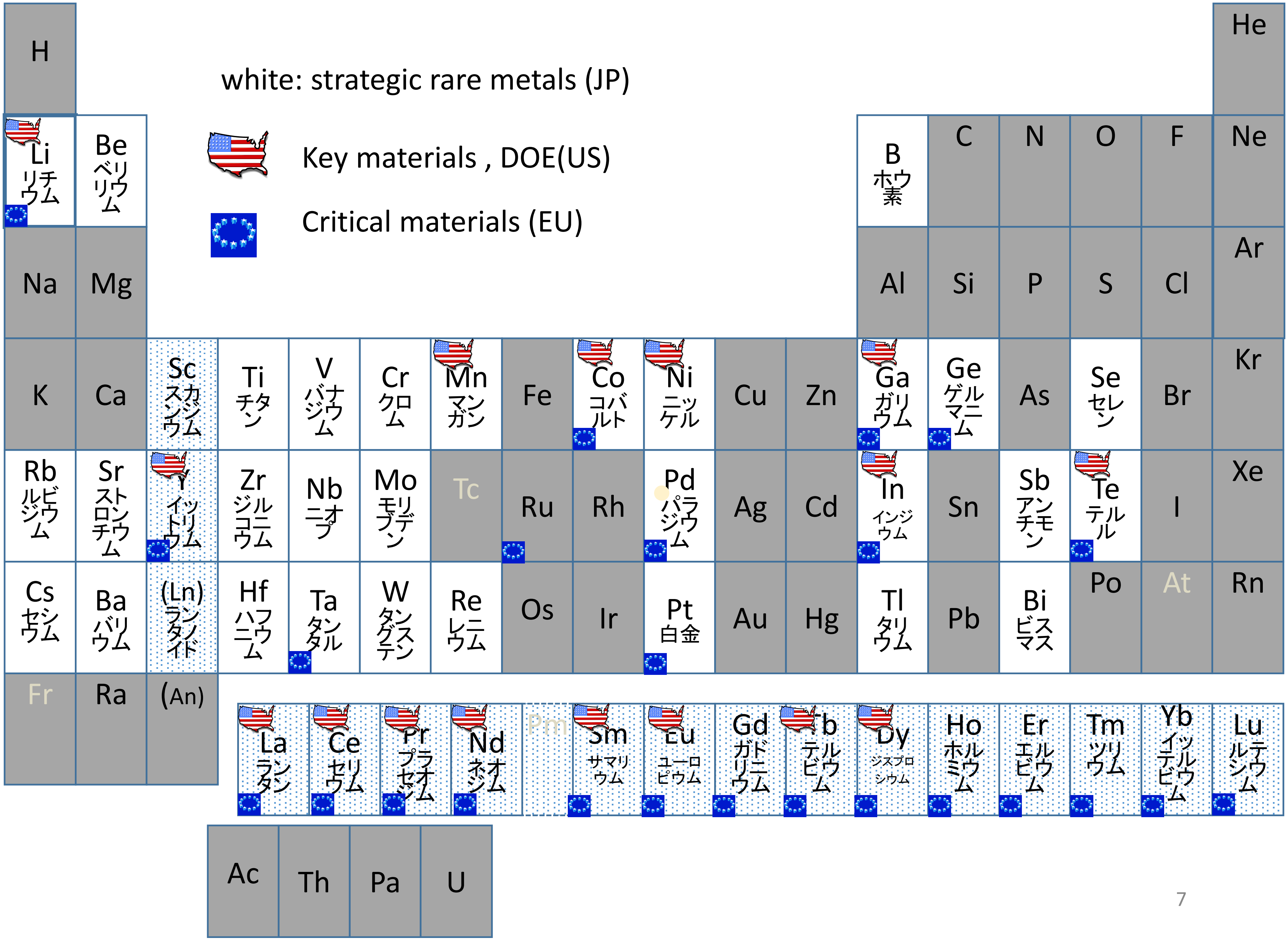
now

Oil shock

World war II

World war I

After the peak, prices shifted higher levels

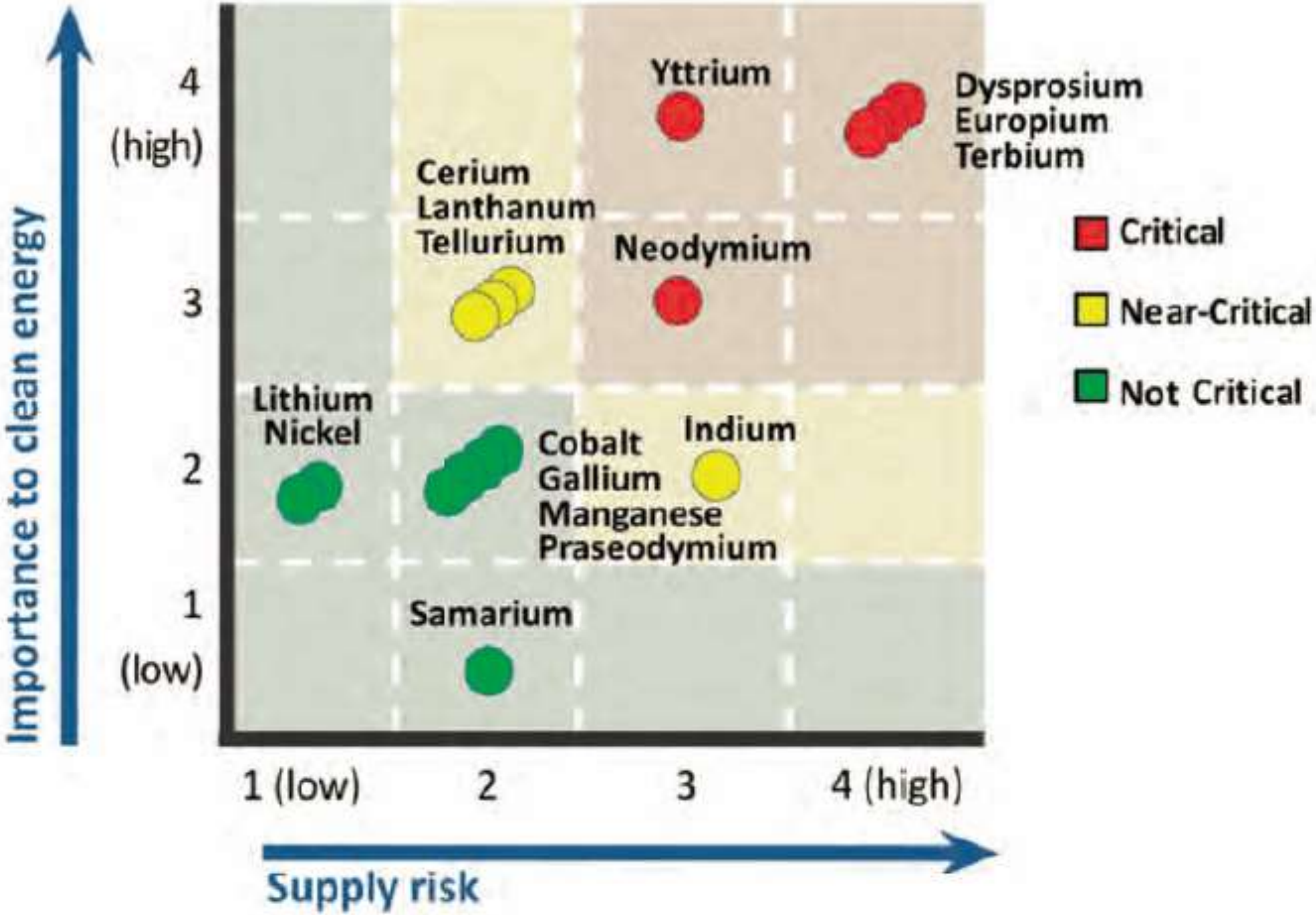


white: strategic rare metals (JP)

🇺🇸 Key materials , DOE(US)

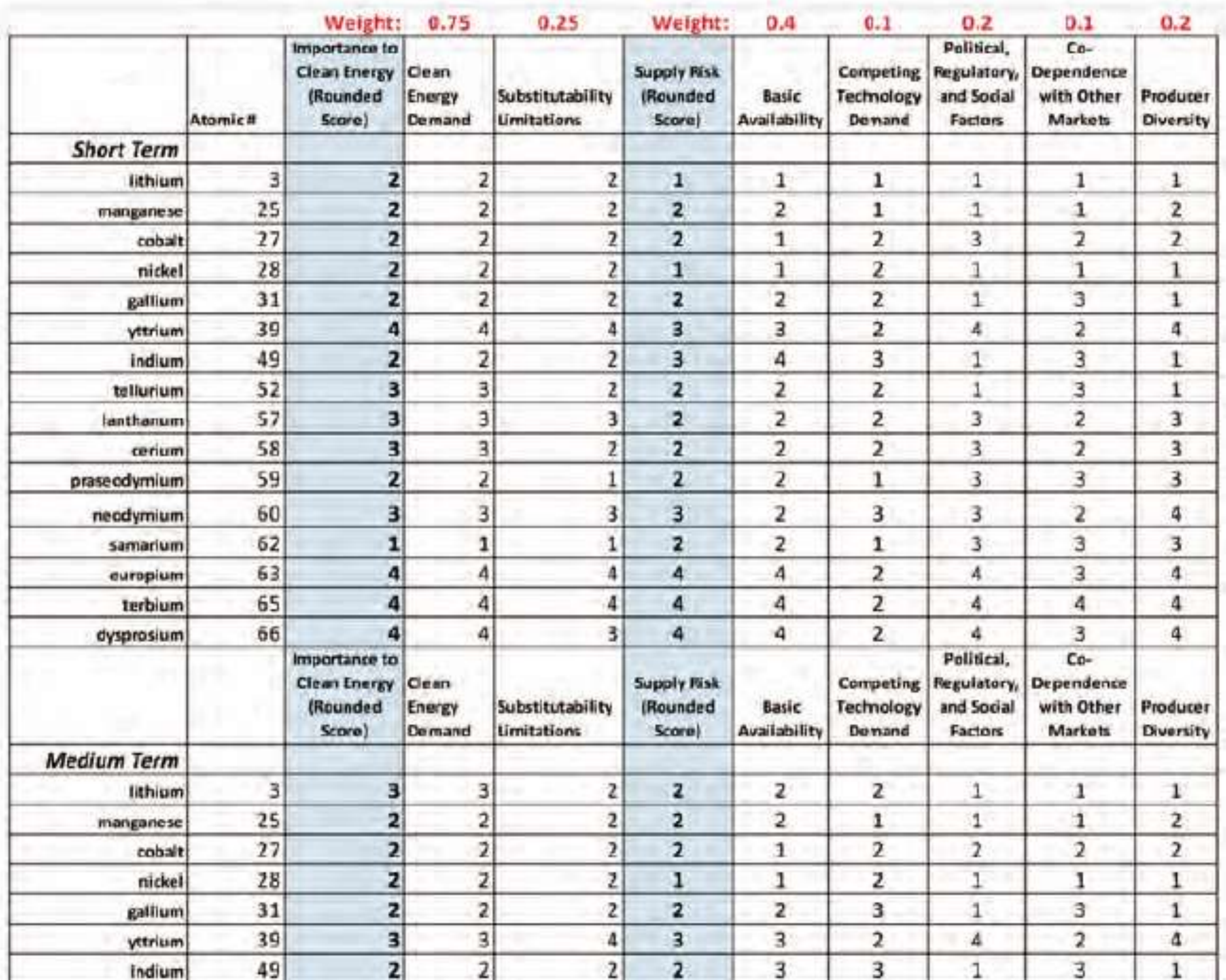
🇪🇺 Critical materials (EU)

H																	He
Li リチウム 🇺🇸 🇪🇺	Be ベリリウム											B ホウ素	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc スカンジウム	Ti チタン	V バナジウム	Cr クロム	Mn マンガン 🇺🇸	Fe	Co コバルト 🇺🇸 🇪🇺	Ni ニッケル 🇺🇸	Cu	Zn	Ga ガリウム 🇺🇸 🇪🇺	Ge ゲルマニウム 🇪🇺	As	Se セレン	Br	Kr
Rb ルビジウム	Sr ストロンチウム	Y イットリウム 🇺🇸 🇪🇺	Zr ジルコニウム	Nb ニオブ	Mo モリブデン	Tc	Ru 🇪🇺	Rh	Pd パラジウム 🇪🇺	Ag	Cd	In インジウム 🇺🇸 🇪🇺	Sn	Sb アンチモン	Te テルル 🇺🇸 🇪🇺	I	Xe
Cs セシウム	Ba バリウム	(Ln) ランタノイド	Hf ハフニウム	Ta タンタル 🇪🇺	W タングステン	Re レニウム	Os	Ir	Pt 白金 🇪🇺	Au	Hg	Tl タリウム	Pb	Bi ビスマス	Po	At	Rn
Fr	Ra	(An)															
			La ランタン 🇺🇸 🇪🇺	Ce セリウム 🇺🇸 🇪🇺	Pr プラセオジム 🇺🇸 🇪🇺	Nd ネオジム 🇺🇸 🇪🇺	Pm	Sm サマリウム 🇺🇸 🇪🇺	Eu ユーロピウム 🇺🇸 🇪🇺	Gd ガドリニウム 🇪🇺	Tb テルビウム 🇺🇸 🇪🇺	Dy ジスプロシウム 🇺🇸 🇪🇺	Ho ホルミウム 🇪🇺	Er エルビウム 🇪🇺	Tm ツリウム 🇪🇺	Yb イッテルビウム 🇪🇺	Lu ルテシウム 🇪🇺
		Ac	Th	Pa	U												



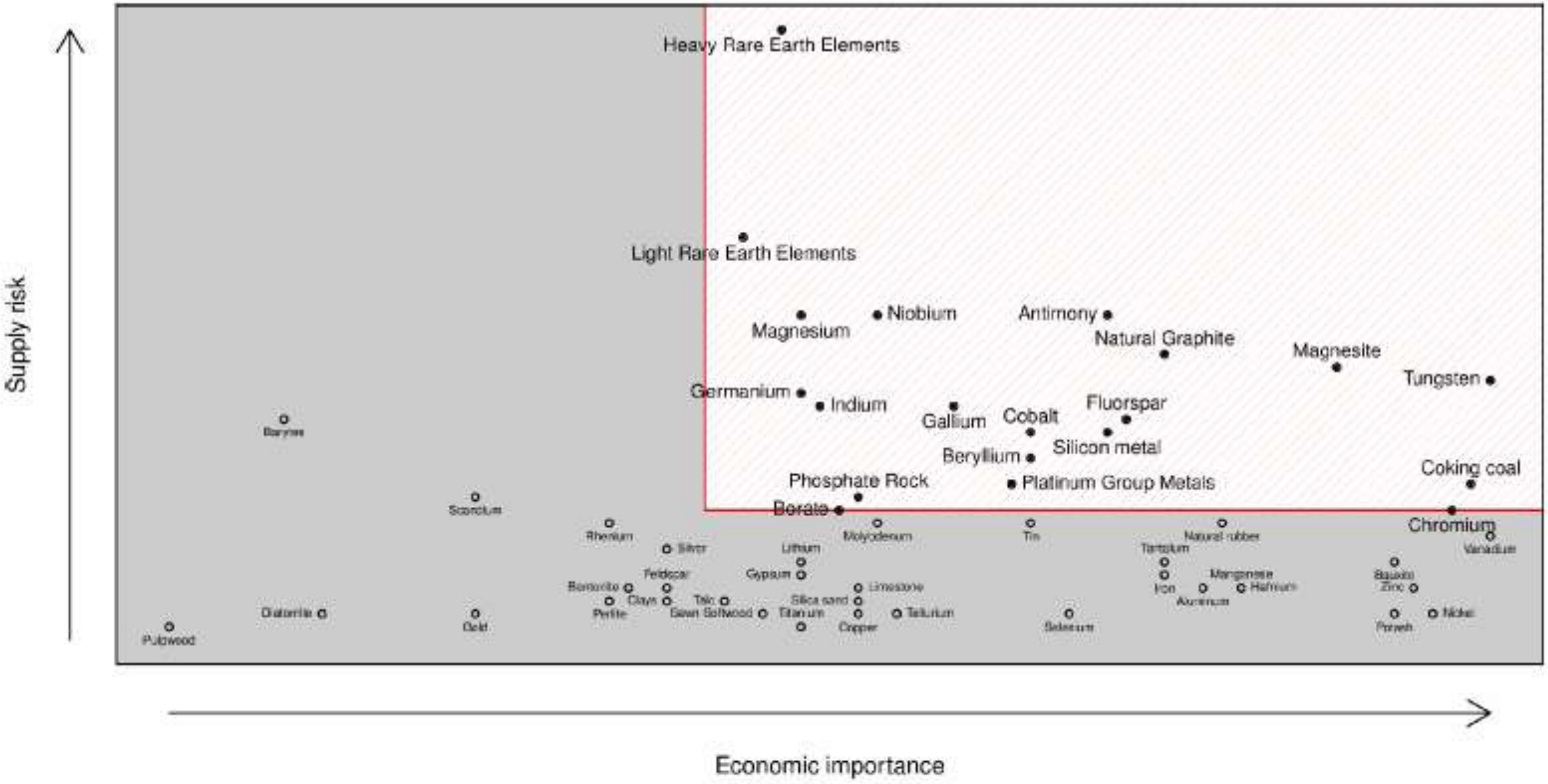
(U.S. DEPARTMENT OF ENERGY:“ Critical Materials Strategy” (Dec. 2011))

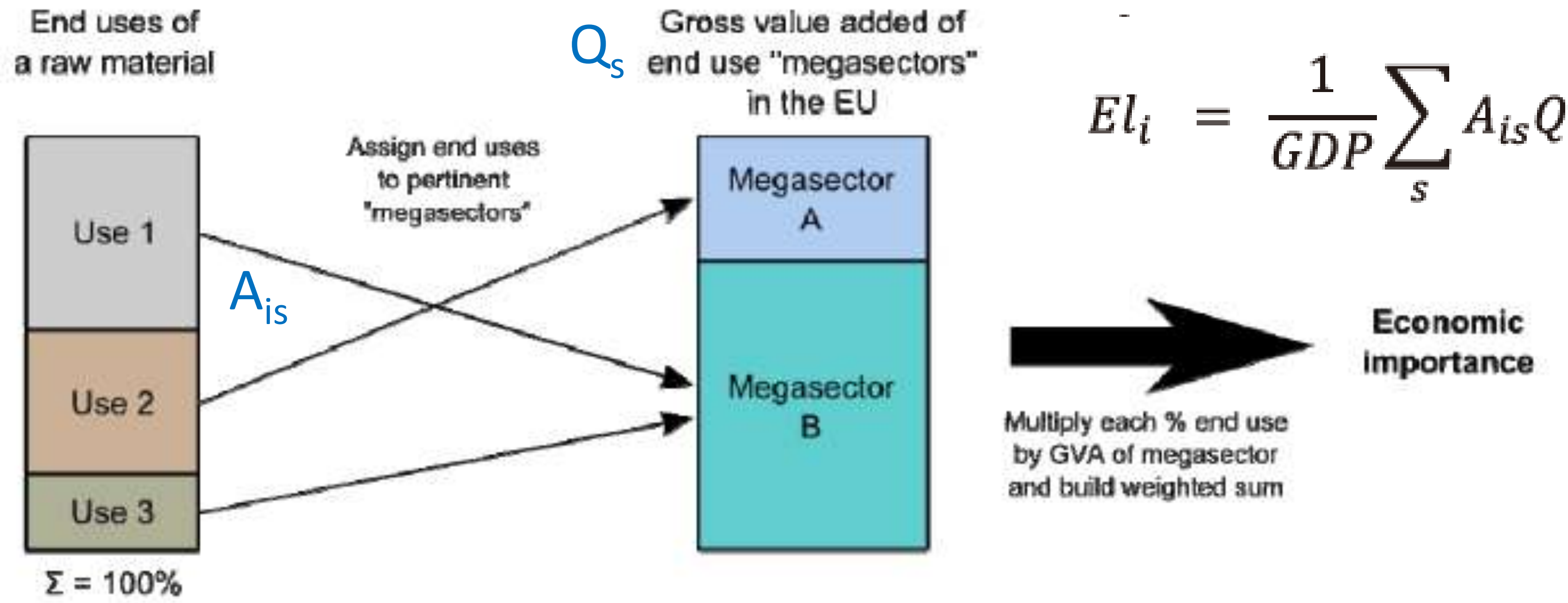
DOE's evaluation method



		Weight:	0.75	0.25	Weight:	0.4	0.1	0.2	0.1	0.2
	Atomic#	Importance to Clean Energy (Rounded Score)	Clean Energy Demand	Substitutability Limitations	Supply Risk (Rounded Score)	Basic Availability	Competing Technology Demand	Political, Regulatory, and Social Factors	Co-Dependence with Other Markets	Producer Diversity
Short Term										
lithium	3	**2**	2	2	**1**	1	1	1	1	1
manganese	25	**2**	2	2	**2**	2	1	1	1	2
cobalt	27	**2**	2	2	**2**	1	2	3	2	2
nickel	28	**2**	2	2	**1**	1	2	1	1	1
gallium	31	**2**	2	2	**2**	2	2	1	3	1
yttrium	39	**4**	4	4	**3**	3	2	4	2	4
indium	49	**2**	2	2	**3**	4	3	1	3	1
tellurium	52	**3**	3	2	**2**	2	2	1	3	1
lanthanum	57	**3**	3	3	**2**	2	2	3	2	3
cerium	58	**3**	3	2	**2**	2	2	3	2	3
praseodymium	59	**2**	2	1	**2**	2	1	3	3	3
neodymium	60	**3**	3	3	**3**	2	3	3	2	4
samarium	62	**1**	1	1	**2**	2	1	3	3	3
europium	63	**4**	4	4	**4**	4	2	4	3	4
terbium	65	**4**	4	4	**4**	4	2	4	4	4
dysprosium	66	**4**	4	3	**4**	4	2	4	3	4
		Importance to Clean Energy (Rounded Score)	Clean Energy Demand	Substitutability Limitations	Supply Risk (Rounded Score)	Basic Availability	Competing Technology Demand	Political, Regulatory, and Social Factors	Co-Dependence with Other Markets	Producer Diversity
Medium Term										
lithium	3	**3**	3	2	**2**	2	2	1	1	1
manganese	25	**2**	2	2	**2**	2	1	1	1	2
cobalt	27	**2**	2	2	**2**	1	2	2	2	2
nickel	28	**2**	2	2	**1**	1	2	1	1	1
gallium	31	**2**	2	2	**2**	2	3	1	3	1
yttrium	39	**3**	3	4	**3**	3	2	4	2	4
indium	49	**2**	2	2	**2**	3	3	1	3	1

(REPORT ON CRITICAL RAW MATERIALS FOR THE EU 2014)





End uses of a raw material

Use 1

Use 2

Use 3

$\Sigma = 100\%$

A_{is}

Assign end uses to pertinent "megasectors"

Q_s

Gross value added of end use "megasectors" in the EU

Megasector A

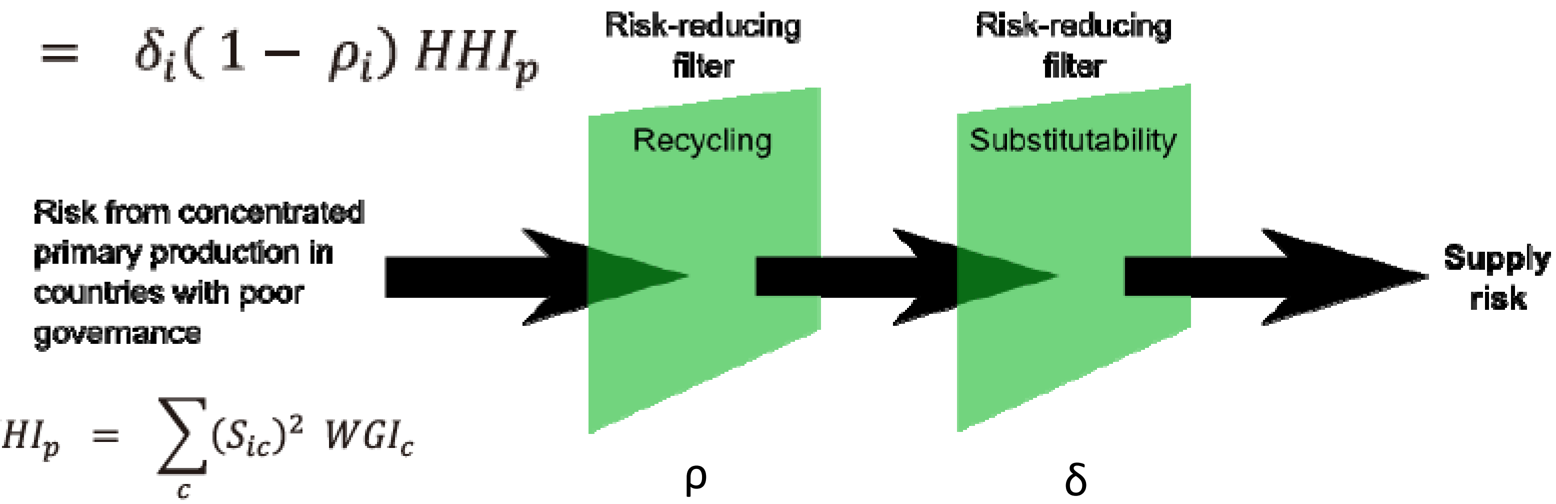
Megasector B

Multiply each % end use by GVA of megasector and build weighted sum

Economic importance

$$EI_i = \frac{1}{GDP}\sum_s A_{is}Q_s$$

$$SR_i = \delta_i(1 - \rho_i)\,HHI_p$$



Risk-reducing filter

Recycling

Risk-reducing filter

Substitutability

Risk from concentrated primary production in countries with poor governance

Supply risk

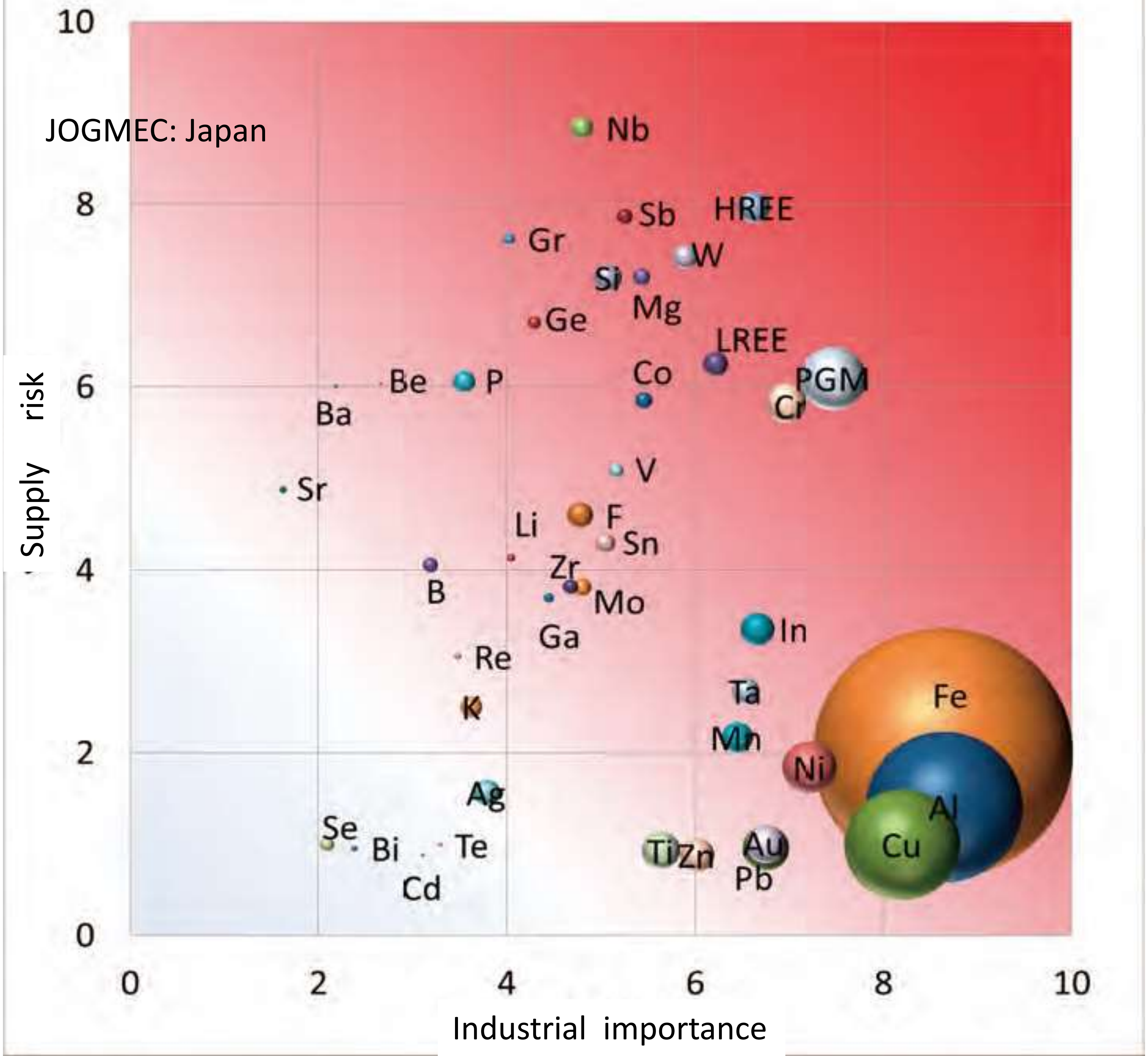
ρ

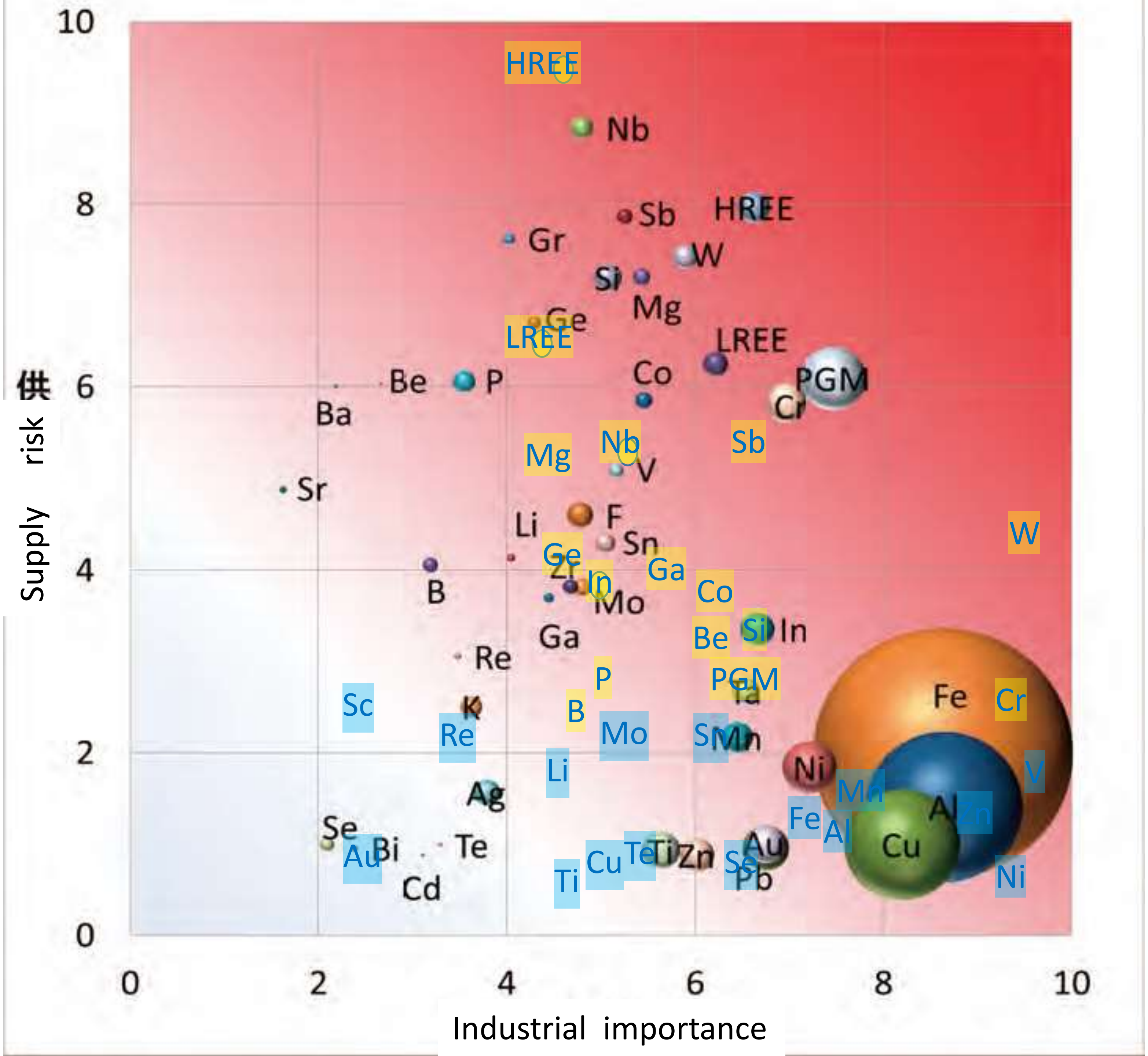
δ

$$HHI_p = \sum_c (S_{ic})^2\ WGI_c$$

WGI: world governance indicator

S : share


JOGMEC: Japan
Supply risk
Industrial importance
0
2
4
6
8
10
0
2
4
6
8
10
Nb
Sb
HREE
Gr
W
Si
Mg
Ge
LREE
Co
PGM
Be
P
Ba
Cr
V
Sr
F
Li
Sn
B
Zr
Mo
Ga
In
Re
Ta
K
Fe
Mn
Ni
Ag
Al
Se
Bi
Te
Ti
Zn
Au
Cu
Cd
Pb


10
8
6
4
2
0
0
2
4
6
8
10
供
Supply risk
Industrial importance
HREE
Nb
Sb
HREE
Gr
W
Si
Mg
Mg
LREE
Ge
LREE
Be
P
Co
PGM
Ba
Cr
Mg
Nb
Sb
V
Sr
Li
F
W
Sn
Ge
Zr
In
Ga
Co
B
Mo
Ga
Si
In
Be
Re
P
PGM
Ta
Sc
K
B
Fe
Cr
Re
Mo
Sn
Mn
Li
Ni
Mn
V
Ag
Al
Zn
Fe
Al
Se
Au
Bi
Te
Cu
Te
Ti
Zn
Se
Au
Cu
Pb
Cd
Ti
Ni

4 types + 1 of resource constraints

Absolute mass Reserve amount is not so enough.
Au, Cu, Zn

Geological, Political unevenly distributed
Pt, Nb, Dy Co

Energy depending on energy situation
Al, Mg, Si

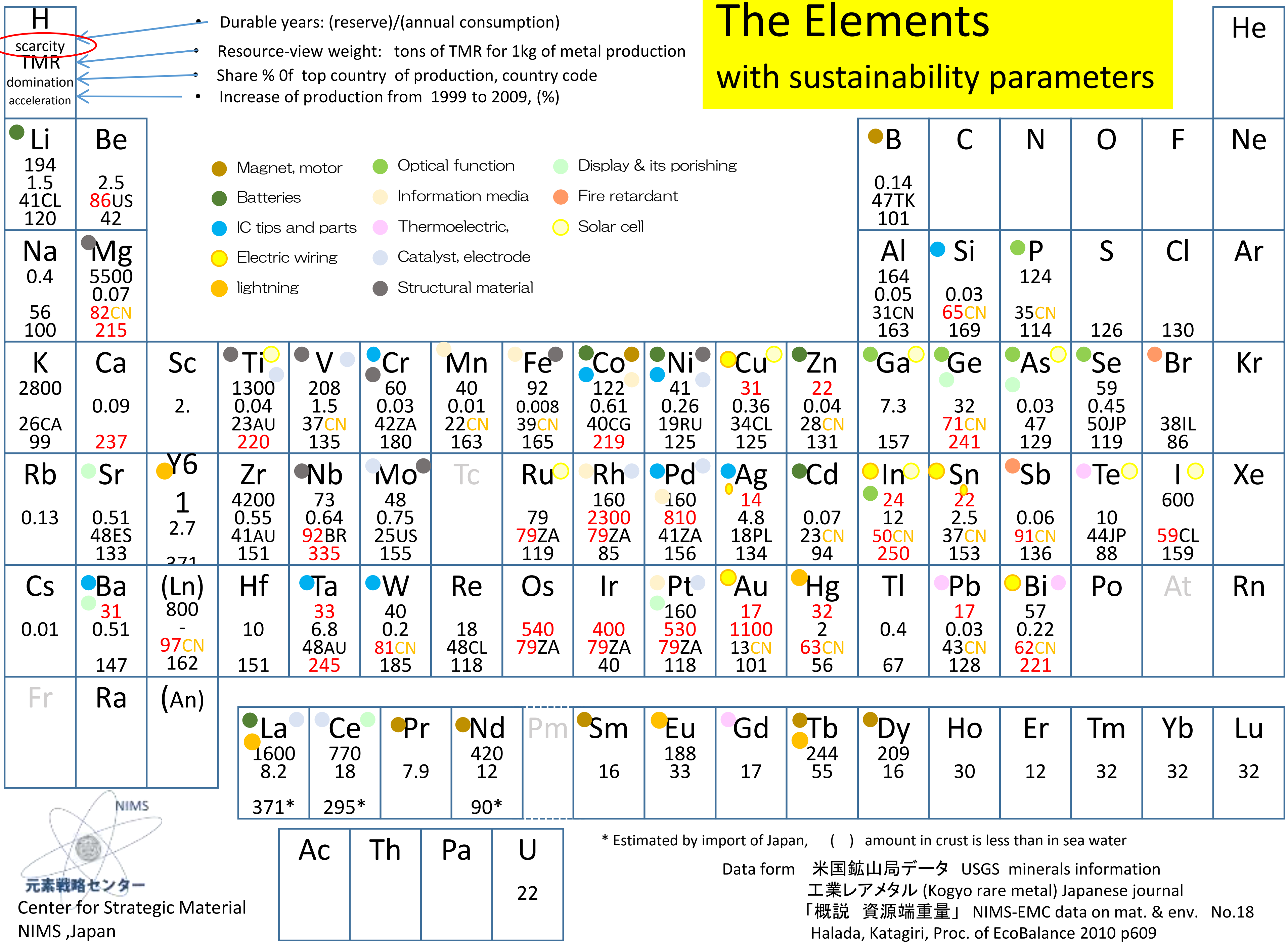
Environmental cost of waste management
REE

plus1 speed of supply
by-products such as LI

The Elements
with sustainability parameters

H: scarcity, TMR, domination, acceleration

- Durable years: (reserve)/(annual consumption)
- Resource-view weight: tons of TMR for 1kg of metal production
- Share % 0f top country of production, country code
- Increase of production from 1999 to 2009, (%)



● Magnet, motor	● Optical function	● Display & its porishing
● Batteries	● Information media	● Fire retardant
● IC tips and parts	● Thermoelectric,	○ Solar cell
○ Electric wiring	● Catalyst, electrode	
● lightning	● Structural material	

H scarcity TMR domination acceleration																	He
Li 194 1.5 41CL 120	Be 2.5 86US 42											B 0.14 47TK 101	C	N	O	F	Ne
Na 0.4 56 100	Mg 5500 0.07 82CN 215											Al 164 0.05 31CN 163	Si 0.03 65CN 169	P 124 35CN 114	S 126	Cl 130	Ar
K 2800 26CA 99	Ca 0.09 237	Sc 2.	Ti 1300 0.04 23AU 220	V 208 1.5 37CN 135	Cr 60 0.03 42ZA 180	Mn 40 0.01 22CN 163	Fe 92 0.008 39CN 165	Co 122 0.61 40CG 219	Ni 41 0.26 19RU 125	Cu 31 0.36 34CL 125	Zn 22 0.04 28CN 131	Ga 7.3 157	Ge 32 71CN 241	As 0.03 47 129	Se 59 0.45 50JP 119	Br 38IL 86	Kr
Rb 0.13	Sr 0.51 48ES 133	Y6 1 2.7 371	Zr 4200 0.55 41AU 151	Nb 73 0.64 92BR 335	Mo 48 0.75 25US 155	Tc	Ru 79 79ZA 119	Rh 160 2300 79ZA 85	Pd 160 810 41ZA 156	Ag 14 4.8 18PL 134	Cd 0.07 23CN 94	In 24 12 50CN 250	Sn 22 2.5 37CN 153	Sb 0.06 91CN 136	Te 10 44JP 88	I 600 59CL 159	Xe
Cs 0.01	Ba 31 0.51 147	(Ln) 800 - 97CN 162	Hf 10 151	Ta 33 6.8 48AU 245	W 40 0.2 81CN 185	Re 18 48CL 118	Os 540 79ZA	Ir 400 79ZA 40	Pt 160 530 79ZA 118	Au 17 1100 13CN 101	Hg 32 2 63CN 56	Tl 0.4 67	Pb 17 0.03 43CN 128	Bi 57 0.22 62CN 221	Po	At	Rn
Fr	Ra	(An)															

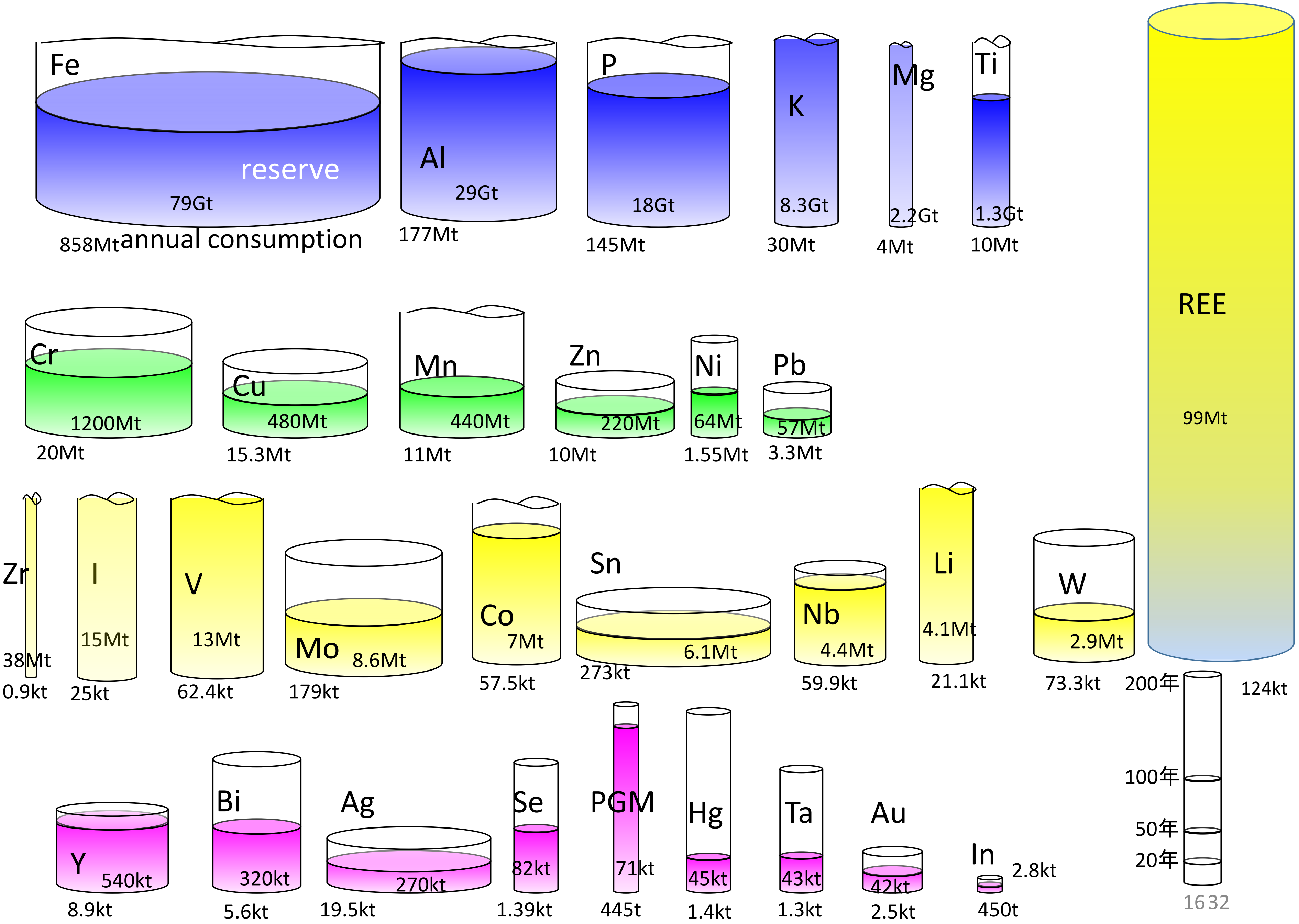
La 1600 8.2 371*	Ce 770 18 295*	Pr 7.9	Nd 420 12 90*	Pm	Sm 16	Eu 188 33	Gd 17	Tb 244 55	Dy 209 16	Ho 30	Er 12	Tm 32	Yb 32	Lu 32

Ac	Th	Pa	U 22

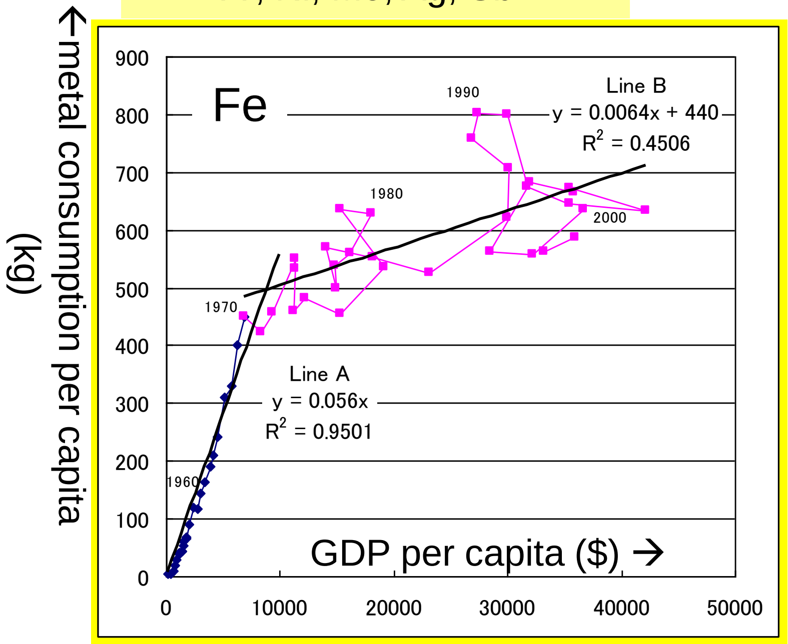
* Estimated by import of Japan, ( ) amount in crust is less than in sea water

Data form 米国鉱山局データ USGS minerals information
工業レアメタル (Kogyo rare metal) Japanese journal
「概説 資源端重量」 NIMS-EMC data on mat. & env. No.18
Halada, Katagiri, Proc. of EcoBalance 2010 p609

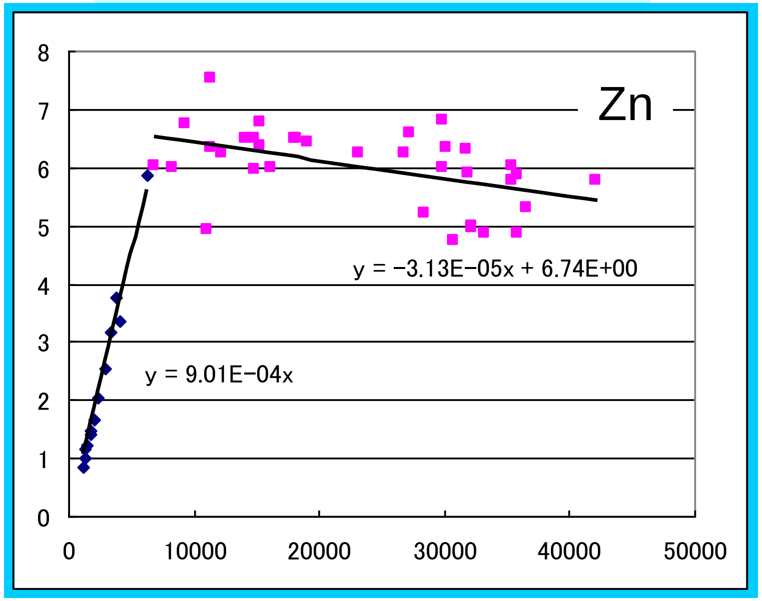
元素戦略センター
Center for Strategic Material
NIMS ,Japan


Fe
reserve
79Gt
858Mt
annual consumption
Al
29Gt
177Mt
P
18Gt
145Mt
K
8.3Gt
30Mt
Mg
2.2Gt
4Mt
Ti
1.3Gt
10Mt
REE
99Mt
124kt
Cr
1200Mt
20Mt
Cu
480Mt
15.3Mt
Mn
440Mt
11Mt
Zn
220Mt
10Mt
Ni
64Mt
1.55Mt
Pb
57Mt
3.3Mt
Zr
38Mt
0.9kt
I
15Mt
25kt
V
13Mt
62.4kt
Mo
8.6Mt
179kt
Co
7Mt
57.5kt
Sn
6.1Mt
273kt
Nb
4.4Mt
59.9kt
Li
4.1Mt
21.1kt
W
2.9Mt
73.3kt
200年
100年
50年
20年
Y
540kt
8.9kt
Bi
320kt
5.6kt
Ag
270kt
19.5kt
Se
82kt
1.39kt
PGM
71kt
445t
Hg
45kt
1.4kt
Ta
43kt
1.3kt
Au
42kt
2.5kt
In
2.8kt
450t

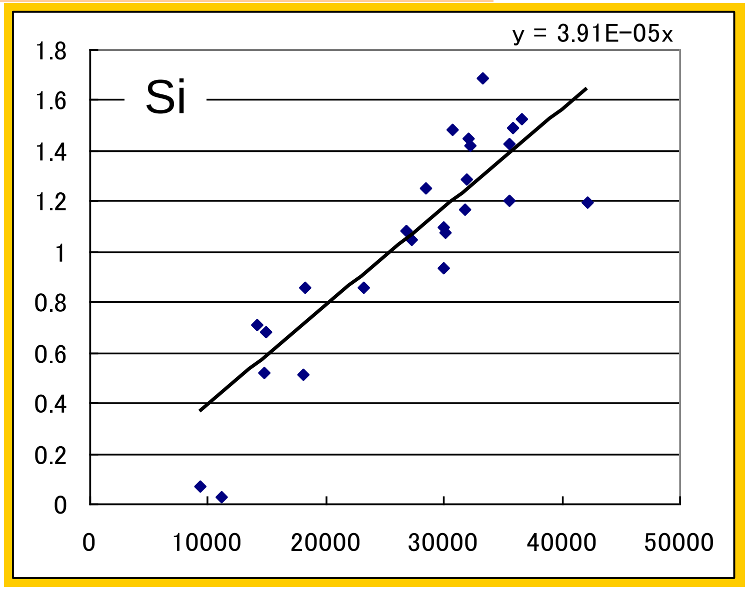
Fe-type: weakly de-coupled
Al, Ni, Mo, Ag, Sb



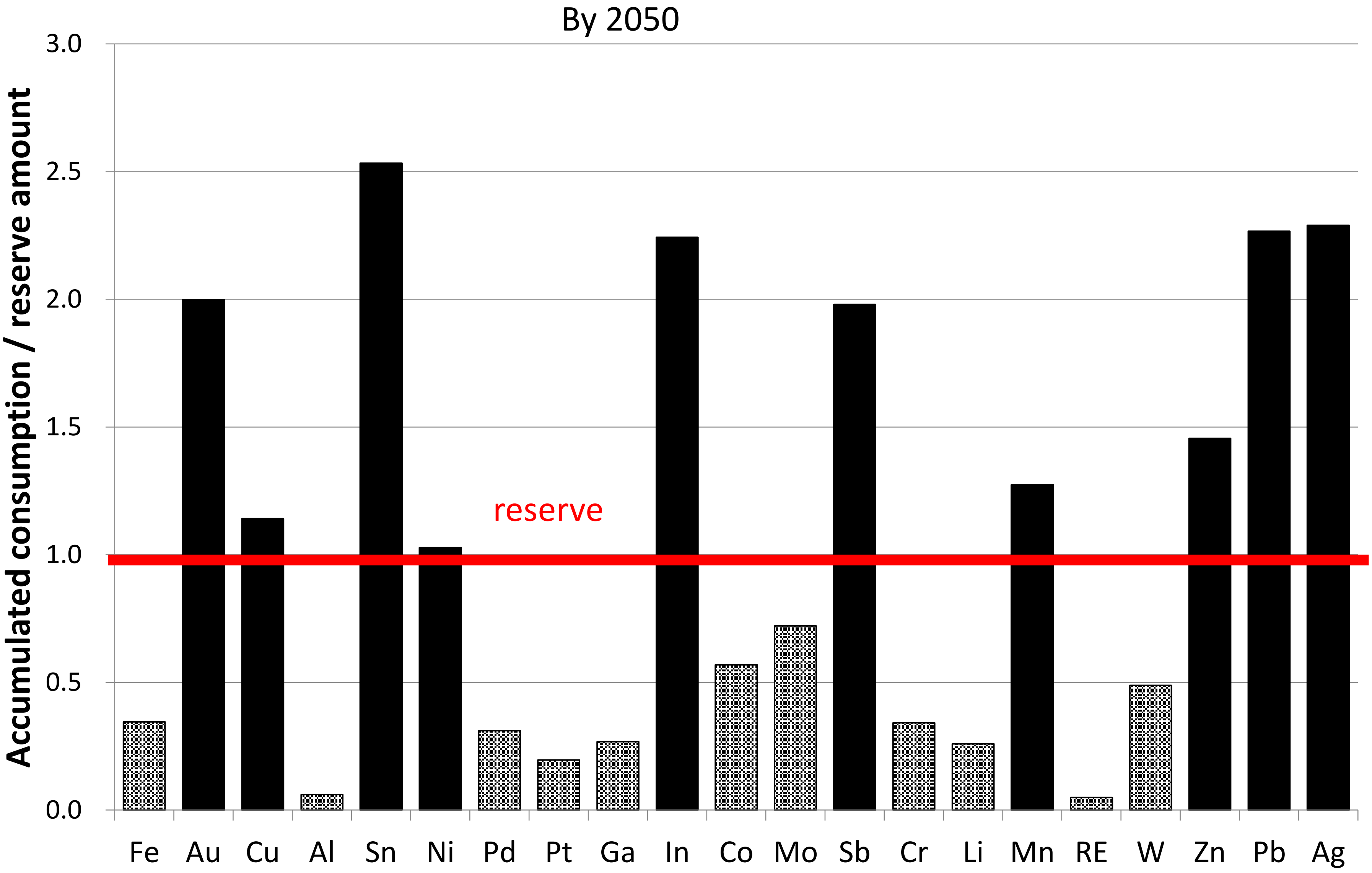
Zn-type: de-coupled
Cu, Sn, Pb, W, Cr, Mn, Au



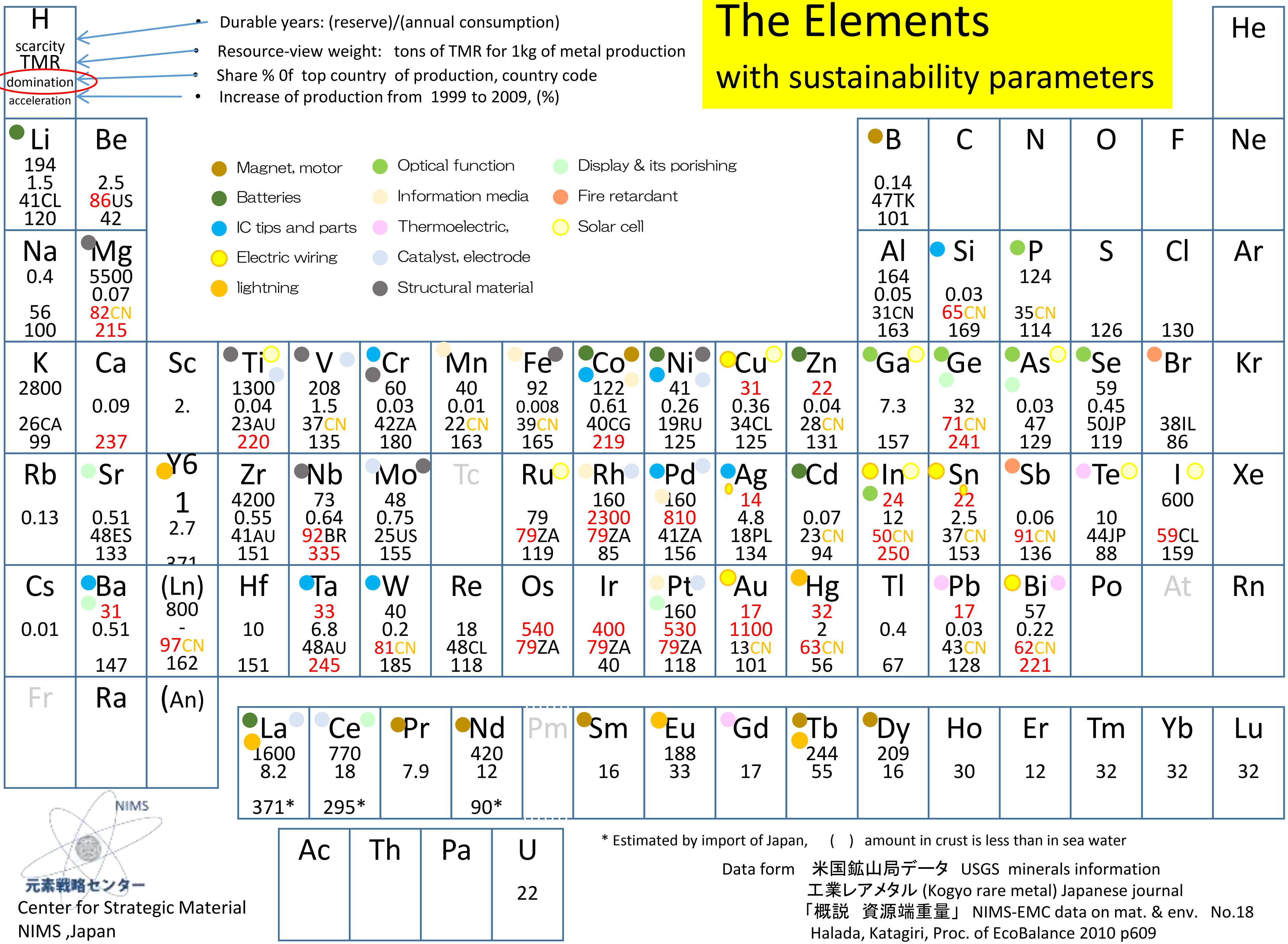
Si-type: still coupling Pt,



Four types of the two step line model of metal consumption v.s. GDP per capita


By 2050
Accumulated consumption / reserve amount
3.0
2.5
2.0
1.5
1.0
0.5
0.0
reserve
Fe
Au
Cu
Al
Sn
Ni
Pd
Pt
Ga
In
Co
Mo
Sb
Cr
Li
Mn
RE
W
Zn
Pb
Ag

The Elements
with sustainability parameters



- Durable years: (reserve)/(annual consumption)
- Resource-view weight: tons of TMR for 1kg of metal production
- Share % 0f top country of production, country code
- Increase of production from 1999 to 2009, (%)

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K 2800 26CA 99	Ca 0.09 237	Sc 2.	Ti 1300 0.04 23AU 220	V 208 1.5 37CN 135	Cr 60 0.03 42ZA 180	Mn 40 0.01 22CN 163	Fe 92 0.008 39CN 165	Co 122 0.61 40CG 219	Ni 41 0.26 19RU 125	Cu 31 0.36 34CL 125	Zn 22 0.04 28CN 131	Ga 7.3 157	Ge 32 71CN 241	As 0.03 47 129	Se 59 0.45 50JP 119	Br 38IL 86	Kr
Rb 0.13	Sr 0.51 48ES 133	Y6 1 2.7 371	Zr 4200 0.55 41AU 151	Nb 73 0.64 92BR 335	Mo 48 0.75 25US 155	Tc	Ru 79 79ZA 119	Rh 160 2300 79ZA 85	Pd 160 810 41ZA 156	Ag 14 4.8 18PL 134	Cd 0.07 23CN 94	In 24 12 50CN 250	Sn 22 2.5 37CN 153	Sb 0.06 91CN 136	Te 10 44JP 88	I 600 59CL 159	Xe
Cs 0.01	Ba 31 0.51 147	(Ln) 800 - 97CN 162	Hf 10 151	Ta 33 6.8 48AU 245	W 40 0.2 81CN 185	Re 18 48CL 118	Os 540 79ZA	Ir 400 79ZA 40	Pt 160 530 79ZA 118	Au 17 1100 13CN 101	Hg 32 2 63CN 56	Tl 0.4 67	Pb 17 0.03 43CN 128	Bi 57 0.22 62CN 221	Po	At	Rn
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NIMS
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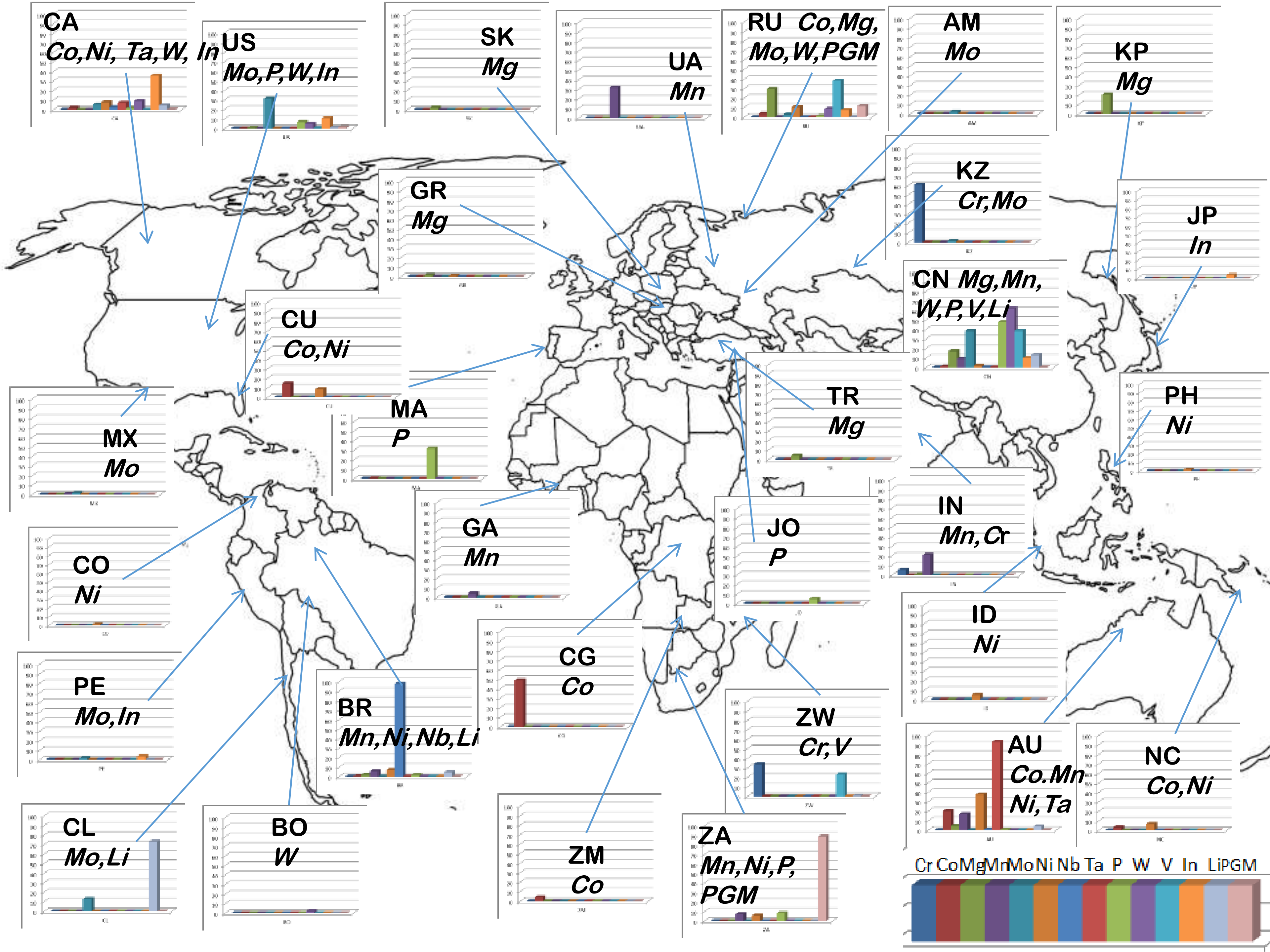
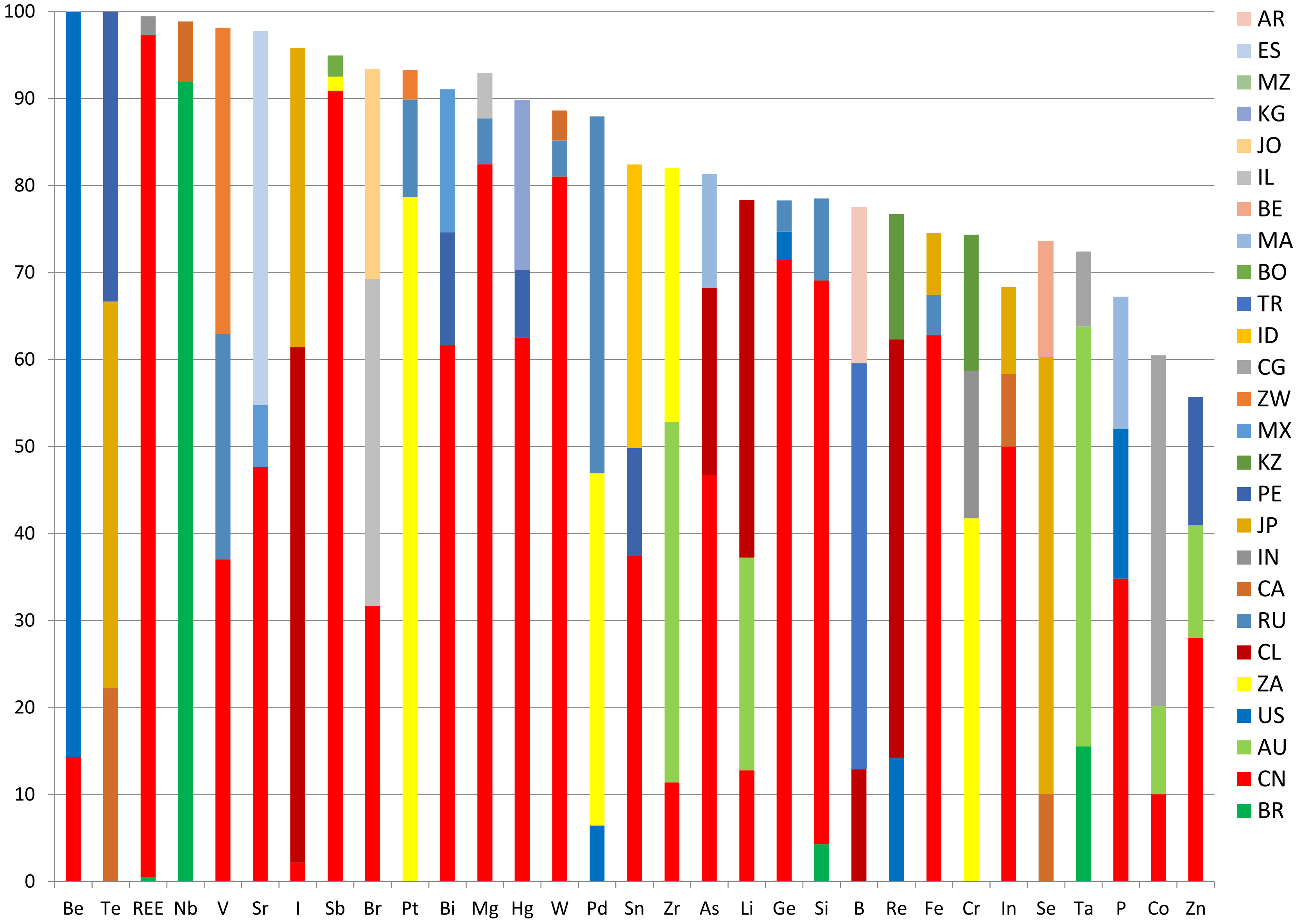
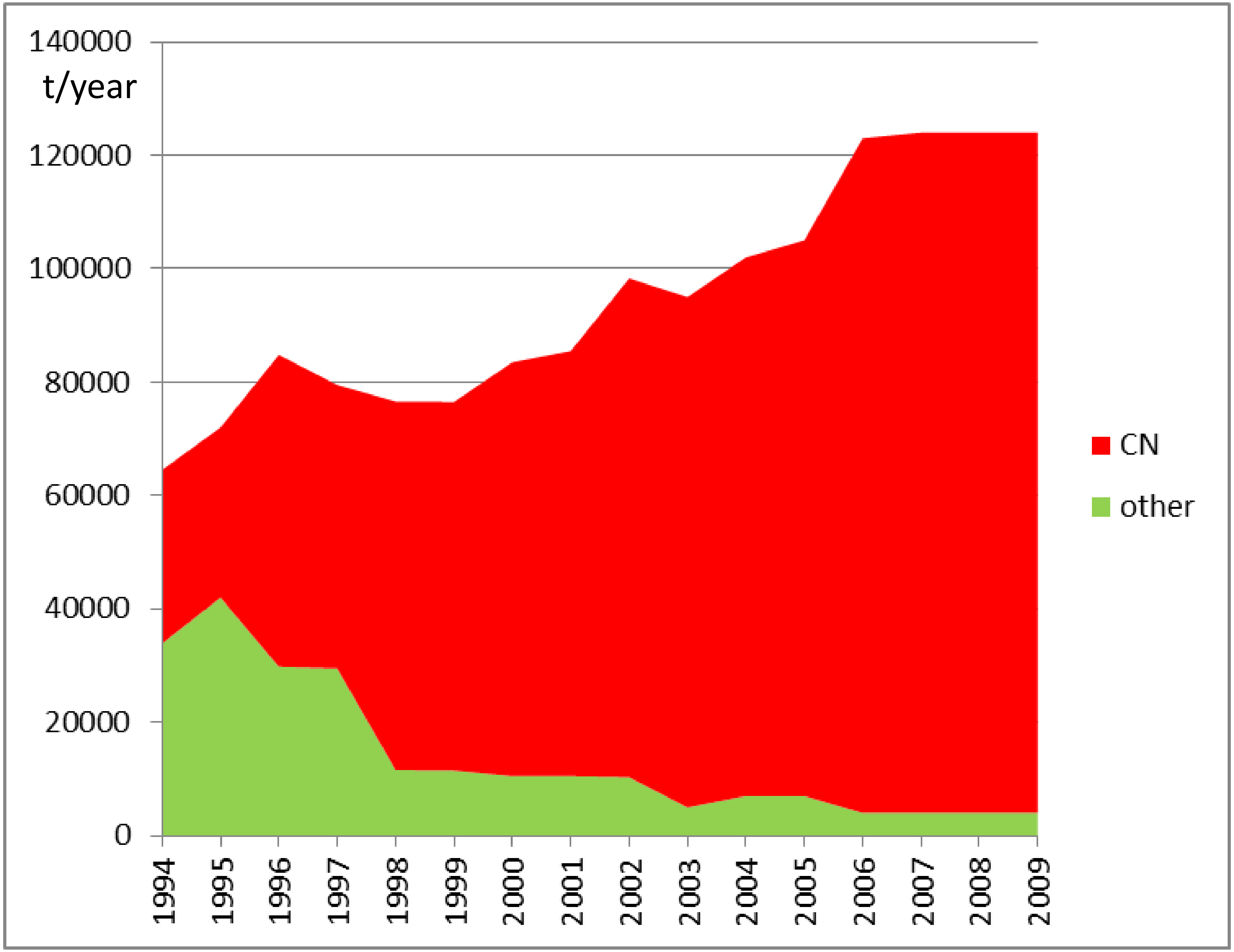

CA
Co,Ni, Ta,W, In
US
Mo,P,W,In
SK
Mg
UA
Mn
RU Co,Mg,
Mo,W,PGM
AM
Mo
KP
Mg
KZ
Cr,Mo
GR
Mg
JP
In
CN Mg,Mn,
W,P,V,Li
CU
Co,Ni
MX
Mo
MA
P
TR
Mg
PH
Ni
IN
Mn,Cr
GA
Mn
JO
P
CO
Ni
ID
Ni
CG
Co
PE
Mo,In
BR
Mn,Ni,Nb,Li
ZW
Cr,V
AU
Co.Mn
Ni,Ta
NC
Co,Ni
CL
Mo,Li
BO
W
ZM
Co
ZA
Mn,Ni,P,
PGM
Cr Co Mg Mn Mo Ni Nb Ta P W V In Li PGM

Three top country produce more than 80% In 18 elements in 31




140000
t/year
120000
100000
80000
60000
40000
20000
0
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
🟥 CN
🟩 other

The Elements
with sustainability parameters

H
- scarcity: Durable years: (reserve)/(annual consumption)
- TMR: Resource-view weight: tons of TMR for 1kg of metal production
- domination: Share % 0f top country of production, country code
- acceleration: Increase of production from 1999 to 2009, (%)

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● Batteries
● IC tips and parts
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● lightning
● Optical function
● Information media
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● Display & its porishing
● Fire retardant
○ Solar cell

H scarcity TMR domination acceleration																	He
Li 194 1.5 41CL 120	Be 2.5 86US 42											B 0.14 47TK 101	C	N	O	F	Ne
Na 0.4 56 100	Mg 5500 0.07 82CN 215											Al 164 0.05 31CN 163	Si 0.03 65CN 169	P 124 35CN 114	S 126	Cl 130	Ar
K 2800 26CA 99	Ca 0.09 237	Sc 2.	Ti 1300 0.04 23AU 220	V 208 1.5 37CN 135	Cr 60 0.03 42ZA 180	Mn 40 0.01 22CN 163	Fe 92 0.008 39CN 165	Co 122 0.61 40CG 219	Ni 41 0.26 19RU 125	Cu 31 0.36 34CL 125	Zn 22 0.04 28CN 131	Ga 7.3 157	Ge 32 71CN 241	As 0.03 47 129	Se 59 0.45 50JP 119	Br 38IL 86	Kr
Rb 0.13	Sr 0.51 48ES 133	Y6 1 2.7 371	Zr 4200 0.55 41AU 151	Nb 73 0.64 92BR 335	Mo 48 0.75 25US 155	Tc	Ru 79 79ZA 119	Rh 160 2300 79ZA 85	Pd 160 810 41ZA 156	Ag 14 4.8 18PL 134	Cd 0.07 23CN 94	In 24 12 50CN 250	Sn 22 2.5 37CN 153	Sb 0.06 91CN 136	Te 10 44JP 88	I 600 59CL 159	Xe
Cs 0.01	Ba 31 0.51 147	(Ln) 800 - 97CN 162	Hf 10 151	Ta 33 6.8 48AU 245	W 40 0.2 81CN 185	Re 18 48CL 118	Os 540 79ZA	Ir 400 79ZA 40	Pt 160 530 79ZA 118	Au 17 1100 13CN 101	Hg 32 2 63CN 56	Tl 0.4 67	Pb 17 0.03 43CN 128	Bi 57 0.22 62CN 221	Po	At	Rn
Fr	Ra	(An)															

La 1600 8.2 371*	Ce 770 18 295*	Pr 7.9	Nd 420 12 90*	Pm	Sm 16	Eu 188 33	Gd 17	Tb 244 55	Dy 209 16	Ho 30	Er 12	Tm 32	Yb 32	Lu 32

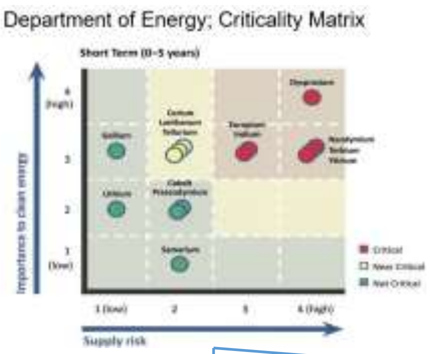
Ac	Th	Pa	U 22

* Estimated by import of Japan, ( ) amount in crust is less than in sea water

Data form 米国鉱山局データ USGS minerals information
工業レアメタル (Kogyo rare metal) Japanese journal
「概説 資源端重量」 NIMS-EMC data on mat. & env. No.18
Halada, Katagiri, Proc. of EcoBalance 2010 p609

NIMS
元素戦略センター
Center for Strategic Material
NIMS ,Japan

Progress of discussion on criticality index of metals



DOE matrix
(importance)
x(supply risk)

Criticality has Different two concepts

Criticality for supply chain
= supply chain risk

Criticality for global
sustainability

damage

risk

probability

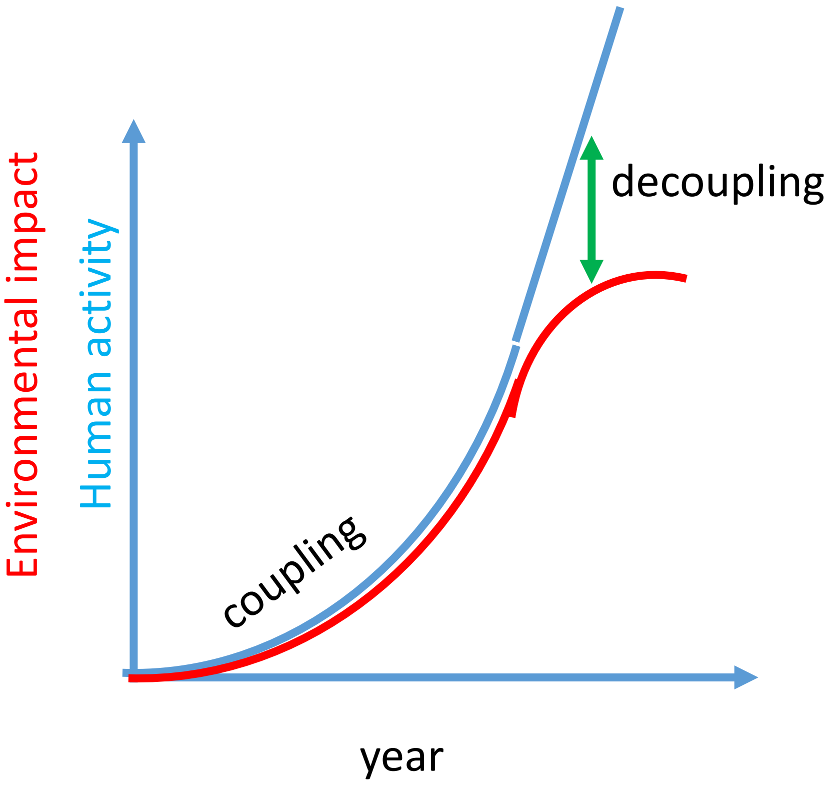
Social damage
through supply
chain damage

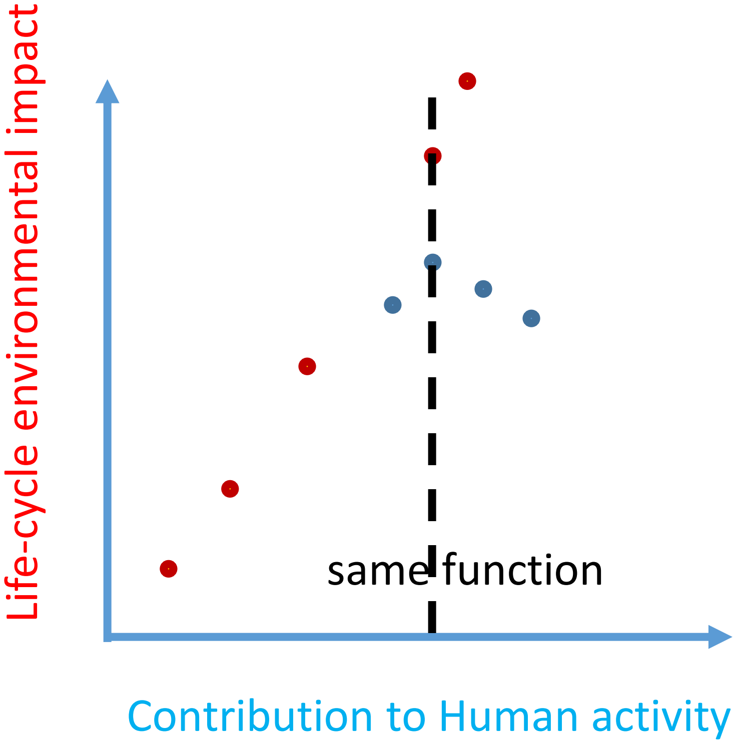
Supply
chain
risk

Probability of
Supply chain is damaged

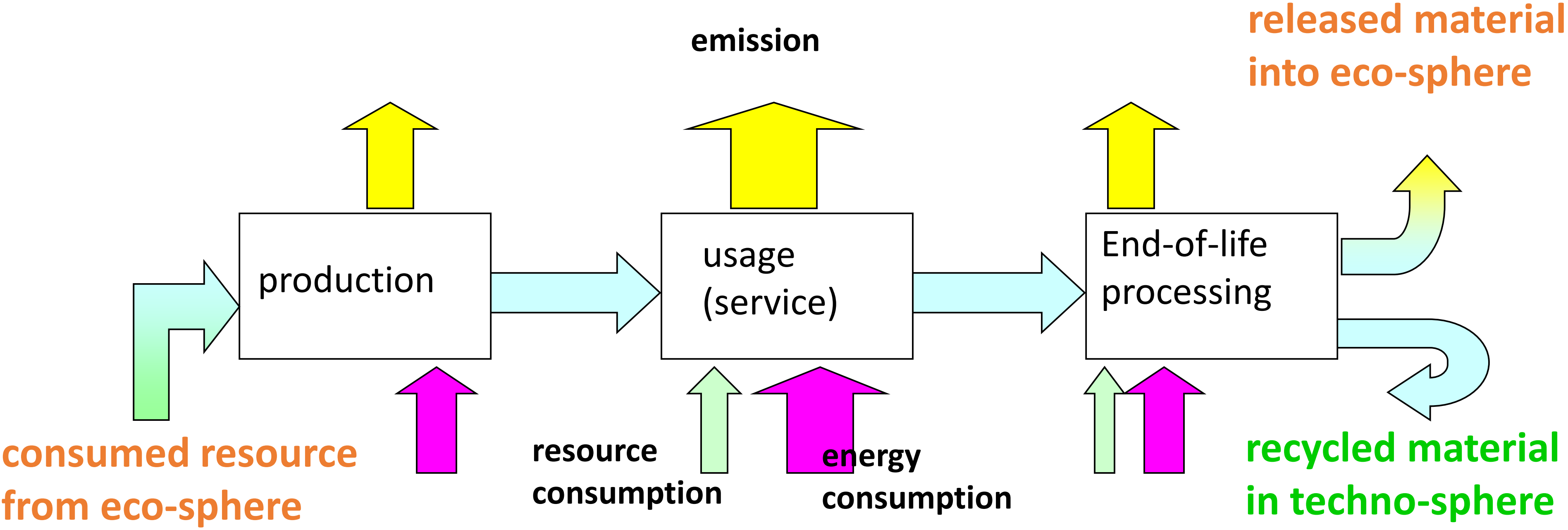
Global environment

Human activity


Environmental impact
Human activity
coupling
decoupling
year


Life-cycle environmental impact
same function
Contribution to Human activity

environmental burden = (emission and release of material)
+ (consumption of material and energy)



emission

released material into eco-sphere

production

usage (service)

End-of-life processing

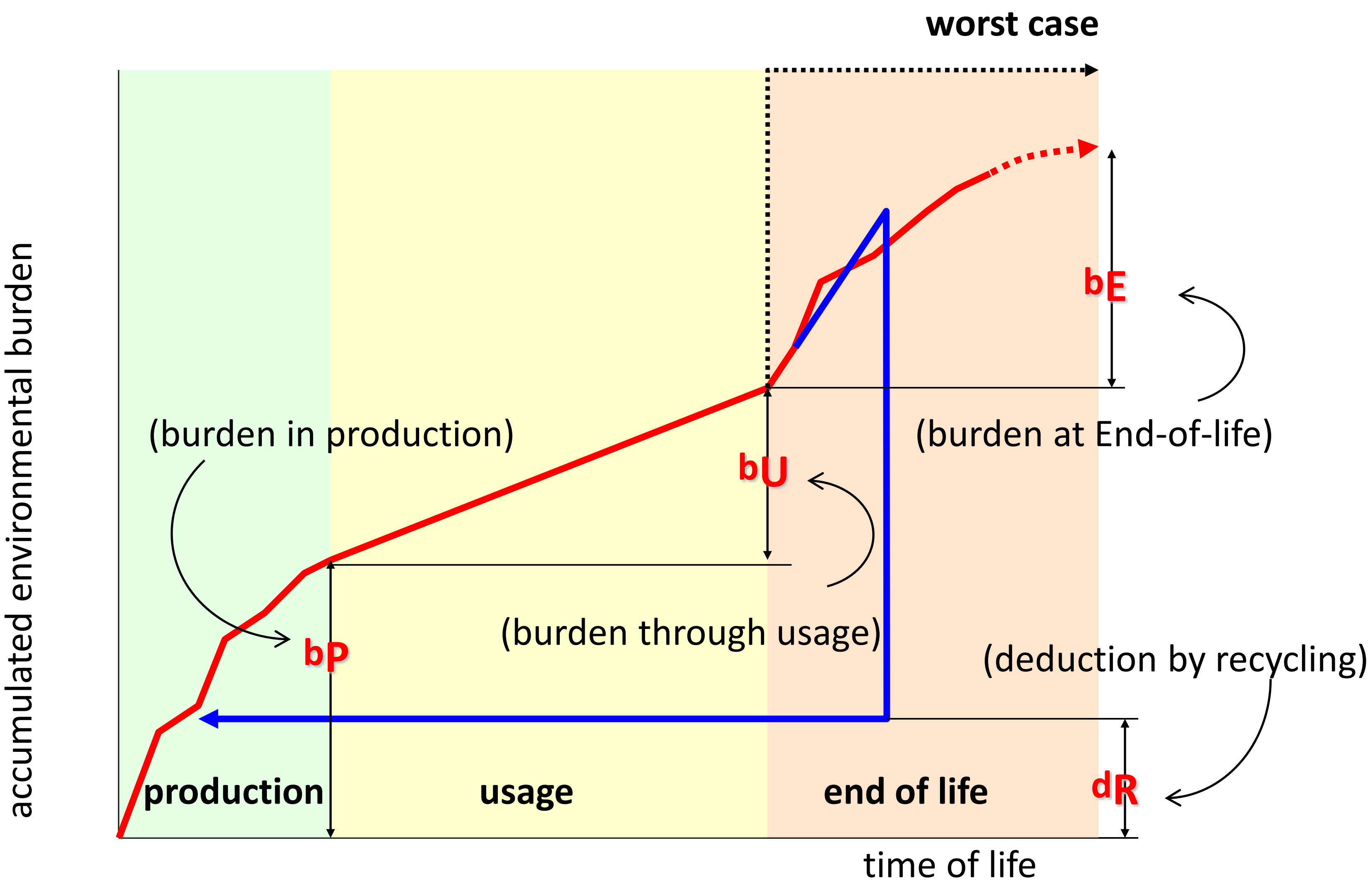
consumed resource from eco-sphere

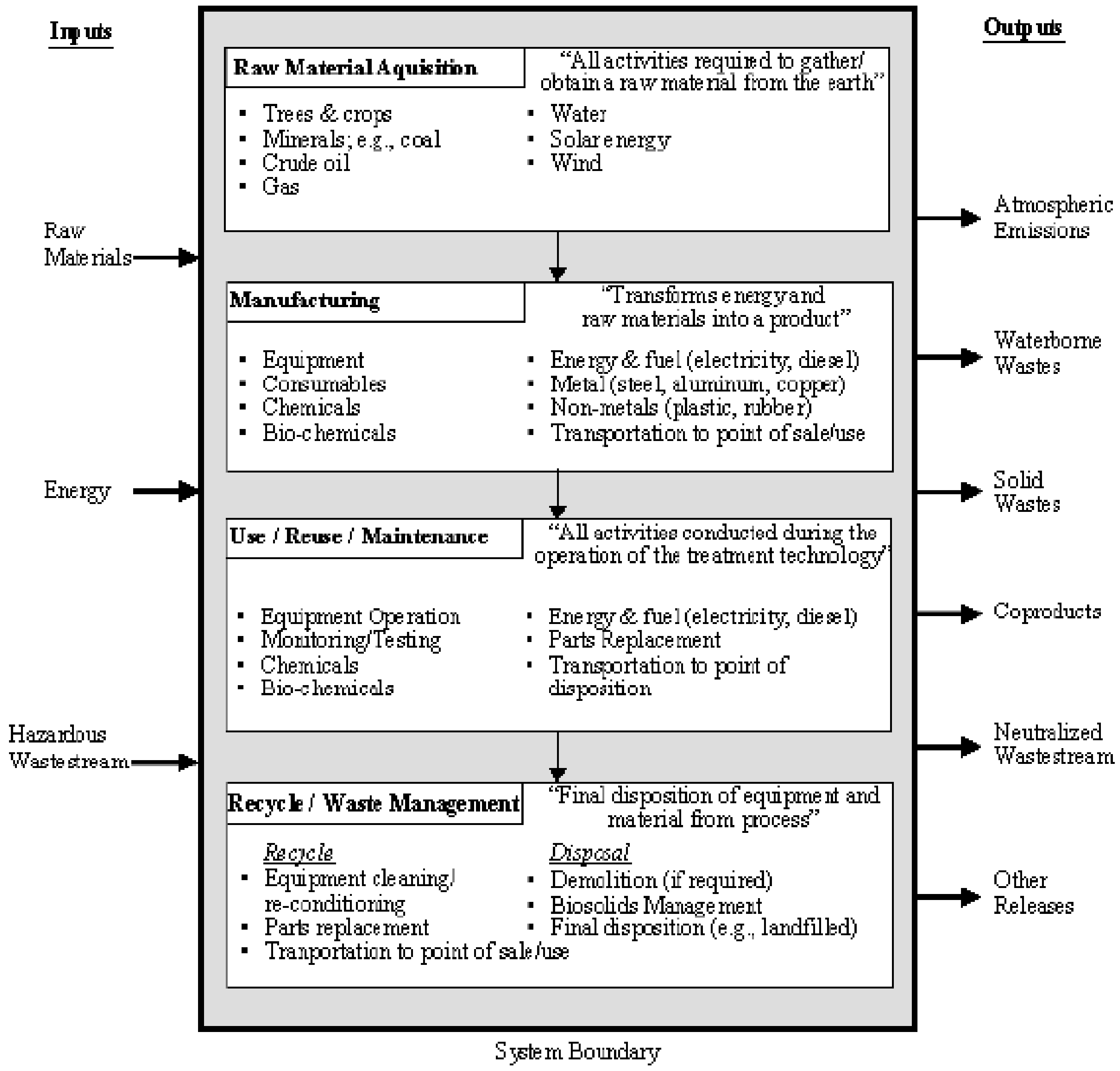
resource consumption

energy consumption

recycled material in techno-sphere

life-cycle environmental burden =
burden in production + burden through usage
+ burden of End-of-Life - deduction by recycling


worst case
accumulated environmental burden
(burden in production)
bP
(burden through usage)
bU
bE
(burden at End-of-life)
(deduction by recycling)
dR
production
usage
end of life
time of life


Inputs
Outputs
Raw Material Aquisition
"All activities required to gather/ obtain a raw material from the earth"
Trees & crops
Minerals; e.g., coal
Crude oil
Gas
Water
Solar energy
Wind
Manufacturing
"Transforms energy and raw materials into a product"
Equipment
Consumables
Chemicals
Bio-chemicals
Energy & fuel (electricity, diesel)
Metal (steel, aluminum, copper)
Non-metals (plastic, rubber)
Transportation to point of sale/use
Use / Reuse / Maintenance
"All activities conducted during the operation of the treatment technology"
Equipment Operation
Monitoring/Testing
Chemicals
Bio-chemicals
Energy & fuel (electricity, diesel)
Parts Replacement
Transportation to point of disposition
Recycle / Waste Management
"Final disposition of equipment and material from process"
Recycle
Equipment cleaning/ re-conditioning
Parts replacement
Tranportation to point of sale/use
Disposal
Demolition (if required)
Biosolids Management
Final disposition (e.g., landfilled)
Raw Materials
Energy
Hazardous Wastestream
Atmospheric Emissions
Waterborne Wastes
Solid Wastes
Coproducts
Neutralized Wastestream
Other Releases
System Boundary

In Toyama framework (G7 summit Ise-Shima)

Policy Guidance on Resource Efficiency

OECD
BETTER POLICIES FOR BETTER LIVES

Key recommendations

Going for green growth and establishing a resource efficient economy is a major environmental, development and economic challenge today. In this context, improving resource productivity and putting in place policies that implement the principles of reduce, reuse, recycle (the 3Rs) is crucial, as recognised by G7 Leaders in the Schloss Elmau's declaration in June 2015.

This report responds to the request by G7 Leaders at the Schloss Elmau Summit asking the OECD to develop policy guidance for resource efficiency. Key findings and recommendations from this report include the following considerations.

Although resource efficiency is first and foremost a matter of national policy decisions, only collective action and co-ordinated efforts will ensure widespread benefits amongst countries. The G7 has an important role to play in this regard.

The G7 can highlight best practices and provide a platform for sharing of experiences both within and beyond its membership. Two key messages from this Guidance are that:

- Resource efficiency policies should target the entire life-cycle of products.
- National policies should put more emphasis on aligning sectoral policies in diverse areas like innovation, investment, trade, education and skills development with resource efficiency objectives.

These broader messages on the life-cycle approach and policy coherence could be explicitly supported by the G7.

The G7 can also strengthen co-ordination and co-operation at the international level by:

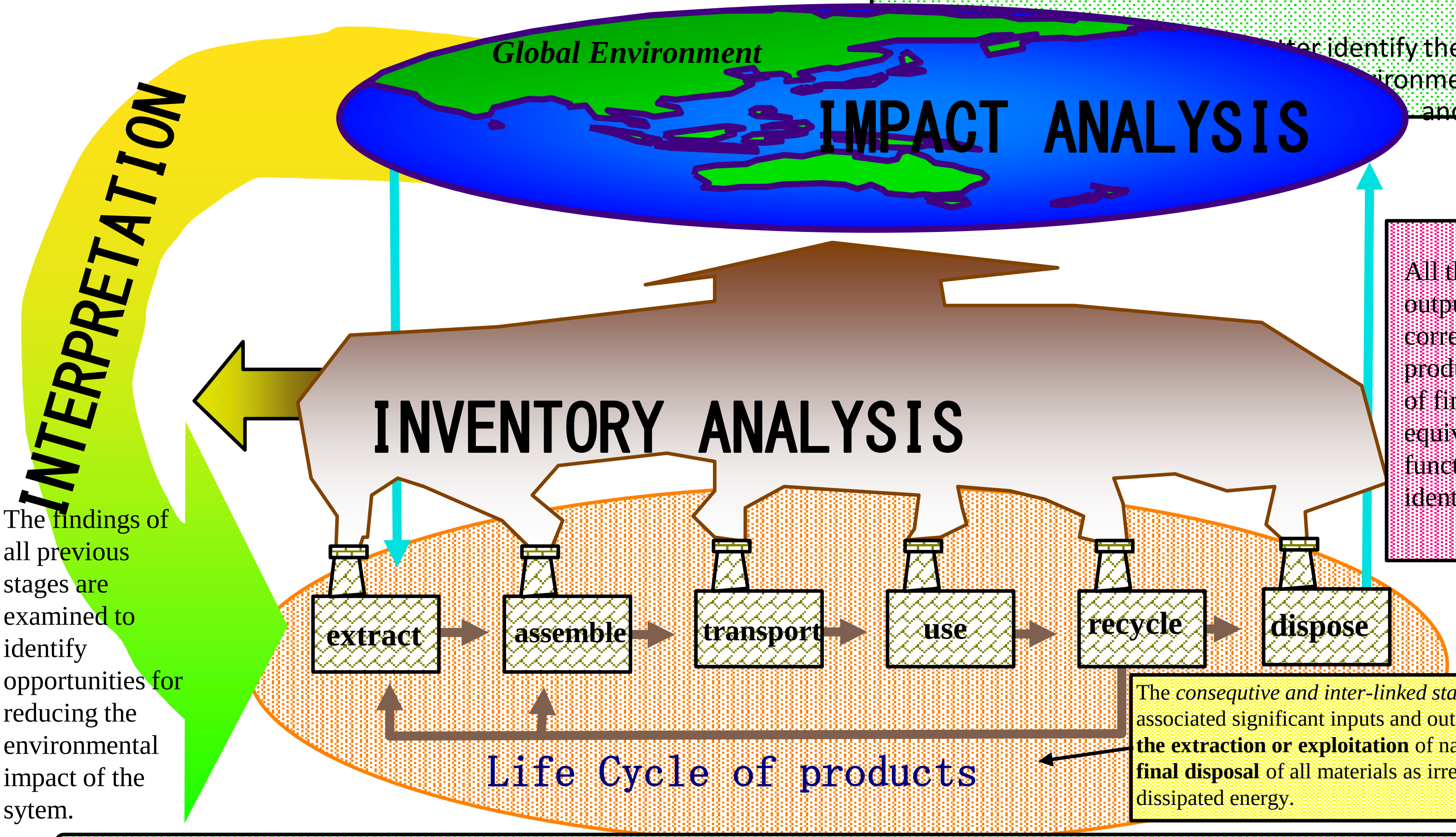
- Facilitating integration of resource efficiency considerations in Global Value Chains by supporting businesses in their supply chain management efforts.
- Addressing trade and investment related obstacles to resource efficiency in supply chains, including export restrictions on secondary raw materials, restrictions on trade in used products, and barriers to trade in environmental goods and services.
- Calling for some degree of harmonisation in the growing field of environmental labelling and information schemes, with the aim of maintaining high standards, allowing for increased mutual recognition of schemes, and countering increased costs associated with scheme multiplication across international markets.

Finally, the G7 can help address key information gaps related to material flows and resource efficiency. These gaps include harmonised data on indirect material flows associated with international trade, information on flows of secondary raw materials, disaggregated information on resource use by industry, and information on the quality and deterioration of natural resource stocks. Similarly, the G7 can support internationally co-ordinated efforts to improve economic analysis of resource efficiency, an area that has currently received very little attention in research.

Life Cycle Assessment

Life-cycle impact assessment examines the mass and energy inventory input and output data for a product system to transrate

ter identify their possible ironmental relevance and significance..



All the inputs and outputs of the system, corresponding to the production of the mass of finished product equivalent to the functional unit, are identified and compiled.

The findings of all previous stages are examined to identify opportunities for reducing the environmental impact of the sytem.

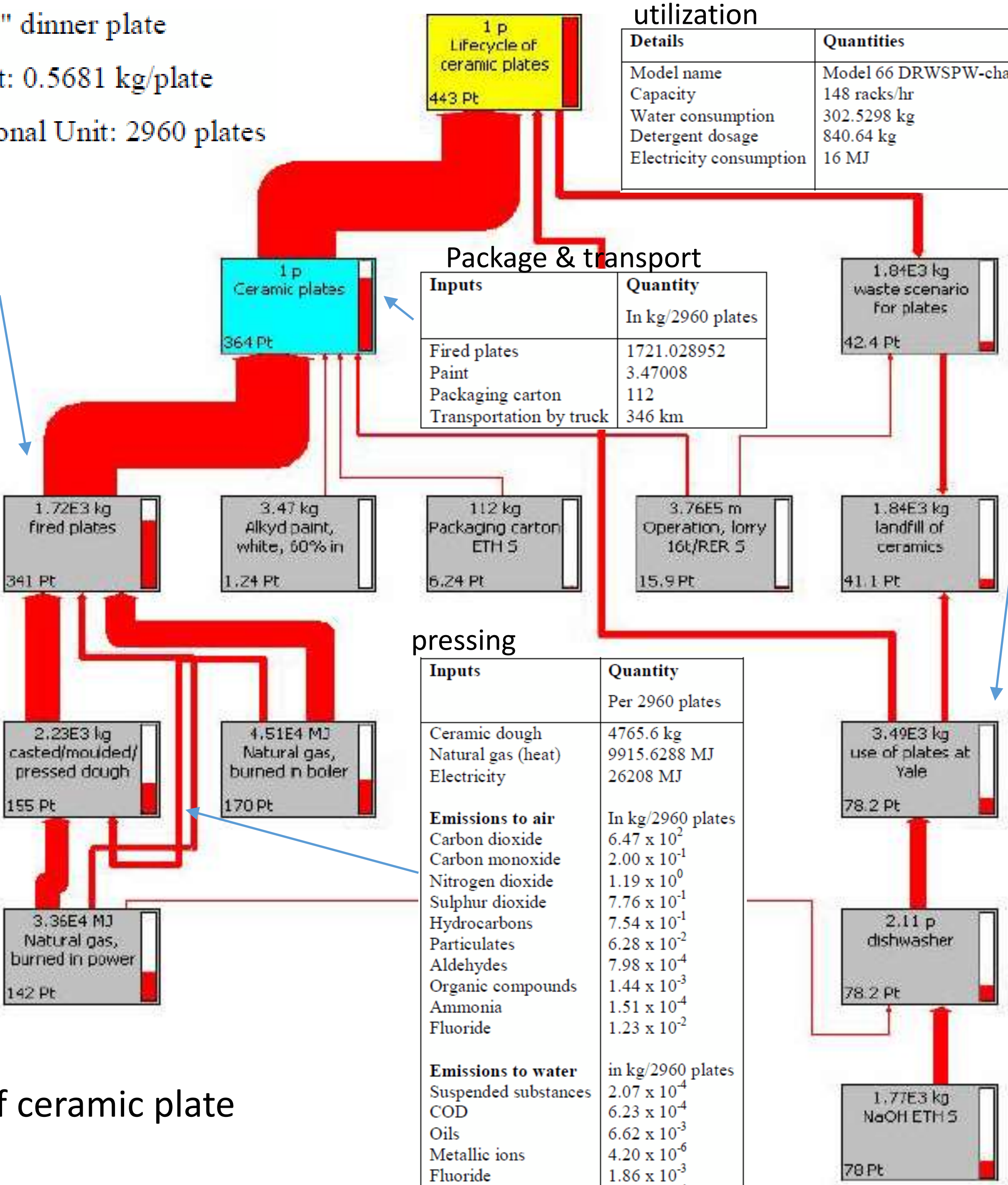
The *consequtive and inter-linked stages*, and all directly associated significant inputs and outputs, of a system **from the extraction or exploitation** of natural resources **to the final disposal** of all materials as irretrievable wastes or dissipated energy.

A systematic set of procedure for compiling and examining the environmental burdens and associated environmental impacys directly attributable to the functioning of an economic system through its life cycle

Size: 9" dinner plate

Weight: 0.5681 kg/plate

Functional Unit: 2960 plates



utilization

Details	Quantities
Model name	Model 66 DRWSPW-champion company
Capacity	148 racks/hr
Water consumption	302.5298 kg
Detergent dosage	840.64 kg
Electricity consumption	16 MJ

firing

Inputs	Quantity Per 2960 plates
Casted, moulded, pressed dough	2228.457312 kg
Natural gas (heat)	35155.4112 MJ
Electricity	7392 MJ
Emissions to air	In kg/2960 plates
Carbon dioxide	2.29×10^{3}
Carbon monoxide	7.08×10^{-1}
Nitrogen dioxide	4.23×10^{0}
Sulphur dioxide	2.75×10^{0}
Hydrocarbons	2.67×10^{0}
Particulates	2.23×10^{-1}
Aldehydes	2.83×10^{-3}
Organic compounds	5.11×10^{-3}
Ammonia	5.35×10^{-4}
Fluoride	4.36×10^{-2}

Package & transport

Inputs	Quantity In kg/2960 plates
Fired plates	1721.028952
Paint	3.47008
Packaging carton	112
Transportation by truck	346 km

pressing

Inputs	Quantity Per 2960 plates
Ceramic dough	4765.6 kg
Natural gas (heat)	9915.6288 MJ
Electricity	26208 MJ
Emissions to air	In kg/2960 plates
Carbon dioxide	6.47×10^{2}
Carbon monoxide	2.00×10^{-1}
Nitrogen dioxide	1.19×10^{0}
Sulphur dioxide	7.76×10^{-1}
Hydrocarbons	7.54×10^{-1}
Particulates	6.28×10^{-2}
Aldehydes	7.98×10^{-4}
Organic compounds	1.44×10^{-3}
Ammonia	1.51×10^{-4}
Fluoride	1.23×10^{-2}
Emissions to water	in kg/2960 plates
Suspended substances	2.07×10^{-4}
COD	6.23×10^{-4}
Oils	6.62×10^{-3}
Metallic ions	4.20×10^{-6}
Fluoride	1.86×10^{-3}
Ammonia	8.67×10^{-4}

Raw material

Inputs	**Quantity** In kg/2960 plates
Kaolinite	840
Silicon	420
Feldspar	420
Water	3108

Life-cycle of ceramic plate

Size: 9" dinner plate

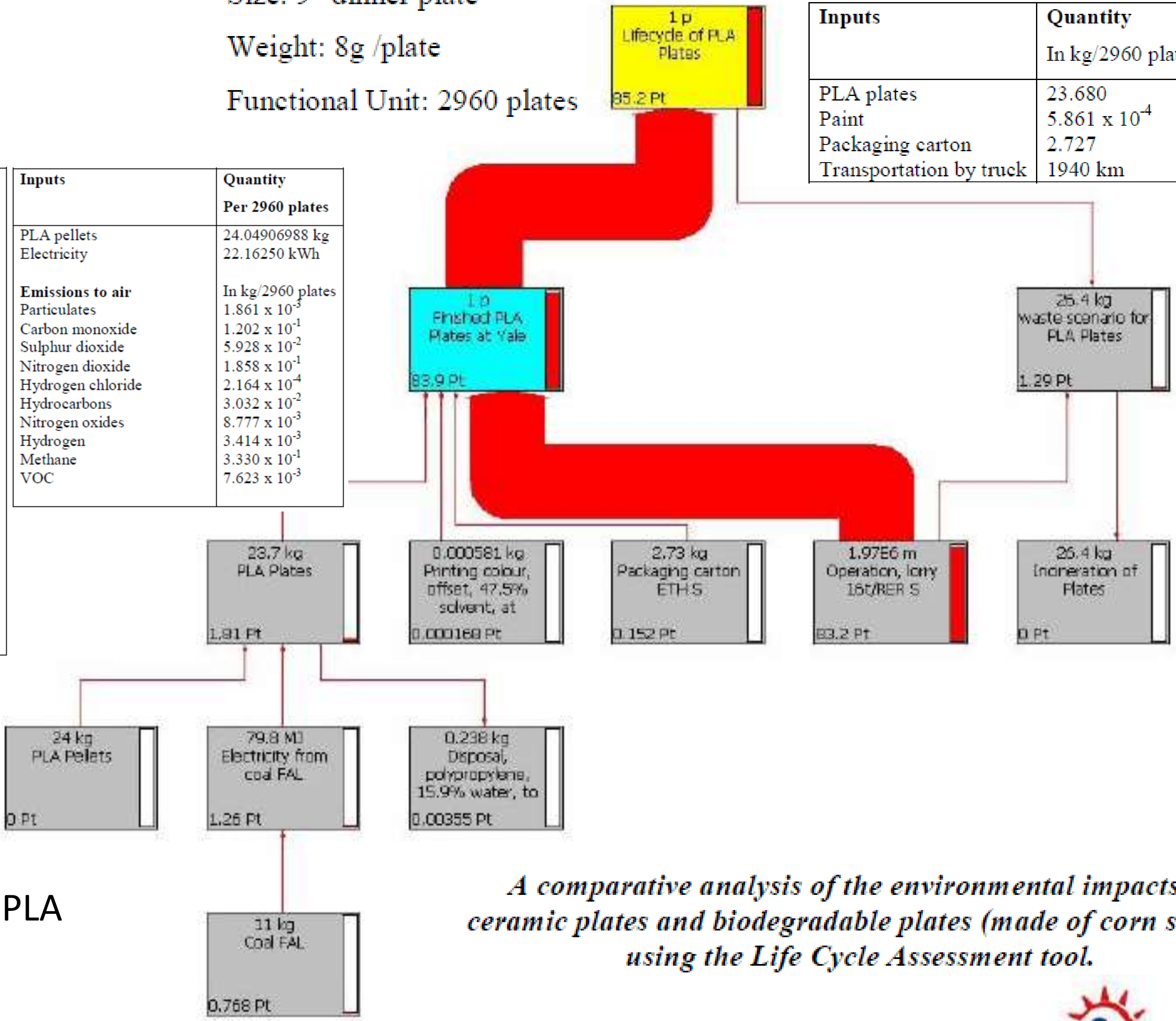
Weight: 8g /plate

Functional Unit: 2960 plates

Inputs	**Quantity** In kg/2960 plates
PLA plates	23.680
Paint	5.861 x 10^{-4}
Packaging carton	2.727
Transportation by truck	1940 km

Emissions to water	In kg/2960 plates
COD	1.419 x 10^{-1}
BOD	2.587 x 10^{-2}
Sodium ion	1.755 x 10^{-2}
Nitrogen oxides	2.900 x 10^{-2}
Chloride	3.915 x 10^{-2}
Suspended solids	7.440 x 10^{-2}
Phosphorous compounds	2.881 x 10^{-4}
Nitrogen	2.031 x 10^{-3}
Sulphate	3.318 x 10^{-3}
Calcium compounds	3.061 x 10^{-3}
TOC	3.770 x 10^{-2}
Calcium ion	5.956 x 10^{-3}
Solid waste	In kg/2960 plates
Plastics	2.404 x 10^{-2}
Unspecified waste	2.404 x 10^{-2}
Mineral waste	4.425 x 10^{-1}
Slags and ashes	2.195 x 10^{-2}
Chemical waste, regulated	1.049 x 10^{-1}
Chemical waste, unregulated	2.404 x 10^{-2}
Waste returned to mine	7.844 x 10^{-2}
Mineral waste from mining	2.339 x 10^{-1}
PLA waste generated	2.381 x 10^{-1}

Inputs	**Quantity** **Per 2960 plates**
PLA pellets	24.04906988 kg
Electricity	22.16250 kWh
Emissions to air	In kg/2960 plates
Particulates	1.861 x 10^{-3}
Carbon monoxide	1.202 x 10^{-1}
Sulphur dioxide	5.928 x 10^{-2}
Nitrogen dioxide	1.858 x 10^{-1}
Hydrogen chloride	2.164 x 10^{-4}
Hydrocarbons	3.032 x 10^{-2}
Nitrogen oxides	8.777 x 10^{-3}
Hydrogen	3.414 x 10^{-3}
Methane	3.330 x 10^{-1}
VOC	7.623 x 10^{-3}



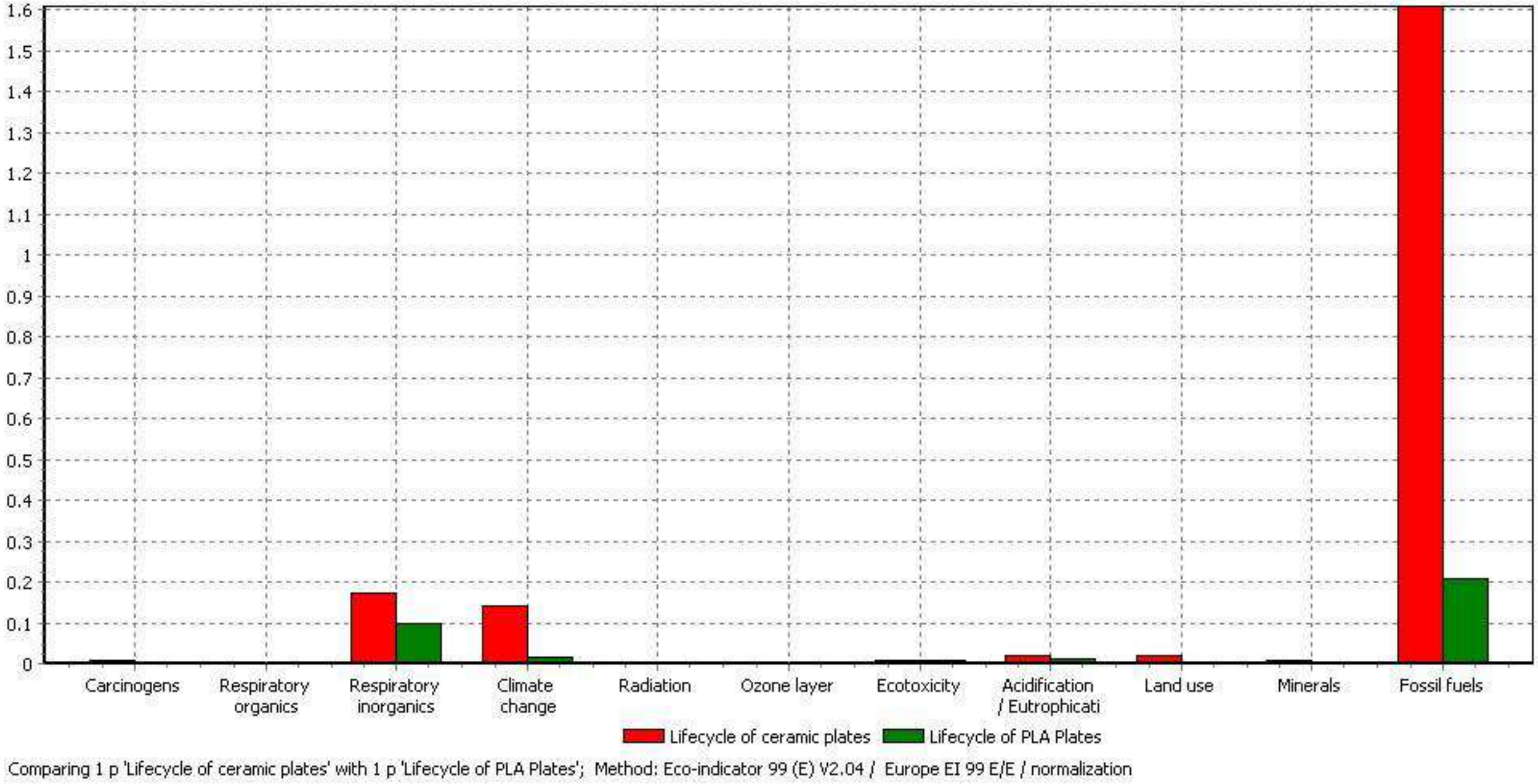
Start from PLA

A comparative analysis of the environmental impacts of ceramic plates and biodegradable plates (made of corn starch) using the Life Cycle Assessment tool.

teri university

Life-cycle of corn-starch biodegradable plate

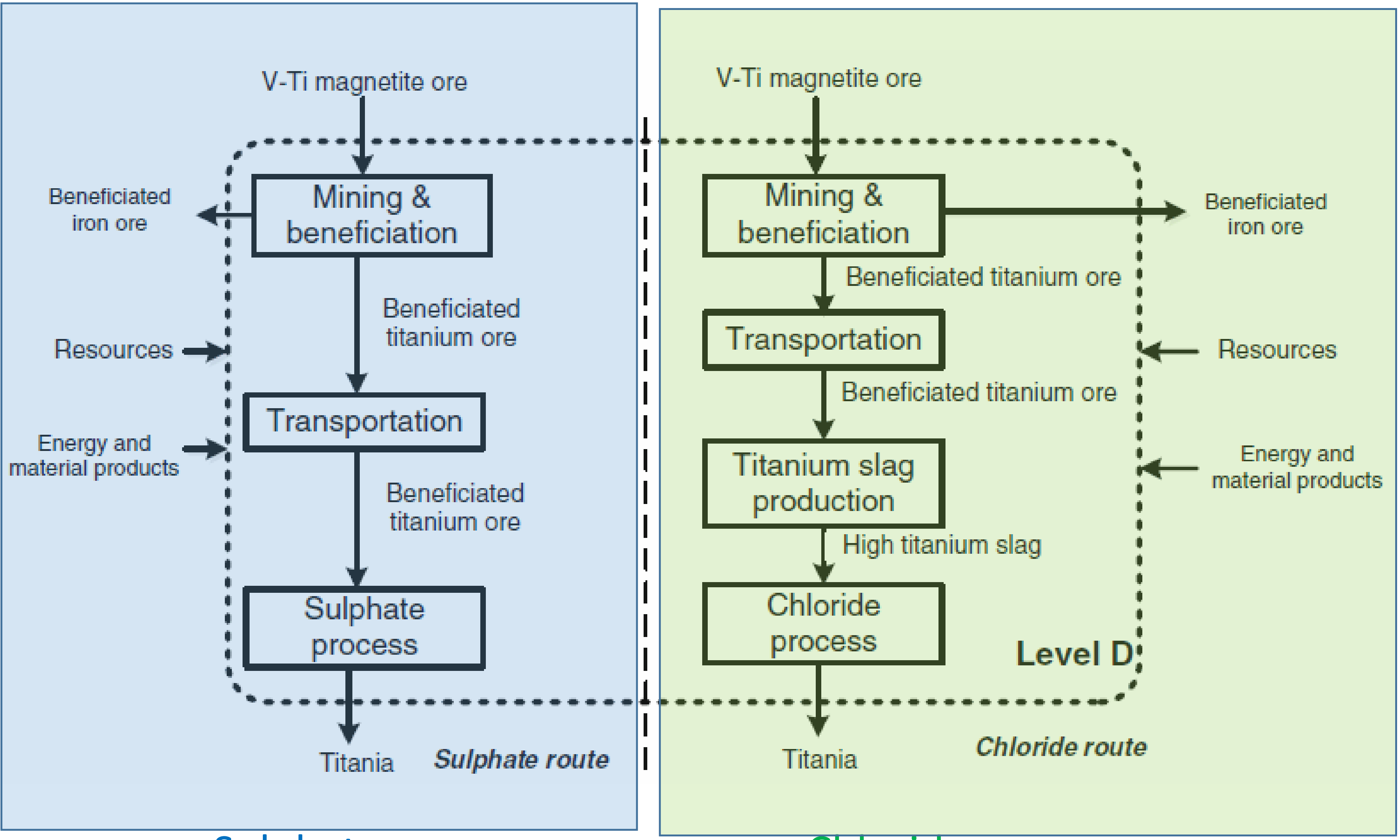
Impact analysis of ceramic plate and biodegradable plate



Comparing 1 p 'Lifecycle of ceramic plates' with 1 p 'Lifecycle of PLA Plates'; Method: Eco-indicator 99 (E) V2.04 / Europe EI 99 E/E / normalization

Thermodynamic resource indicators in LCA: a case study on the titania produced in Panzhihua city, southwest China

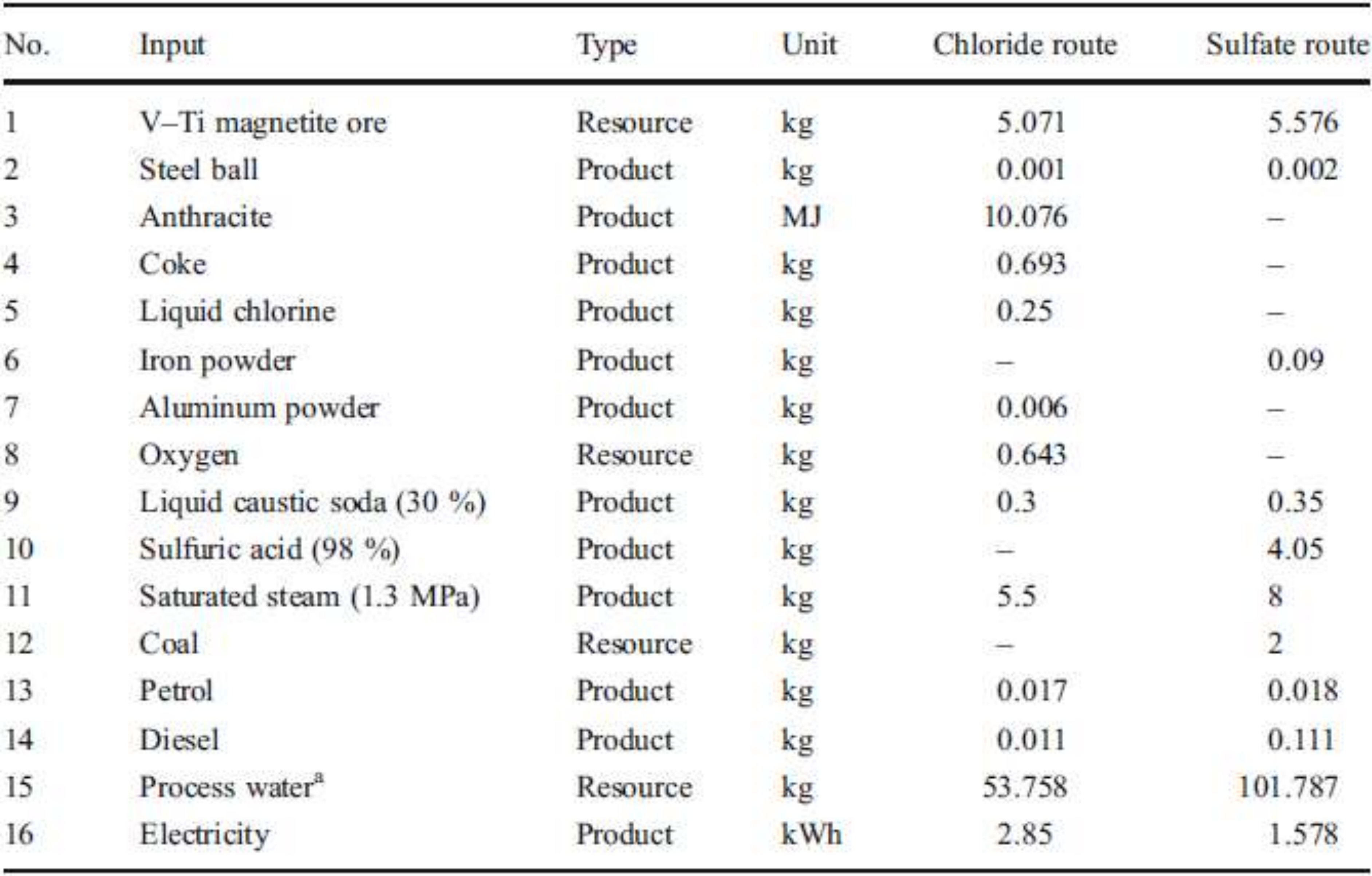
Wenjie Liao & Reinout Heijungs & Gjalt Huppes Int J Life Cycle Assess



Sulphate process Chloride process

Thermodynamic resource indicators in LCA: a case study on the titania produced in Panzhihua city, southwest China

Wenjie Liao & Reinout Heijungs & Gjalt Huppes Int J Life Cycle Assess

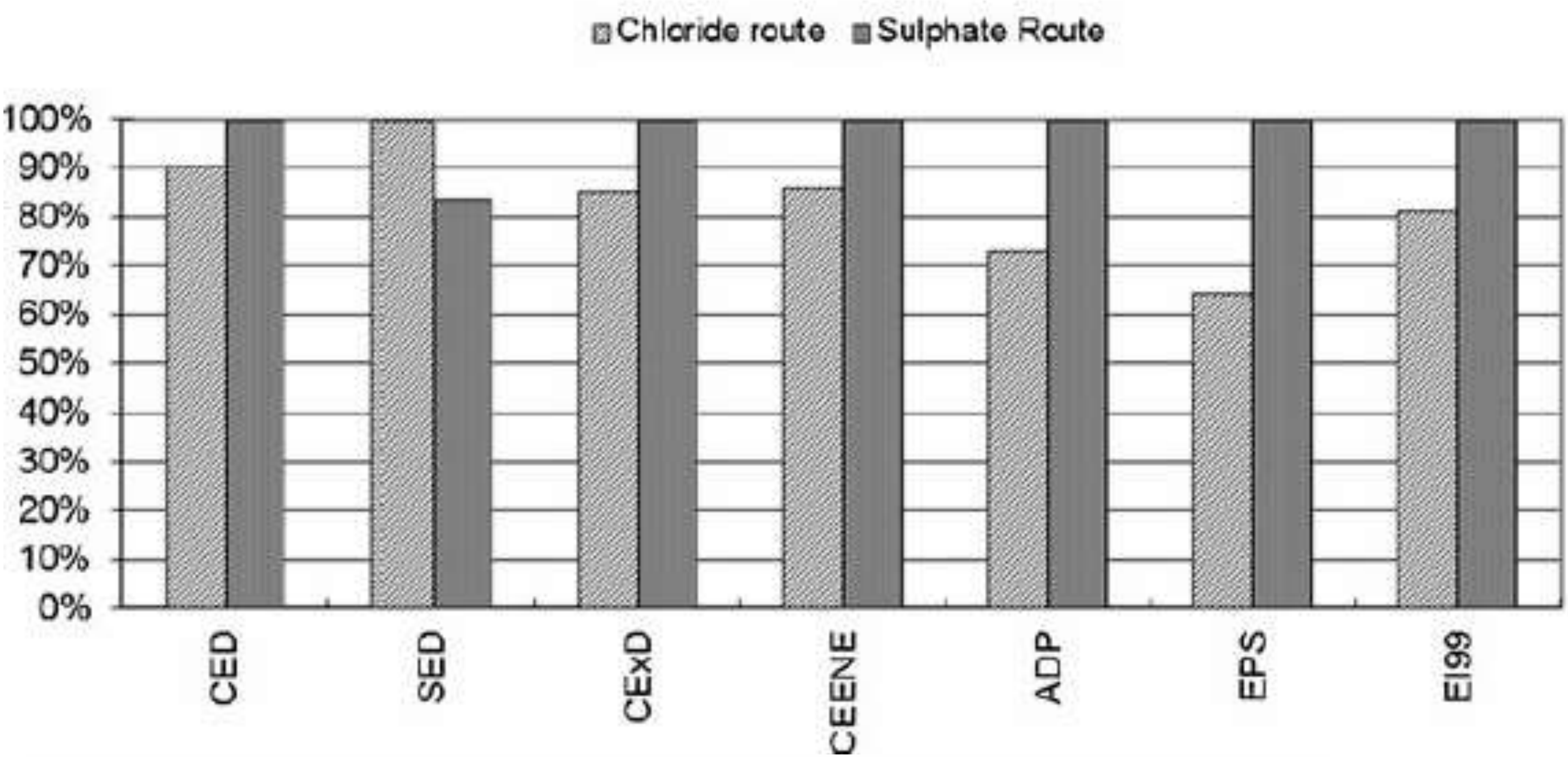


No.	Input	Type	Unit	Chloride route	Sulfate route
1	V–Ti magnetite ore	Resource	kg	5.071	5.576
2	Steel ball	Product	kg	0.001	0.002
3	Anthracite	Product	MJ	10.076	–
4	Coke	Product	kg	0.693	–
5	Liquid chlorine	Product	kg	0.25	–
6	Iron powder	Product	kg	–	0.09
7	Aluminum powder	Product	kg	0.006	–
8	Oxygen	Resource	kg	0.643	–
9	Liquid caustic soda (30 %)	Product	kg	0.3	0.35
10	Sulfuric acid (98 %)	Product	kg	–	4.05
11	Saturated steam (1.3 MPa)	Product	kg	5.5	8
12	Coal	Resource	kg	–	2
13	Petrol	Product	kg	0.017	0.018
14	Diesel	Product	kg	0.011	0.111
15	Process water[a]	Resource	kg	53.758	101.787
16	Electricity	Product	kWh	2.85	1.578

Thermodynamic resource indicators in LCA: a case study on the titania produced in Panzhihua city, southwest China

Wenjie Liao & Reinout Heijungs & Gjalt Huppes

Int J Life Cycle Assess



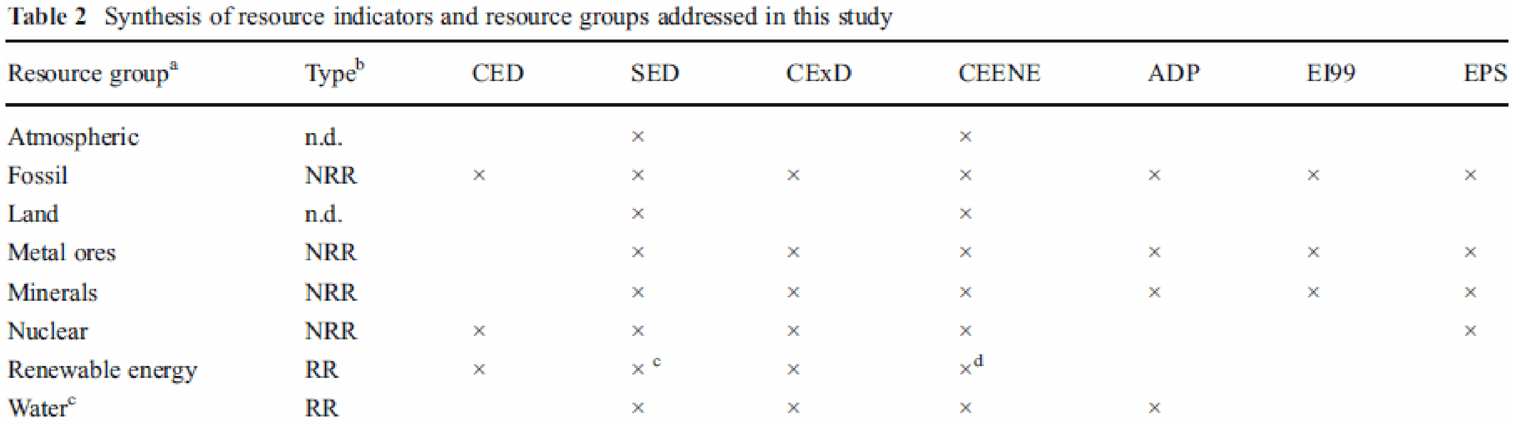


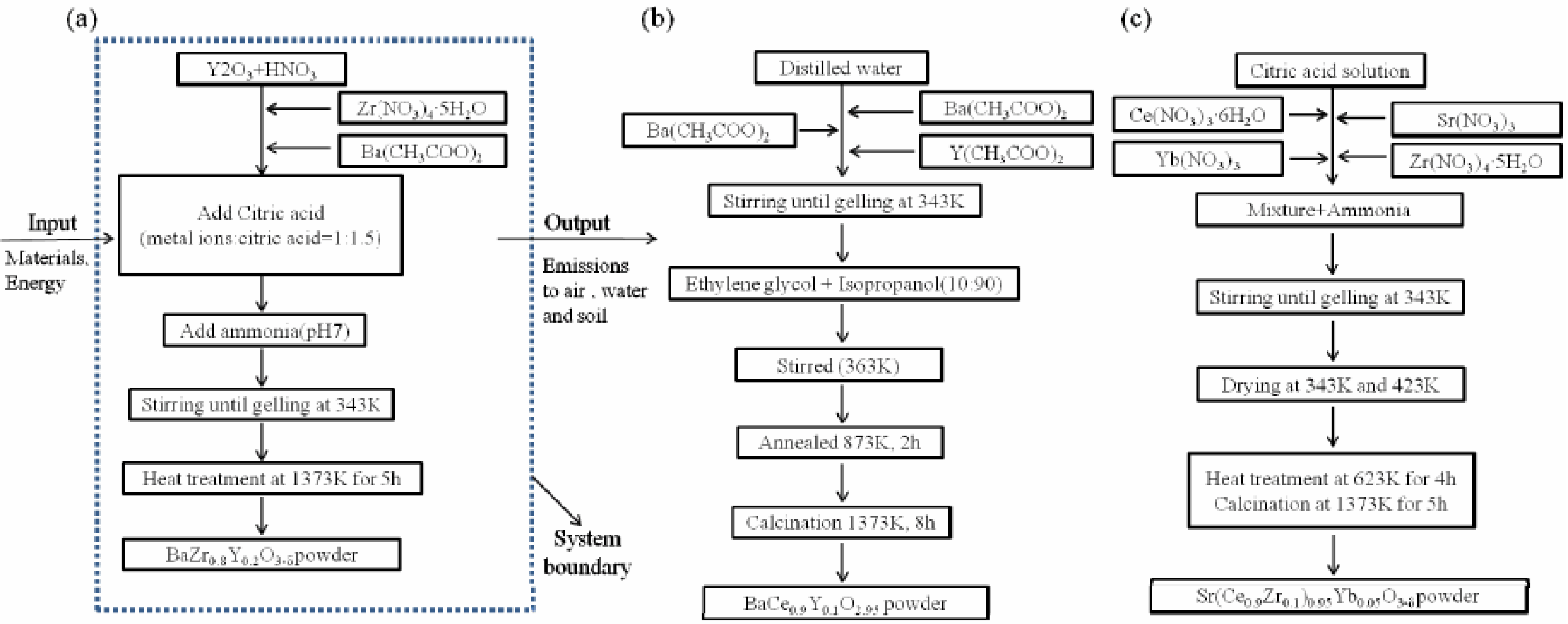
Table 2 Synthesis of resource indicators and resource groups addressed in this study

Resource group[a]	Type[b]	CED	SED	CExD	CEENE	ADP	EI99	EPS
Atmospheric	n.d.		×		×			
Fossil	NRR	×	×	×	×	×	×	×
Land	n.d.		×		×			
Metal ores	NRR		×	×	×	×	×	×
Minerals	NRR		×	×	×	×	×	×
Nuclear	NRR	×	×	×	×			×
Renewable energy	RR	×	×[c]	×	×[d]			
Water[c]	RR		×	×	×	×		

Life Cycle Assessment for Proton Conducting Ceramics Synthesized by the Sol-Gel Process :Soo-Sun Lee and Tae-Whan Hong, *Materials* **2014**, *7*, 6677-6685;

- The proton conducting ceramics BaZr0.8Y0.2O3-δ (BZY), BaCe0.9Y0.1O2.95 (BCY10),and Sr(Ce0.9Zr0.1)0.95Yb0.05O3-δ (SCZY)

Figure 1. Flow charts of experimental procedures of (a) BZY20 ($BaZr_{0.8}Y_{0.2}O_{3-\delta}$); (b) BCY10 ($BaCe_{0.9}Y_{0.1}O_{2.95}$); (c) SCZY ($Sr(Ce_{1-x}Zr_x)_{0.95}Yb_{0.05}O_{3-\delta}$).



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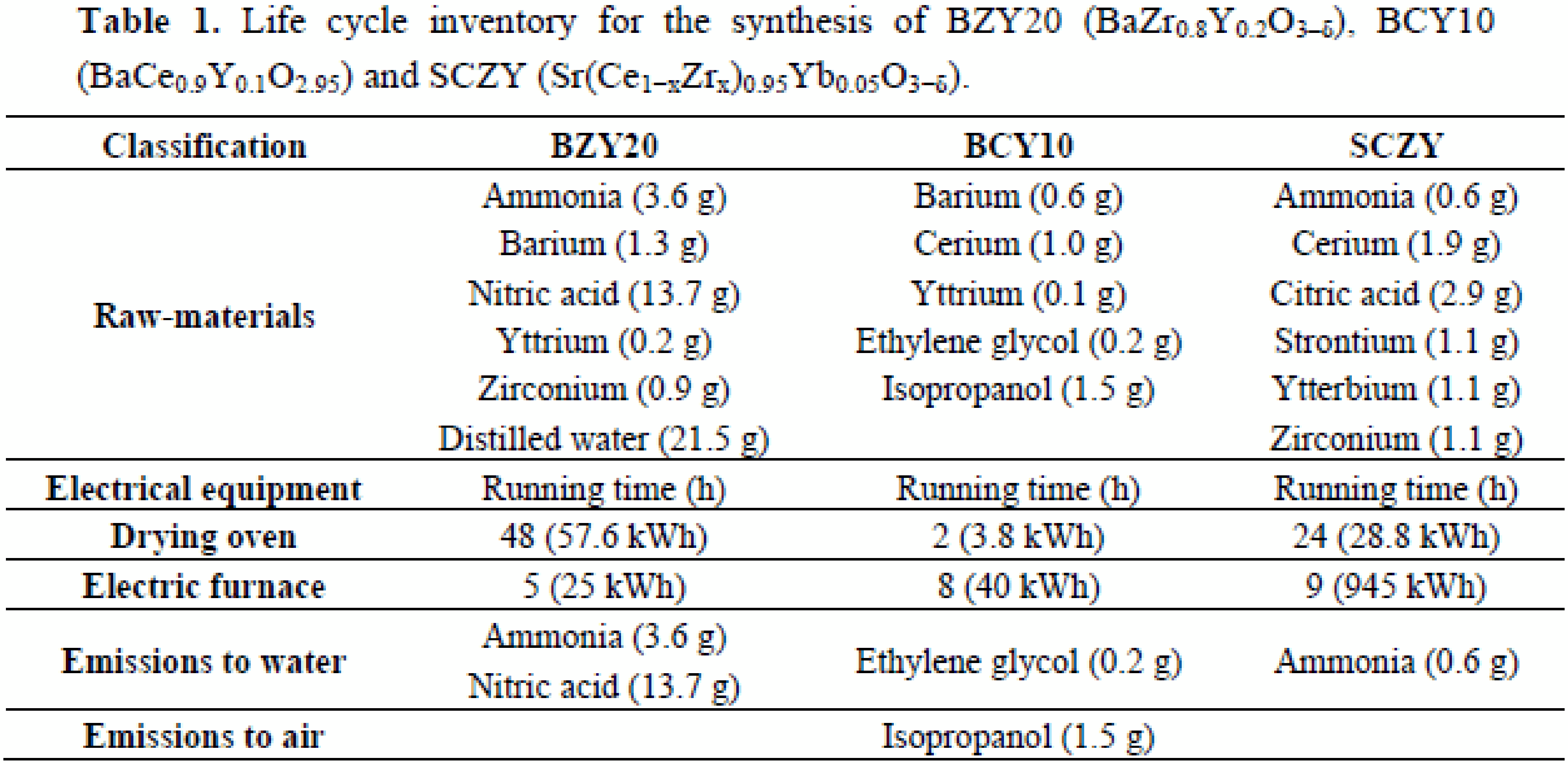
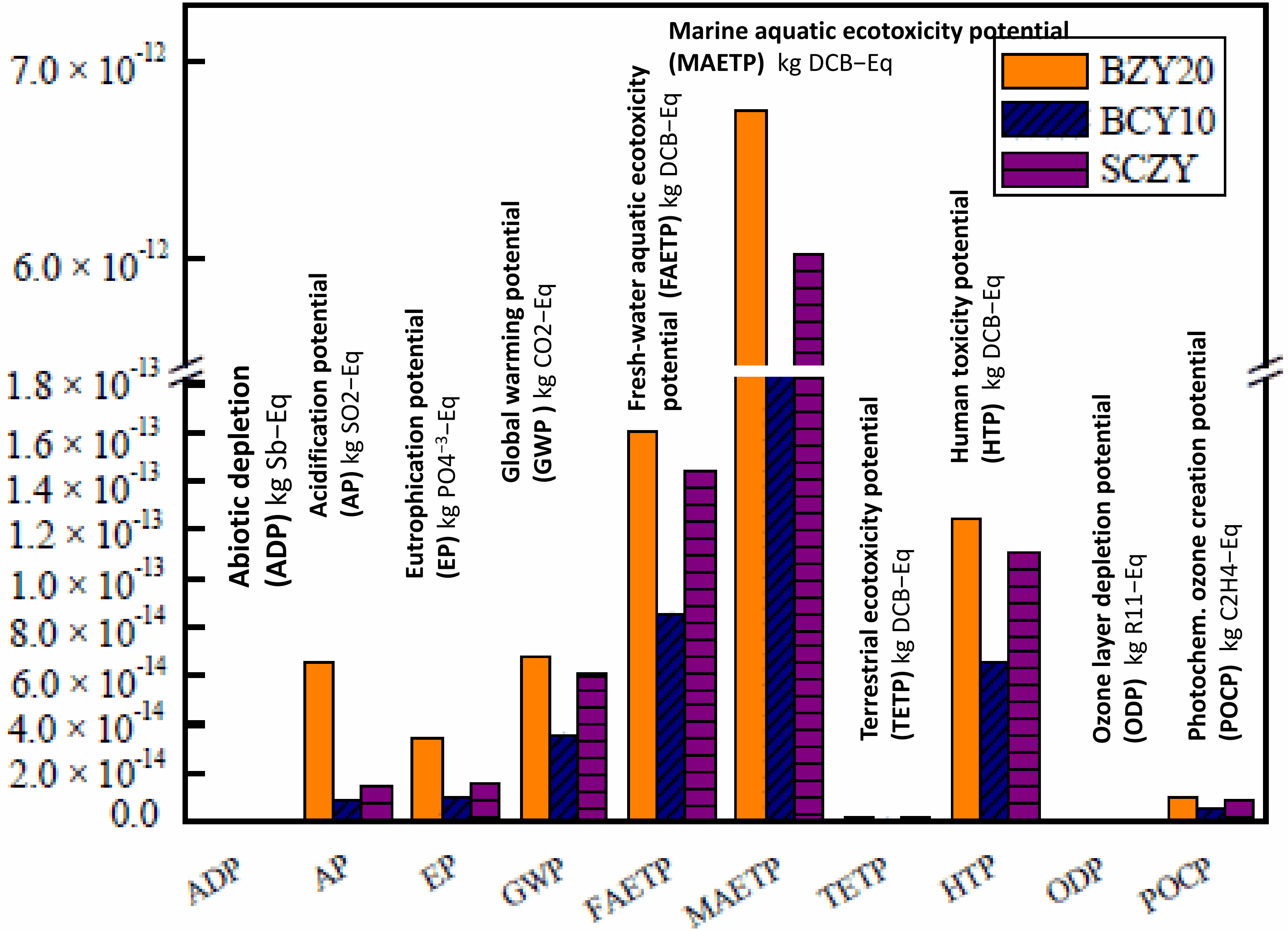


Table 1. Life cycle inventory for the synthesis of BZY20 ($BaZr_{0.8}Y_{0.2}O_{3-\delta}$), BCY10 ($BaCe_{0.9}Y_{0.1}O_{2.95}$) and SCZY ($Sr(Ce_{1-x}Zr_x)_{0.95}Yb_{0.05}O_{3-\delta}$).

Classification	BZY20	BCY10	SCZY
Raw-materials	Ammonia (3.6 g) Barium (1.3 g) Nitric acid (13.7 g) Yttrium (0.2 g) Zirconium (0.9 g) Distilled water (21.5 g)	Barium (0.6 g) Cerium (1.0 g) Yttrium (0.1 g) Ethylene glycol (0.2 g) Isopropanol (1.5 g)	Ammonia (0.6 g) Cerium (1.9 g) Citric acid (2.9 g) Strontium (1.1 g) Ytterbium (1.1 g) Zirconium (1.1 g)
Electrical equipment	Running time (h)	Running time (h)	Running time (h)
Drying oven	48 (57.6 kWh)	2 (3.8 kWh)	24 (28.8 kWh)
Electric furnace	5 (25 kWh)	8 (40 kWh)	9 (945 kWh)
Emissions to water	Ammonia (3.6 g) Nitric acid (13.7 g)	Ethylene glycol (0.2 g)	Ammonia (0.6 g)
Emissions to air		Isopropanol (1.5 g)	

Life Cycle Assessment for Proton Conducting Ceramics Synthesized by the Sol-Gel Process :Soo-Sun Lee and Tae-Whan Hong, *Materials* **2014**, *7*, 6677-6685;

Figure 2. Normalized impacts of BZY20, BZY10 and SCZY the according to CML 2001.



Life Cycle Assessment for Proton Conducting Ceramics Synthesized by the Sol-Gel Process :Soo-Sun Lee and Tae-Whan Hong, *Materials* **2014**, *7*, 6677-6685;

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Figure 3. Normalized impacts of BZY20, BZY10 and SCZY (without electricity).

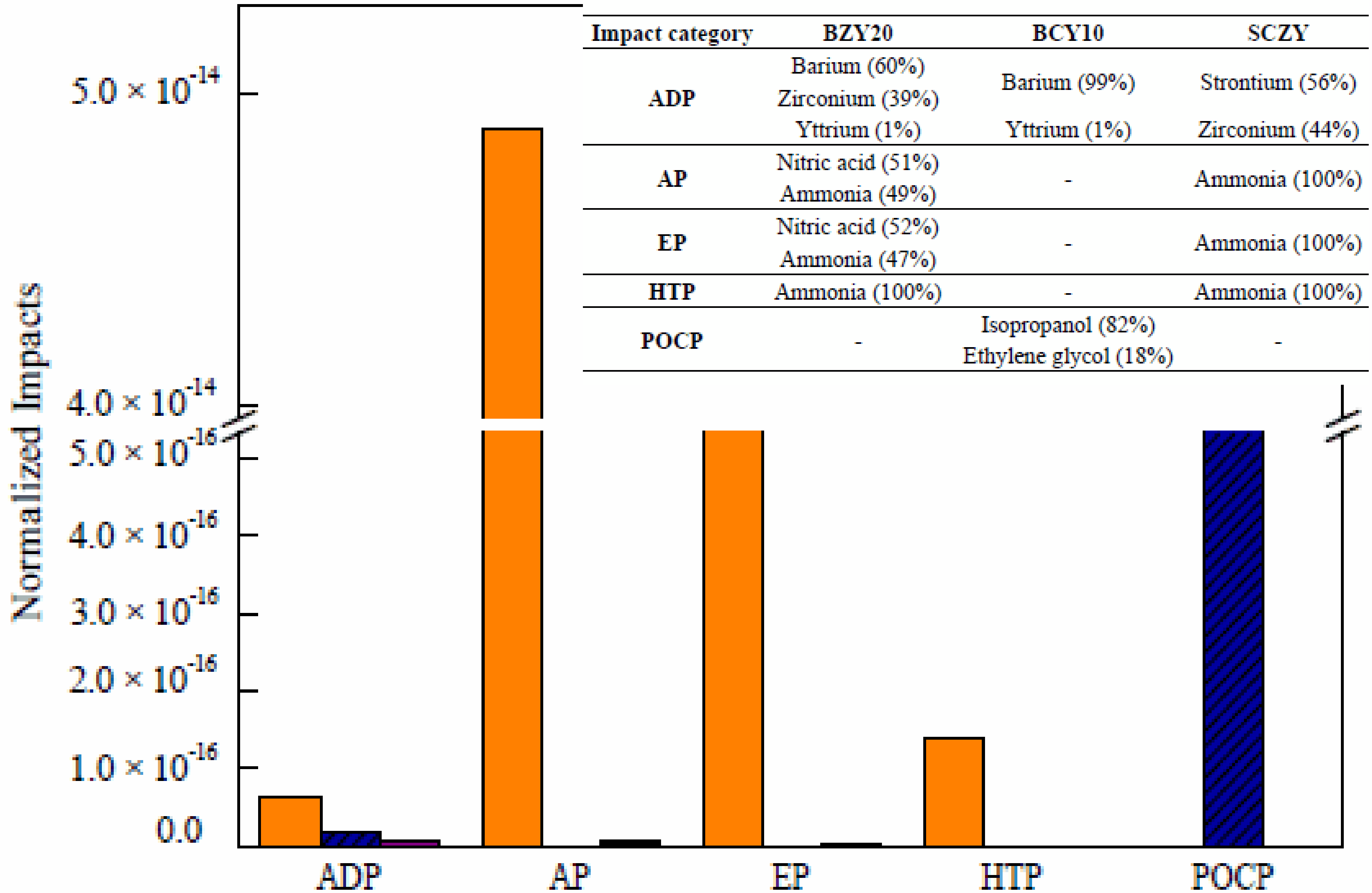
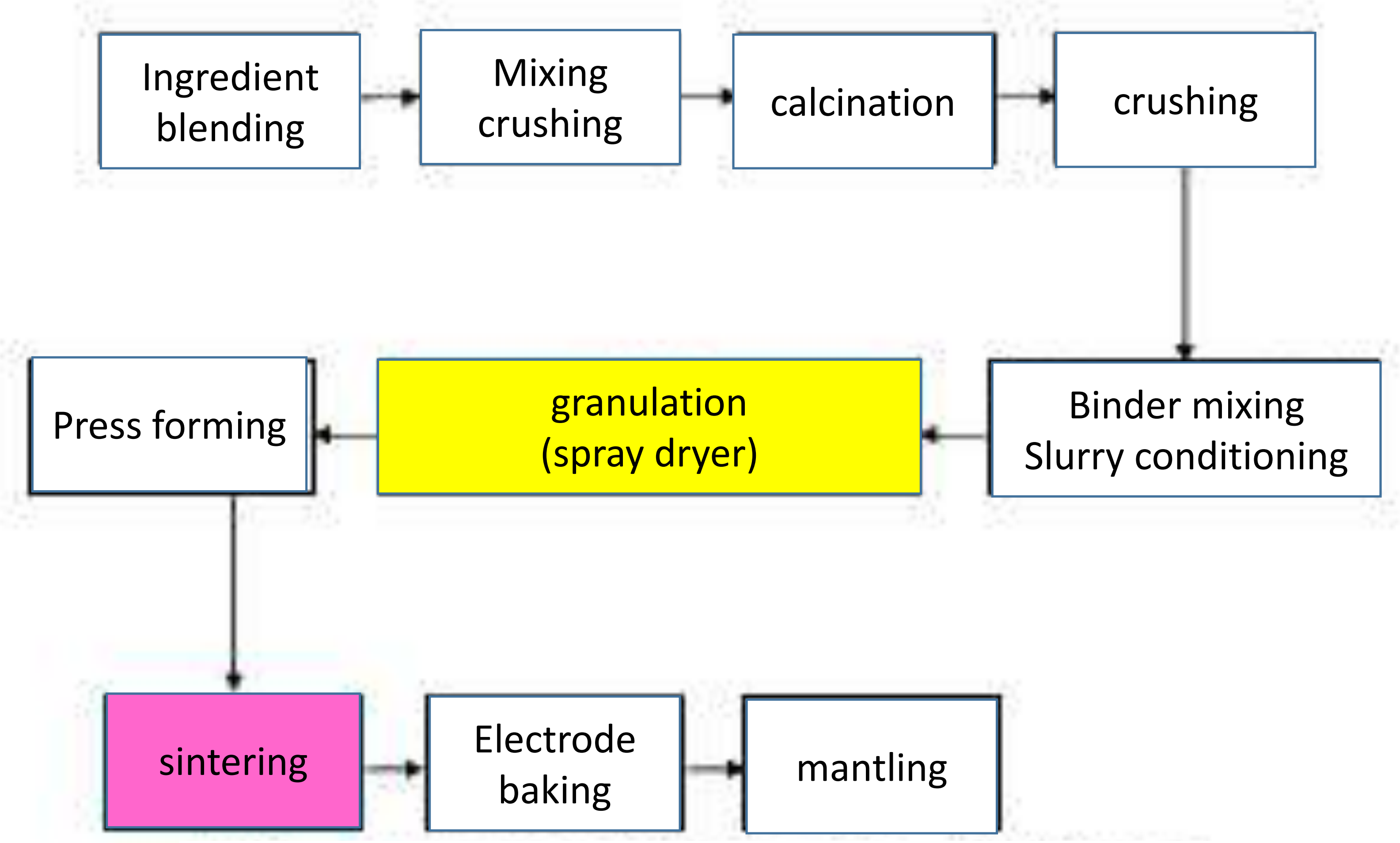


Table 3. Contribution to Environmental Impacts.

Impact category	BZY20	BCY10	SCZY
ADP	Barium (60%) Zirconium (39%) Yttrium (1%)	Barium (99%) Yttrium (1%)	Strontium (56%) Zirconium (44%)
AP	Nitric acid (51%) Ammonia (49%)	-	Ammonia (100%)
EP	Nitric acid (52%) Ammonia (47%)	-	Ammonia (100%)
HTP	Ammonia (100%)	-	Ammonia (100%)
POCP	-	Isopropanol (82%) Ethylene glycol (18%)	-

The study on LCA of the zirconia device

Koji Noda, Ruilu Liang, Takao soma, Eiji Kikuti, Hiroto Kawashima



Ingredient blending

Mixing crushing

calcination

crushing

Binder mixing Slurry conditioning

granulation (spray dryer)

Press forming

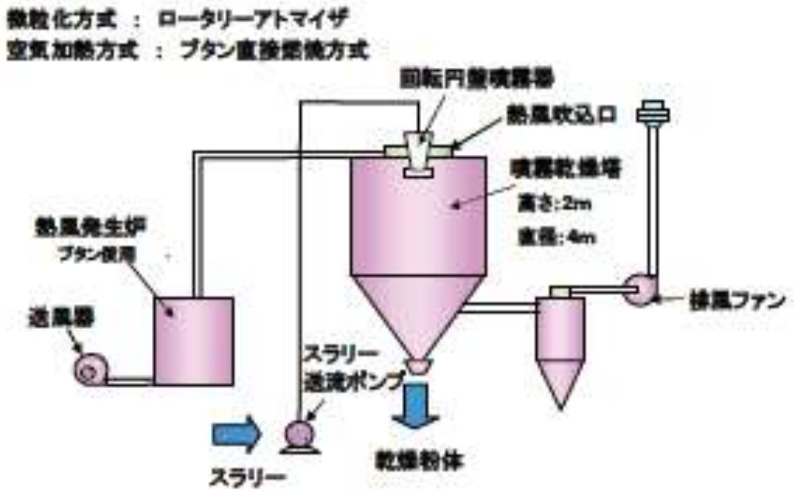
sintering

Electrode baking

mantling

Manufacturing process of ZrO2 sensor

Spry dryer process



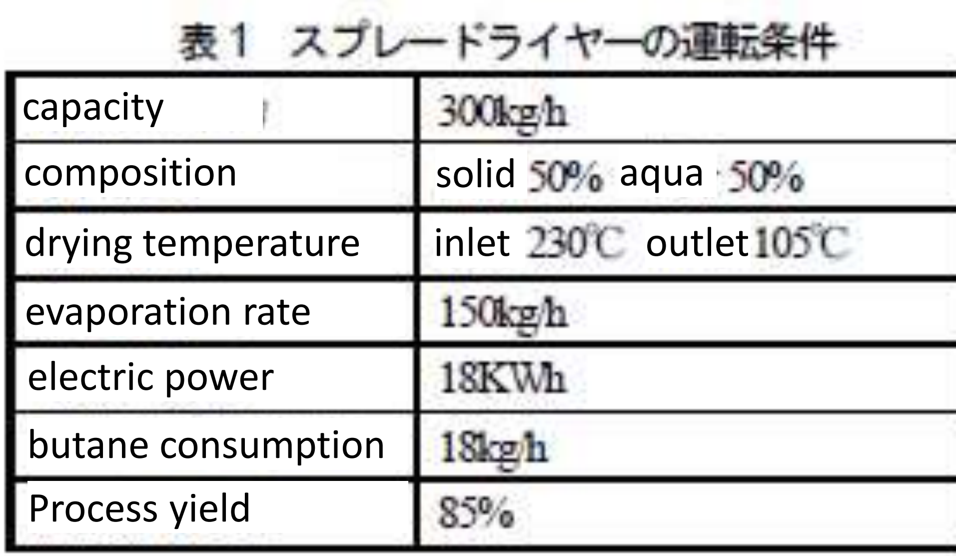


表１ スプレードライヤーの運転条件

capacity	300kg/h
composition	solid 50% aqua 50%
drying temperature	inlet 230℃ outlet 105℃
evaporation rate	150kg/h
electric power	18KWh
butane consumption	18kg/h
Process yield	85%

sintering process

Electric furnace 200*200*250mm
ZrO2 7.8kg
Heat-up to 600℃ at 50℃/h
De-binder 600℃ 2h
Heat-up to 1400℃ at 100℃/h
Calcining 1400℃ 2h

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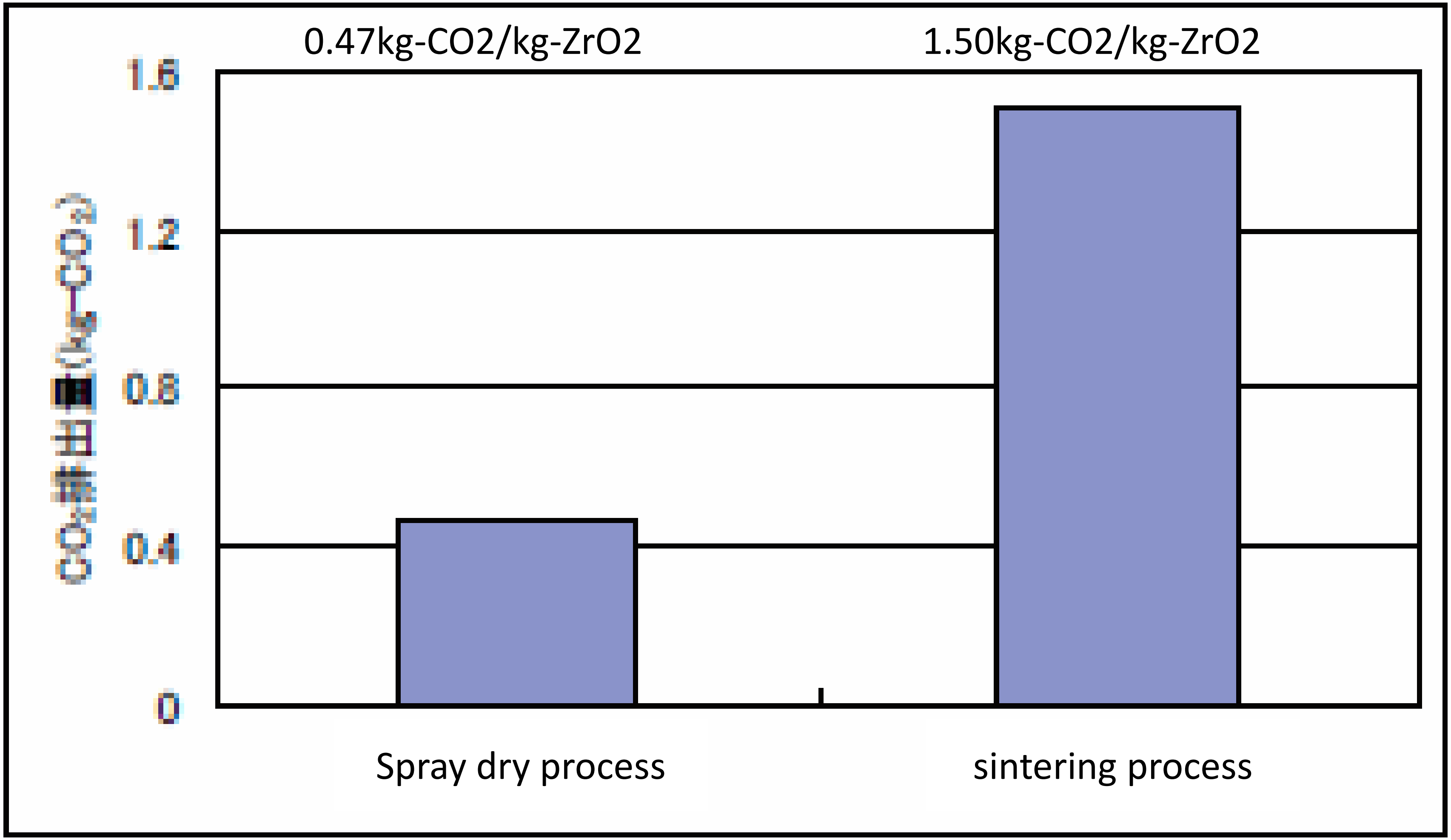
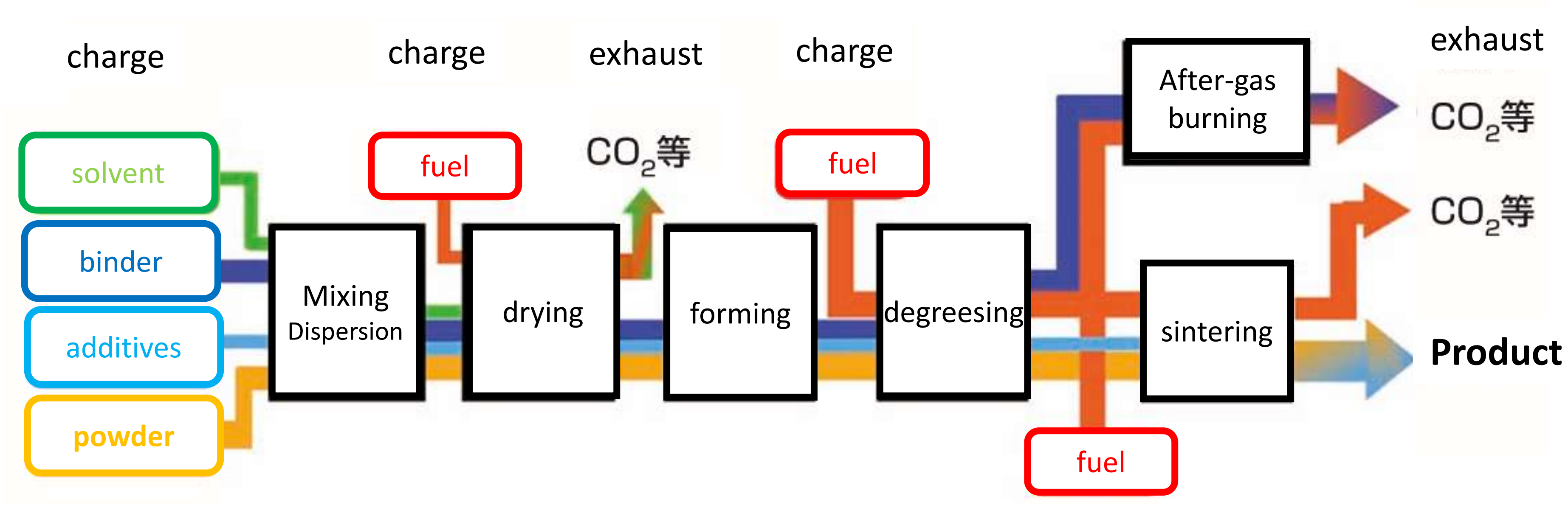


Comparison of CO2 emission in each process

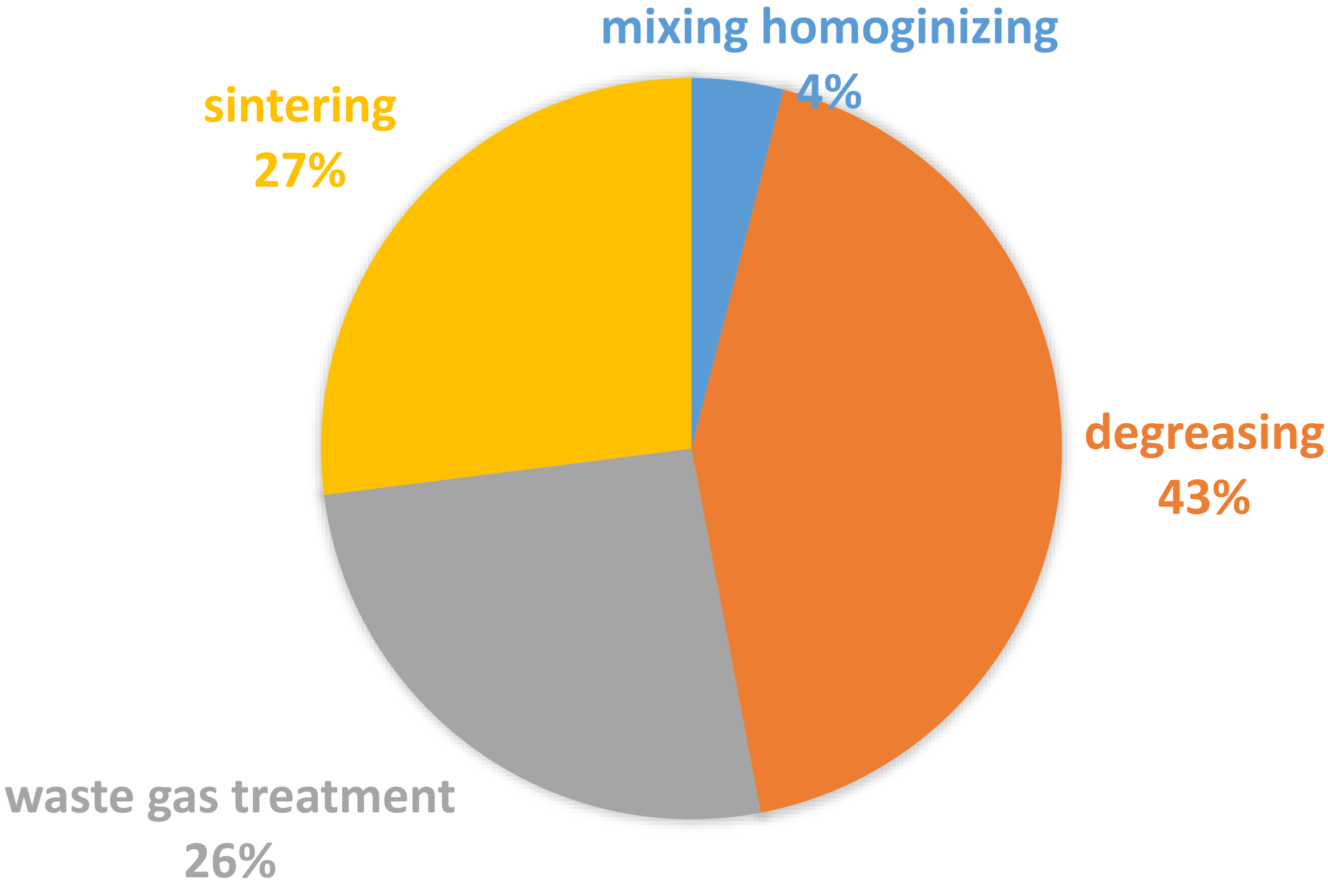


Process and material flow in ceramic production

1kg sintering of Al2O3

Powder production;　out of scope

Binder: 10 mass%
Degreasing: 600℃ 1h (12℃/h)
Waste gas: 900℃ keeping
Sintering: 1400℃ 4h　(600℃/h)



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Binder: 10 mass%
Degreasing: 600℃ 1h
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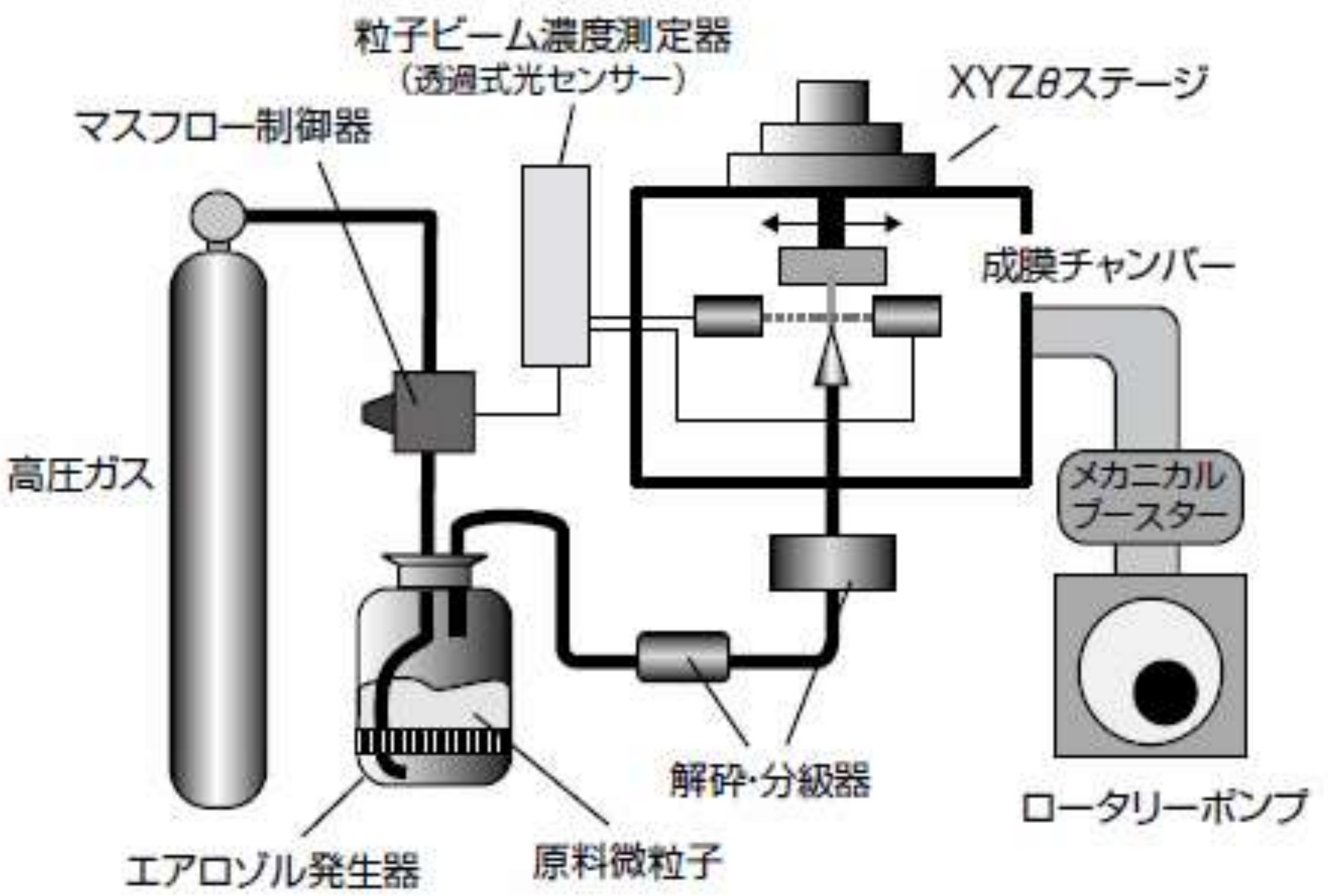
Waste gas: 900℃ keeping
Sintering: 1400℃ 4h
(600℃/h)

Aerosol deposition method

Akedo , AIST



Akedo , AIST

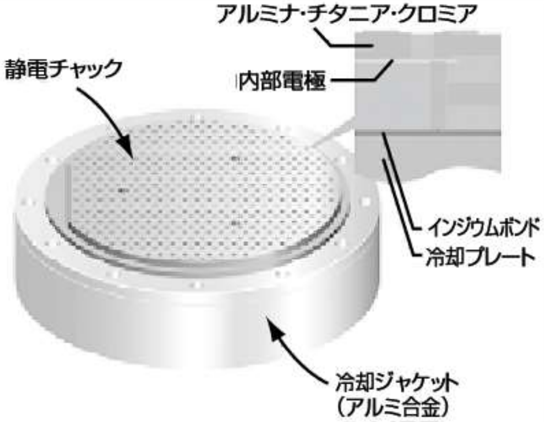
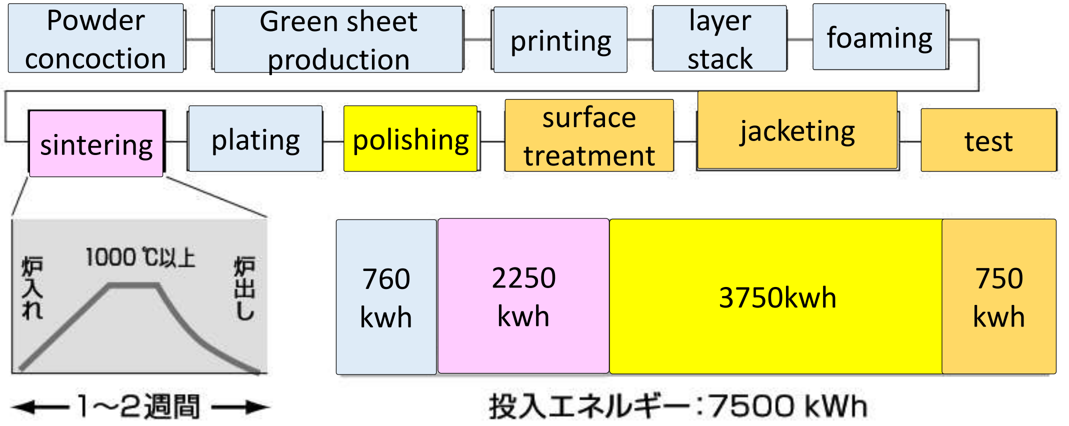
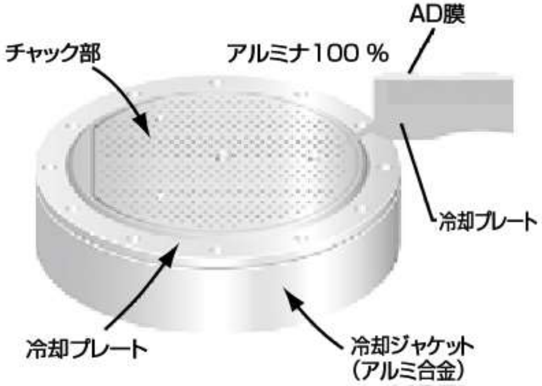
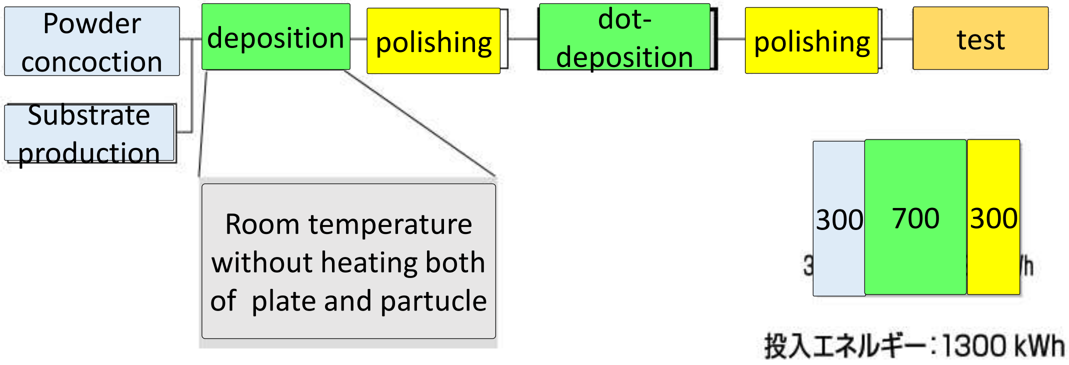
	構　成	工　程
焼成法 (従来製法)	 	 Powder concoction → Green sheet production → printing → layer stack → foaming → sintering → plating → polishing → surface treatment → jacketing → test 760 kwh 2250 kwh 3750kwh 750 kwh 投入エネルギー:7500 kWh
AD法	 	 Powder concoction / Substrate production → deposition → polishing → dot-deposition → polishing → test Room temperature without heating both of plate and partucle 投入エネルギー:1300 kWh
AD法の 特　長	●アルミナ100 %でウェハへの重金属汚染がない。 ●薄いセラミック膜であるため、熱伝導性に優れる。	●従来の焼成プロセスに対してAD成膜プロセスは、投入エネルギーで82 %の削減効果(7500 kWh →1300 kWh)時間で96 %の削減効果(288時間 →10時間)

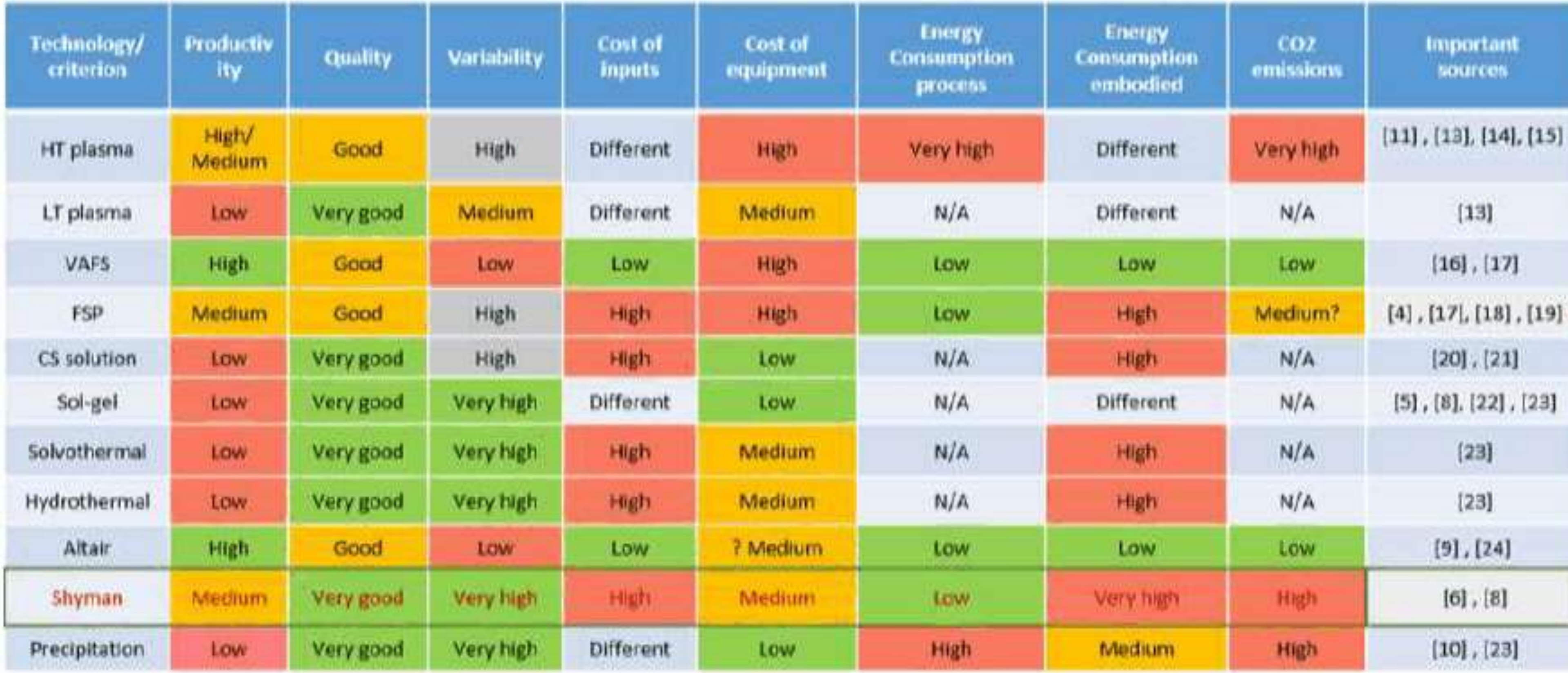
図4　静電チャックの構造とAD法導入による製造工程のエネルギー消費比較

By AIST, Japan

COMPARATIVE STUDY OF NANOPARTICLE PRODUCTION TECHNOLOGIES FOCUSED ON ENVIRONMETAL ASPECTS

Barbora STIEBEROVÁ, Miroslav ŽILKA, Marie TICHÁ, František FREIBERG, Jan HOŠEK

Czech Technical University in Prague, Faculty of Mechanical Engineering, Technická 4, 16607 Praha 6, Barbora.Stieberova@fs.cvut.cz



Technology/ criterion	Productivity	Quality	Variability	Cost of inputs	Cost of equipment	Energy Consumption process	Energy Consumption embodied	CO2 emissions	Important sources
HT plasma	High/ Medium	Good	High	Different	High	Very high	Different	Very high	[11] , [13], [14], [15]
LT plasma	Low	Very good	Medium	Different	Medium	N/A	Different	N/A	[13]
VAFS	High	Good	Low	Low	High	Low	Low	Low	[16] , [17]
FSP	Medium	Good	High	High	High	Low	High	Medium?	[4] , [17], [18] , [19]
CS solution	Low	Very good	High	High	Low	N/A	High	N/A	[20] , [21]
Sol-gel	Low	Very good	Very high	Different	Low	N/A	Different	N/A	[5] , [8], [22] , [23]
Solvothermal	Low	Very good	Very high	High	Medium	N/A	High	N/A	[23]
Hydrothermal	Low	Very good	Very high	High	Medium	N/A	High	N/A	[23]
Altair	High	Good	Low	Low	? Medium	Low	Low	Low	[9] , [24]
Shyman	Medium	Very good	Very high	High	Medium	Low	Very high	High	[6] , [8]
Precipitation	Low	Very good	Very high	Different	Low	High	Medium	High	[10] , [23]

Fig. 1 The overall comparison of the different NP production technologies (HT- high temperat., LT- lo temperat., VAFS – vapour-fed aerosol flame synth., FSP – flame spray pyrolysis, CS – combustion synth Altair – Altair hydrochloride process, SHYMAN – continuous supercritical hydrothermal syntheses)

COMPARATIVE STUDY OF NANOPARTICLE PRODUCTION TECHNOLOGIES FOCUSED ON ENVIRONMETAL ASPECTS

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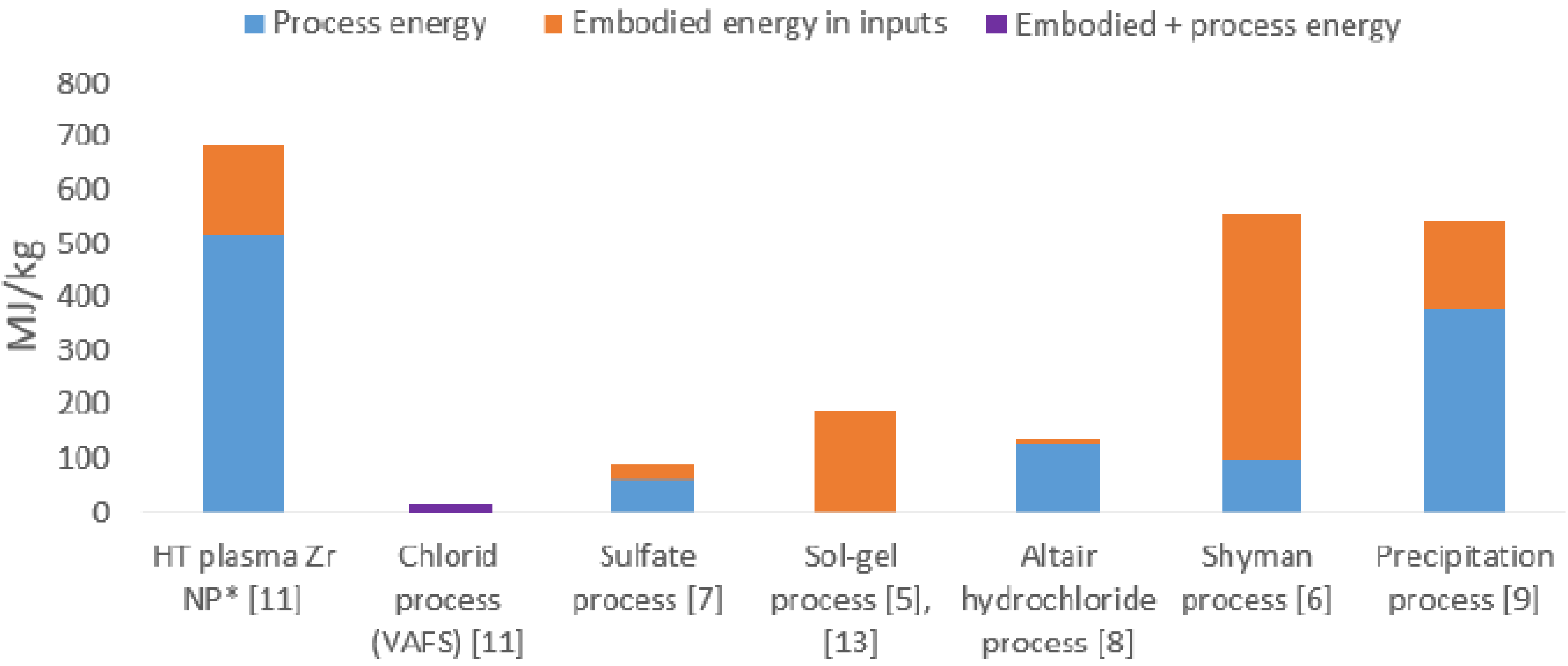
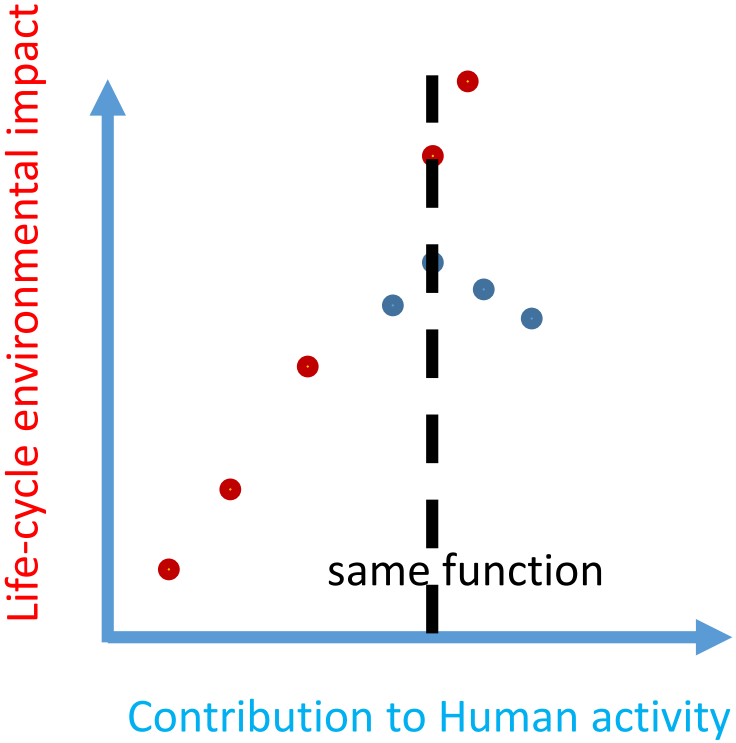
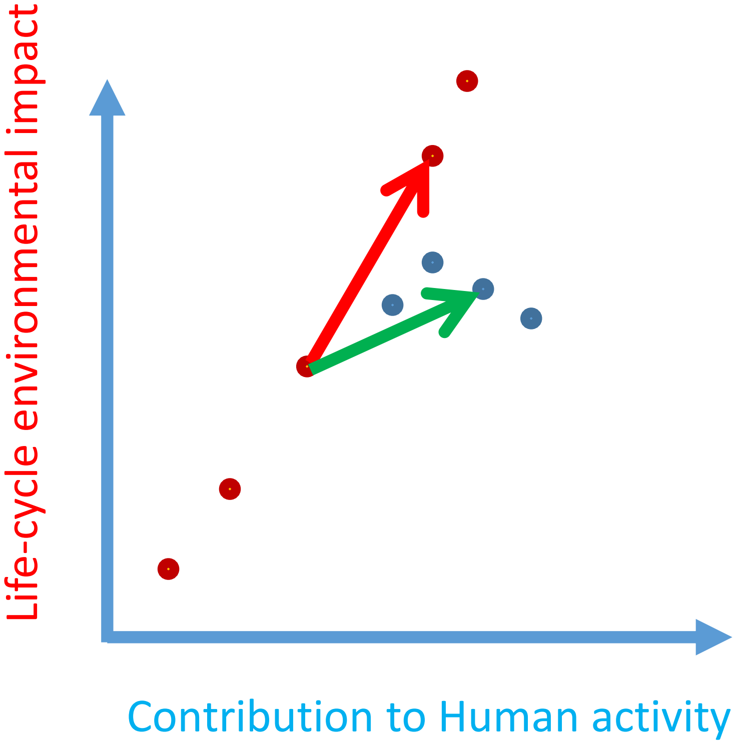
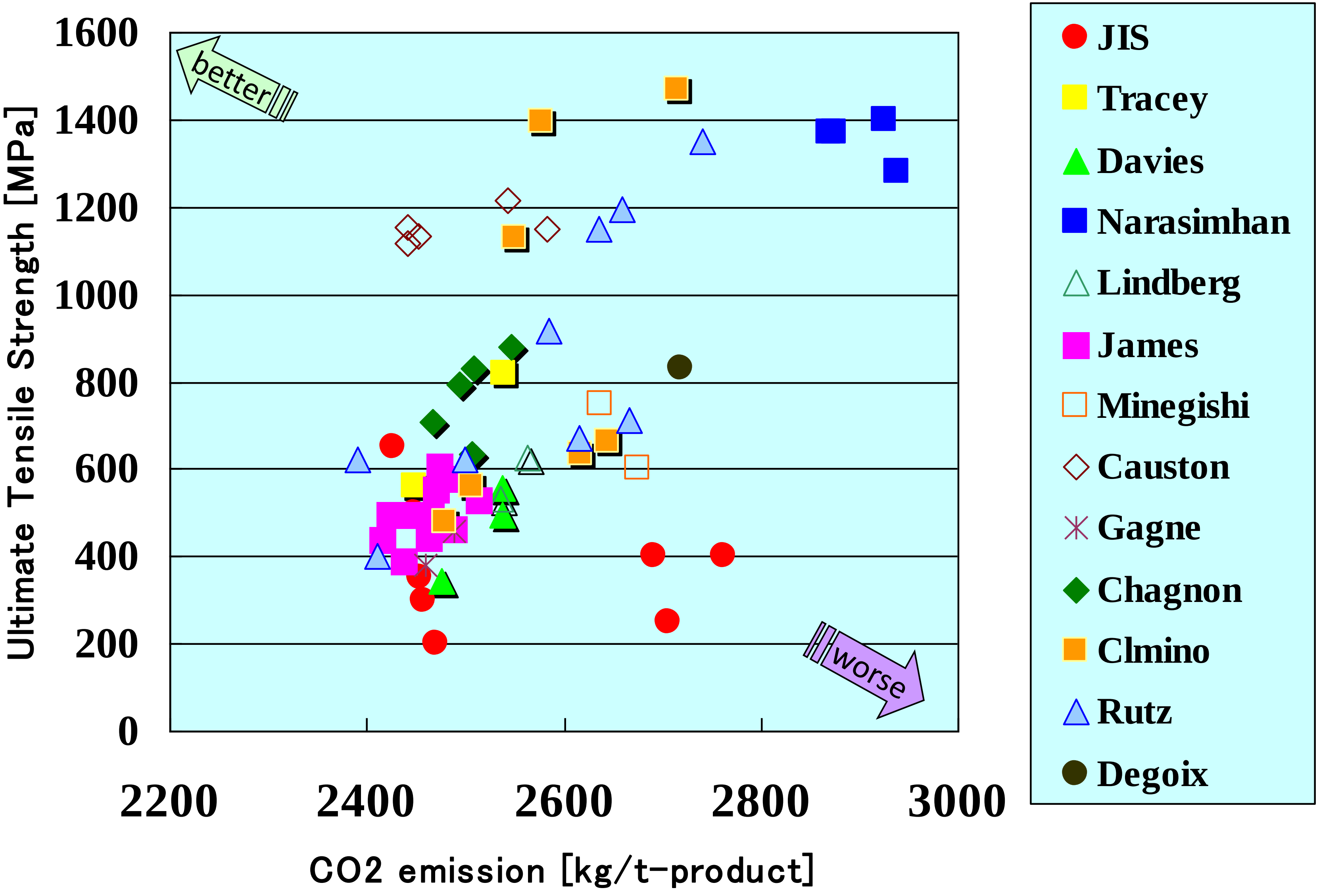
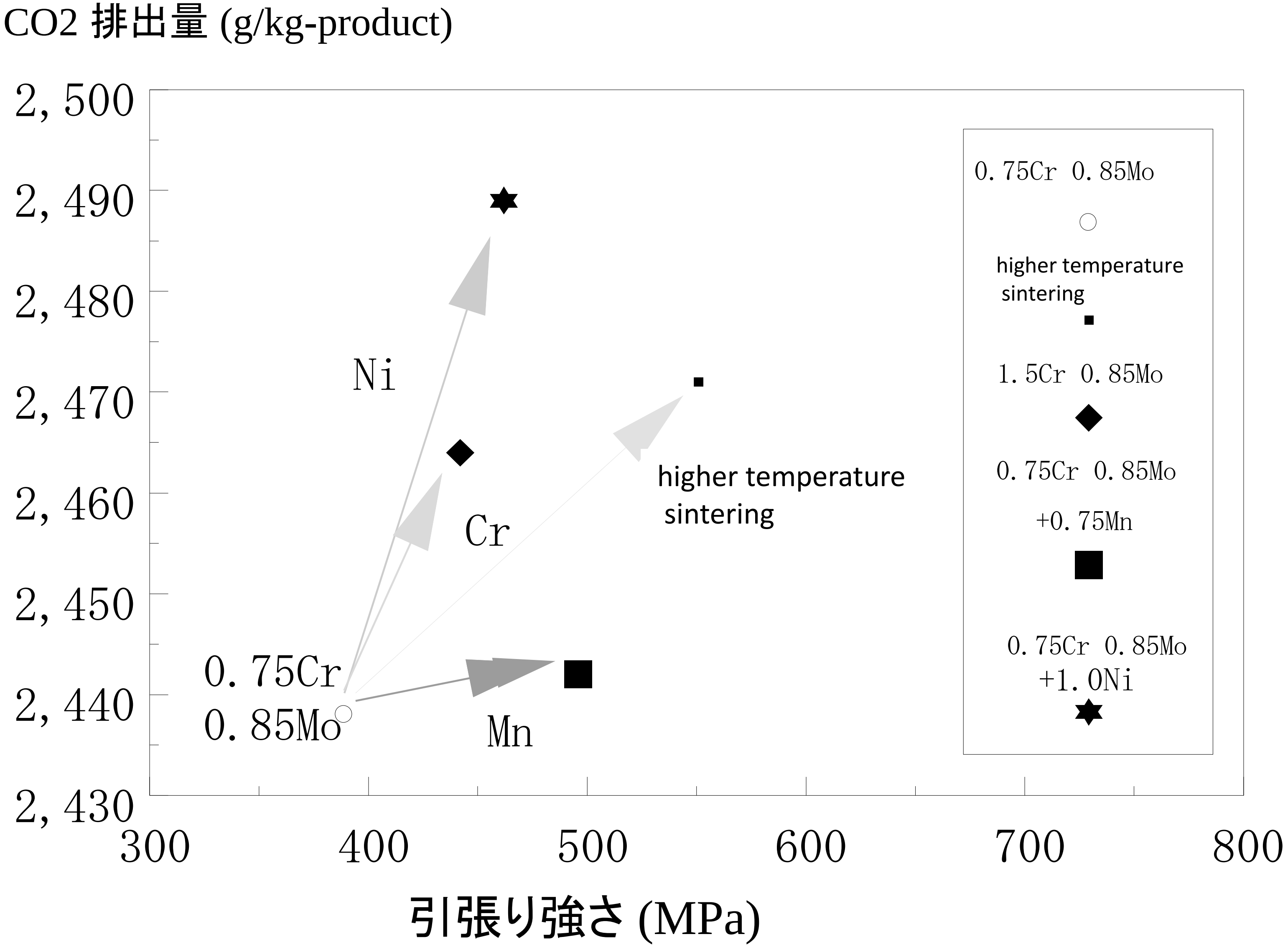



Life-cycle environmental impact
same function
Contribution to Human activity


Life-cycle environmental impact
Contribution to Human activity

Life-cycle Emission v.s. Strength of PM Products




CO2 排出量 (g/kg-product)
2, 500
2, 490
2, 480
2, 470
2, 460
2, 450
2, 440
2, 430
300
400
500
600
700
800
引張り強さ (MPa)
Ni
Cr
Mn
0. 75Cr
0. 85Mo
higher temperature
sintering
0. 75Cr 0. 85Mo
○
higher temperature
sintering
■
1. 5Cr 0. 85Mo
◆
0. 75Cr 0. 85Mo
+0. 75Mn
■
0. 75Cr 0. 85Mo
+1. 0Ni
✶

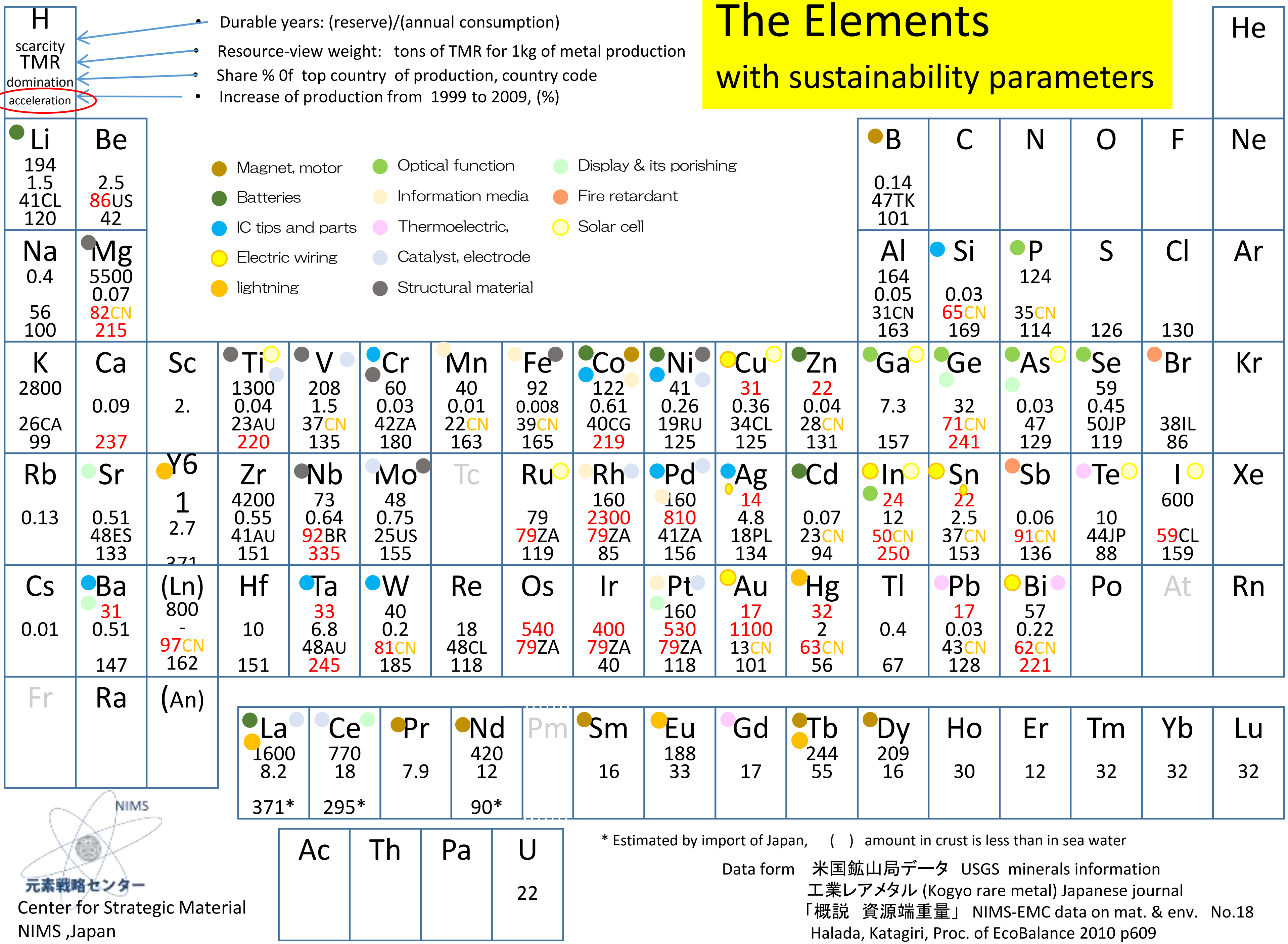
service=func.(work, provide, support)

$$\frac{\text{service=func.(work, provide, support)}}{\textbf{burden in production + burden through usage + burden of End-of-Life - deduction by recycling}}$$

life-cycle environmental burden =
burden in production + burden through usage
+ burden of End-of-Life - deduction by recycling

Resource Efficiency

The Elements
with sustainability parameters



- Durable years: (reserve)/(annual consumption)
- Resource-view weight: tons of TMR for 1kg of metal production
- Share % 0f top country of production, country code
- Increase of production from 1999 to 2009, (%)

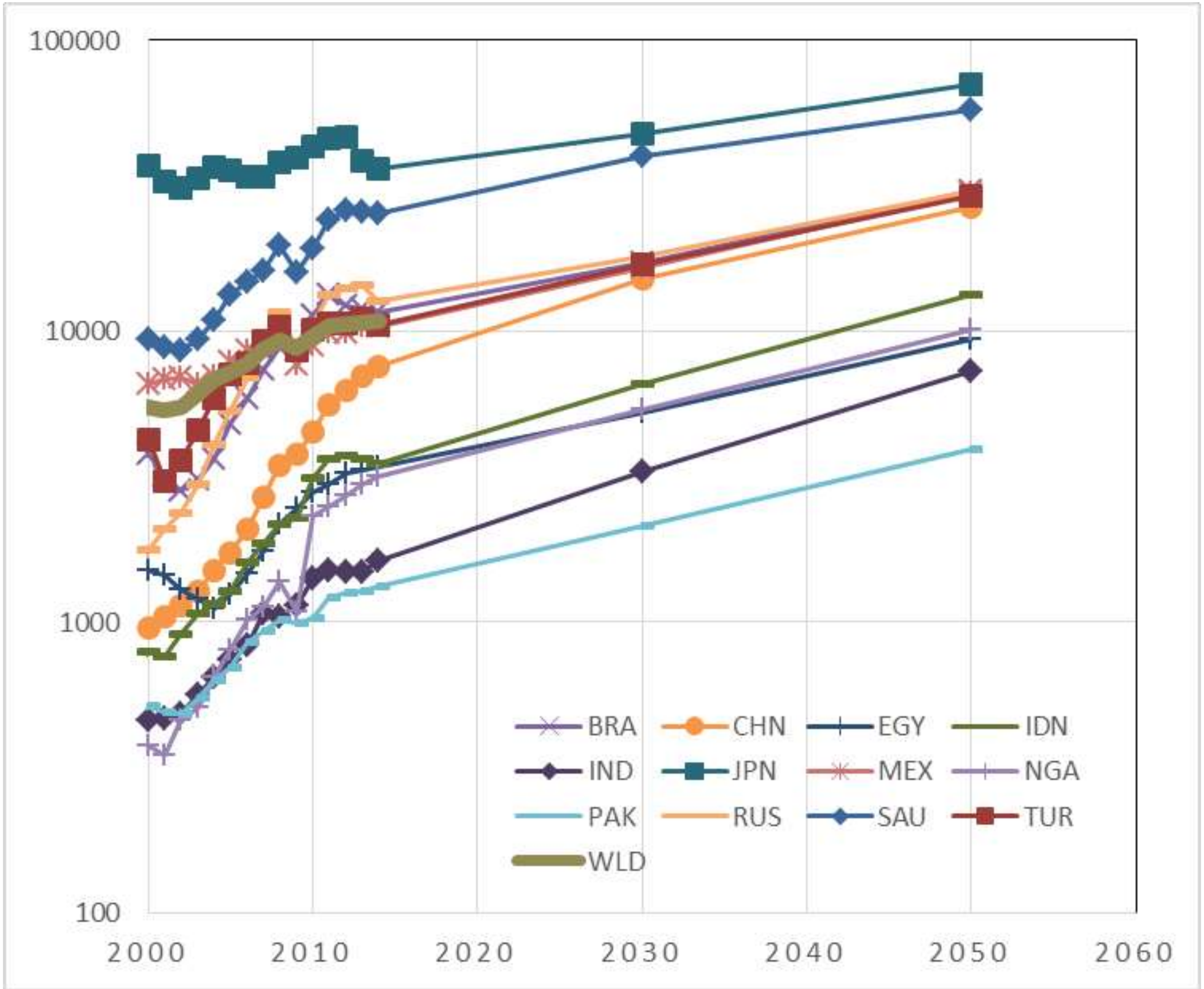
● Magnet, motor
● Batteries
● IC tips and parts
● Electric wiring
● lightning
● Optical function
● Information media
● Thermoelectric,
● Catalyst, electrode
● Structural material
● Display & its porishing
● Fire retardant
● Solar cell

H scarcity TMR domination acceleration																	He
Li 194 1.5 41CL 120	Be 2.5 86US 42											B 0.14 47TK 101	C	N	O	F	Ne
Na 0.4 56 100	Mg 5500 0.07 82CN 215											Al 164 0.05 31CN 163	Si 0.03 65CN 169	P 124 35CN 114	S 126	Cl 130	Ar
K 2800 26CA 99	Ca 0.09 237	Sc 2.	Ti 1300 0.04 23AU 220	V 208 1.5 37CN 135	Cr 60 0.03 42ZA 180	Mn 40 0.01 22CN 163	Fe 92 0.008 39CN 165	Co 122 0.61 40CG 219	Ni 41 0.26 19RU 125	Cu 31 0.36 34CL 125	Zn 22 0.04 28CN 131	Ga 7.3 157	Ge 32 71CN 241	As 0.03 47 129	Se 59 0.45 50JP 119	Br 38IL 86	Kr
Rb 0.13	Sr 0.51 48ES 133	Y6 1 2.7 371	Zr 4200 0.55 41AU 151	Nb 73 0.64 92BR 335	Mo 48 0.75 25US 155	Tc	Ru 79 79ZA 119	Rh 160 2300 79ZA 85	Pd 160 810 41ZA 156	Ag 14 4.8 18PL 134	Cd 0.07 23CN 94	In 24 12 50CN 250	Sn 22 2.5 37CN 153	Sb 0.06 91CN 136	Te 10 44JP 88	I 600 59CL 159	Xe
Cs 0.01	Ba 31 0.51 147	(Ln) 800 - 97CN 162	Hf 10 151	Ta 33 6.8 48AU 245	W 40 0.2 81CN 185	Re 18 48CL 118	Os 540 79ZA	Ir 400 79ZA 40	Pt 160 530 79ZA 118	Au 17 1100 13CN 101	Hg 32 2 63CN 56	Tl 0.4 67	Pb 17 0.03 43CN 128	Bi 57 0.22 62CN 221	Po	At	Rn
Fr	Ra	(An)															
			La 1600 8.2 371*	Ce 770 18 295*	Pr 7.9	Nd 420 12 90*	Pm	Sm 16	Eu 188 33	Gd 17	Tb 244 55	Dy 209 16	Ho 30	Er 12	Tm 32	Yb 32	Lu 32
			Ac	Th	Pa	U 22											

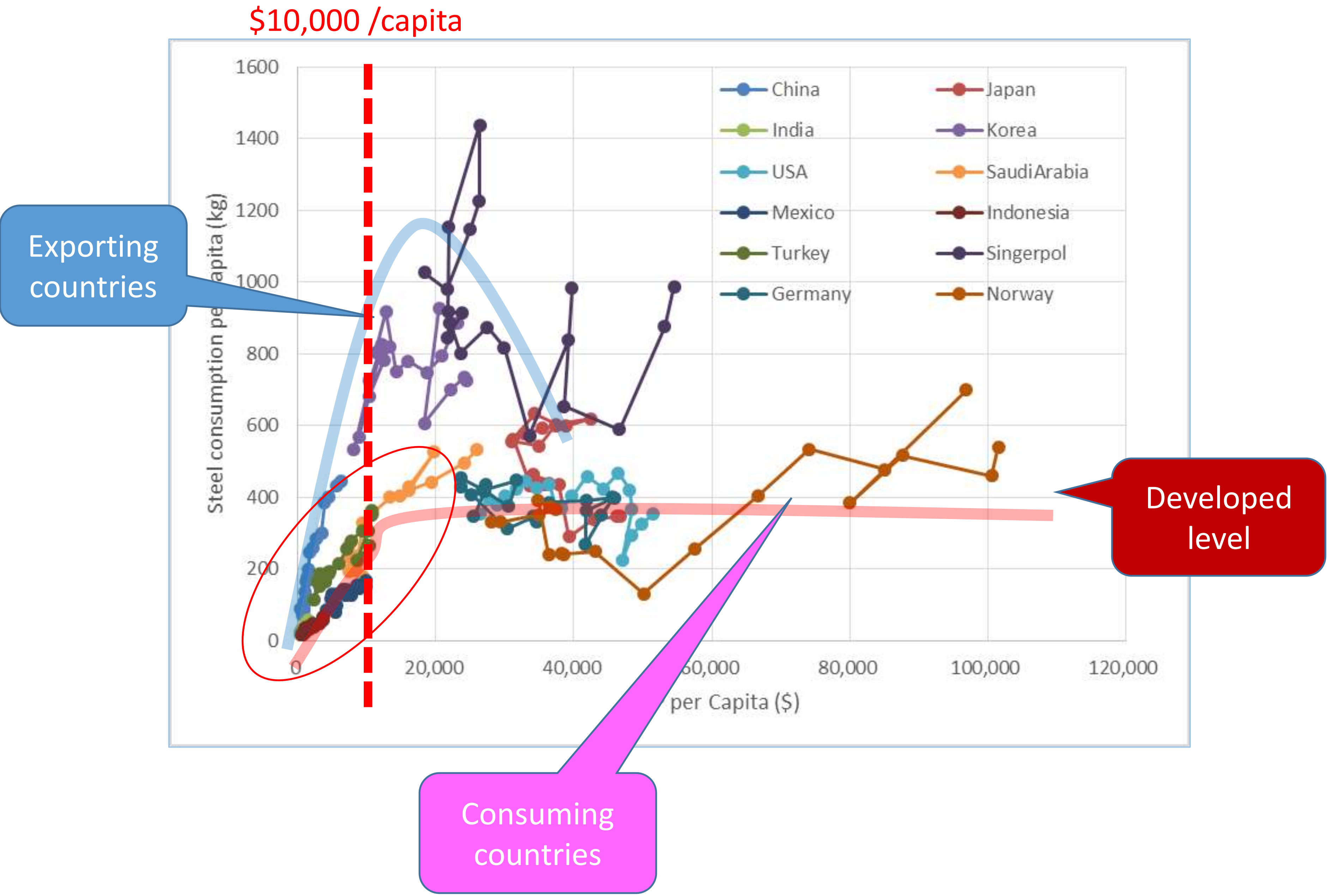
* Estimated by import of Japan, ( ) amount in crust is less than in sea water

Data form 米国鉱山局データ USGS minerals information
工業レアメタル (Kogyo rare metal) Japanese journal
「概説 資源端重量」 NIMS-EMC data on mat. & env. No.18
Halada, Katagiri, Proc. of EcoBalance 2010 p609

NIMS
元素戦略センター
Center for Strategic Material
NIMS ,Japan


100000
10000
1000
100
2000
2010
2020
2030
2040
2050
2060
BRA
CHN
EGY
IDN
IND
JPN
MEX
NGA
PAK
RUS
SAU
TUR
WLD

Fe consumption / capita v.s. GDP/ capita from 1994 to 2014



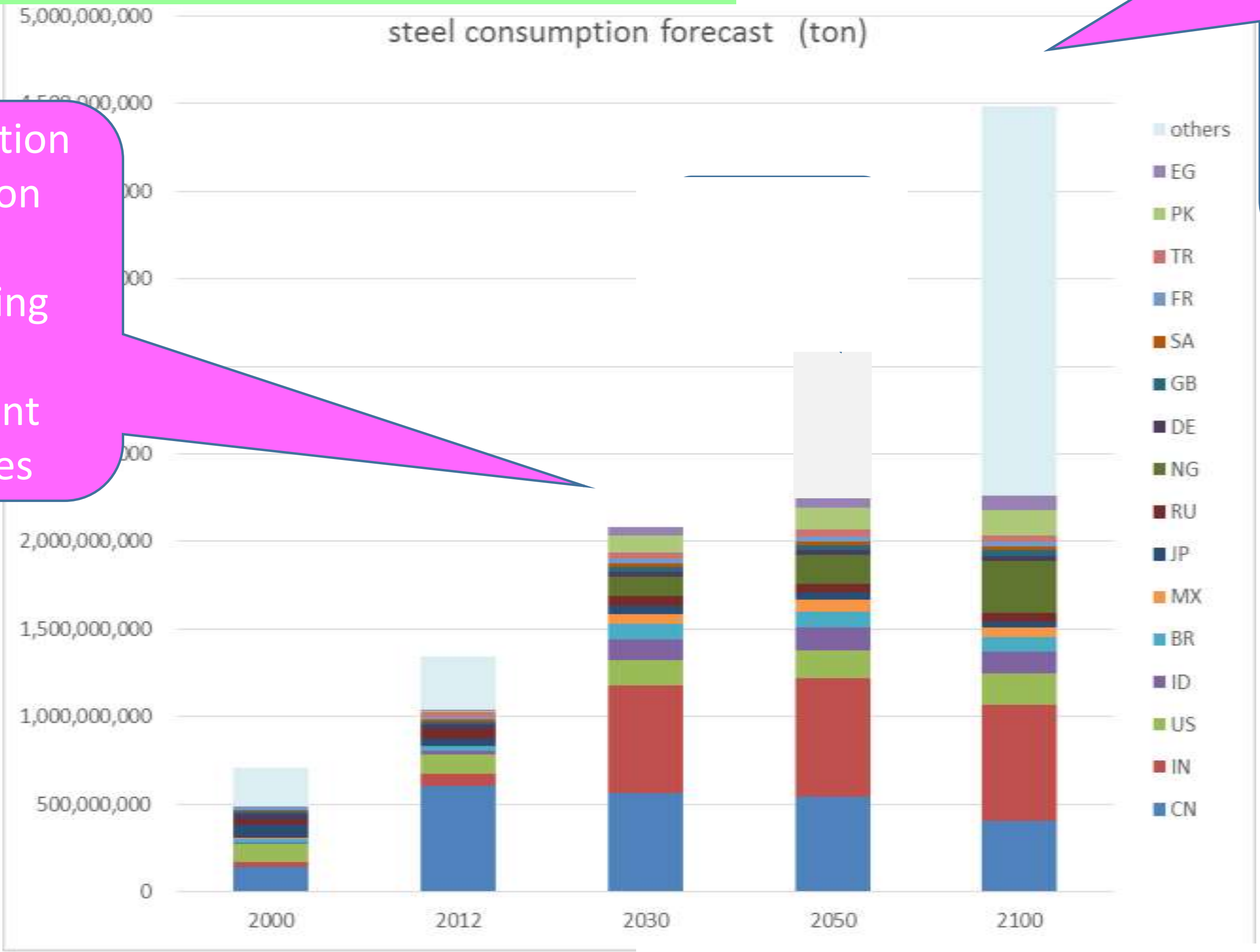
$10,000 /capita

Exporting countries

Developed level

Consuming countries

Rough forecast gets to be simpler,
(population) x (developed consumption level)

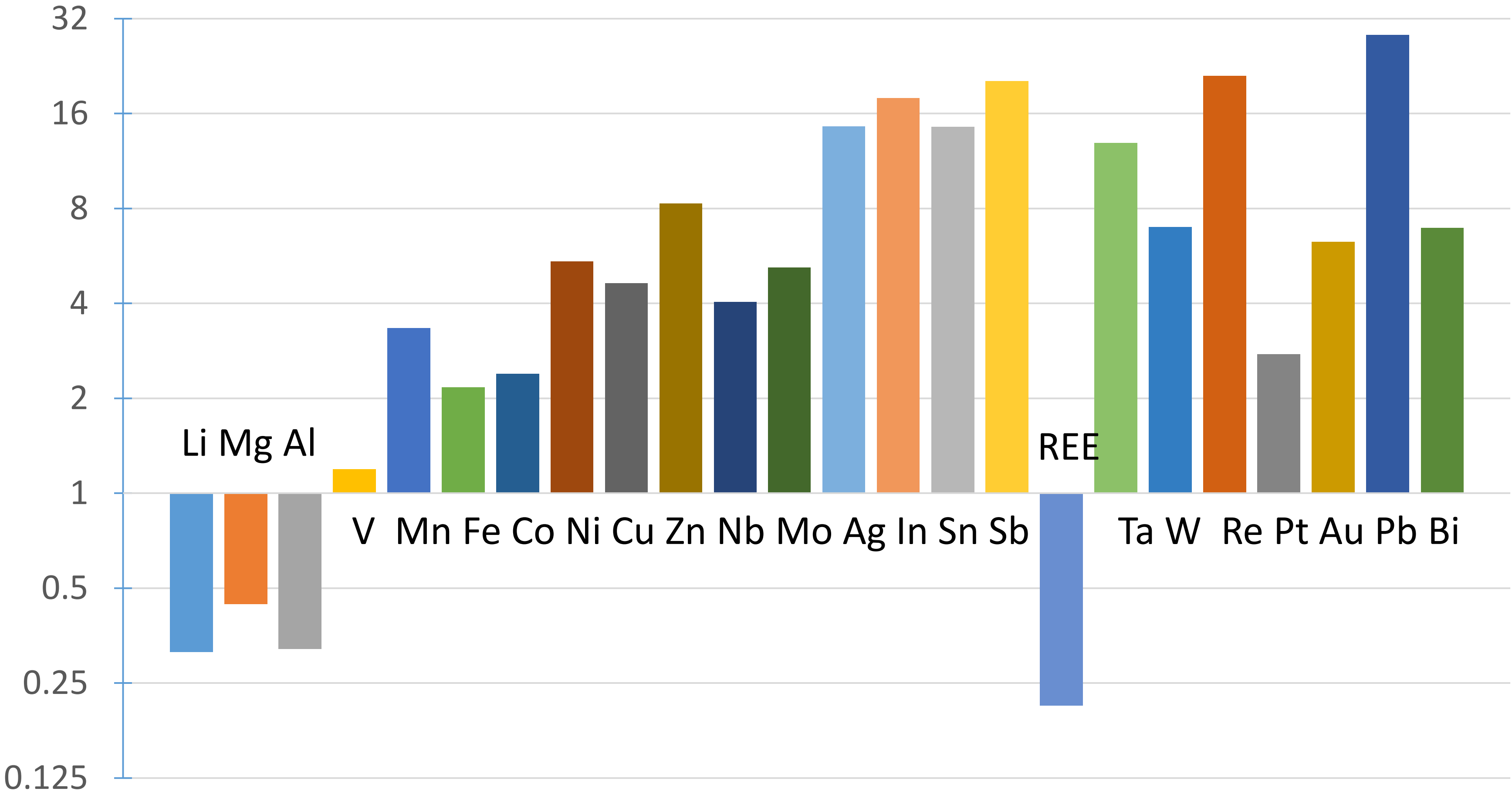


Consumption prediction with concerning only prepotent countries

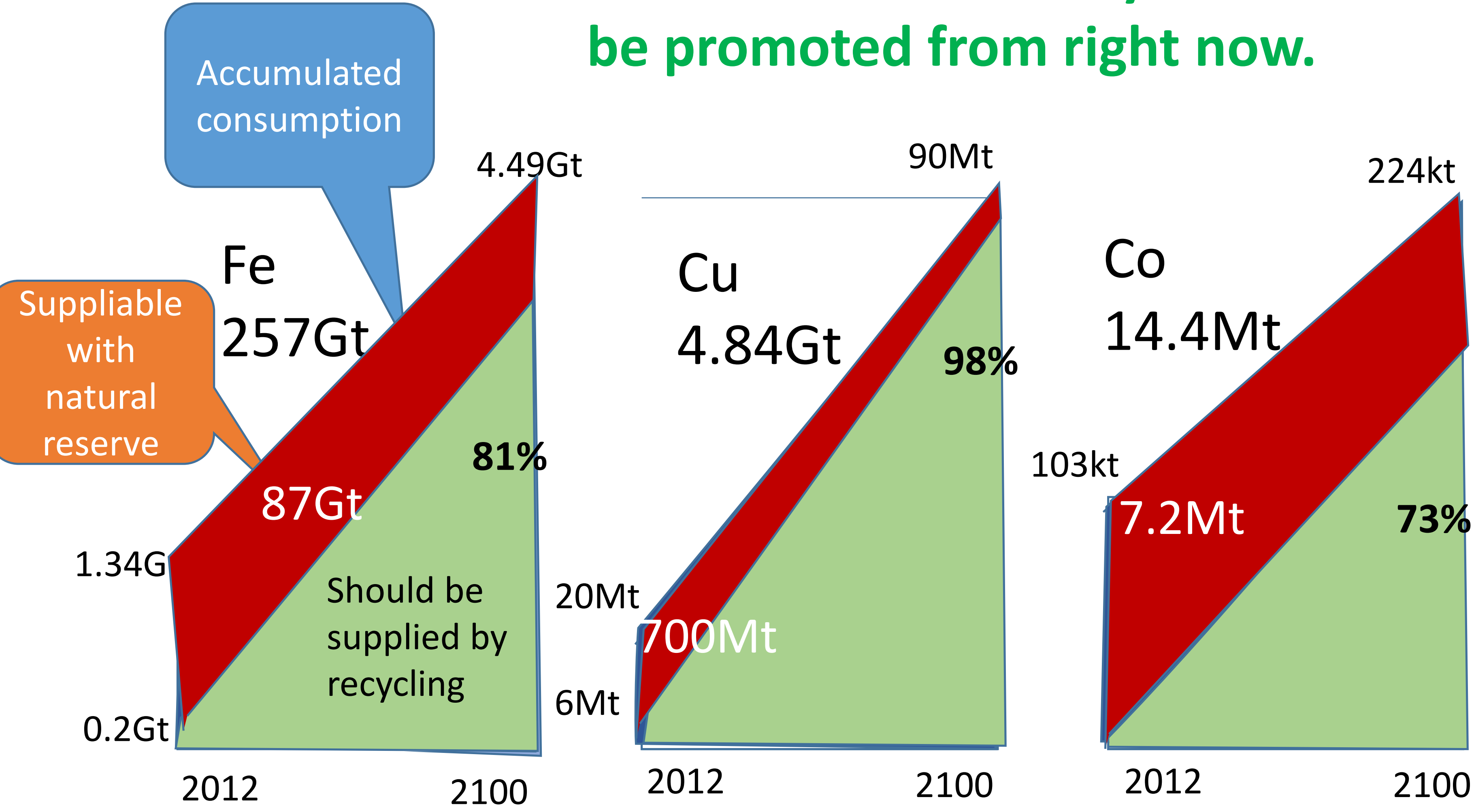
Every country reaches developed level of consumption per capita

metal	Fe
Consumption/year at 10Gperson world	4.5Gton/year
Reserve	87Gton

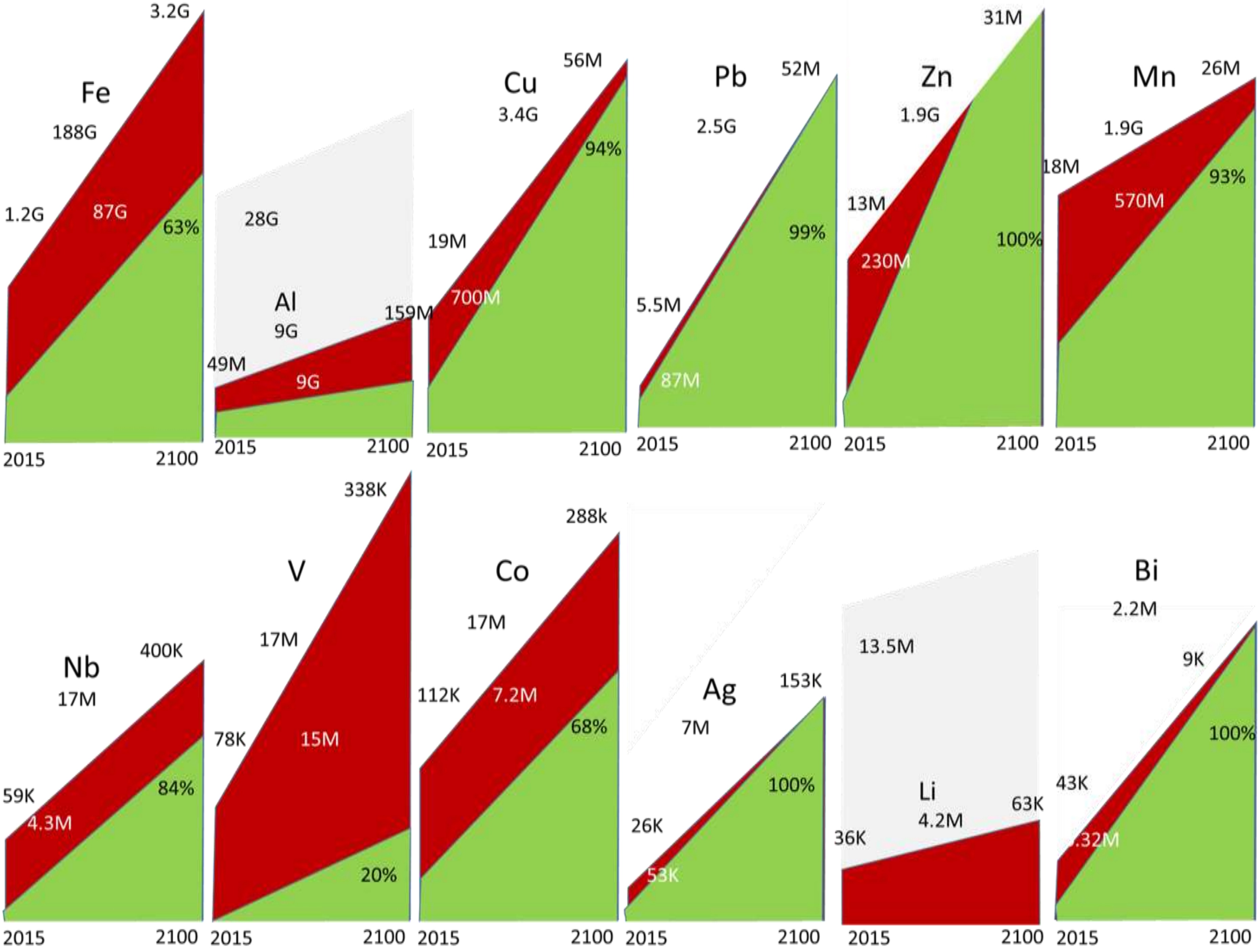
Estimated demand up to 2100 v.s. current reserve amount

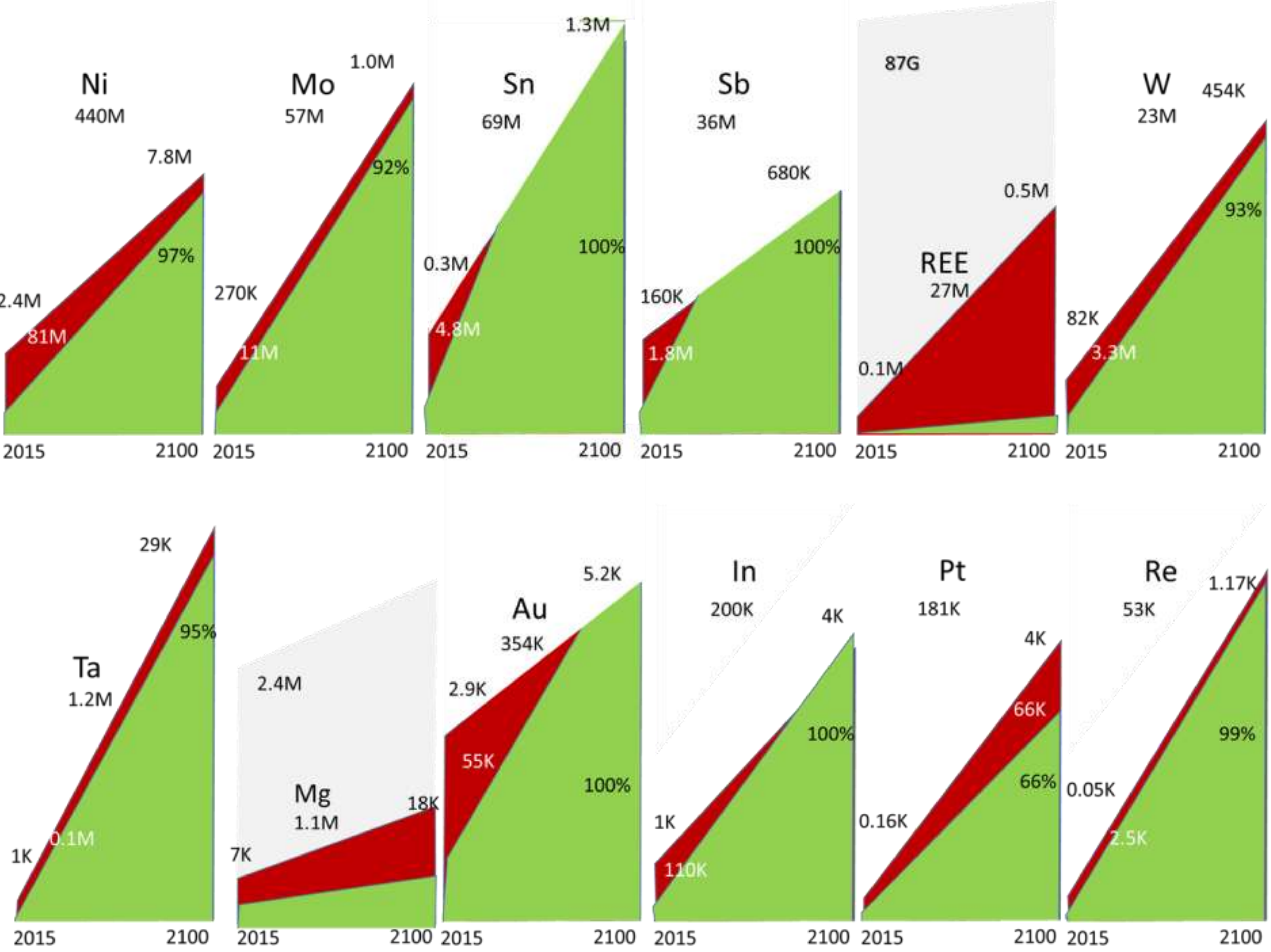


The circulation society must be promoted from right now.



Estimated accumulated consumptions till 2100
with simple assumption of linear growth


Fe
3.2G
188G
1.2G
87G
63%
2015
2100
Al
28G
9G
159M
49M
9G
2015
2100
Cu
56M
3.4G
94%
19M
700M
2015
2100
Pb
52M
2.5G
99%
5.5M
87M
2015
2100
Zn
31M
1.9G
13M
230M
100%
2015
2100
Mn
26M
1.9G
18M
570M
93%
2015
2100
Nb
400K
17M
59K
4.3M
84%
2015
2100
V
338K
17M
78K
15M
20%
2015
2100
Co
288k
17M
112K
7.2M
68%
2015
2100
Ag
153K
7M
26K
53K
100%
2015
2100
Li
13.5M
4.2M
36K
63K
2015
2100
Bi
2.2M
9K
43K
.32M
100%
2015
2100


Ni
440M
7.8M
97%
2.4M
81M
2015
2100
Mo
1.0M
57M
92%
270K
11M
2015
2100
Sn
1.3M
69M
100%
0.3M
4.8M
2015
2100
Sb
36M
680K
100%
160K
1.8M
2015
2100
87G
0.5M
REE
27M
0.1M
2015
2100
W
454K
23M
93%
82K
3.3M
2015
2100
Ta
29K
95%
1.2M
1K
0.1M
2015
2100
2.4M
Mg
1.1M
18K
7K
2015
2100
Au
5.2K
354K
2.9K
55K
100%
2015
2100
In
200K
4K
100%
1K
110K
2015
2100
Pt
181K
4K
66K
66%
0.16K
2015
2100
Re
1.17K
53K
99%
0.05K
2.5K
2015
2100

NATURE | COMMENT

The circular economy

Walter R. Stahel

23 March 2016

A new relationship with our goods and materials would save resources and energy and create local jobs, explains Walter R. Stahel.

Subject terms: Economics · Society · Materials science · Policy

Gaming the gamers

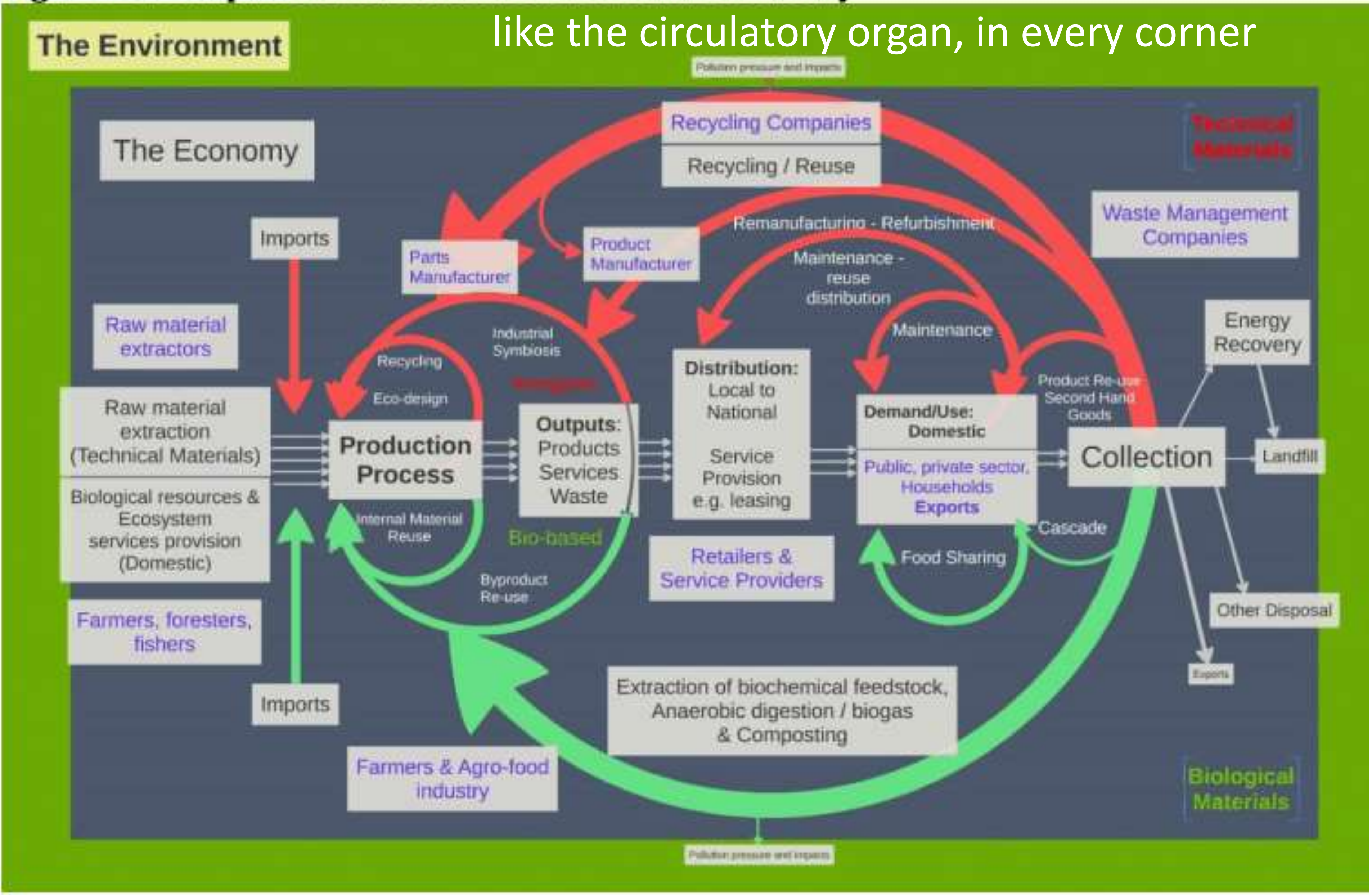
Can a video game company tame toxic behaviour?

Scientists are helping to stop antisocial behaviour in the world's most popular online game. The next stop could be a kinder Internet.

Naoko Okamura and 243,150 others like this.

Figure E2: Simplified illustration of a circular economy

like the circulatory organ, in every corner

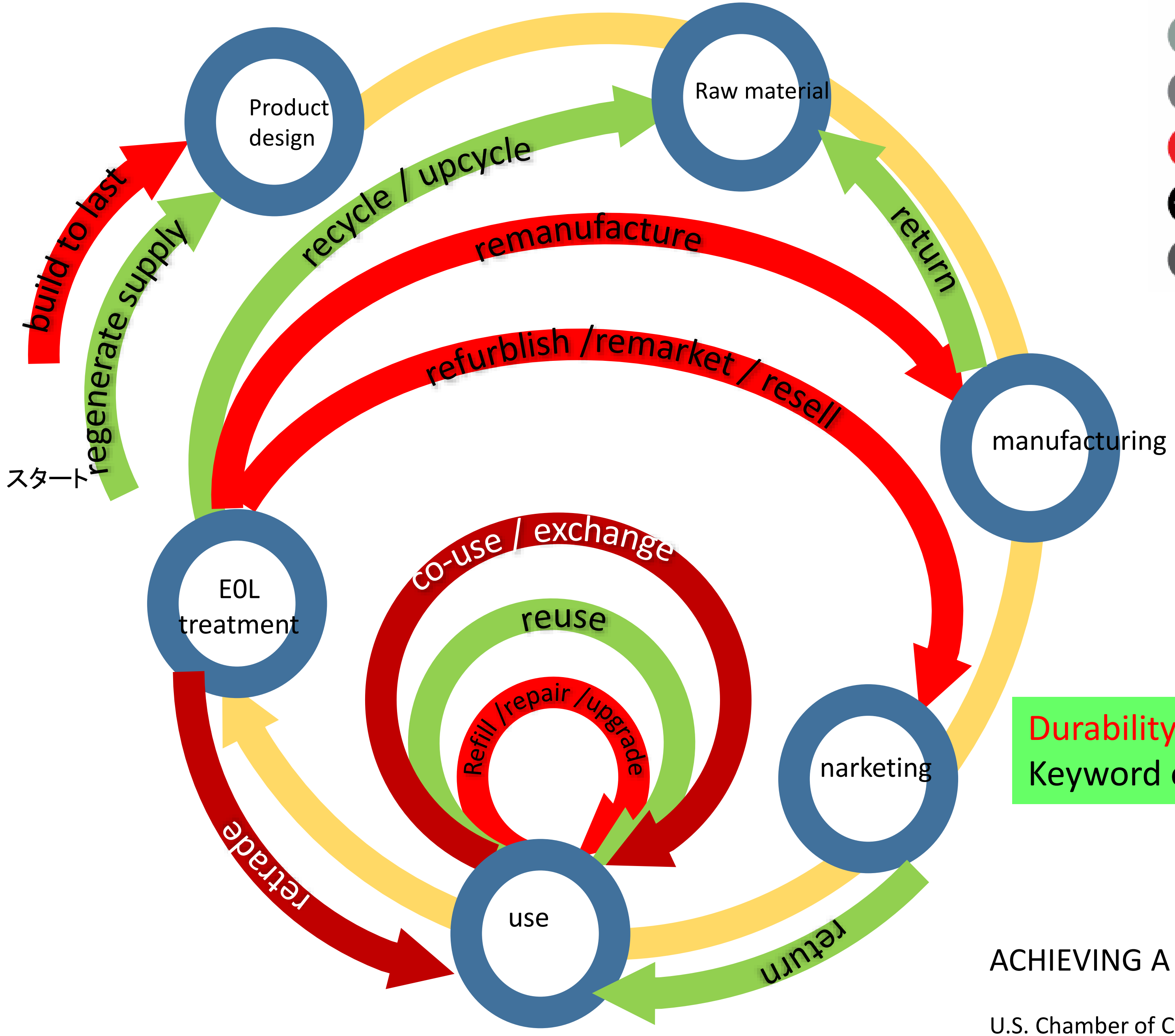


Source: Own representation, P ten Brink, P Razzini, S. Withana and E. van Dijl (IEEP), 2014

Resource Efficiency and the 3Rs

Achieving the sustainable management and efficient use of resources is addressed in the 2030 Agenda and is crucial for the protection of the environment, climate and planet. Having in mind the importance of sustainable materials management and material cycle societies, we endorse the *Toyama Framework on Material Cycles*. This new framework provides a common vision and a guide for future actions to deepen our efforts on resource efficiency and the 3Rs (Reduce, Reuse, Recycle). We will continue to cooperate through the G7 Alliance on Resource Efficiency. We will work with business and other stakeholders to improve resource efficiency with the aim of also fostering innovation, competitiveness, economic growth and job creation. We encourage all countries to join us in these efforts.

We reaffirm our commitment to address marine litter, recognizing that our efforts on resource efficiency and the 3Rs also contribute to the prevention and reduction of marine litter, particularly plastic, from land-based sources. Furthermore, we support scientific work to enhance global ocean observation and assessment for the science-based management, conservation and sustainable use of marine resources.



BUSINESS MODELS

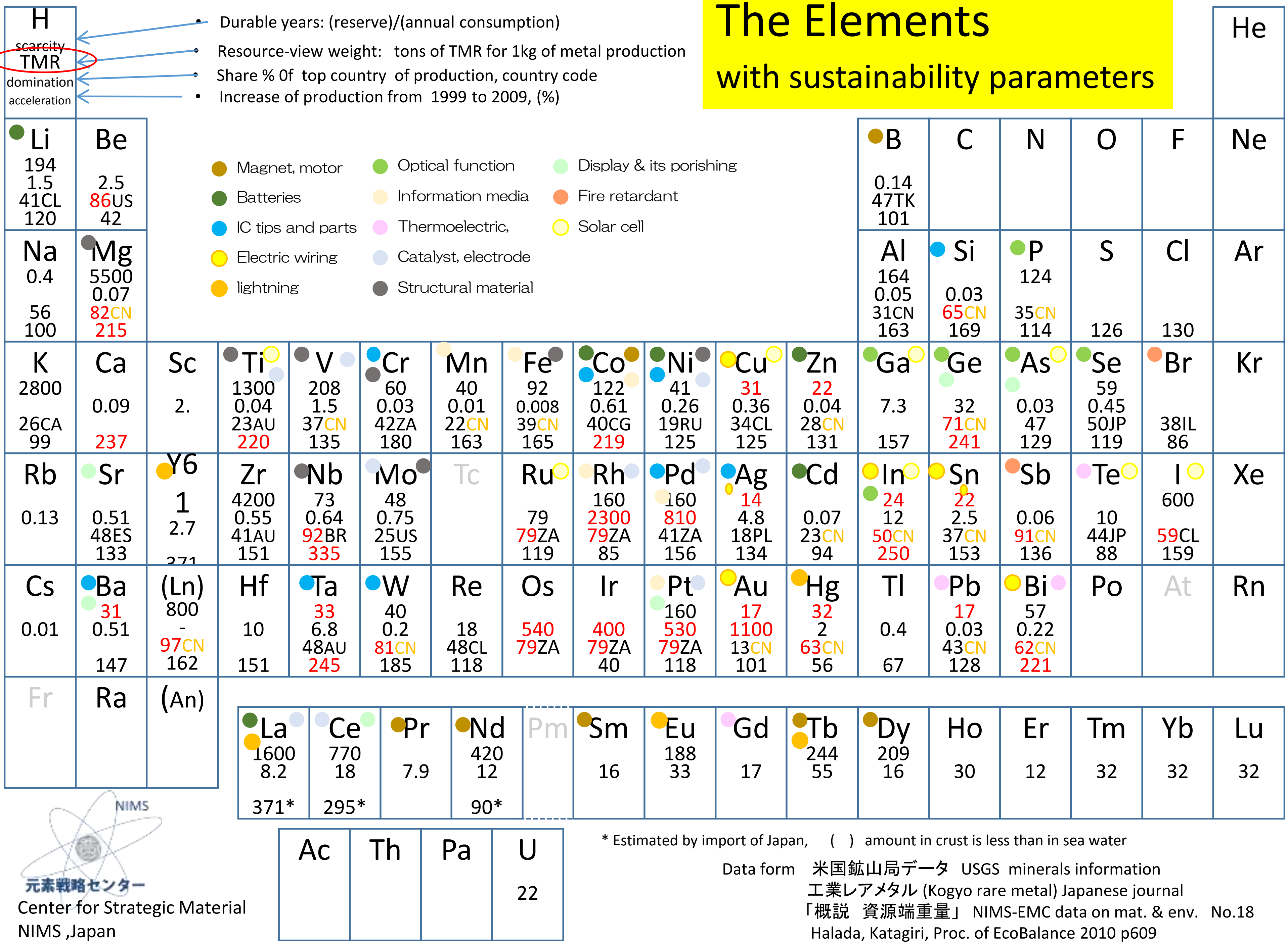
- CIRCULAR SUPPLY-CHAIN
- RECOVERY & RECYCLING
- PRODUCT LIFE-EXTENSION
- SHARING PLATFORM
- PRODUCT AS A SERVICE

Durability becomes the greatest
Keyword of Ecodesign

ACHIEVING A CIRCULAR ECONOMY

U.S. Chamber of Commerce Foundation,
Supported by CCC's Circular Economy Network

The Elements
with sustainability parameters



- Durable years: (reserve)/(annual consumption)
- Resource-view weight: tons of TMR for 1kg of metal production
- Share % 0f top country of production, country code
- Increase of production from 1999 to 2009, (%)

● Magnet, motor
● Batteries
● IC tips and parts
● Electric wiring
● lightning
● Optical function
● Information media
● Thermoelectric,
● Catalyst, electrode
● Structural material
● Display & its porishing
● Fire retardant
● Solar cell

H scarcity TMR domination acceleration																	He
Li 194 1.5 41CL 120	Be 2.5 86US 42											B 0.14 47TK 101	C	N	O	F	Ne
Na 0.4 56 100	Mg 5500 0.07 82CN 215											Al 164 0.05 31CN 163	Si 0.03 65CN 169	P 124 35CN 114	S 126	Cl 130	Ar
K 2800 26CA 99	Ca 0.09 237	Sc 2.	Ti 1300 0.04 23AU 220	V 208 1.5 37CN 135	Cr 60 0.03 42ZA 180	Mn 40 0.01 22CN 163	Fe 92 0.008 39CN 165	Co 122 0.61 40CG 219	Ni 41 0.26 19RU 125	Cu 31 0.36 34CL 125	Zn 22 0.04 28CN 131	Ga 7.3 157	Ge 32 71CN 241	As 0.03 47 129	Se 59 0.45 50JP 119	Br 38IL 86	Kr
Rb 0.13	Sr 0.51 48ES 133	Y6 1 2.7 371	Zr 4200 0.55 41AU 151	Nb 73 0.64 92BR 335	Mo 48 0.75 25US 155	Tc	Ru 79 79ZA 119	Rh 160 2300 79ZA 85	Pd 160 810 41ZA 156	Ag 14 4.8 18PL 134	Cd 0.07 23CN 94	In 24 12 50CN 250	Sn 22 2.5 37CN 153	Sb 0.06 91CN 136	Te 10 44JP 88	I 600 59CL 159	Xe
Cs 0.01	Ba 31 0.51 147	(Ln) 800 - 97CN 162	Hf 10 151	Ta 33 6.8 48AU 245	W 40 0.2 81CN 185	Re 18 48CL 118	Os 540 79ZA	Ir 400 79ZA 40	Pt 160 530 79ZA 118	Au 17 1100 13CN 101	Hg 32 2 63CN 56	Tl 0.4 67	Pb 17 0.03 43CN 128	Bi 57 0.22 62CN 221	Po	At	Rn
Fr	Ra	(An)															

La 1600 8.2 371*	Ce 770 18 295*	Pr 7.9	Nd 420 12 90*	Pm	Sm 16	Eu 188 33	Gd 17	Tb 244 55	Dy 209 16	Ho 30	Er 12	Tm 32	Yb 32	Lu 32

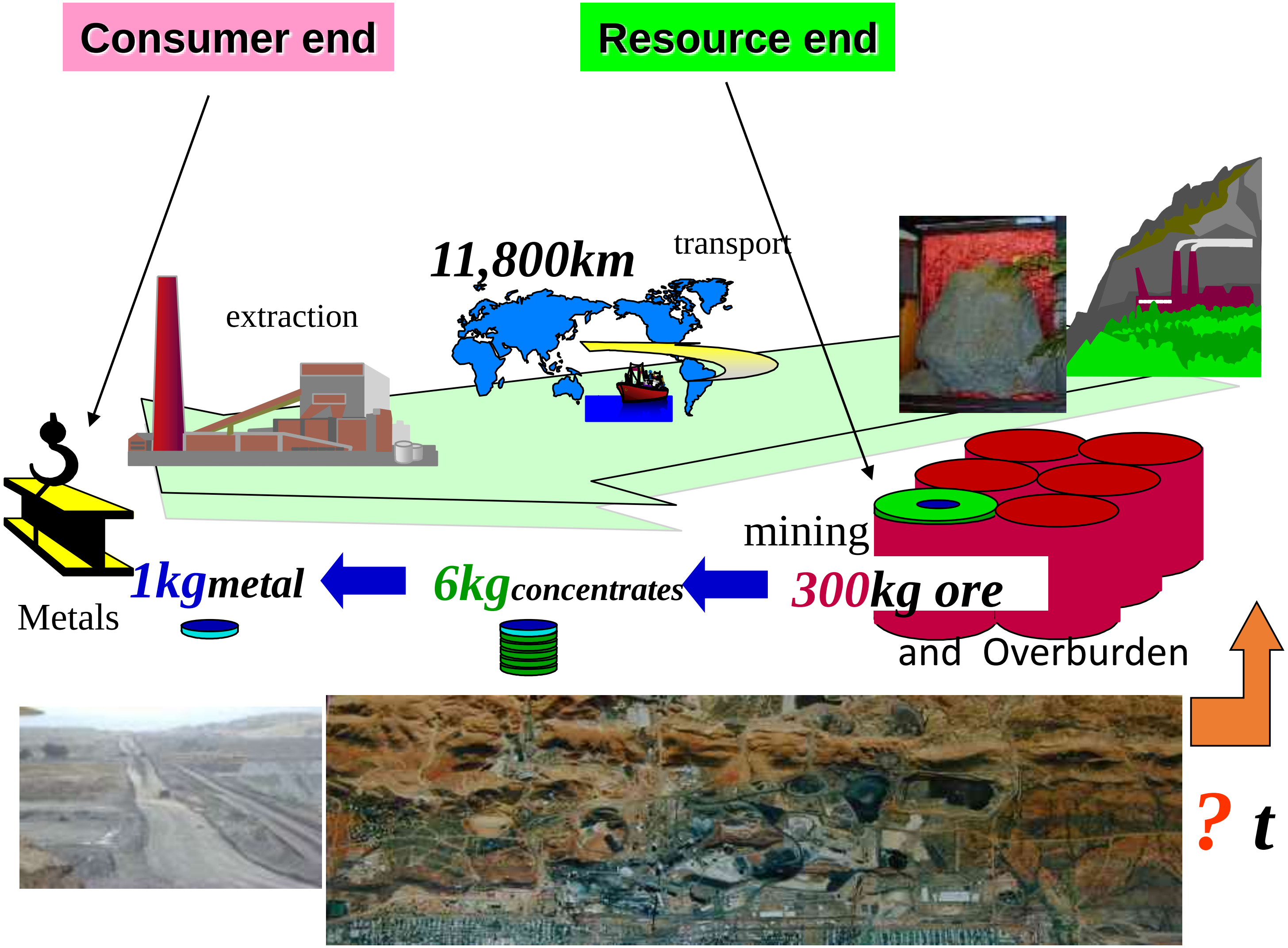
Ac	Th	Pa	U 22

* Estimated by import of Japan, ( ) amount in crust is less than in sea water

Data form 米国鉱山局データ USGS minerals information
工業レアメタル (Kogyo rare metal) Japanese journal
「概説 資源端重量」 NIMS-EMC data on mat. & env. No.18
Halada, Katagiri, Proc. of EcoBalance 2010 p609

NIMS
元素戦略センター
Center for Strategic Material
NIMS ,Japan

Resource(-end)-view weight



Consumer end

Resource end

11,800km transport

extraction

mining

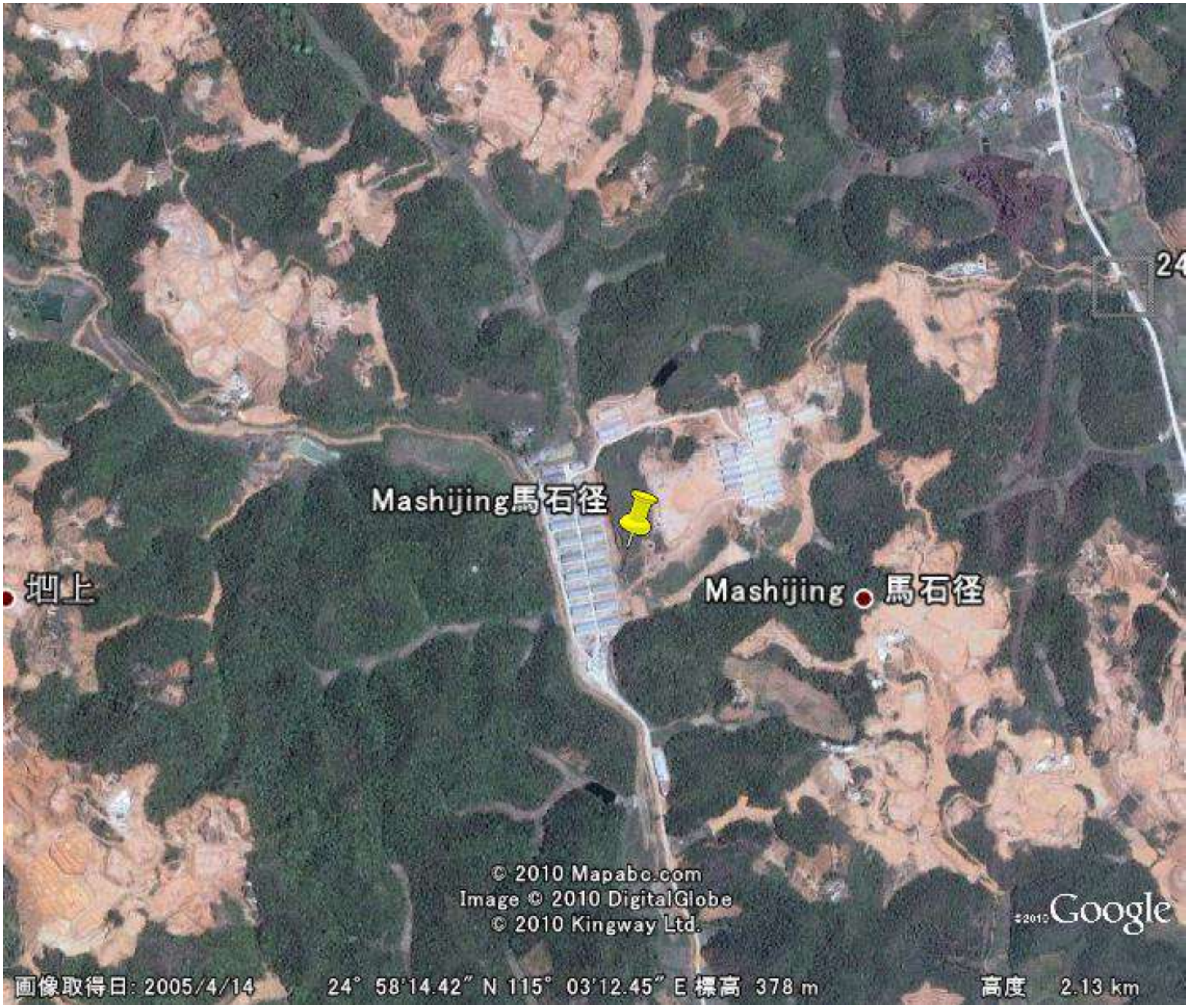
Metals

1kg**metal* ← ***6kg**concentrates* ← ***300kg ore

and Overburden

? t

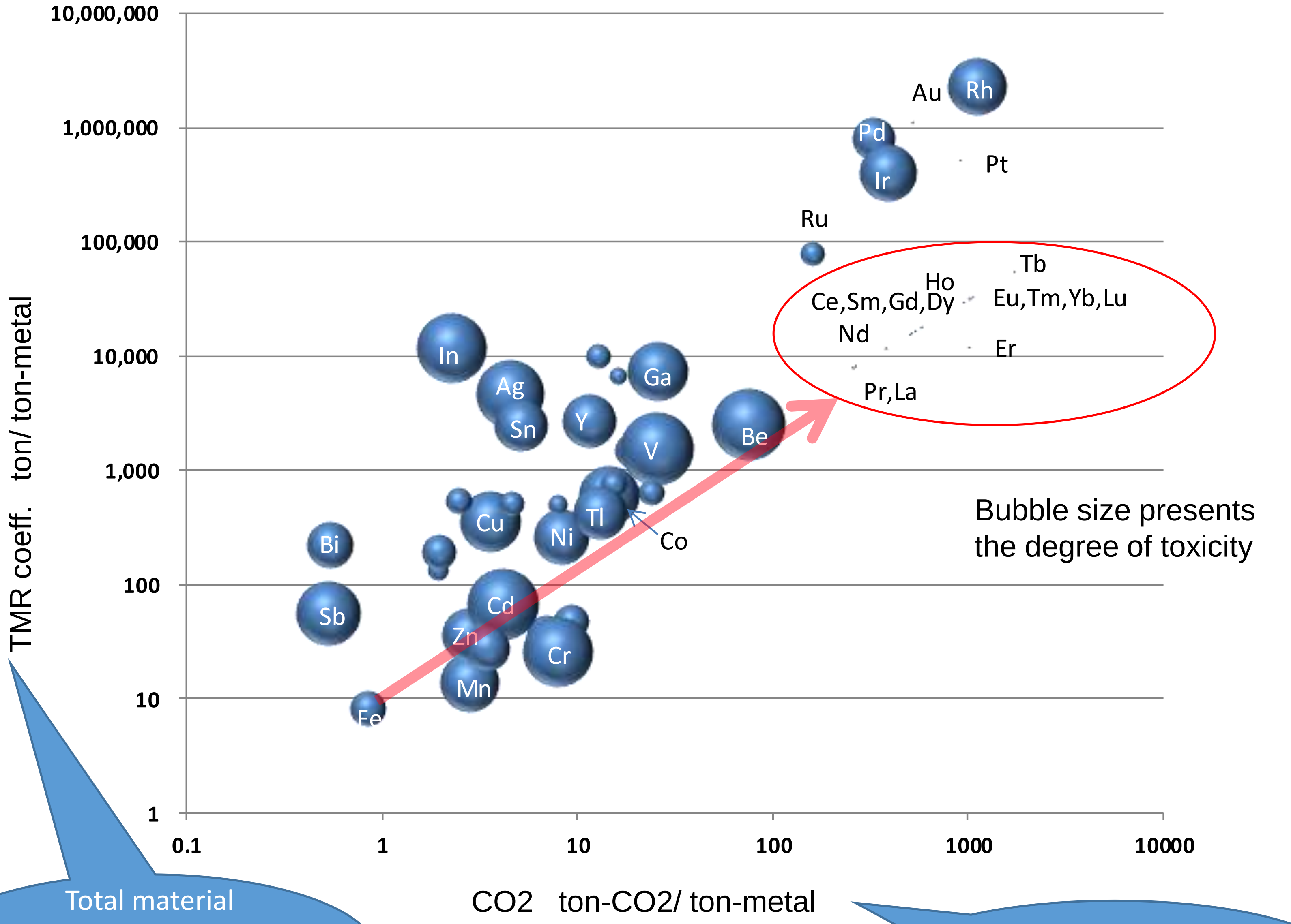
TMR: Total Materials Requirements, or Ecological rucksacks


24
Mashijing馬石径
垇上
Mashijing 馬石径
© 2010 Mapabc.com
Image © 2010 DigitalGlobe
© 2010 Kingway Ltd.
©2010 Google
画像取得日: 2005/4/14
24° 58'14.42" N 115° 03'12.45" E 標高 378 m
高度 2.13 km

3g platinum ring

More than 1.5ton ecological rucksack

1kg R.E.E. is nearly equivalent to 1 ton Fe by environmental view

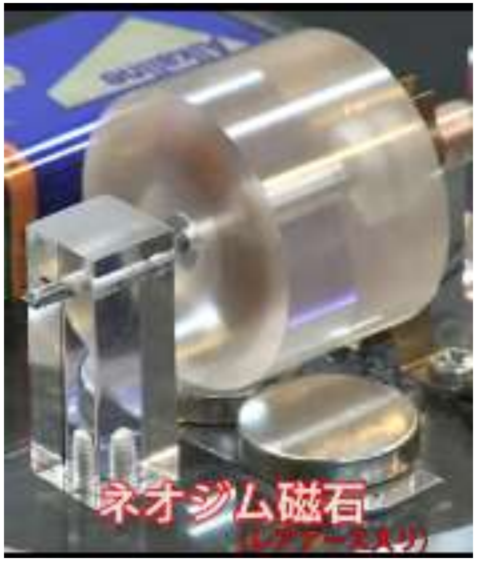


Bubble size presents the degree of toxicity

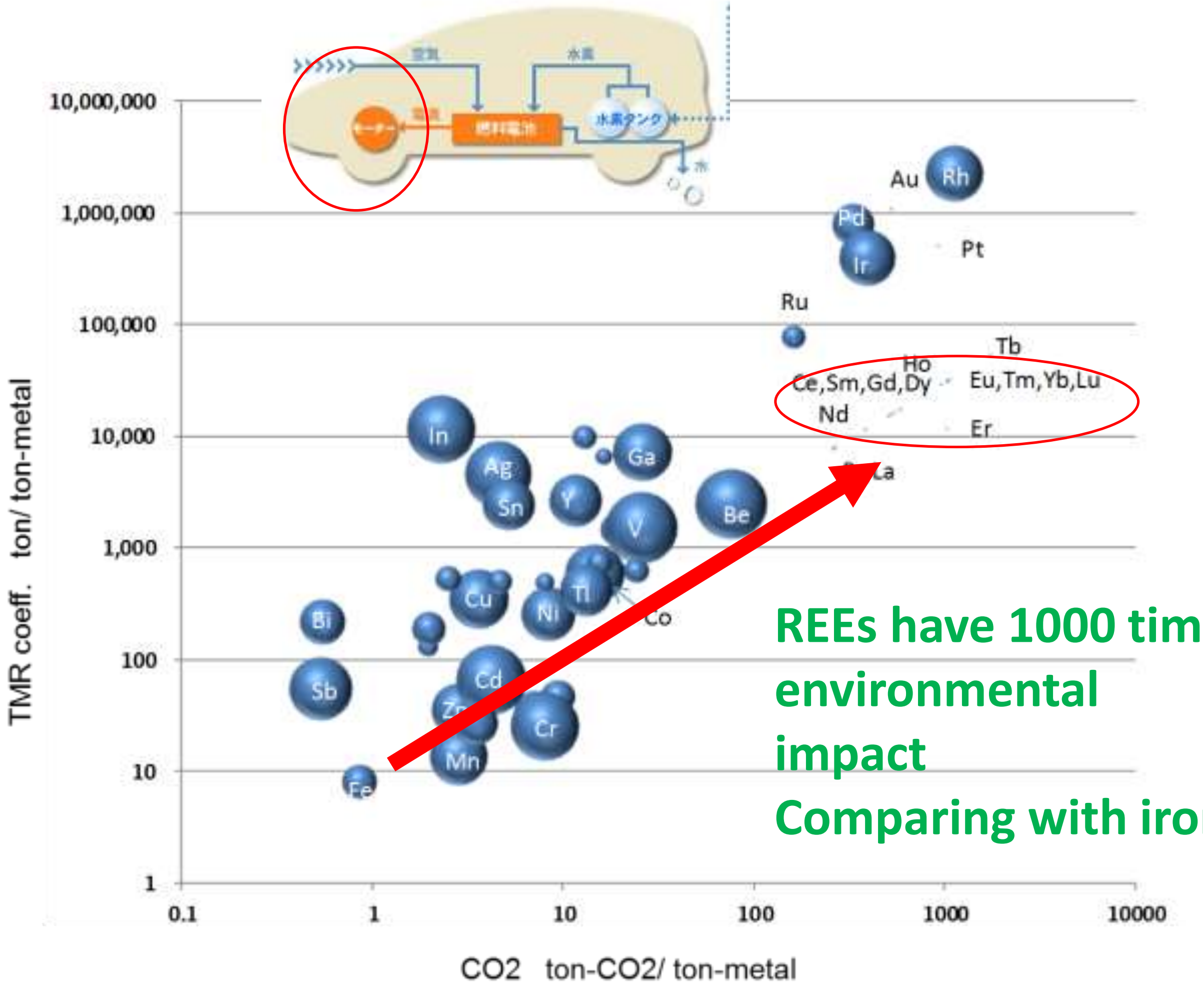
Total material requirement
≈
Waist from mining

CO2 emission during mining and extraction

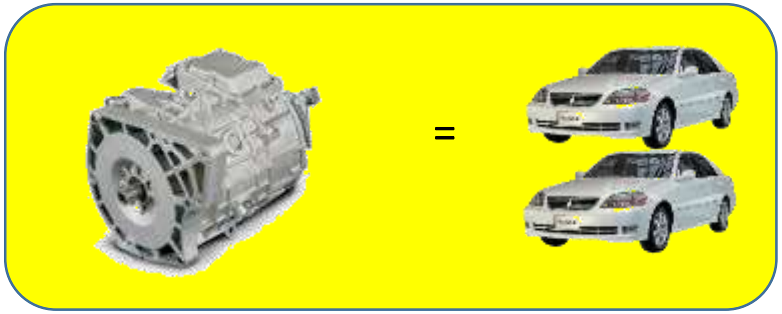
EV motor
(Rare Earth)



1.2kg Nd magnet/car



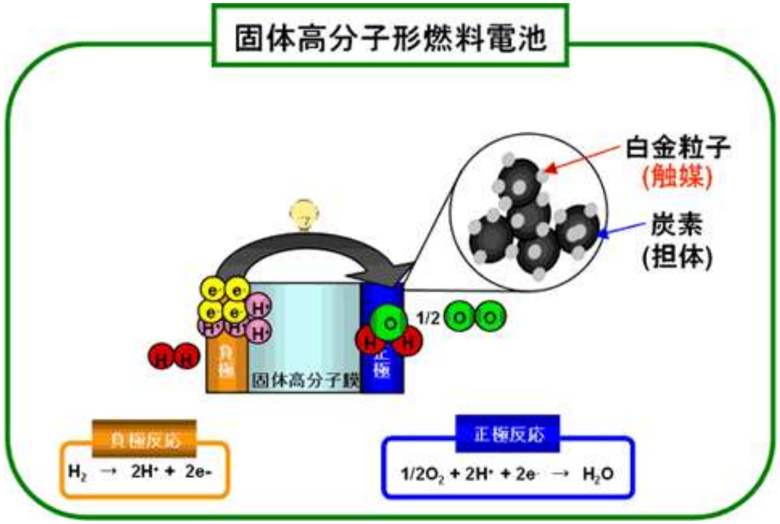
REEs have 1000 times environmental impact
Comparing with iron

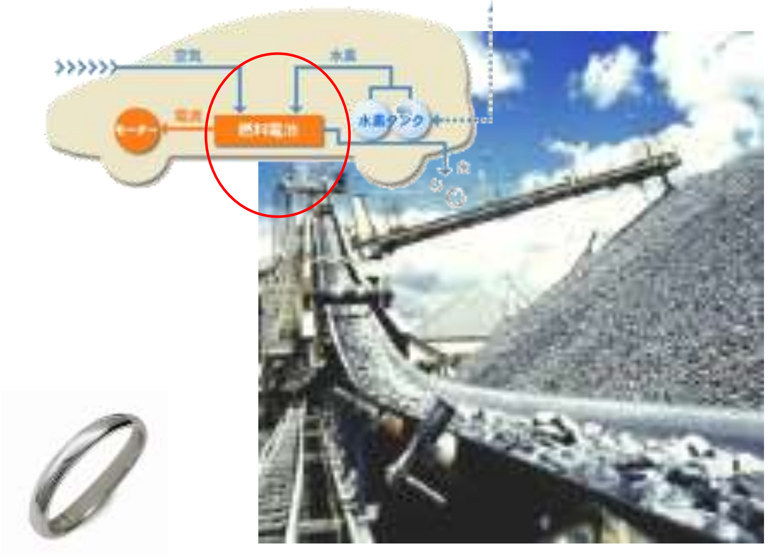


Small mass but Great impact

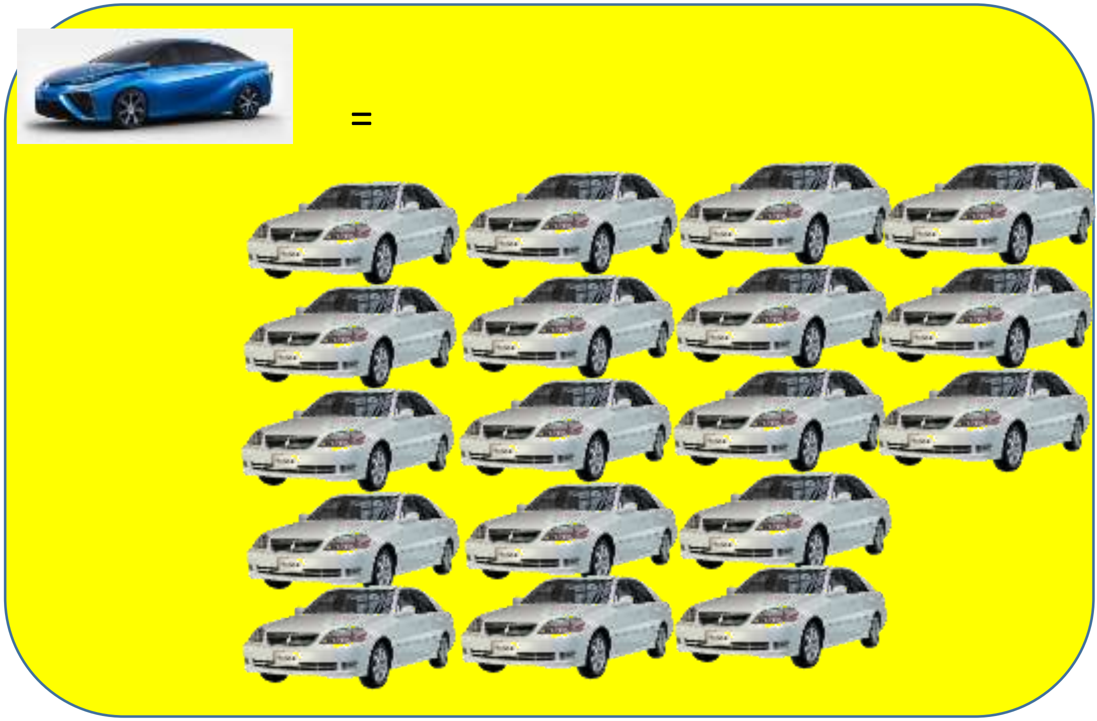
Fuel Cell (Pt)

	Pt consimption g/car
Small car 80kW	32
Medium car 150kW	60
Large car 250kW	150
average 120kW	50





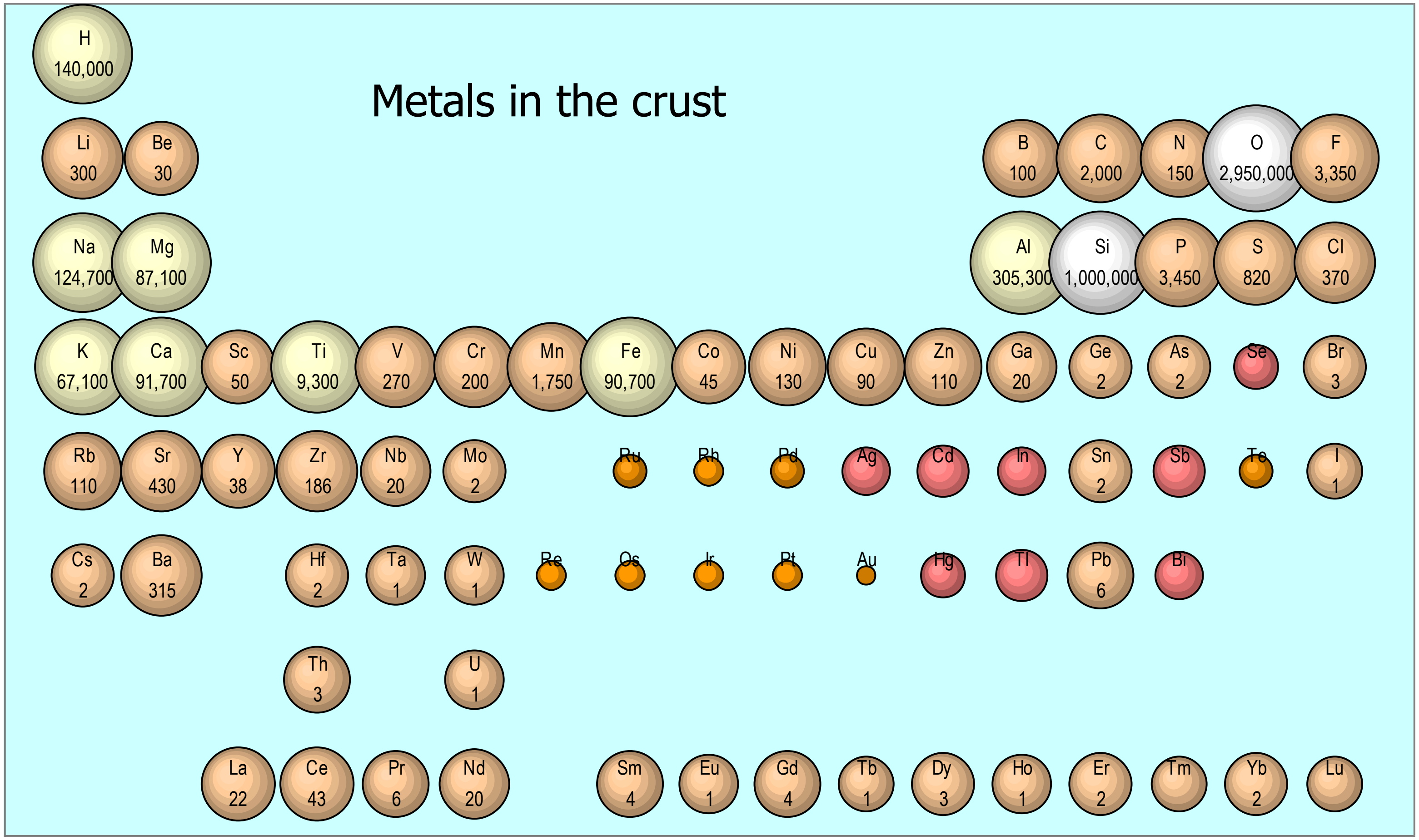
3g platinum = 3.6ton resource = iron for 1 automobile

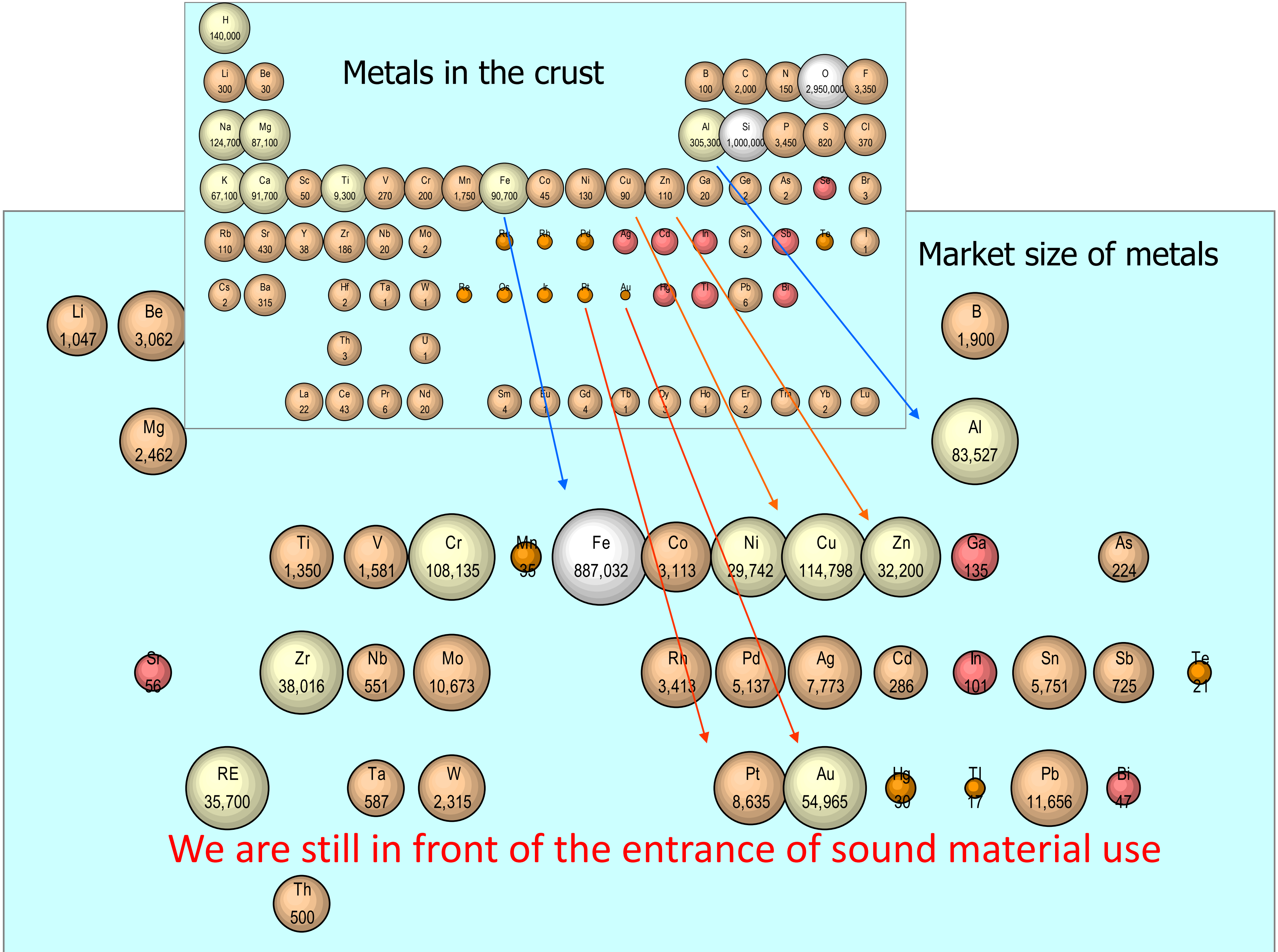


To promote the resource efficiency,

it is important to use common element in the crust.

educing functions by controlling electron orbit of chemical compounds.





Metals in the crust

Market size of metals

We are still in front of the entrance of sound material use

In order to achieve the decoupling of development and environmental impact,

Life-cycle consideration and the pursuit of Resource Efficiency are required.

Ceramics have advantage of Resource Efficiency in resource view weight and durability.

,but have to consider the environmental impact in processing processes.

Grazie per l' attenzione !!