Sound Circulation Society for Sustainable Resource Use

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Invited Senior Scientist,
National Institute for Materials Science

white: strategic rare metals (JP)

Key materials , DOE(US)

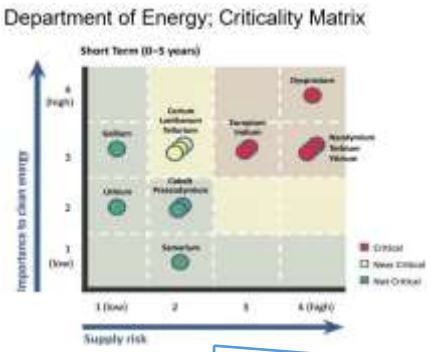
Critical materials (EU)

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 アンモチン	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 ルテチウム

Ac	Th	Pa	U

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

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

																	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 2.7 271	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)															

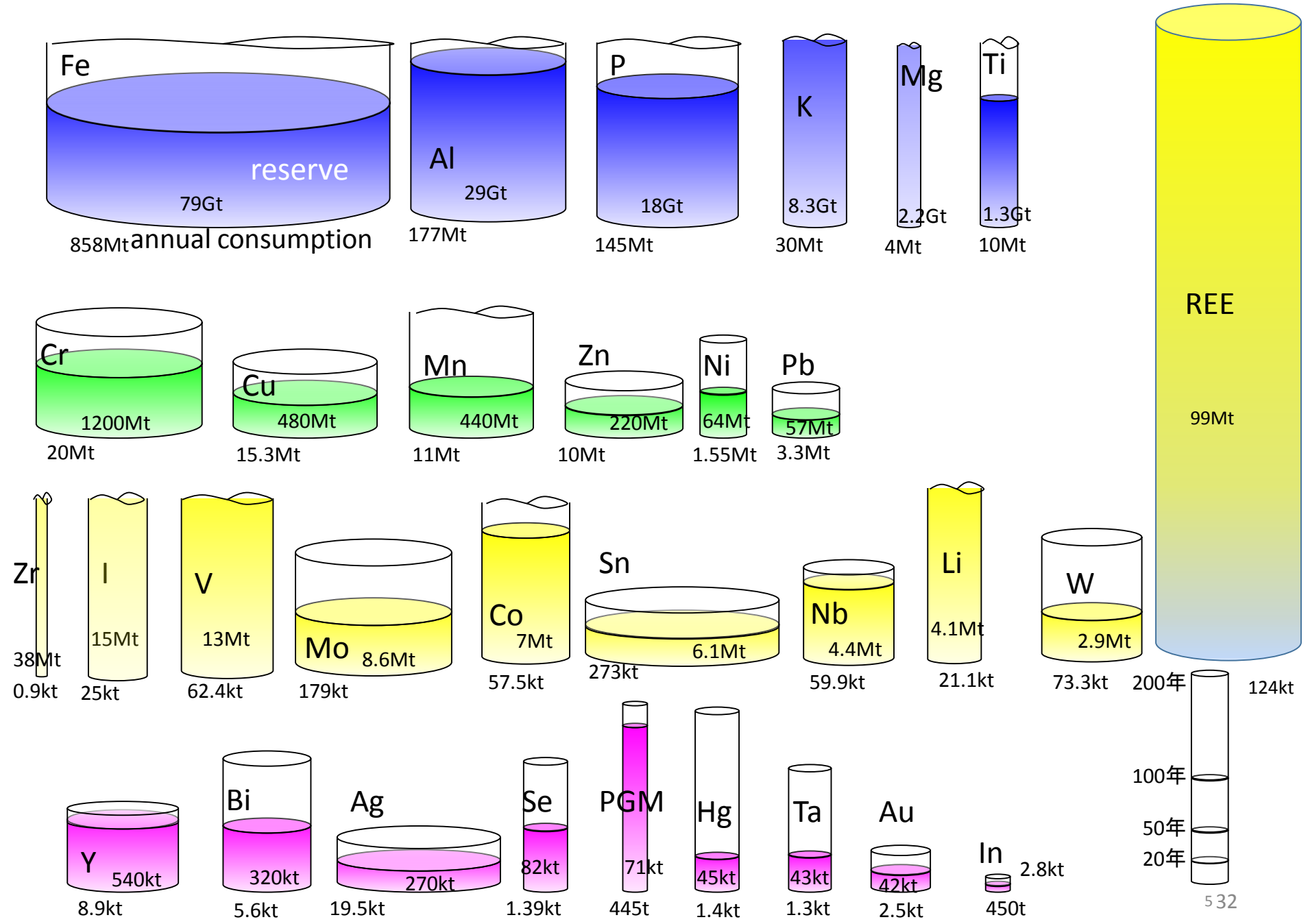
La 1600 8.2 371*	Ce 770 18 295*	Pr 7.9	Nd 420 12 90*	Pm	Sm 16	Eu 188 33	Gd 17	Tb 244 55	Dy 209 16	Ho 30	Er 12	Tm 32	Yb 32	Lu 32

Ac	Th	Pa	U 22

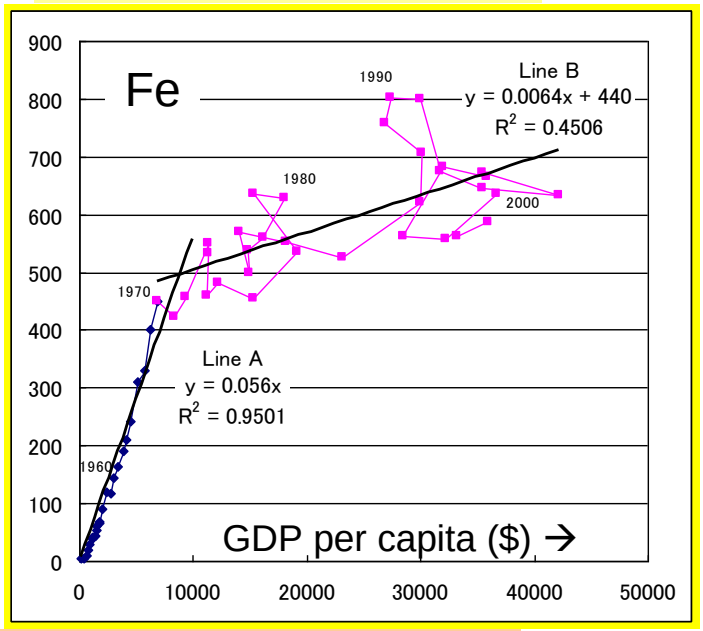
* Estimated by import of Japan, ( ) amount in crust is less than in sea water

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

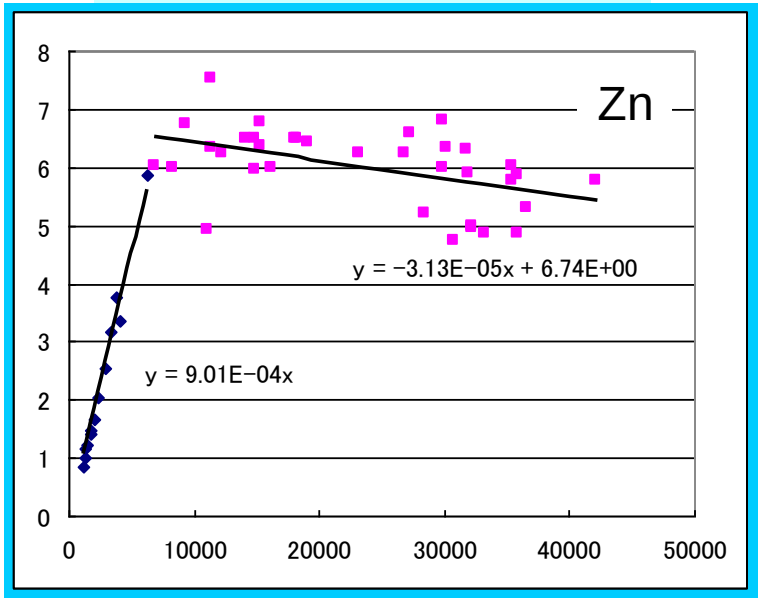
NIMS
元素戦略センター
Center for Strategic Material
NIMS ,Japan


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
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
124kt
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

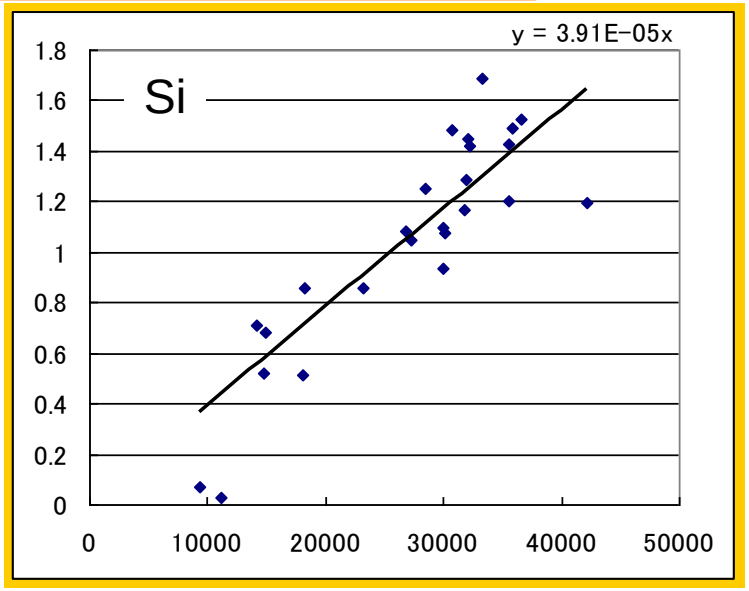
Fe-type: weakly de-coupled
Al, Ni, Mo, Ag, Sb



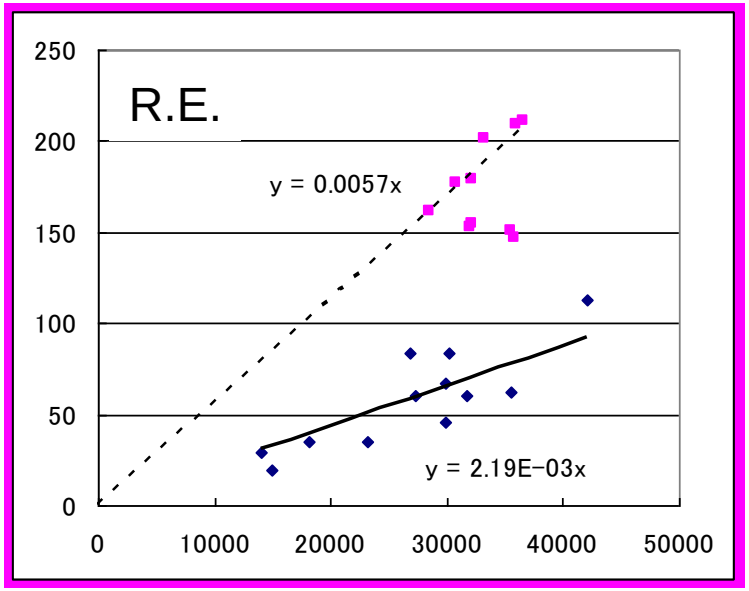
Zn-type: de-coupled
Cu, Sn, Pb, W, Cr, Mn, Au



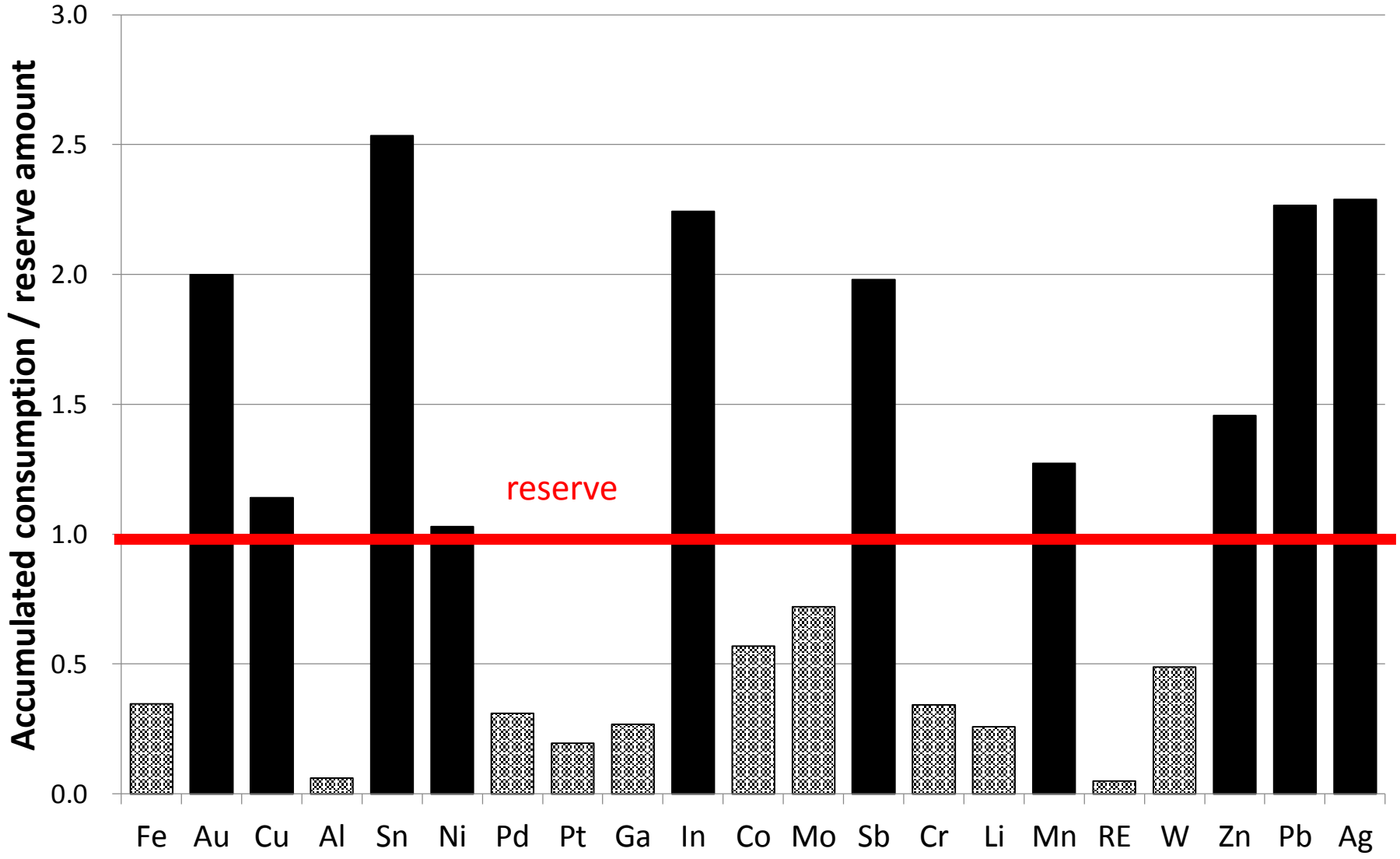
Si-type: still coupling Pt, Co



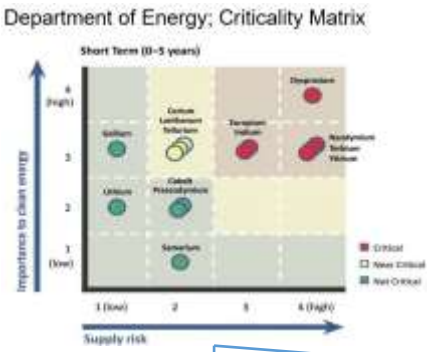
R.E.-type: further coupling Li, In, Ga



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


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

Progress of discussion on criticality index of metals



DOE matrix
(importance)
x(supply risk)

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= supply chain risk

Criticality for global sustainability

damage

risk

probability

Social damage through supply chain damage

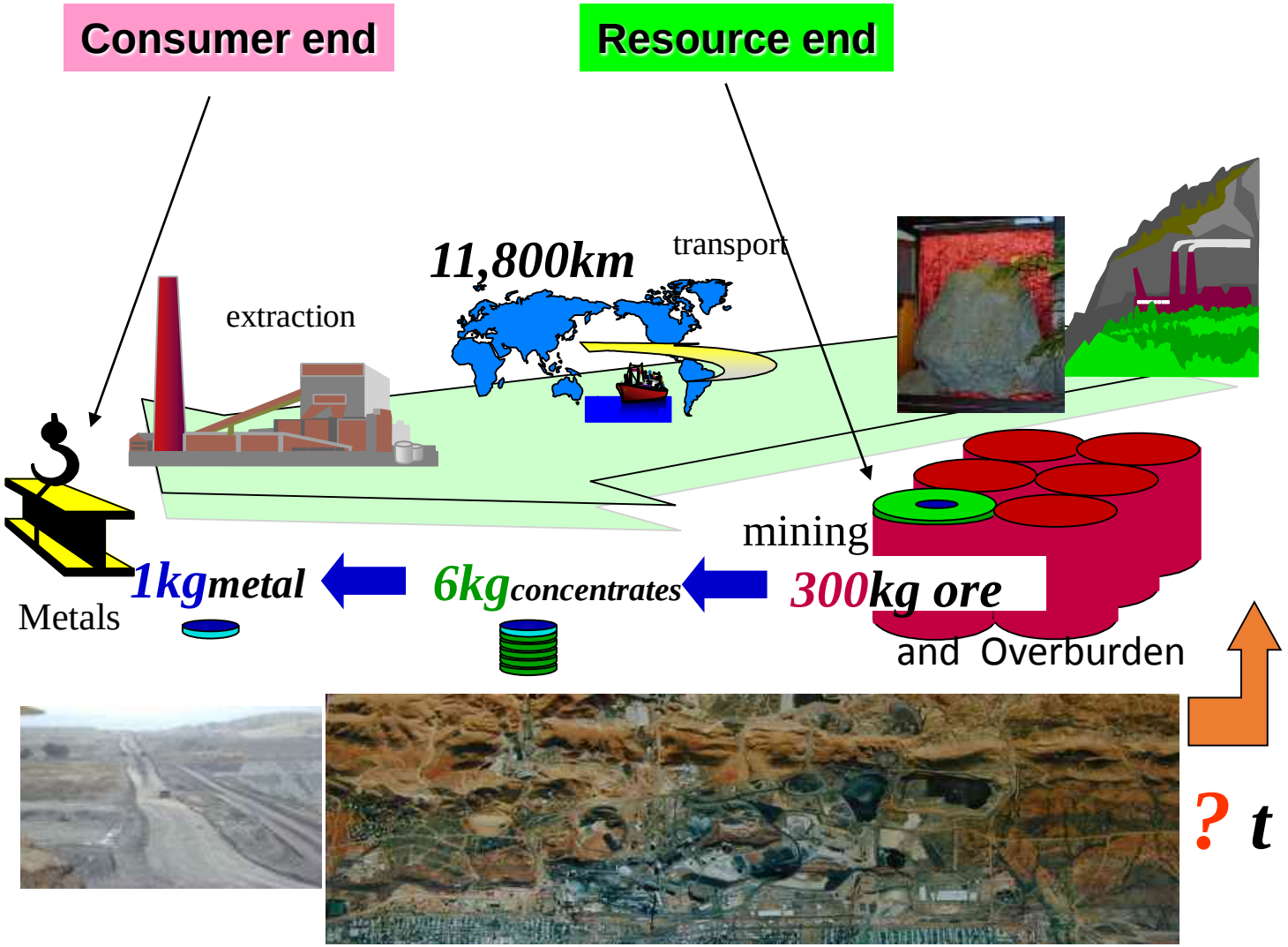
Supply chain risk

Probability of
Supply chain is damaged

Global environment

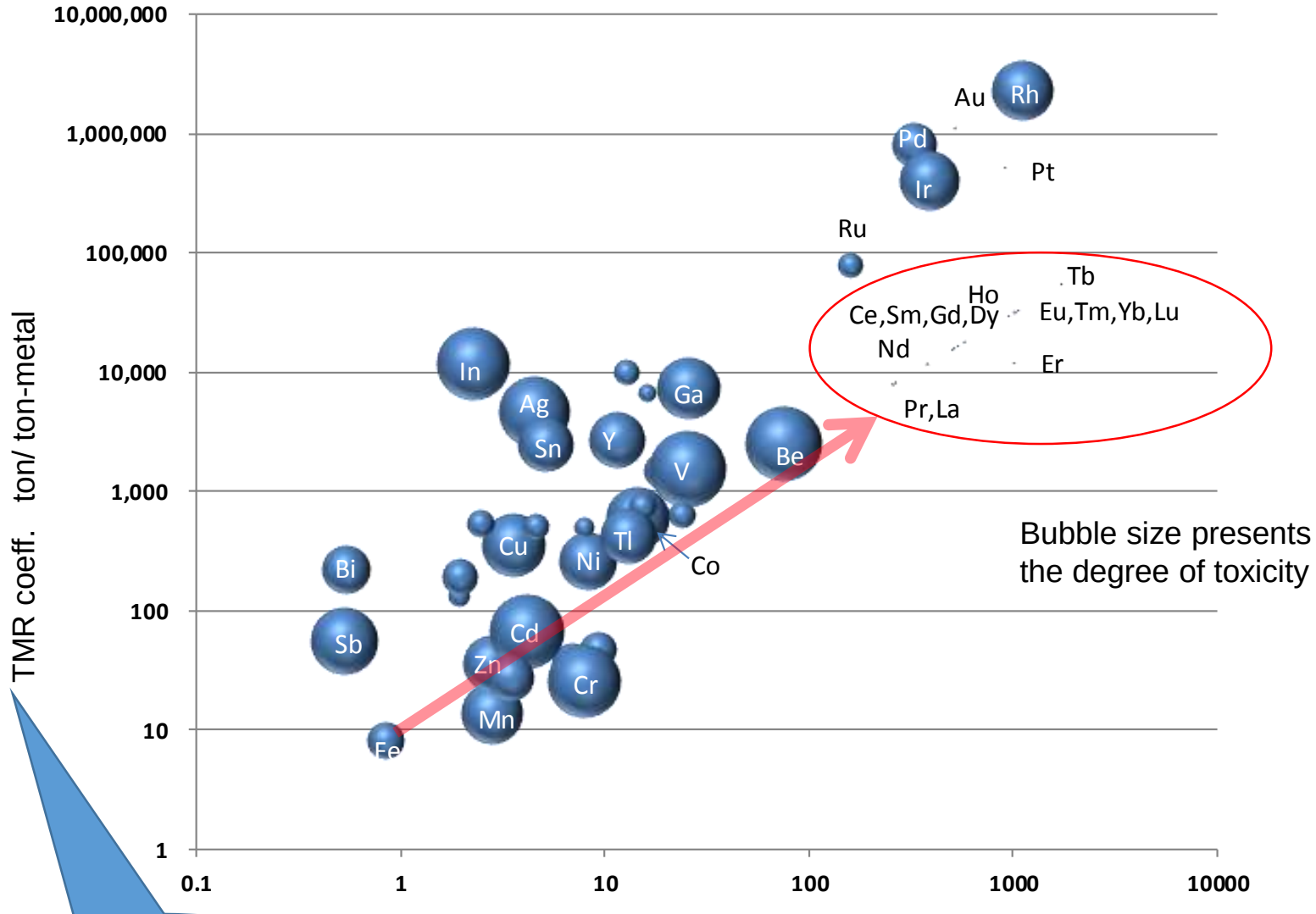
Human activity

Resource(-end)-view weight



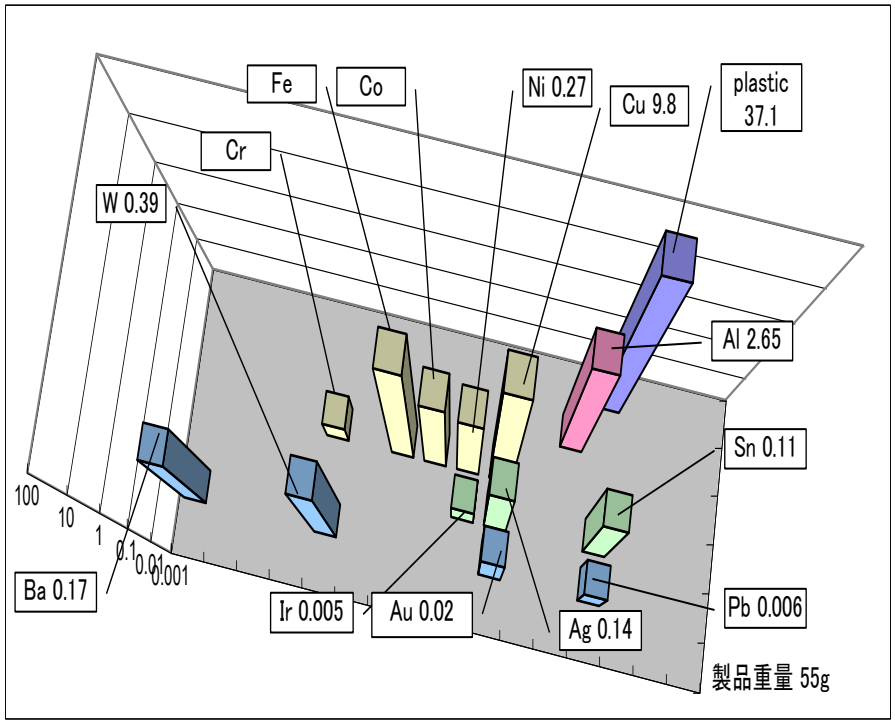
TMR: Total Materials Requirements, or Ecological rucksacks

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

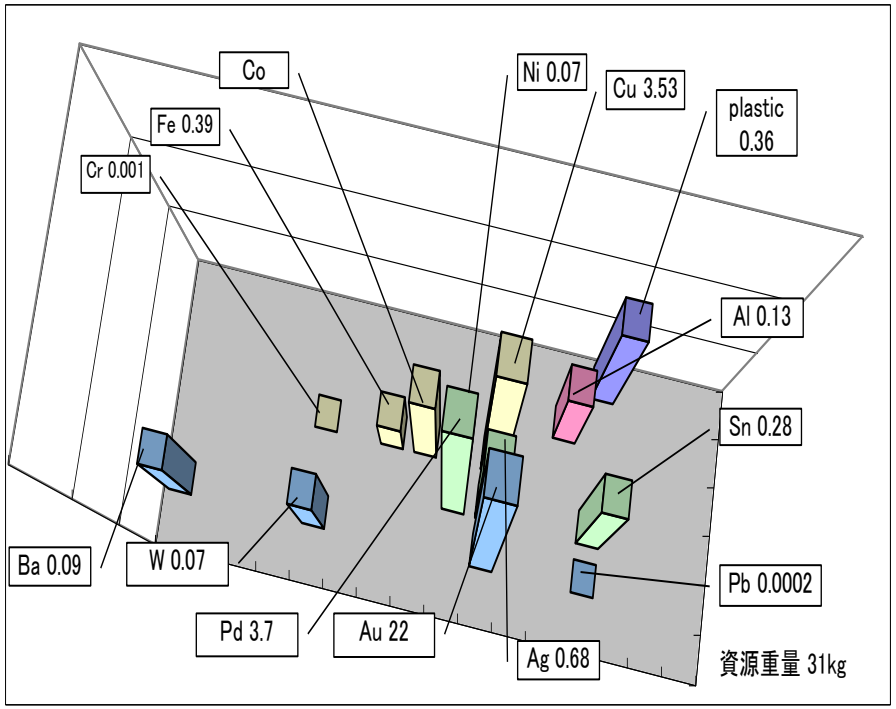


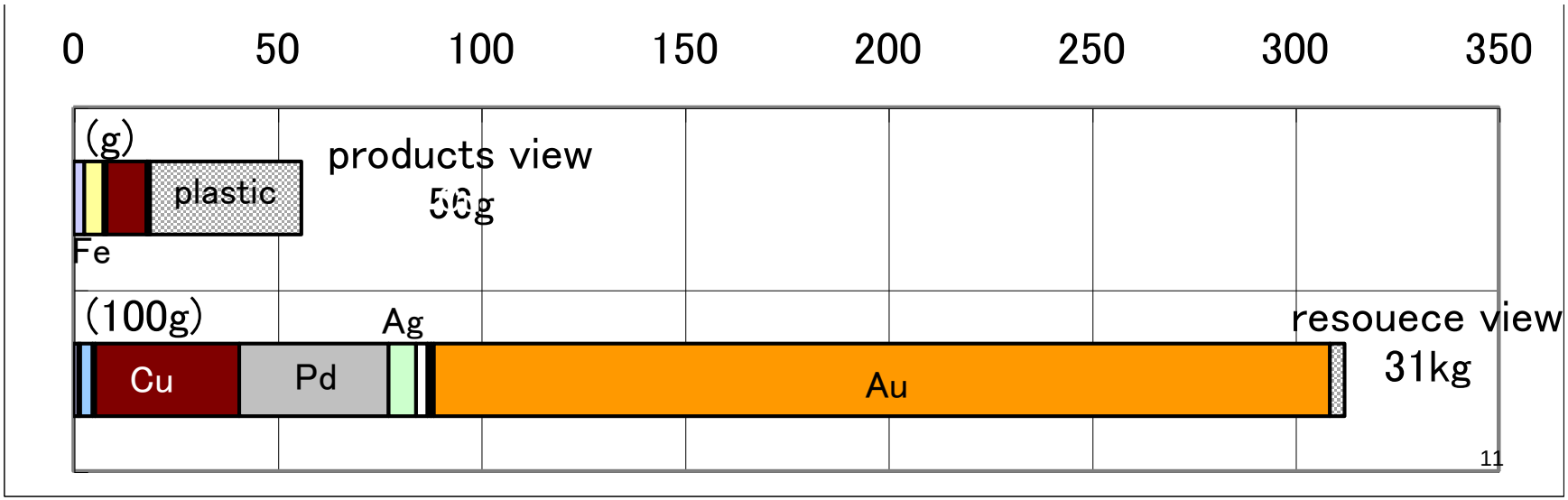
Cell Phone

Product-end

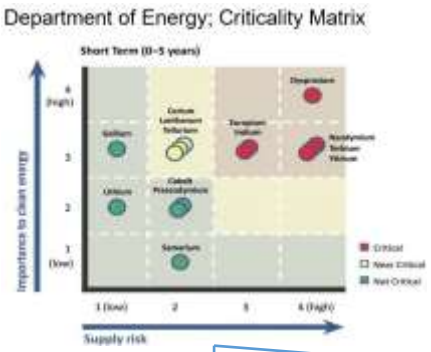


Resource-end





Progress of discussion on criticality index of metals



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risk

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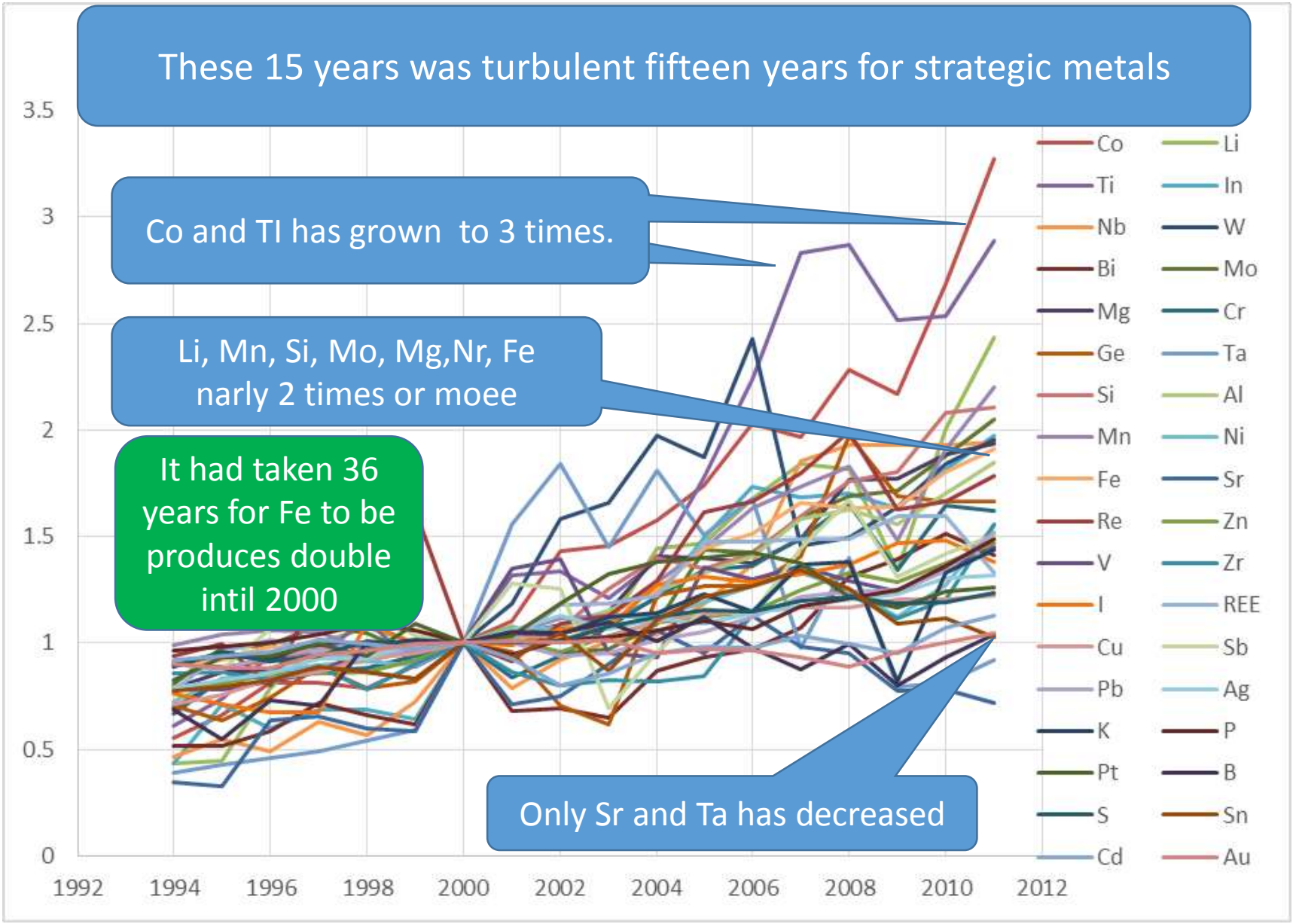
Supply
chain
risk

Probability of
Supply chain is damaged
Difficulty & Instability of supply

Global environment

Human activity


These 15 years was turbulent fifteen years for strategic metals
Co and TI has grown to 3 times.
Li, Mn, Si, Mo, Mg,Nr, Fe narly 2 times or moee
It had taken 36 years for Fe to be produces double intil 2000
Only Sr and Ta has decreased
3.5
3
2.5
2
1.5
1
0.5
0
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
Co
Li
Ti
In
Nb
W
Bi
Mo
Mg
Cr
Ge
Ta
Si
Al
Mn
Ni
Fe
Sr
Re
Zn
V
Zr
I
REE
Cu
Sb
Pb
Ag
K
P
Pt
B
S
Sn
Cd
Au

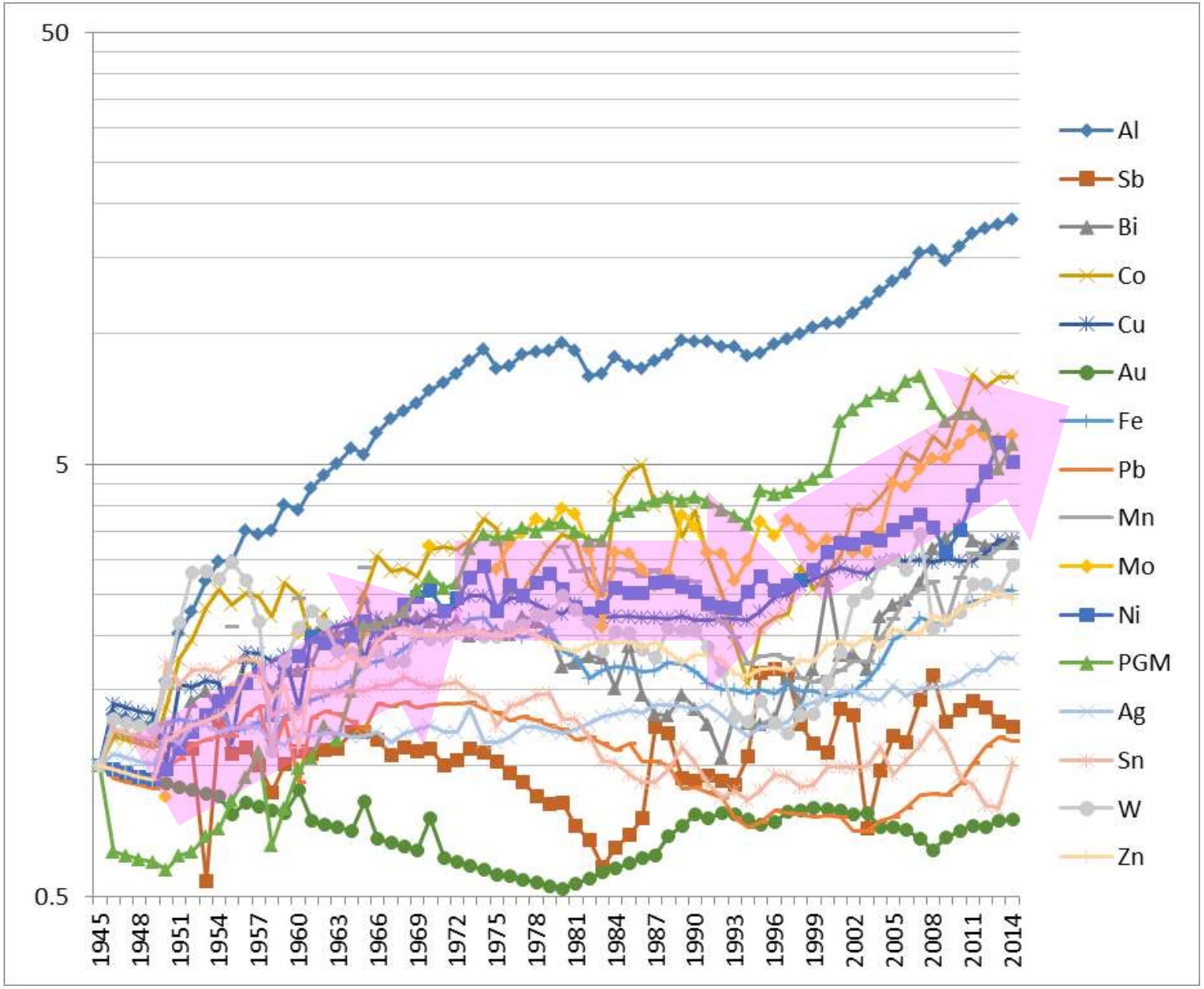


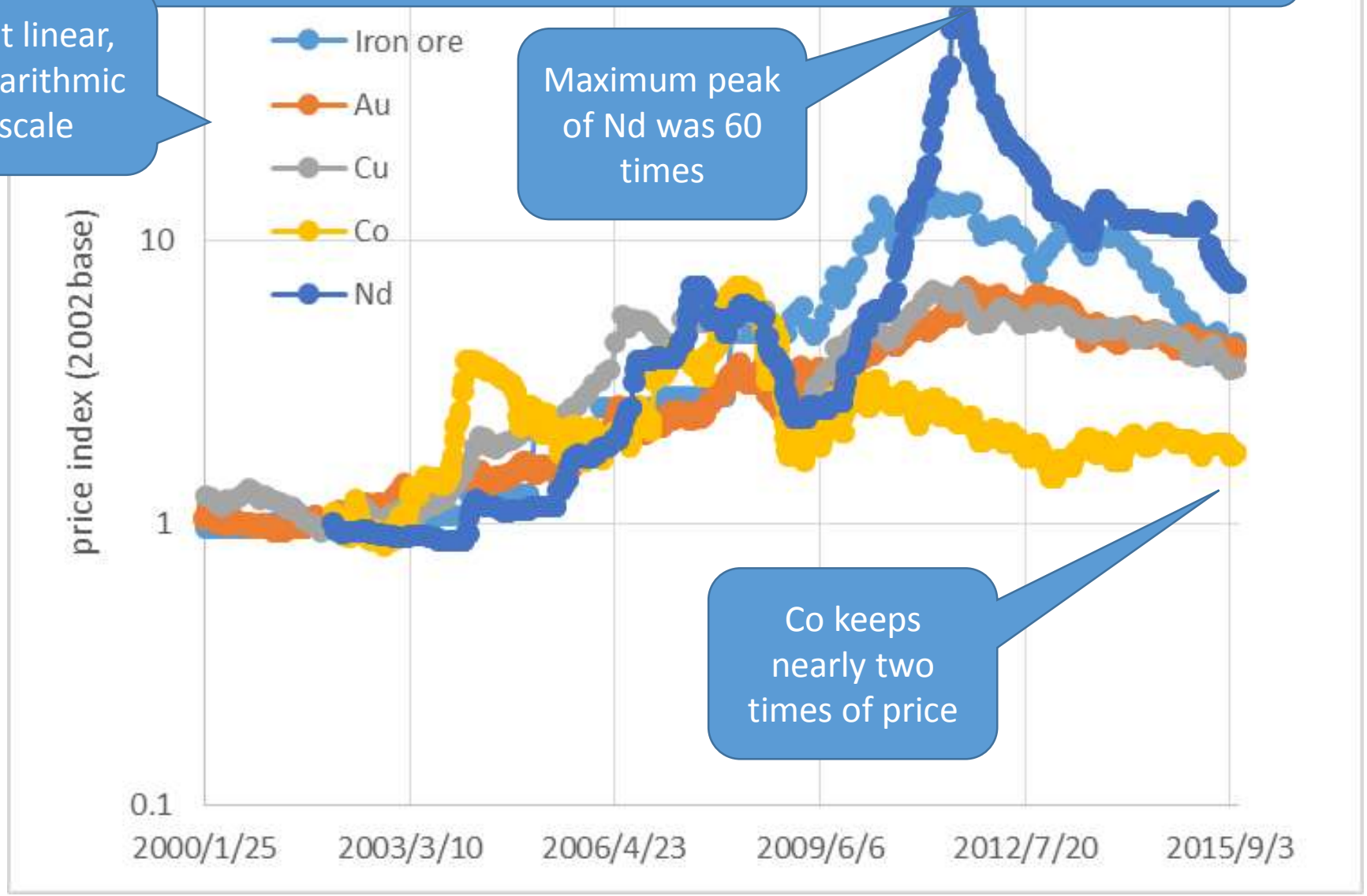
Fig.1 meta production index (1945base)

Prices have changed more drastically

Not linear, Logarithmic scale

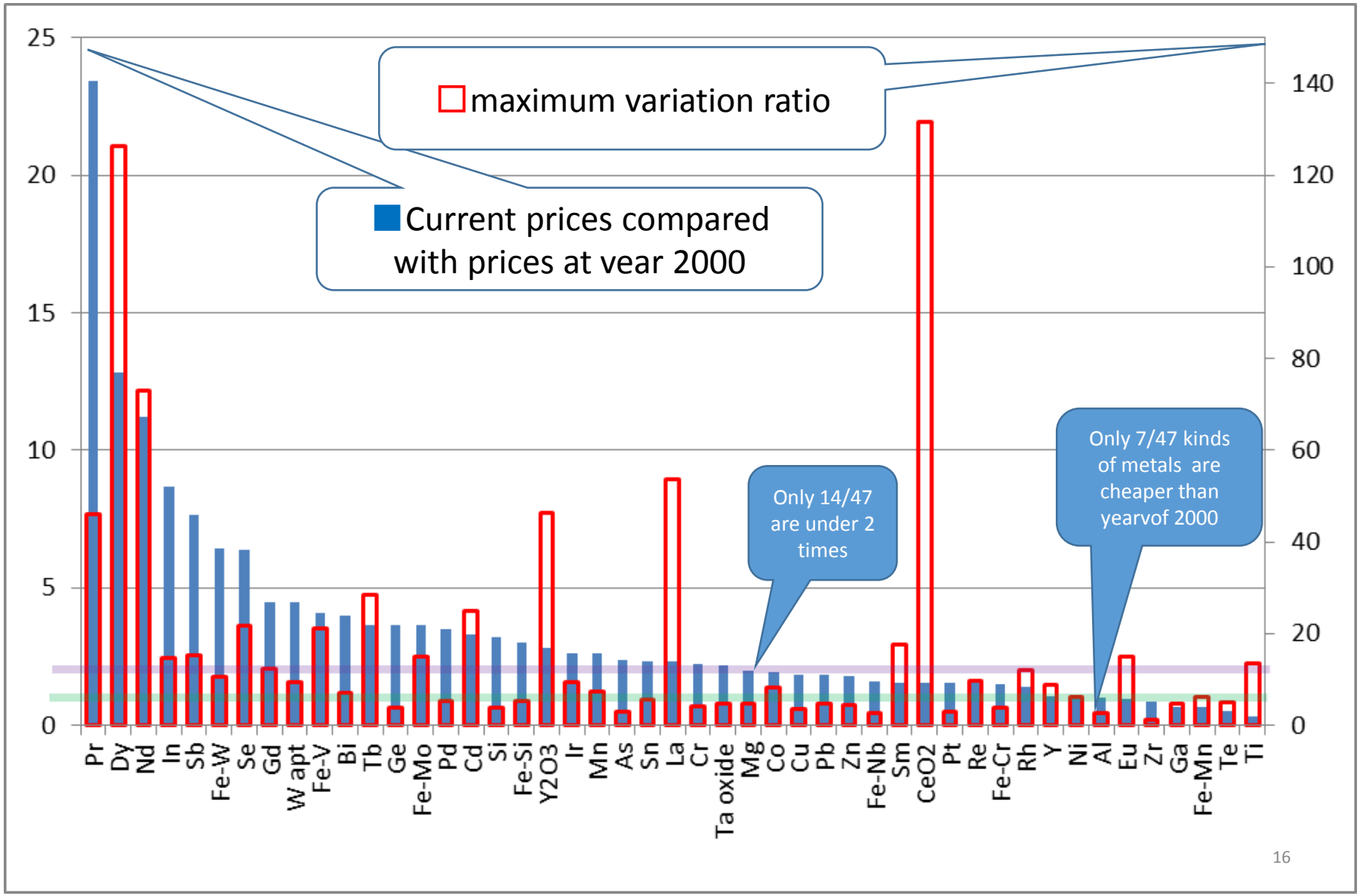
Maximum peak of Nd was 60 times

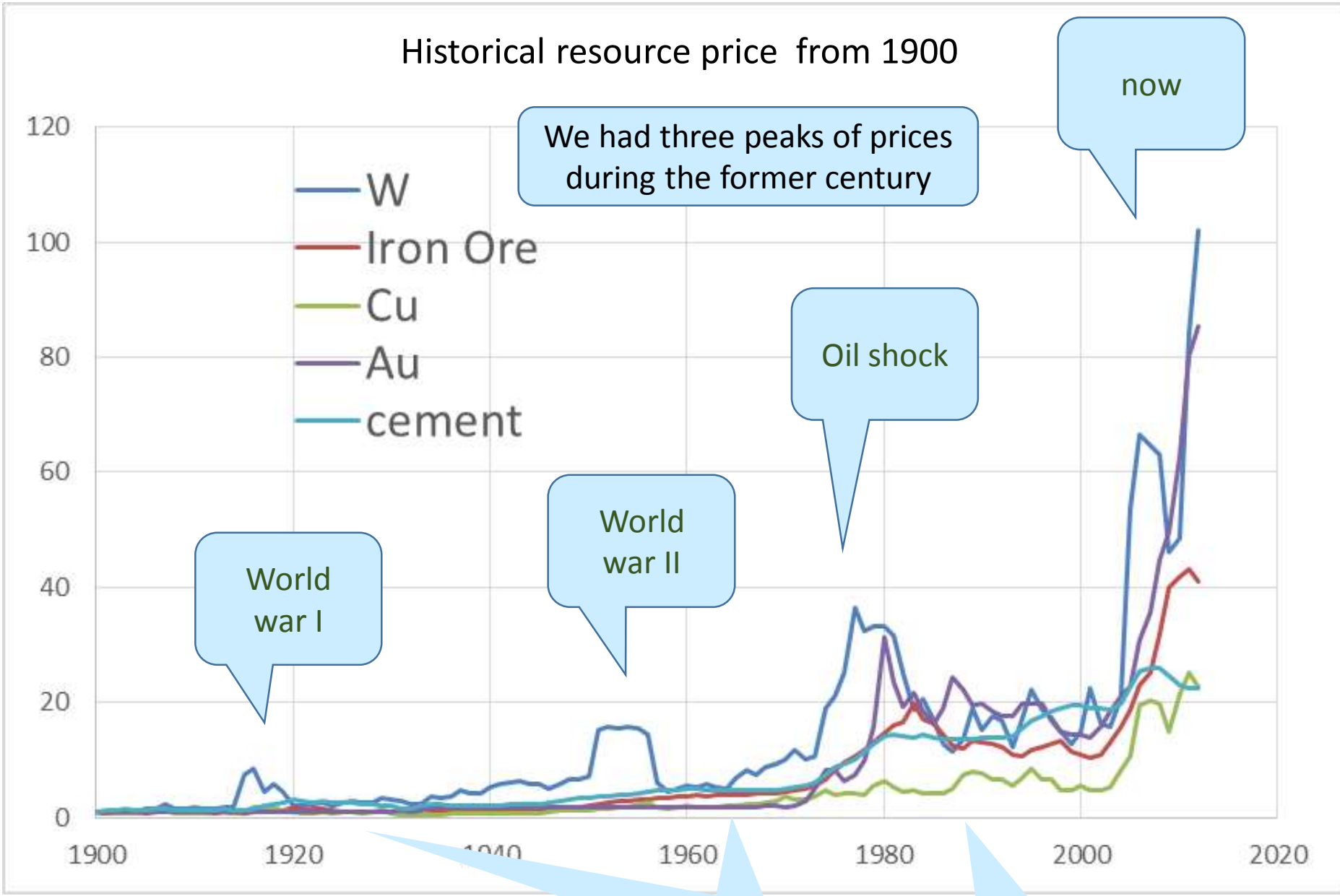
Co keeps nearly two times of price



From several dozens times to more than a hundred times of price swing occurred In these 15 years.

Prices stays higher level comparing the prices at the beginning of this century

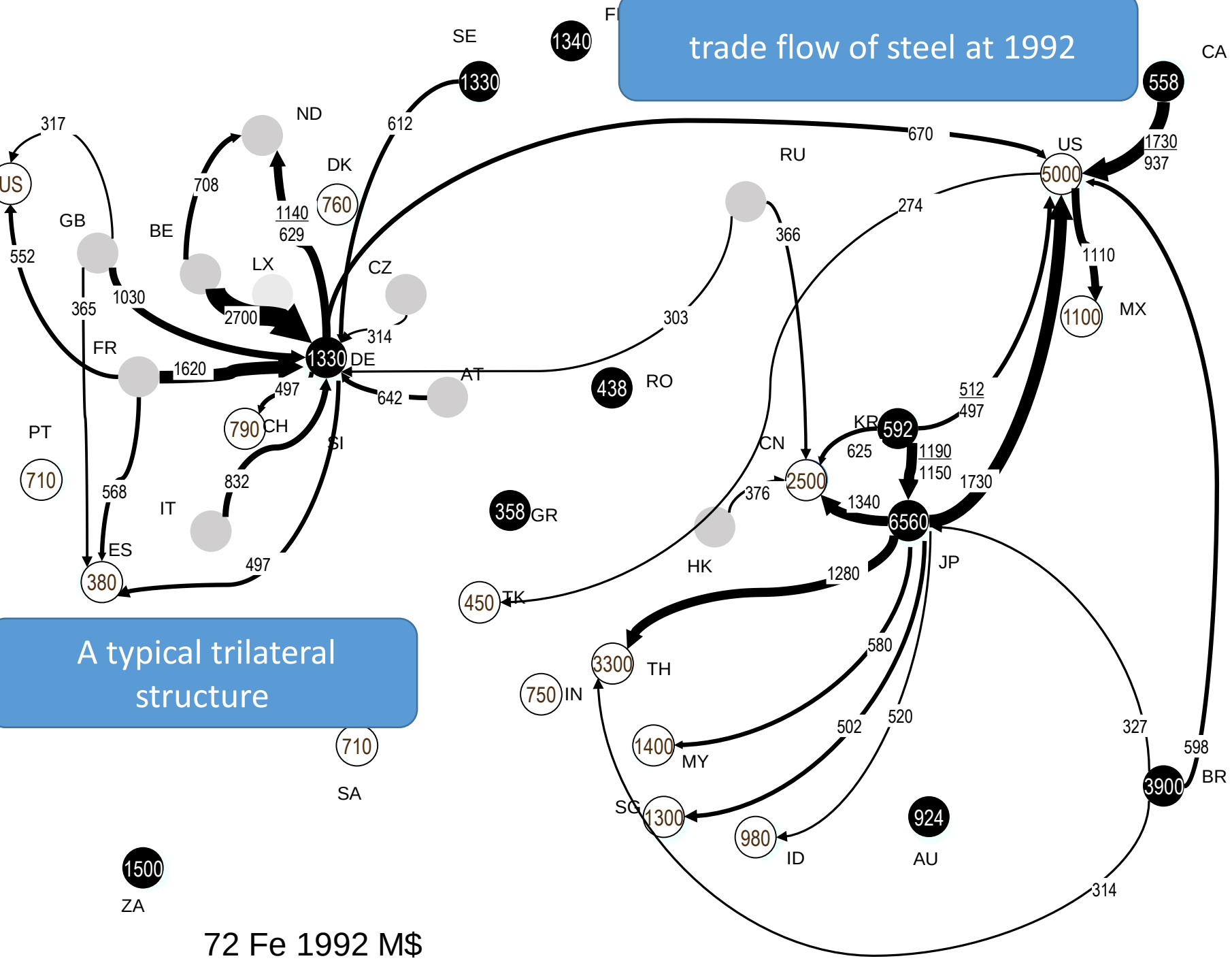


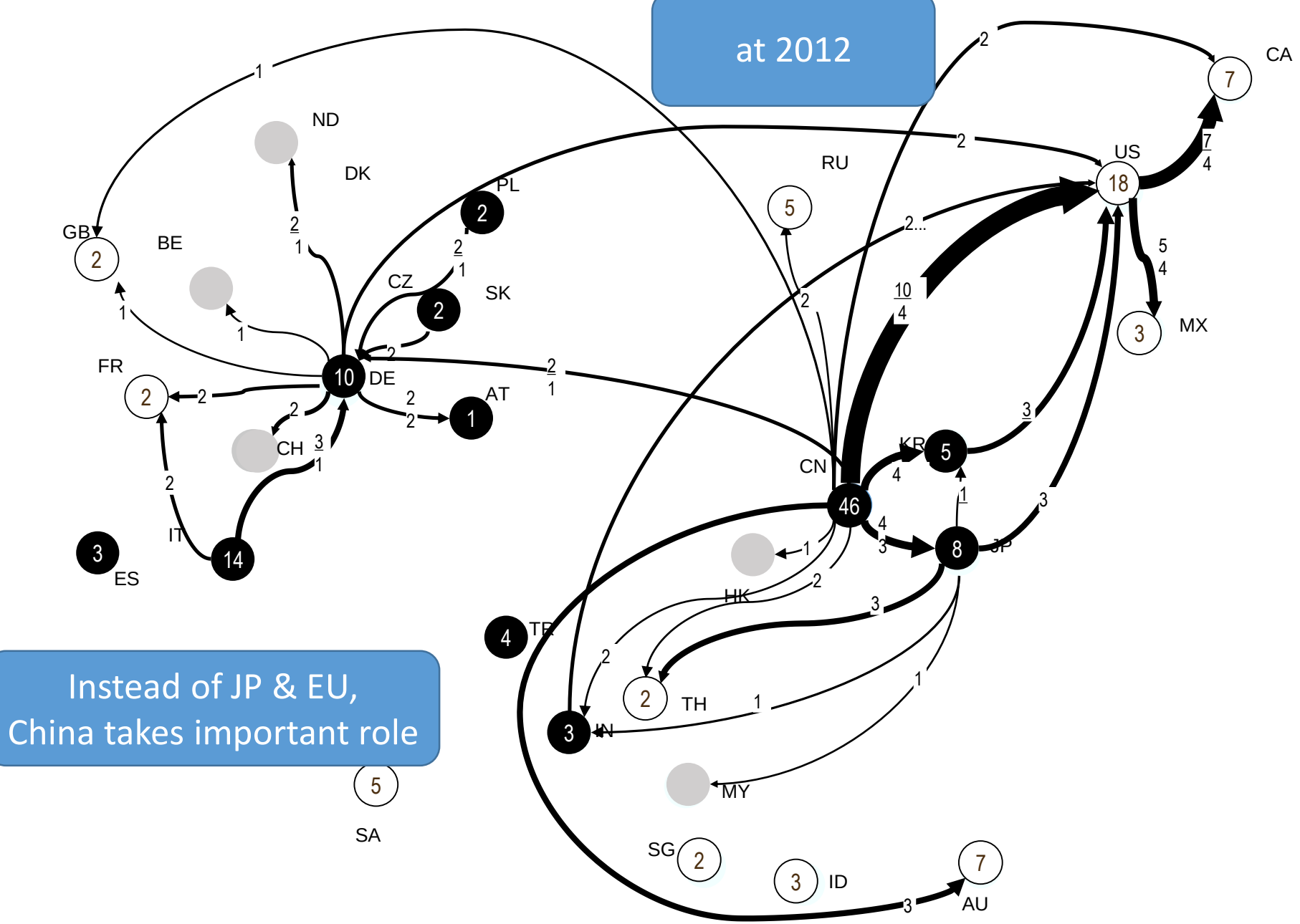

Historical resource price from 1900
now
We had three peaks of prices during the former century
W
Iron Ore
Cu
Au
cement
Oil shock
World war II
World war I
120
100
80
60
40
20
0
1900
1920
1960
1980
2000
2020
After the peak, prices shifted higher levels

What is happening ? What will come after?

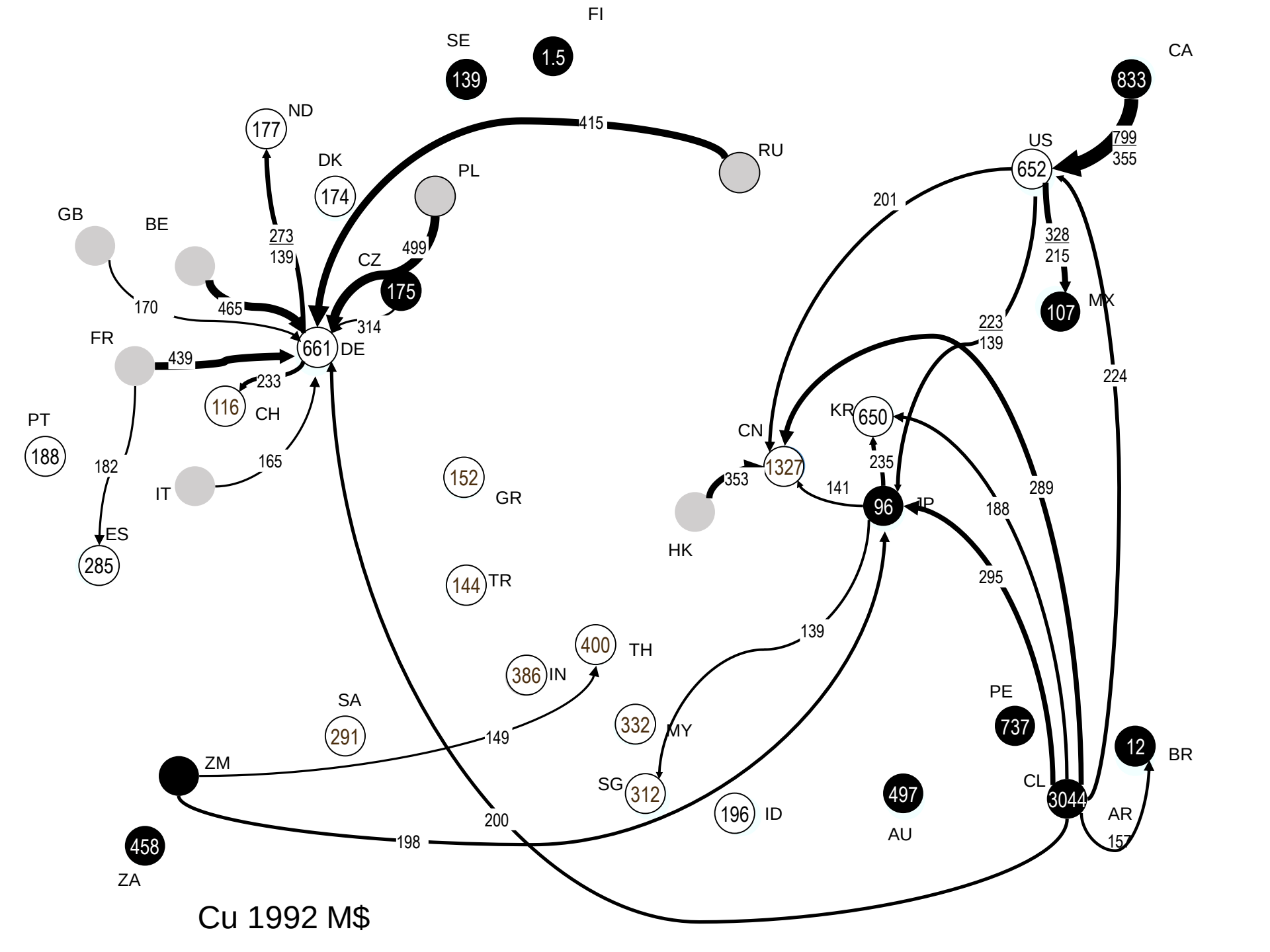
Shift form the structure of the 20th century to the 21th century.

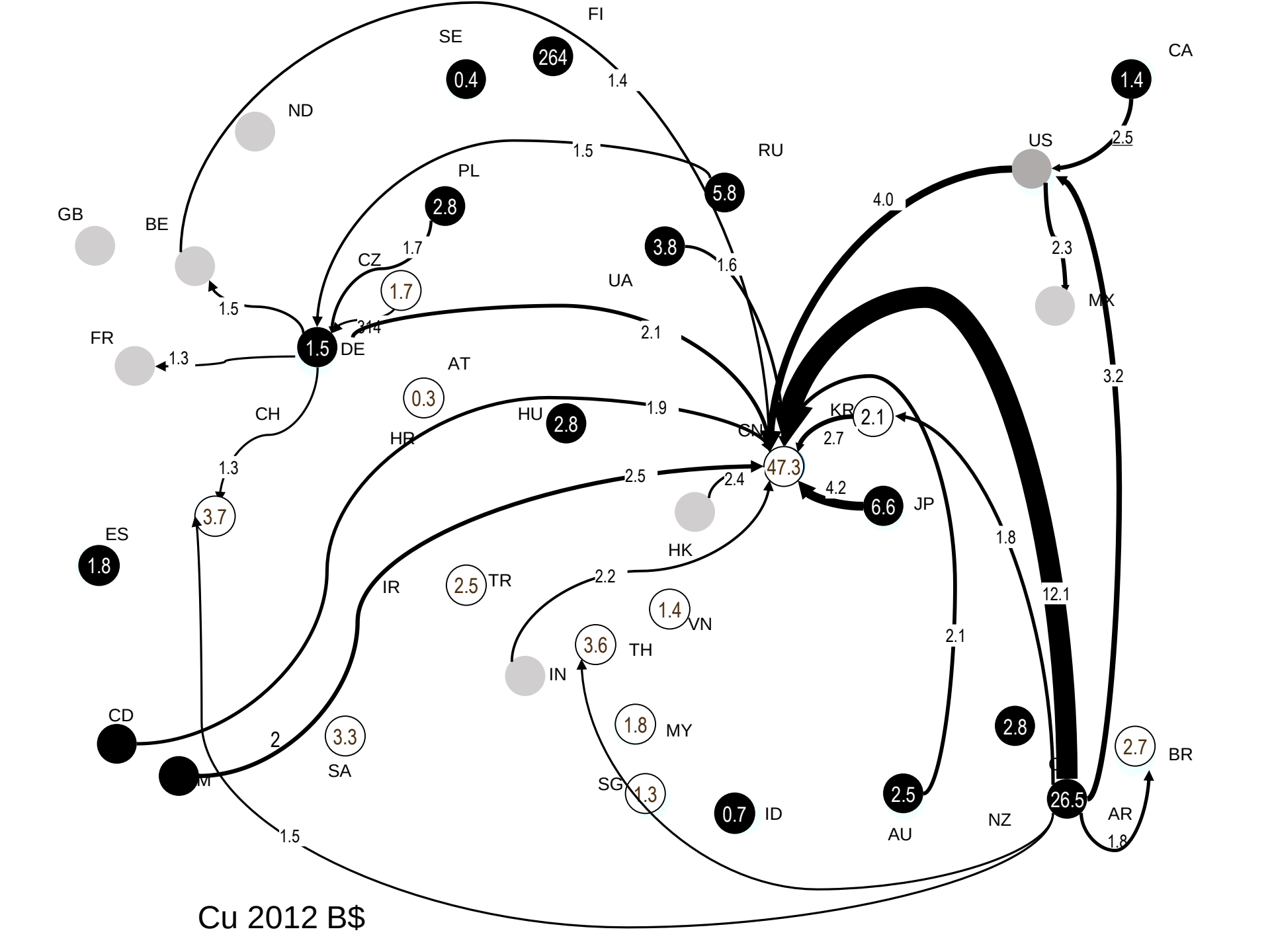
From trilateral structure of EU, US, JP to *universal power economy* through "the factory of the world"

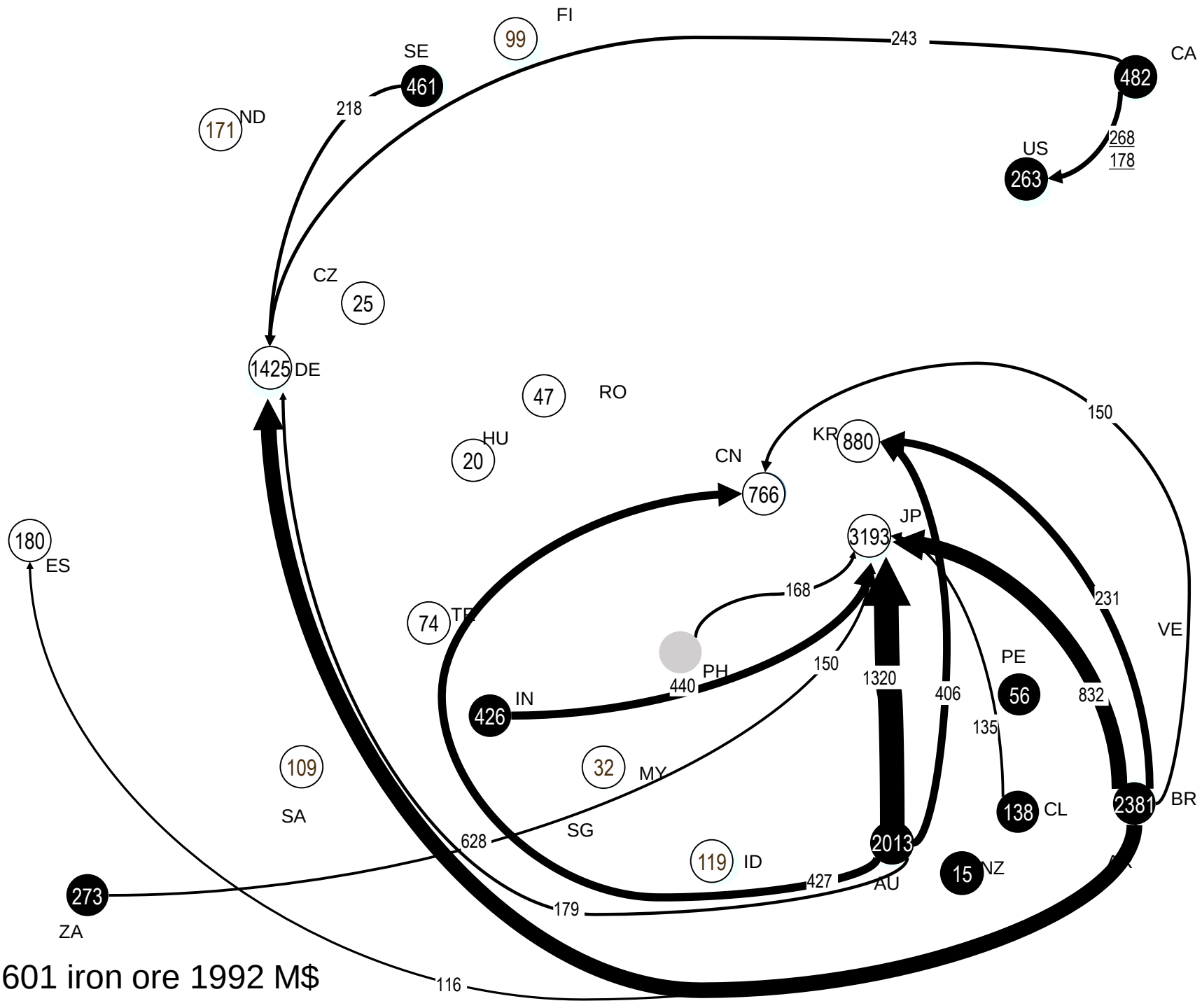

trade flow of steel at 1992
A typical trilateral structure
72 Fe 1992 M$
SE
1340
1330
CA
558
317
ND
612
670
US
1730
937
US
DK
RU
5000
708
760
1140
629
GB
BE
366
274
552
LX
CZ
1110
365
1030
2700
303
1100
MX
314
FR
1330
DE
1620
AT
497
438
RO
642
512
497
790
CH
KR
592
PT
SI
CN
625
1190
1150
710
568
832
2500
376
1730
IT
1340
358
GR
6560
ES
497
HK
JP
380
1280
450
TK
580
3300
TH
750
IN
710
SA
1400
MY
502
520
327
598
3900
BR
SG
1300
980
ID
924
AU
1500
ZA
314


at 2012
Instead of JP & EU,
China takes important role
ND
DK
PL
RU
US
CA
GB
BE
CZ
SK
FR
DE
AT
CH
IT
ES
CN
KR
JP
HK
TW
TH
IN
MY
SG
ID
AU
SA
MX

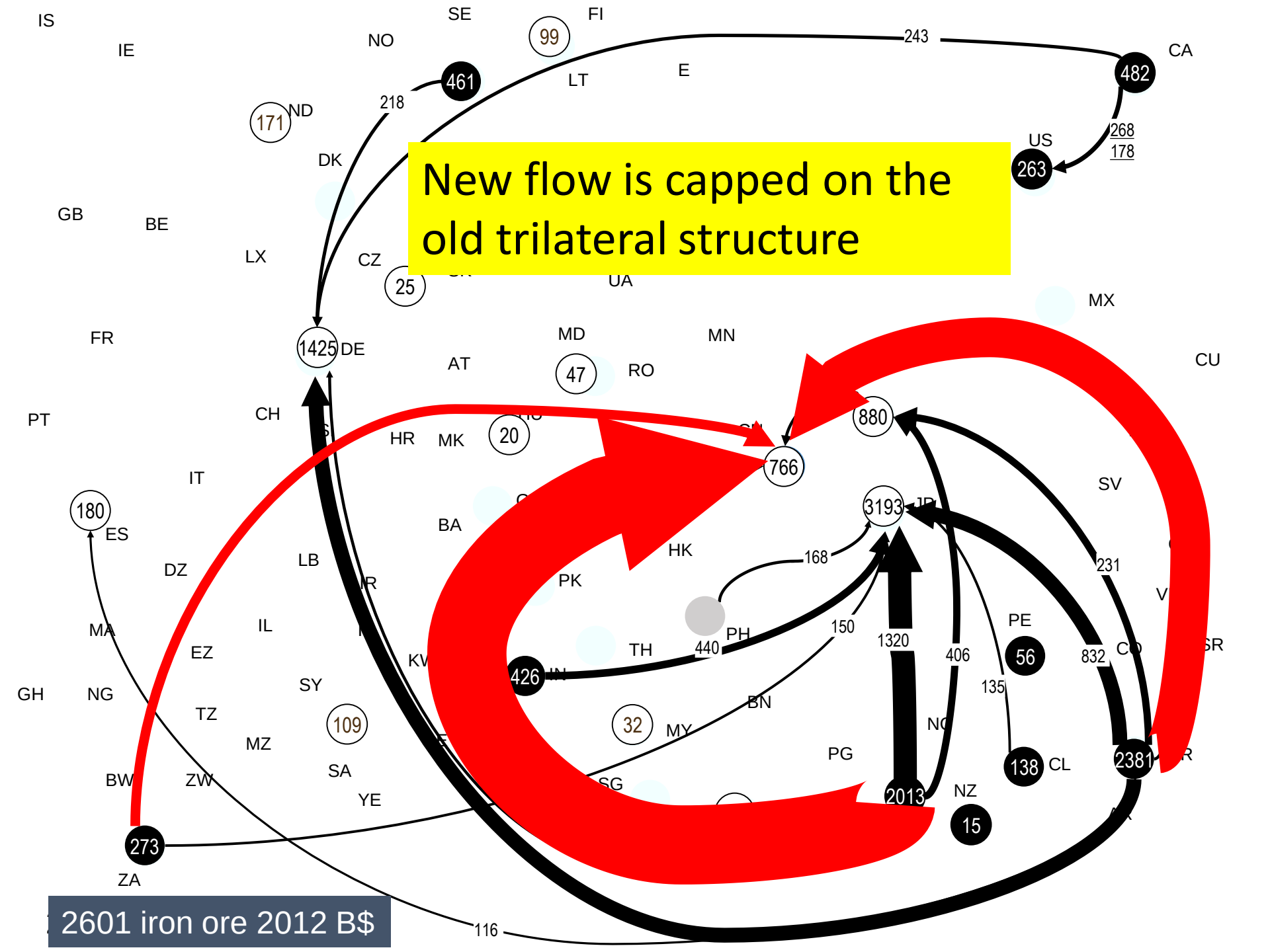
72 Fe 2012 B$

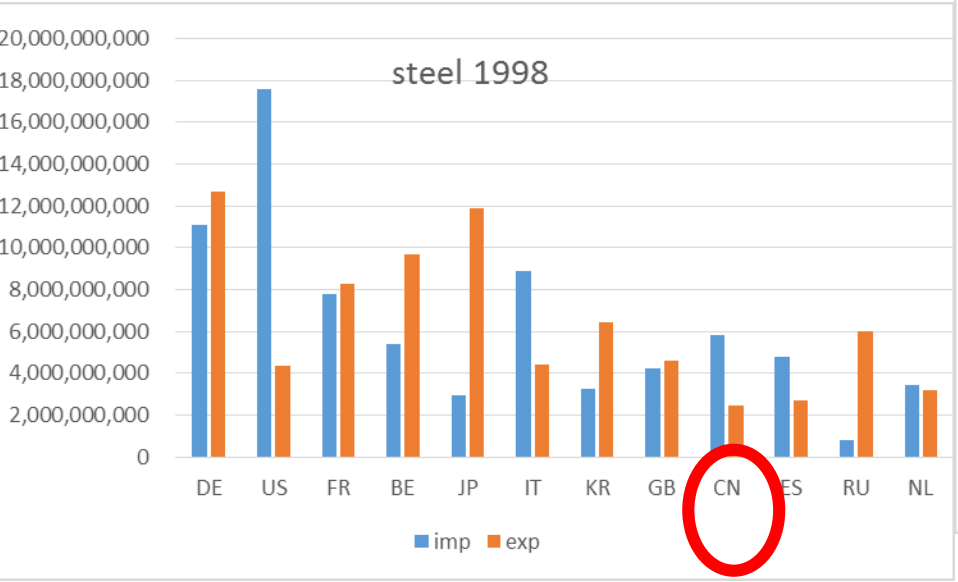

FI
SE
1.5
139
CA
833
ND
177
415
RU
799
355
US
652
DK
174
PL
201
GB
BE
273
139
CZ
499
175
328
215
107
MX
170
465
314
223
139
FR
661
DE
439
224
233
116
CH
KR
650
PT
188
CN
1327
182
165
235
353
141
289
152
GR
96
IP
188
IT
HK
ES
285
295
144
TR
139
400
TH
386
IN
PE
737
SA
291
332
MY
12
BR
149
ZM
SG
312
CL
3044
497
AR
196
ID
AU
200
198
458
ZA
Cu 1992 M$

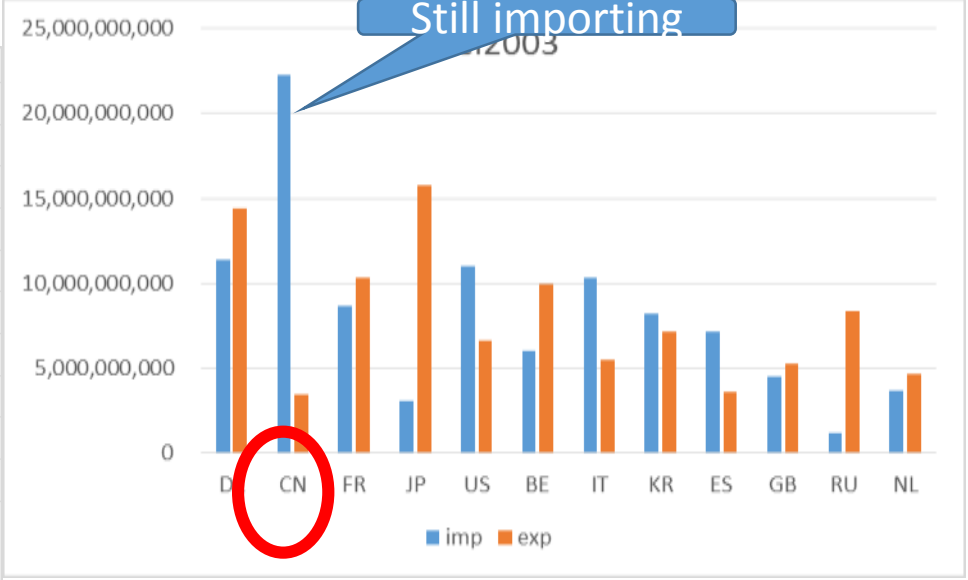

FI
SE
264
0.4
1.4
CA
1.4
ND
RU
1.5
US
2.5
PL
5.8
2.8
4.0
GB
BE
3.8
1.6
2.3
CZ
1.7
UA
MX
1.7
1.5
2.1
FR
1.5
DE
1.3
AT
3.2
0.3
CH
HU
2.8
1.9
KR
2.1
HR
CN
2.7
1.3
47.3
2.5
2.4
4.2
6.6
JP
3.7
ES
1.8
HK
1.8
IR
2.5
TR
2.2
12.1
1.4
VN
3.6
TH
2.1
IN
CD
1.8
MY
2.8
2.7
BR
2
3.3
SA
SG
1.3
0.7
ID
2.5
AU
NZ
26.5
AR
1.8
1.5
Cu 2012 B$

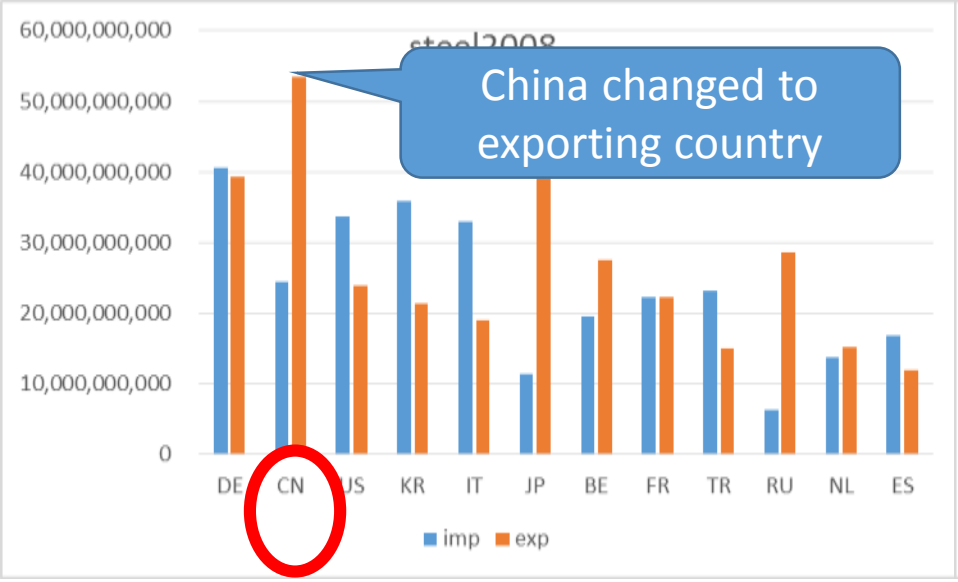


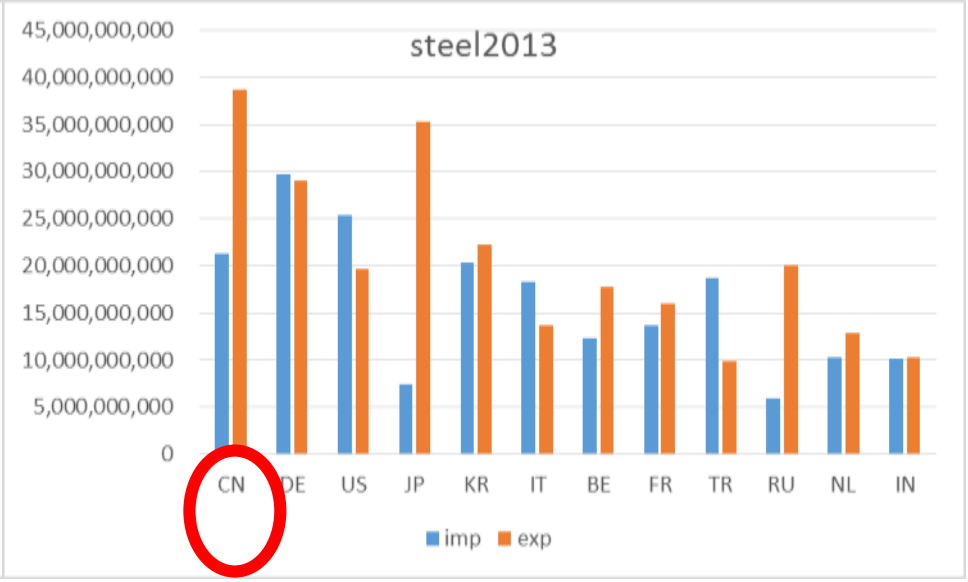
2601 iron ore 1992 M$


New flow is capped on the old trilateral structure
2601 iron ore 2012 B$
IS
IE
SE
NO
FI
99
243
CA
482
461
218
LT
E
171
ND
DK
US
263
268
178
GB
BE
LX
CZ
25
UA
MX
FR
1425
DE
MD
MN
CU
AT
47
RO
PT
CH
HR
MK
20
880
766
IT
SV
180
ES
3193
BA
HK
168
231
DZ
LB
PK
MA
IL
EZ
PH
150
1320
406
PE
56
832
CO
SR
426
TH
440
KW
GH
NG
SY
BN
135
TZ
109
32
MY
MZ
PG
138
CL
2381
BW
ZW
SA
SG
2013
NZ
YE
15
273
ZA
116


steel 1998
20,000,000,000
18,000,000,000
16,000,000,000
14,000,000,000
12,000,000,000
10,000,000,000
8,000,000,000
6,000,000,000
4,000,000,000
2,000,000,000
0
DE US FR BE JP IT KR GB CN ES RU NL
imp exp

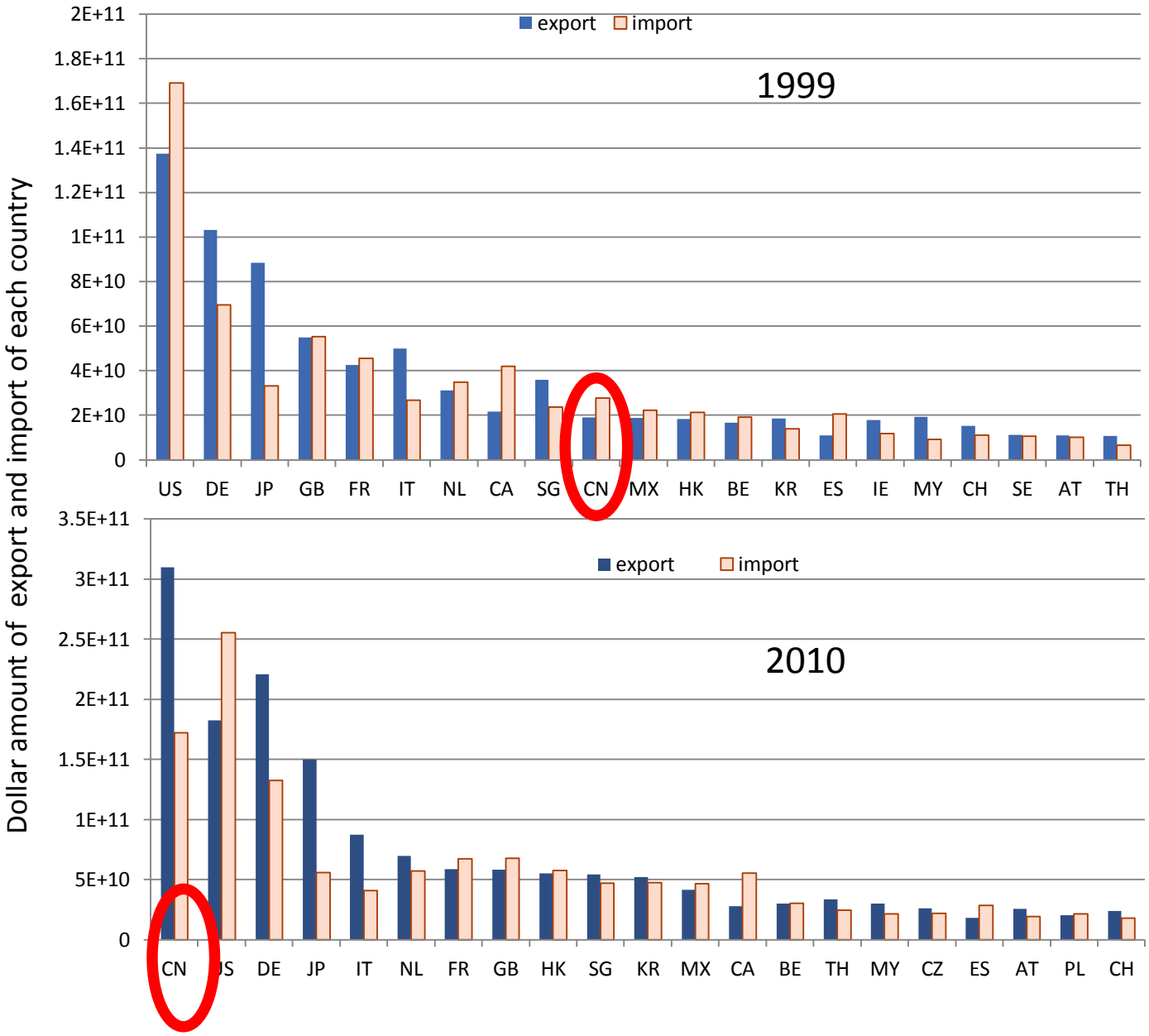

Still importing
25,000,000,000
20,000,000,000
15,000,000,000
10,000,000,000
5,000,000,000
0
CN FR JP US BE IT KR ES GB RU NL
imp exp


China changed to exporting country
60,000,000,000
50,000,000,000
40,000,000,000
30,000,000,000
20,000,000,000
10,000,000,000
0
DE CN US KR IT JP BE FR TR RU NL ES
imp exp


steel2013
45,000,000,000
40,000,000,000
35,000,000,000
30,000,000,000
25,000,000,000
20,000,000,000
15,000,000,000
10,000,000,000
5,000,000,000
0
CN DE US JP KR IT BE FR TR RU NL IN
imp exp

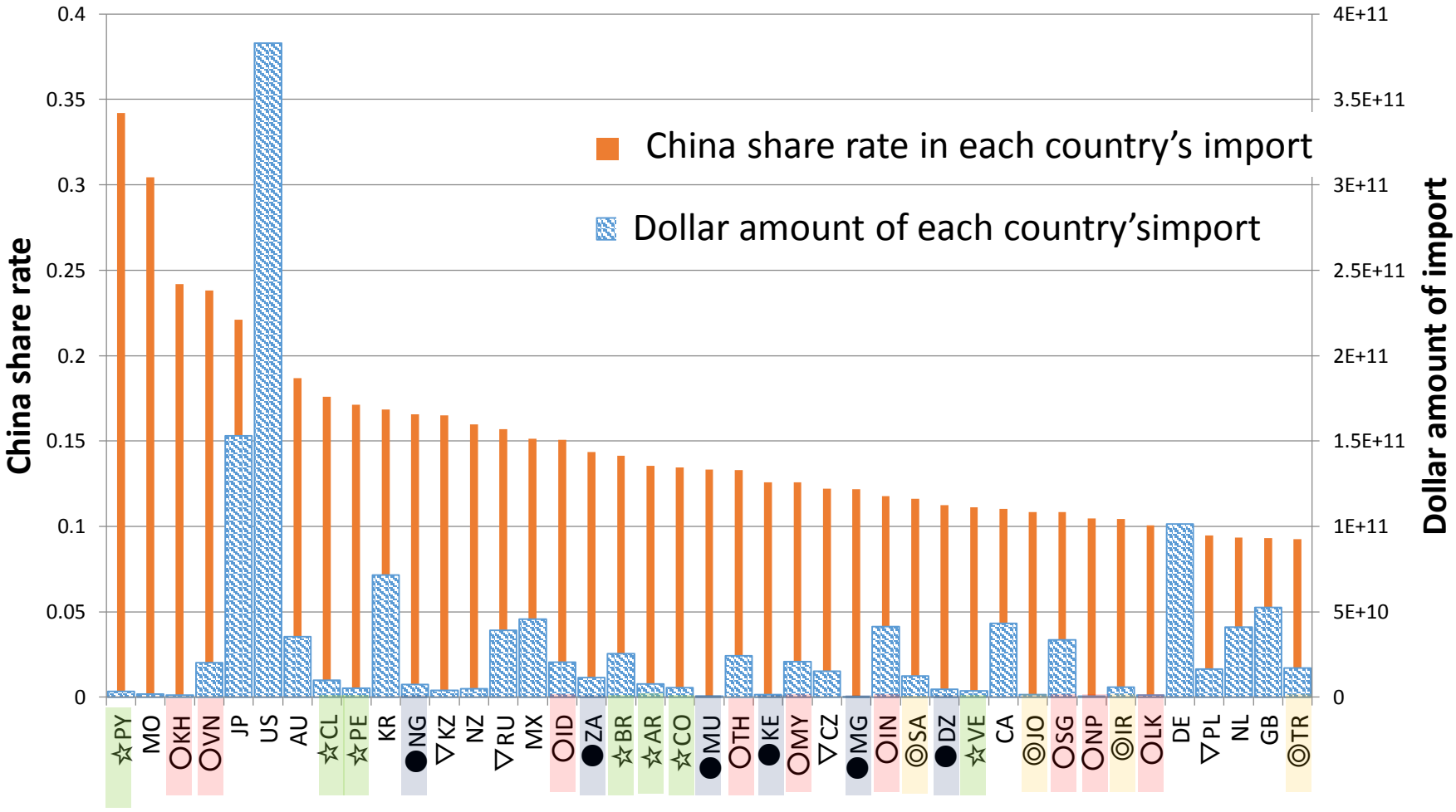
	Import		Export			Import		Export	
	1998	2013	1998	2013		1998	2013	1998	2013
Fe	US		JP	**CN**	W	DE	DE	US	**CN**
Cu	US	**CN**	CL	CL	Mo	DE	KR	AT	**CN**
Ni	US	**CN**	CA	CA	Ta	MX	US	US	CN
Al	US			**CN**	Co	US	**CN**	CA	
Zn	US	**CN**	CA	CA	Au		**HK**	KR	GB
Pb	US	US	AU	AU	Ag	GB	(IN)		(MX)
Mg	US		CN	**CN**	Pt	US	**CN**	ZA	ZA

Table 1: change of leading country of each metal trade from 1998 to 2013

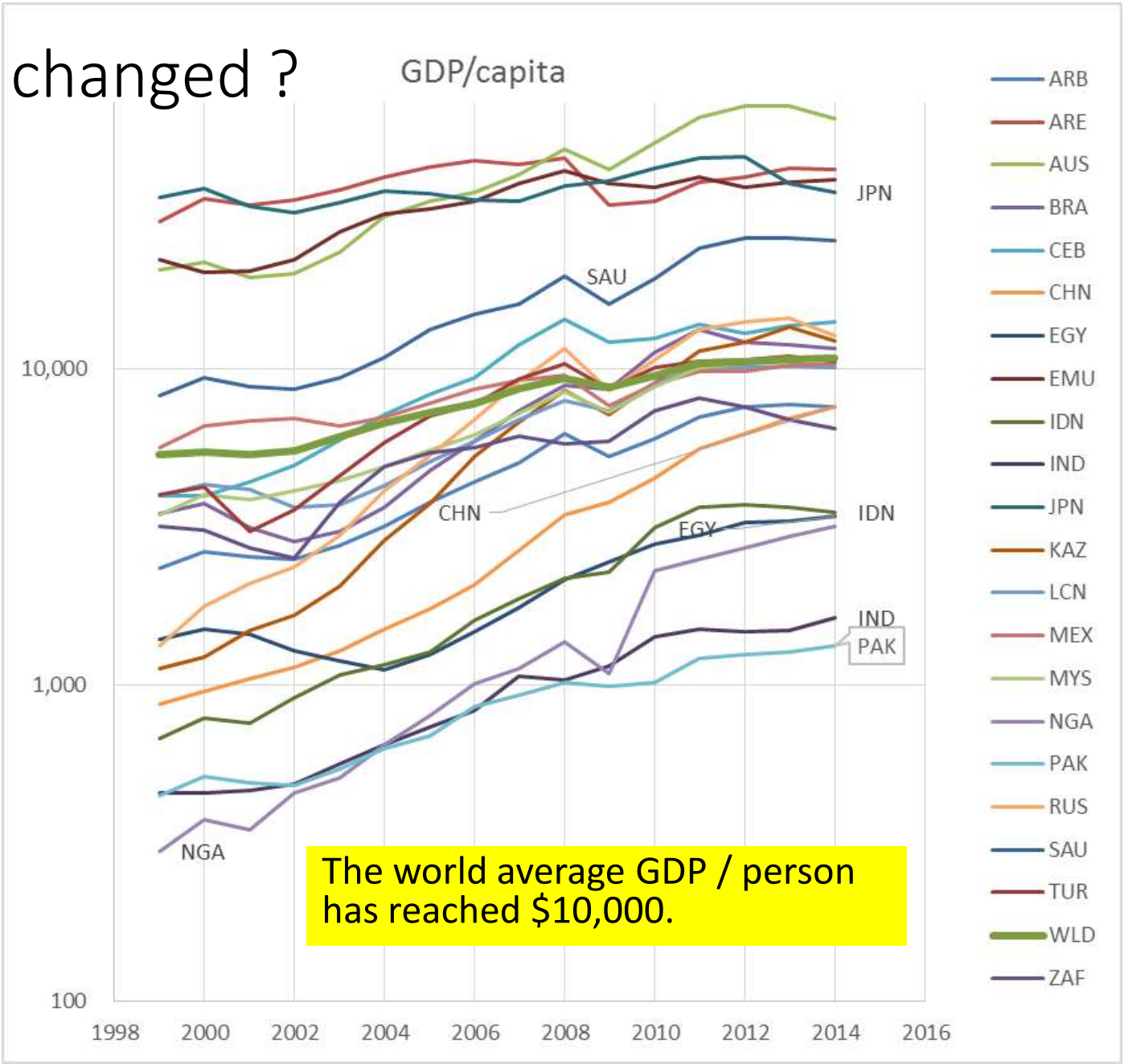

Dollar amount of export and import of each country
export
import
1999
2E+11
1.8E+11
1.6E+11
1.4E+11
1.2E+11
1E+11
8E+10
6E+10
4E+10
2E+10
0
US DE JP GB FR IT NL CA SG CN MX HK BE KR ES IE MY CH SE AT TH
export
import
2010
3.5E+11
3E+11
2.5E+11
2E+11
1.5E+11
1E+11
5E+10
0
CN US DE JP IT NL FR GB HK SG KR MX CA BE TH MY CZ ES AT PL CH

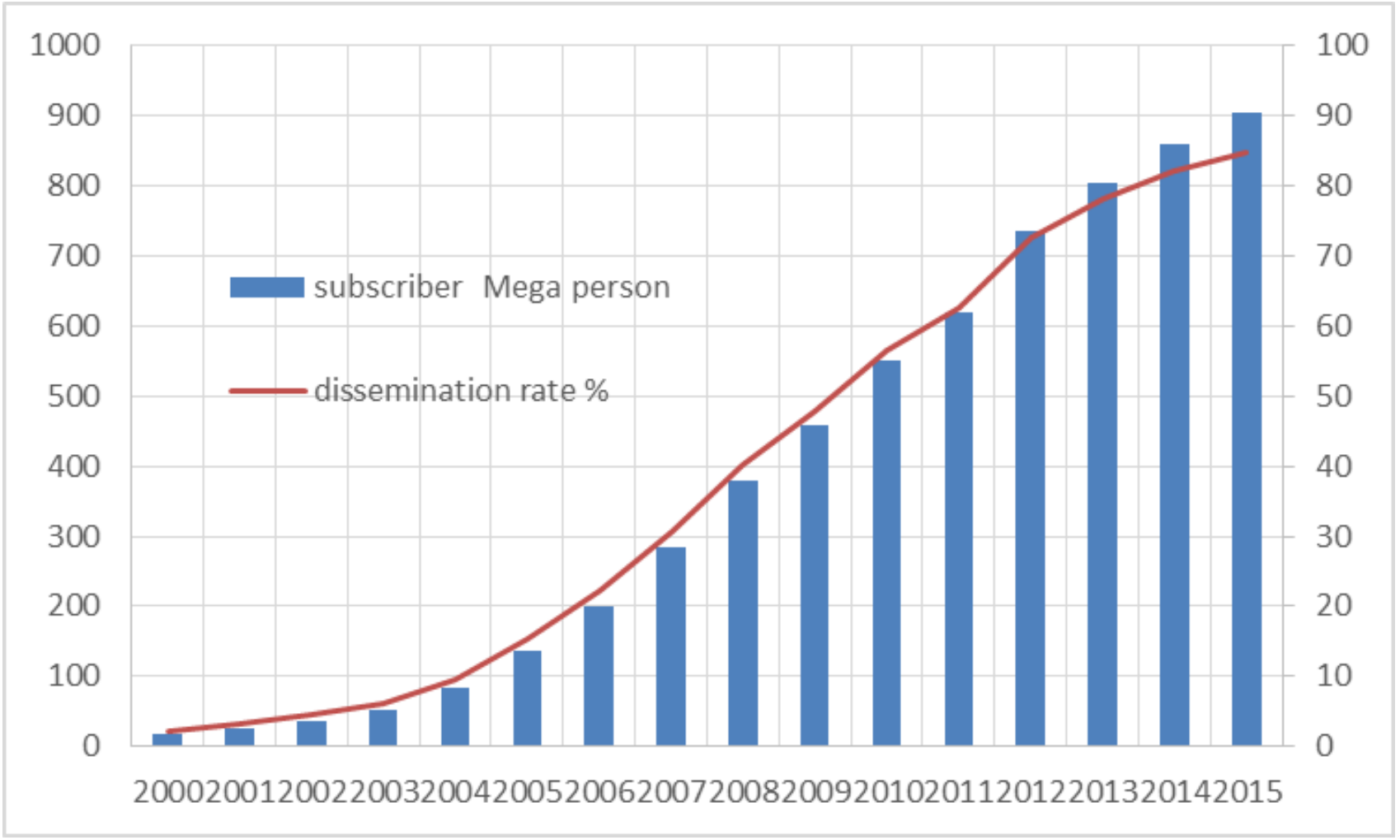
China exports products to developing countries all over the world as “the factory of the world.

Behind the concentration of resources to China, the requirement of developing countries exists widely.

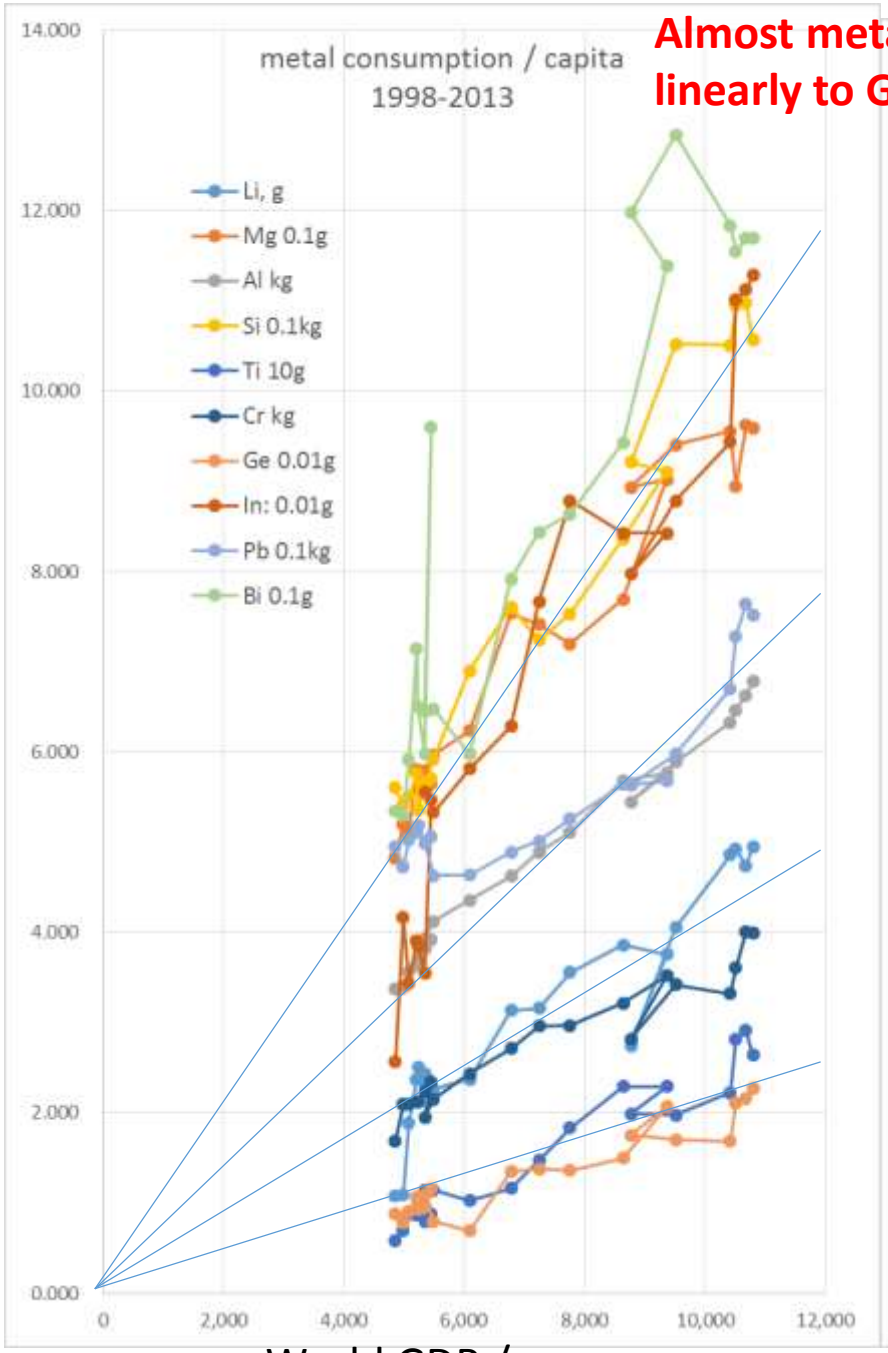


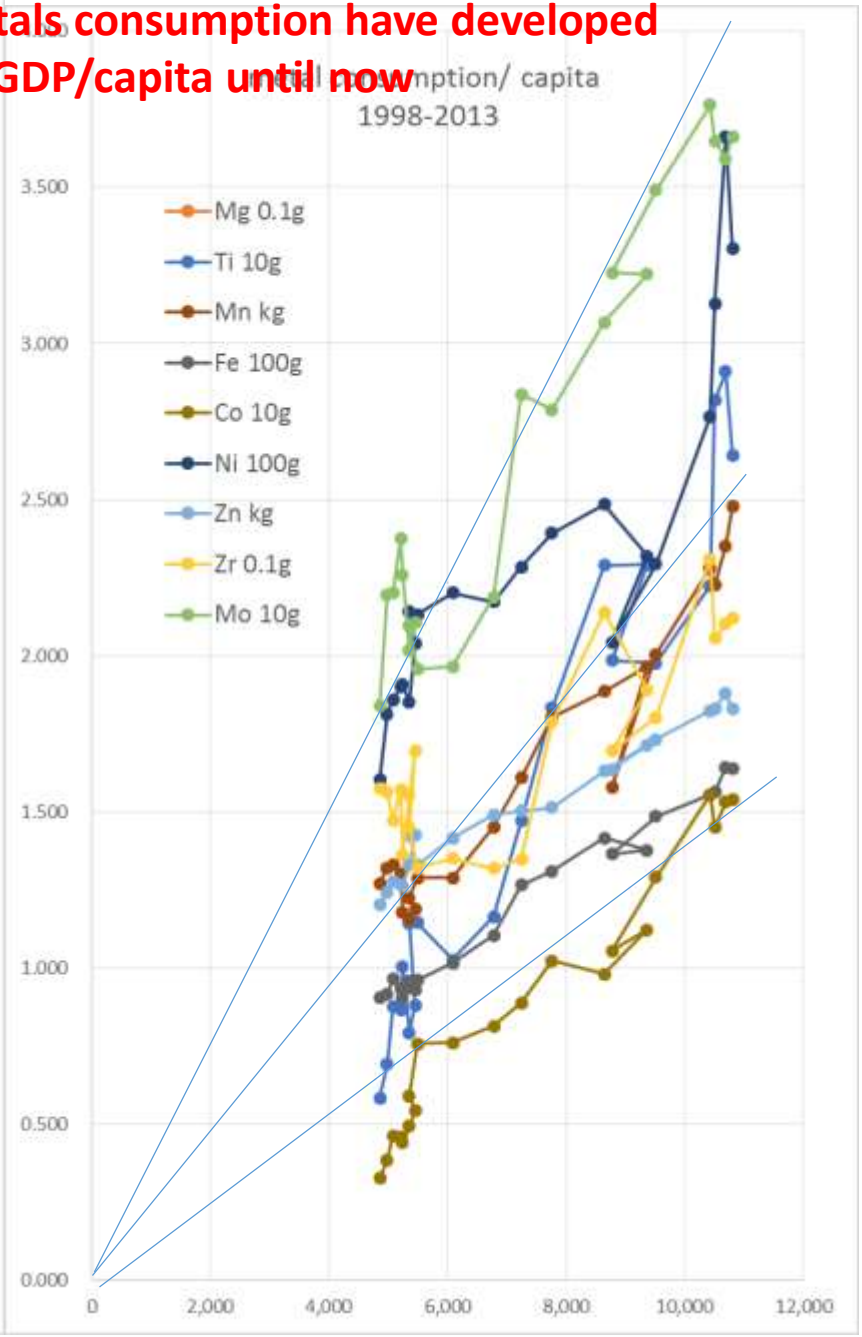
What has changed ?




1000
900
800
700
600
500
400
300
200
100
0
100
90
80
70
60
50
40
30
20
10
0
subscriber Mega person
dissemination rate %
2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015

Almost metals consumption have developed linearly to GDP/capita until now

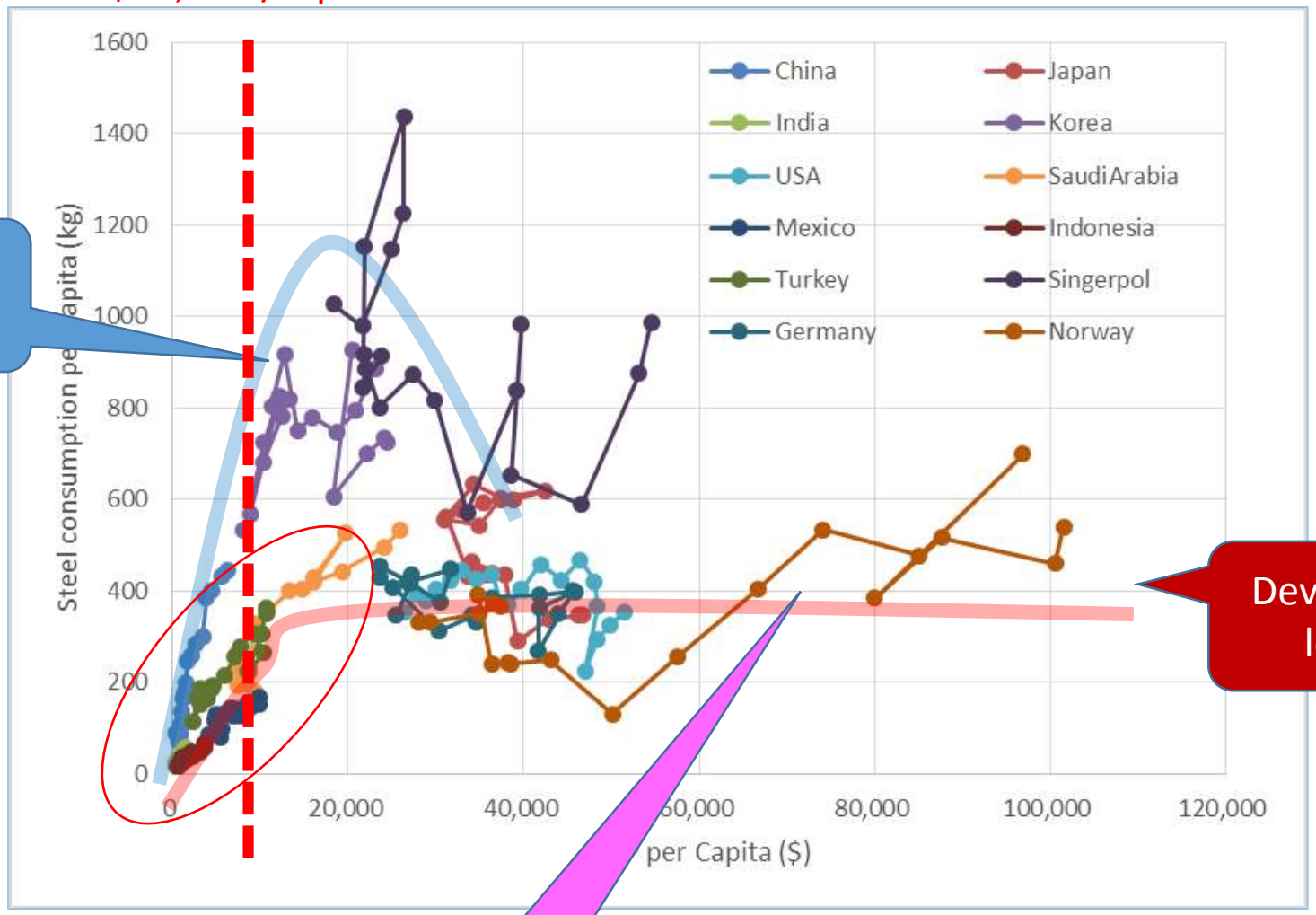




World GDP / person

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

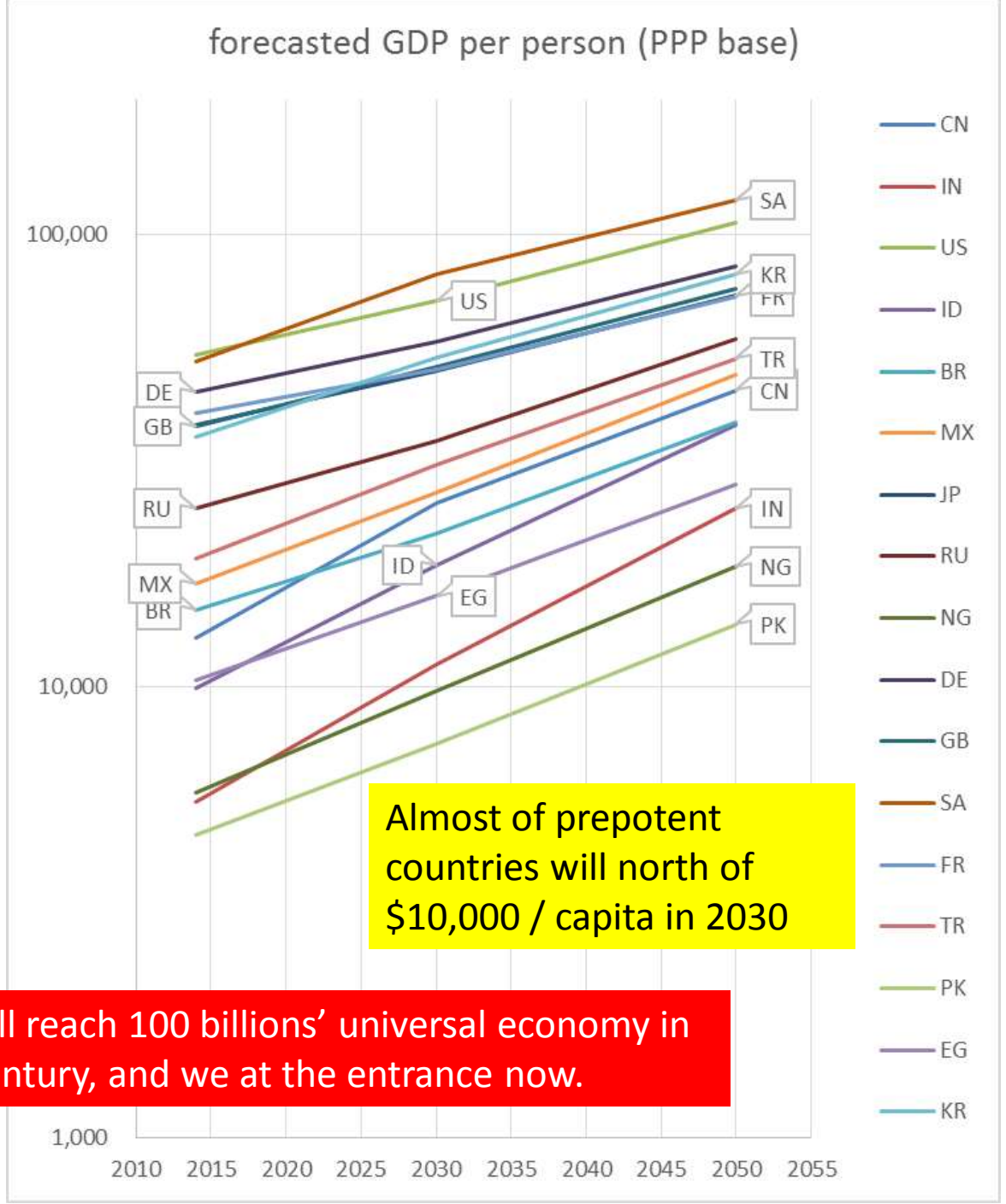
$10,000 /capita



Exporting countries

Developed level

Consuming countries

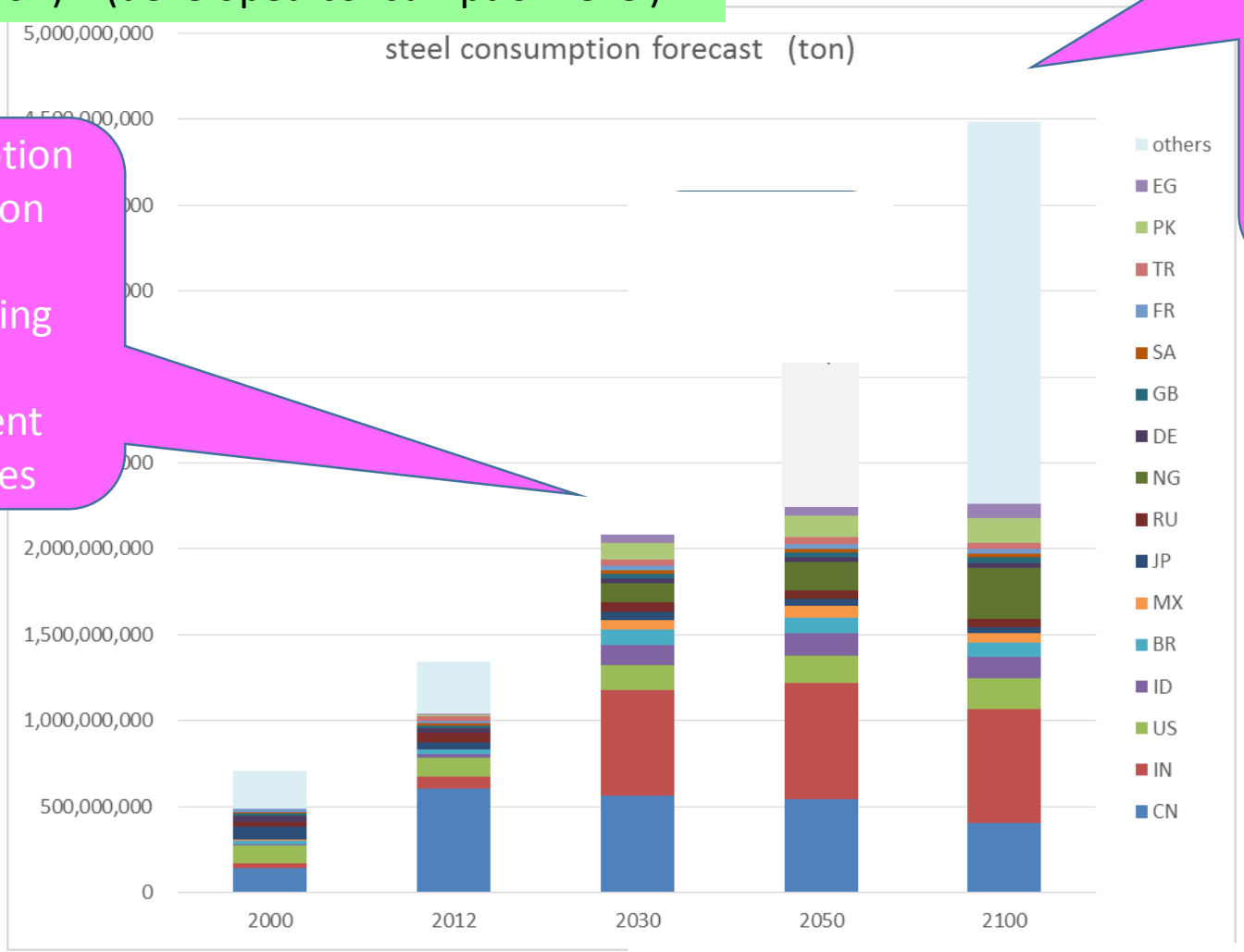


We will reach 100 billions' universal economy in this century, and we at the entrance now.

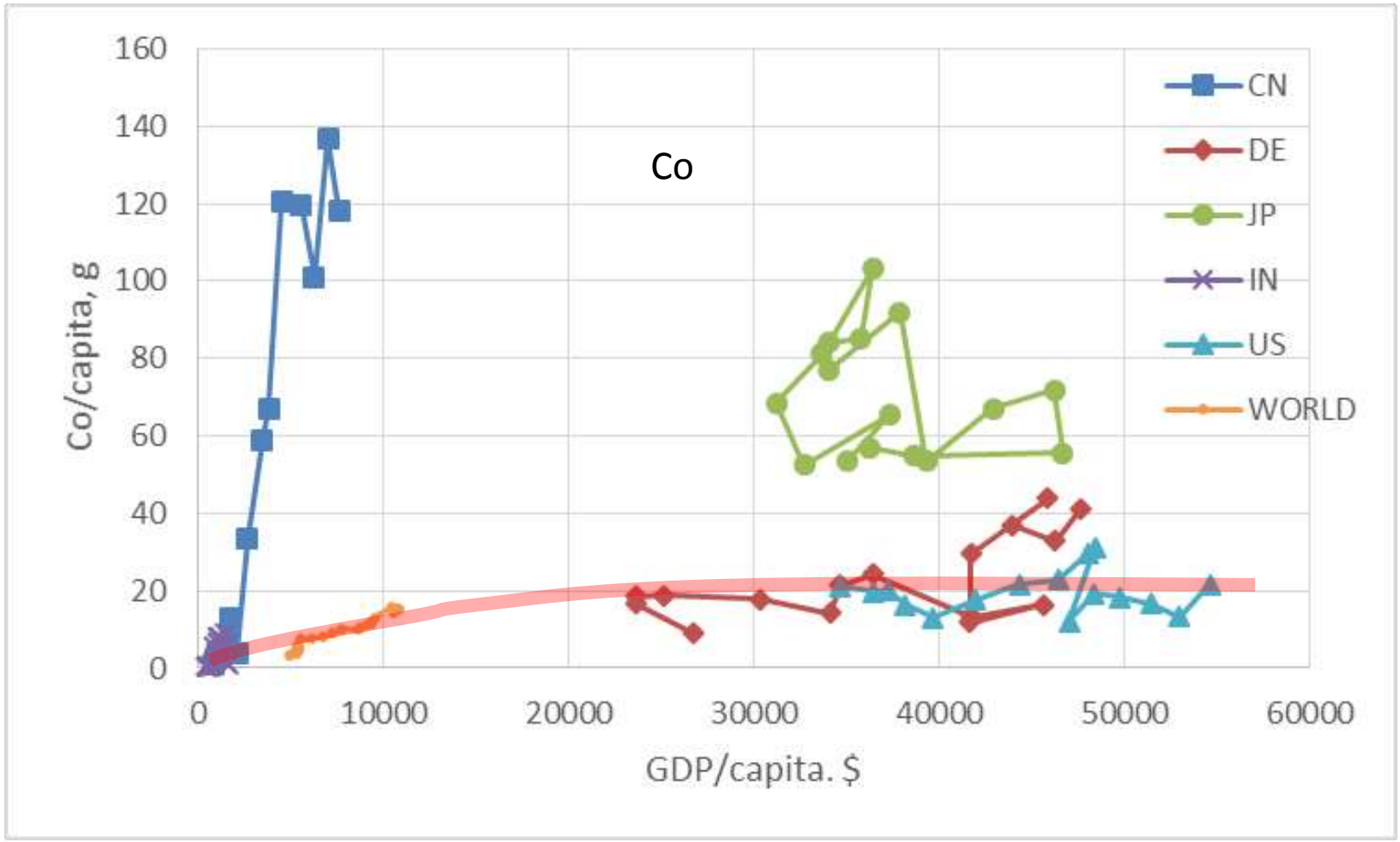
Rough forecast gets to be simpler,
(population) x (developed consumption level)

Every country reaches developed level of consumption per capita

Consumption prediction with concerning only prepotent countries



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

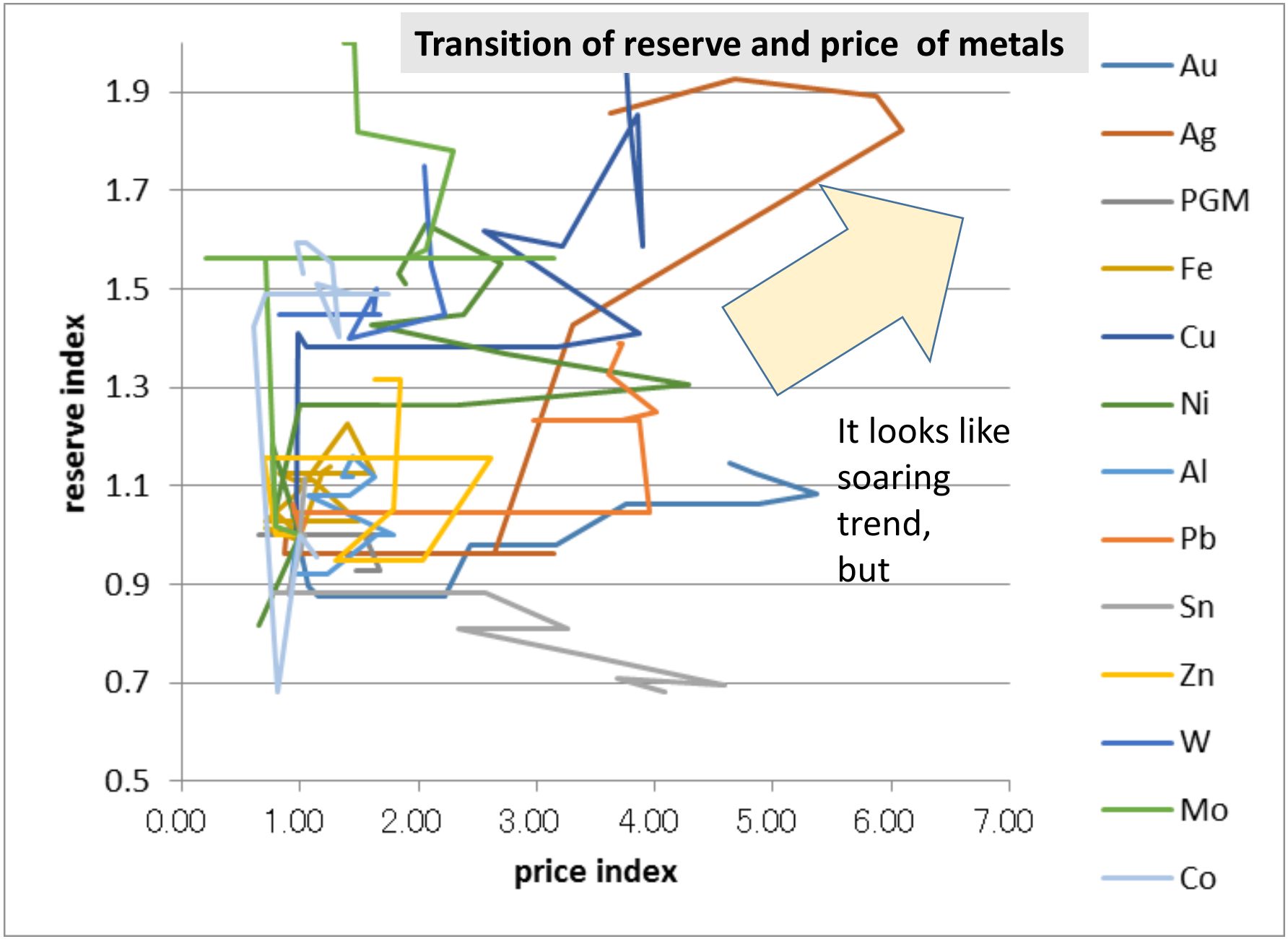

Co
Co/capita, g
GDP/capita. $
0
20
40
60
80
100
120
140
160
0
10000
20000
30000
40000
50000
60000
CN
DE
JP
IN
US
WORLD

Are the reserves enough for the 10 billions’ universal economy?

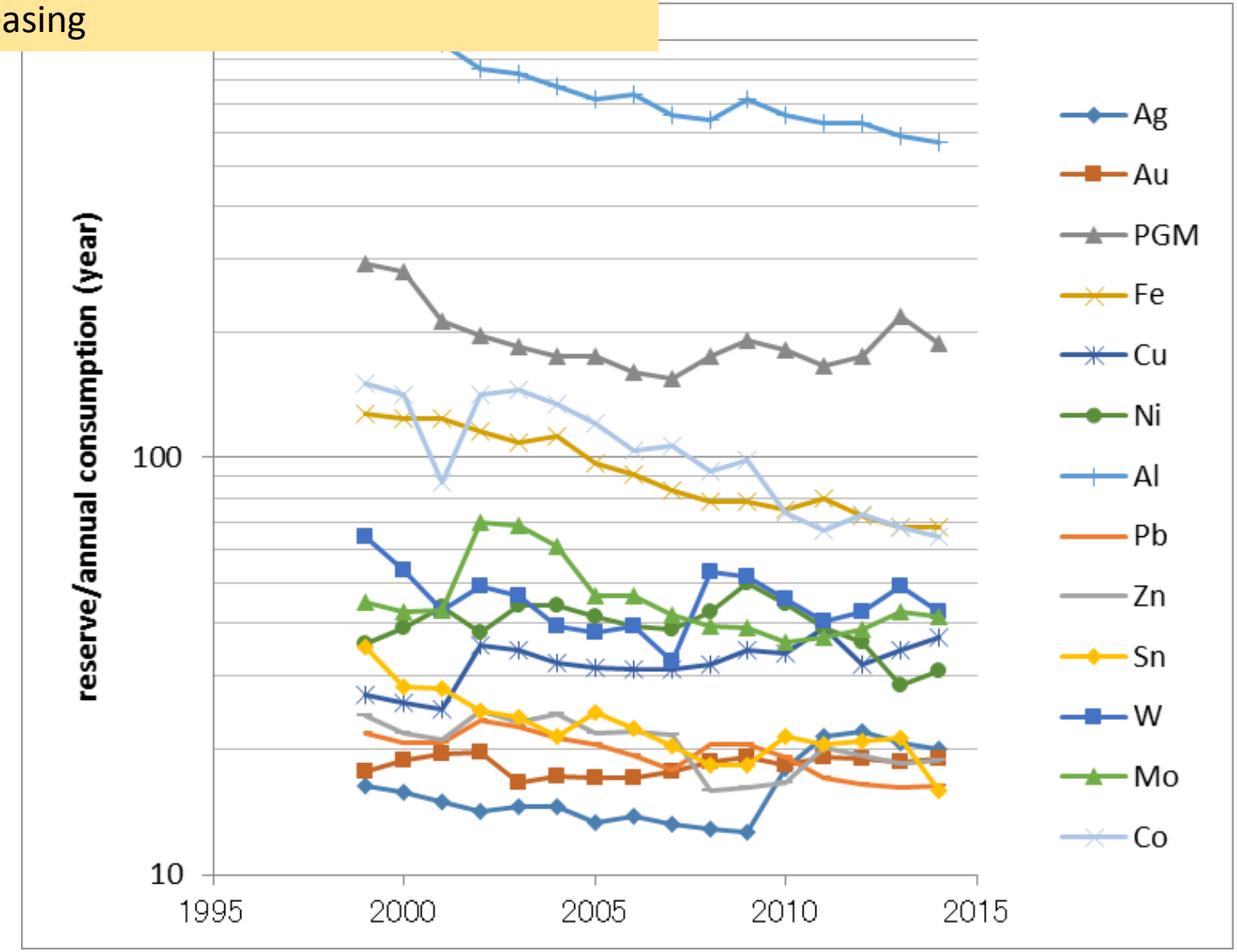
metal	Fe	Cu	Co
Consumption/year at 10Gperson world	4.5Gton/year	90Mt/year	224kt/year
Reserve	87Gton	700Mt	7.2Mt

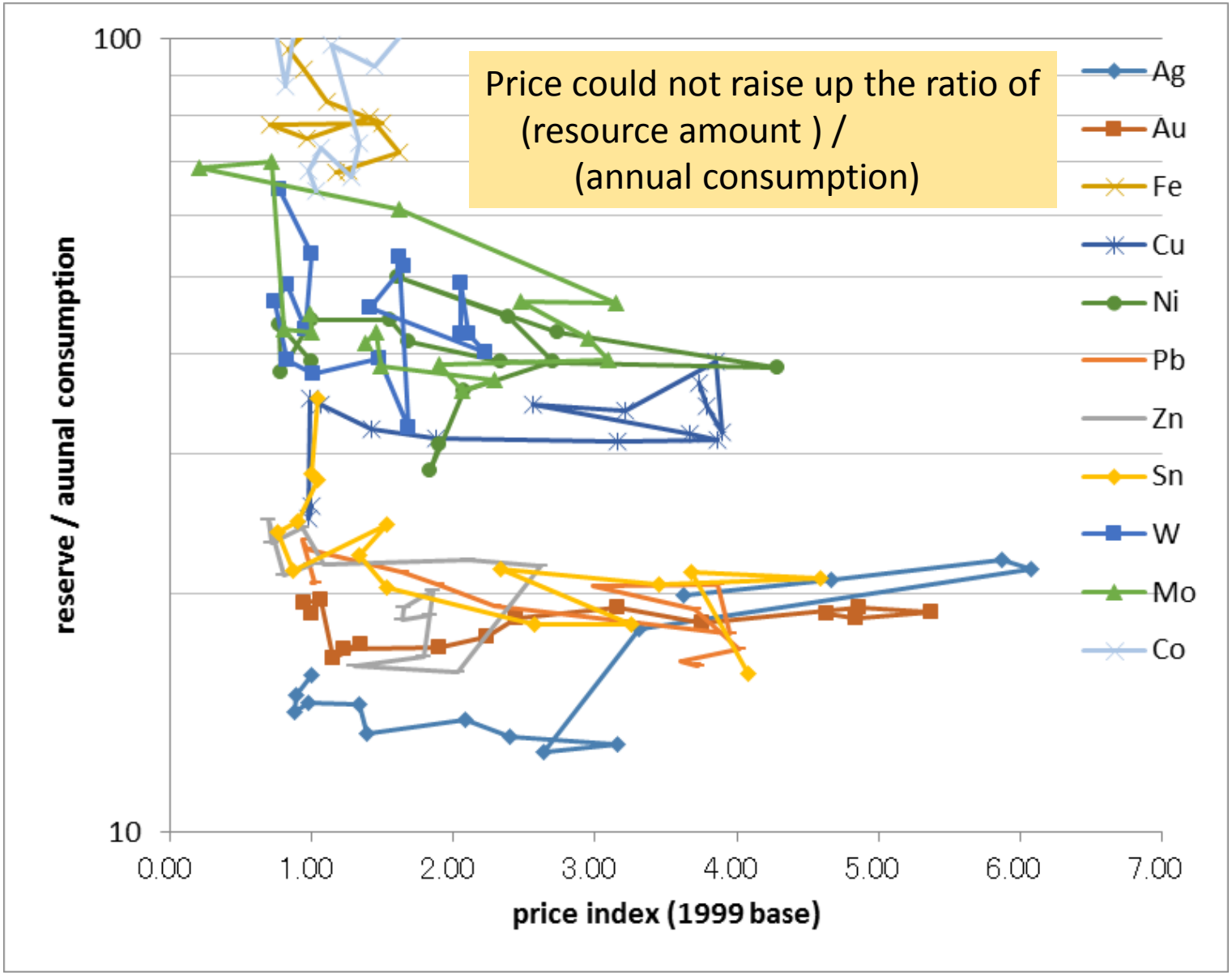
It is said that reserve increase when the price rises.

Prices had risen in these dozen of years.
How are reserves?

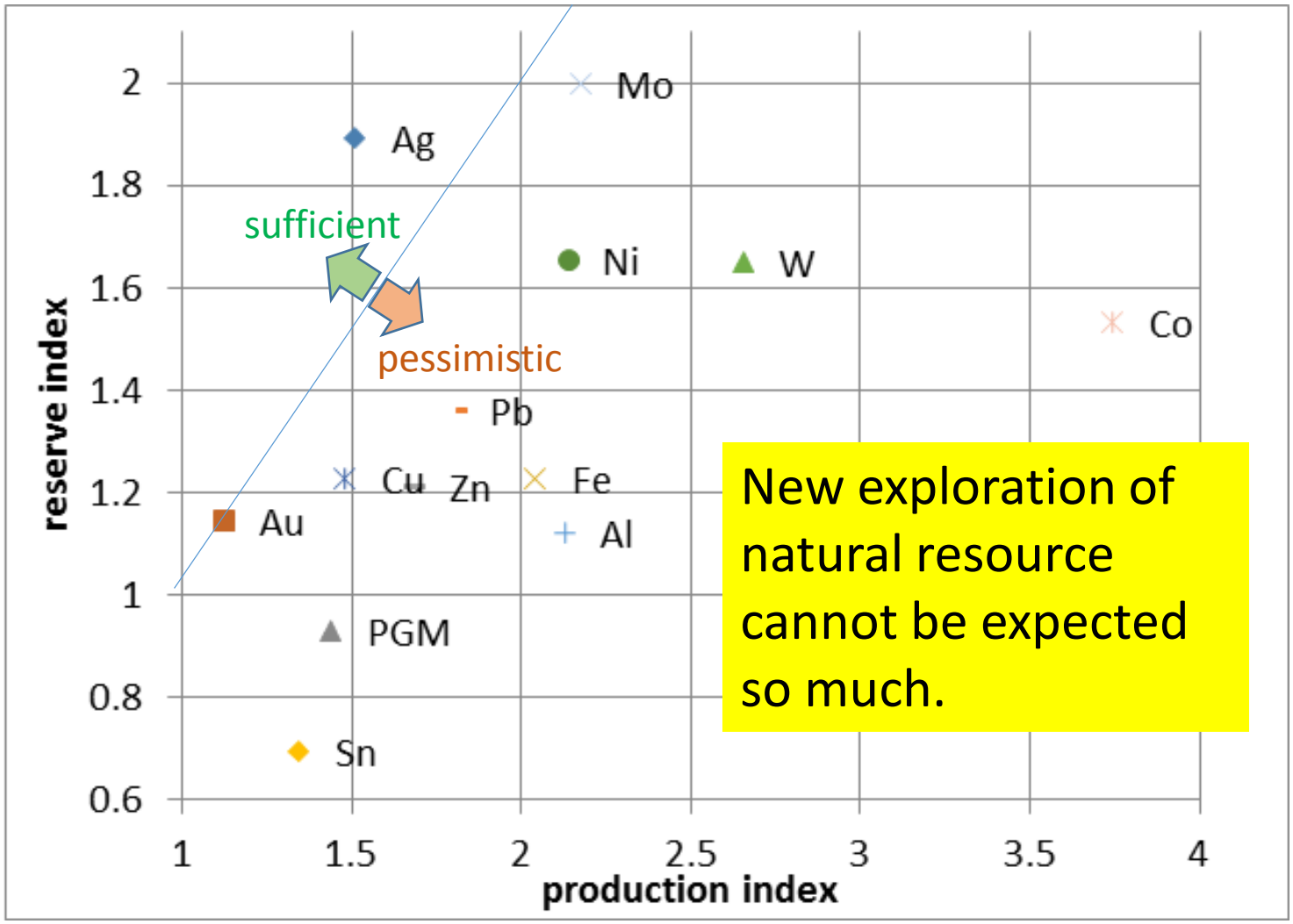

Transition of reserve and price of metals
reserve index
1.9
1.7
1.5
1.3
1.1
0.9
0.7
0.5
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
price index
It looks like soaring trend, but
Au
Ag
PGM
Fe
Cu
Ni
Al
Pb
Sn
Zn
W
Mo
Co

Reserve ratio to annual consumption is decreasing




Price could not raise up the ratio of
(resource amount) /
(annual consumption)
100
10
reserve / auunal consumption
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
price index (1999 base)
Ag
Au
Fe
Cu
Ni
Pb
Zn
Sn
W
Mo
Co

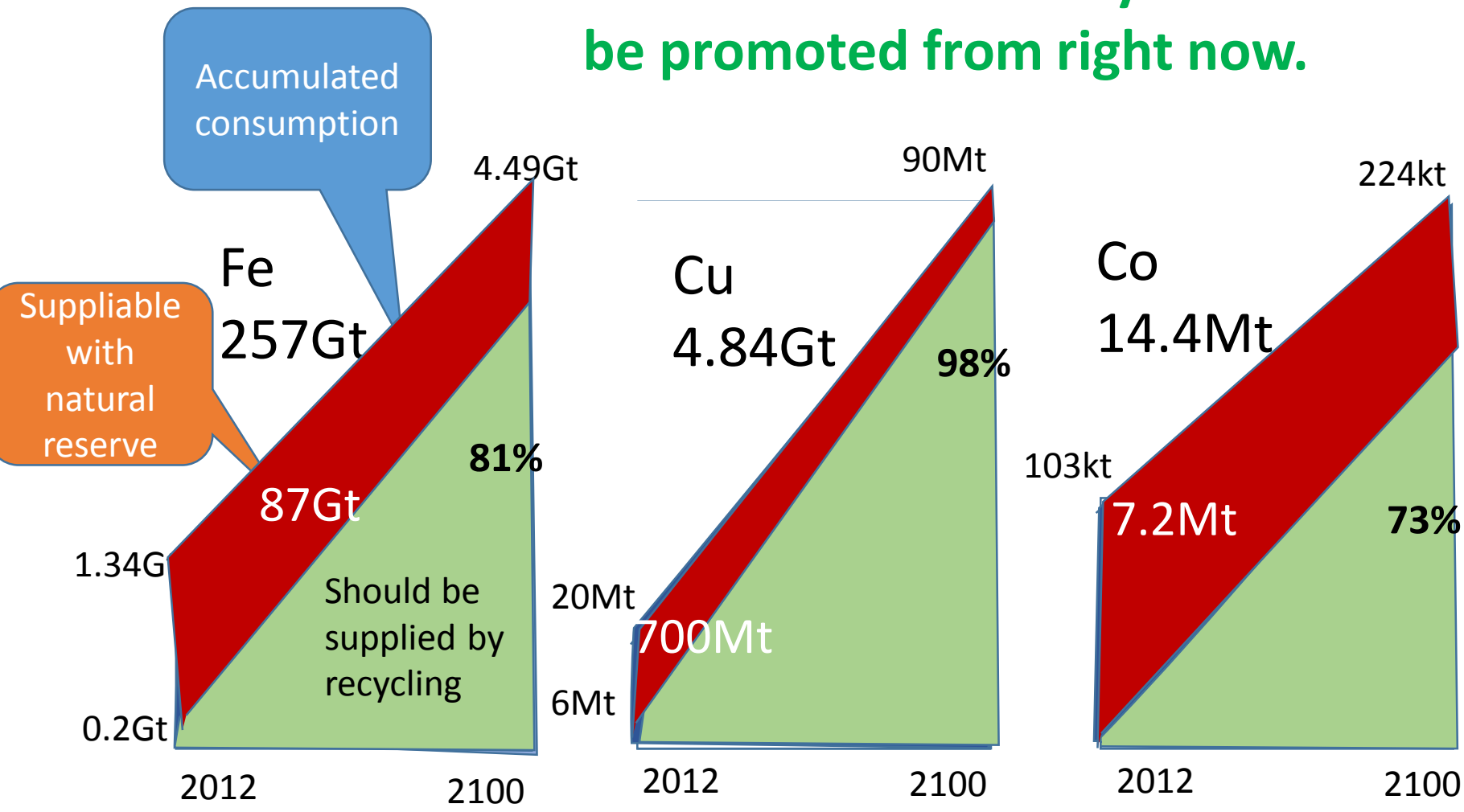
Sustainable reserve development line



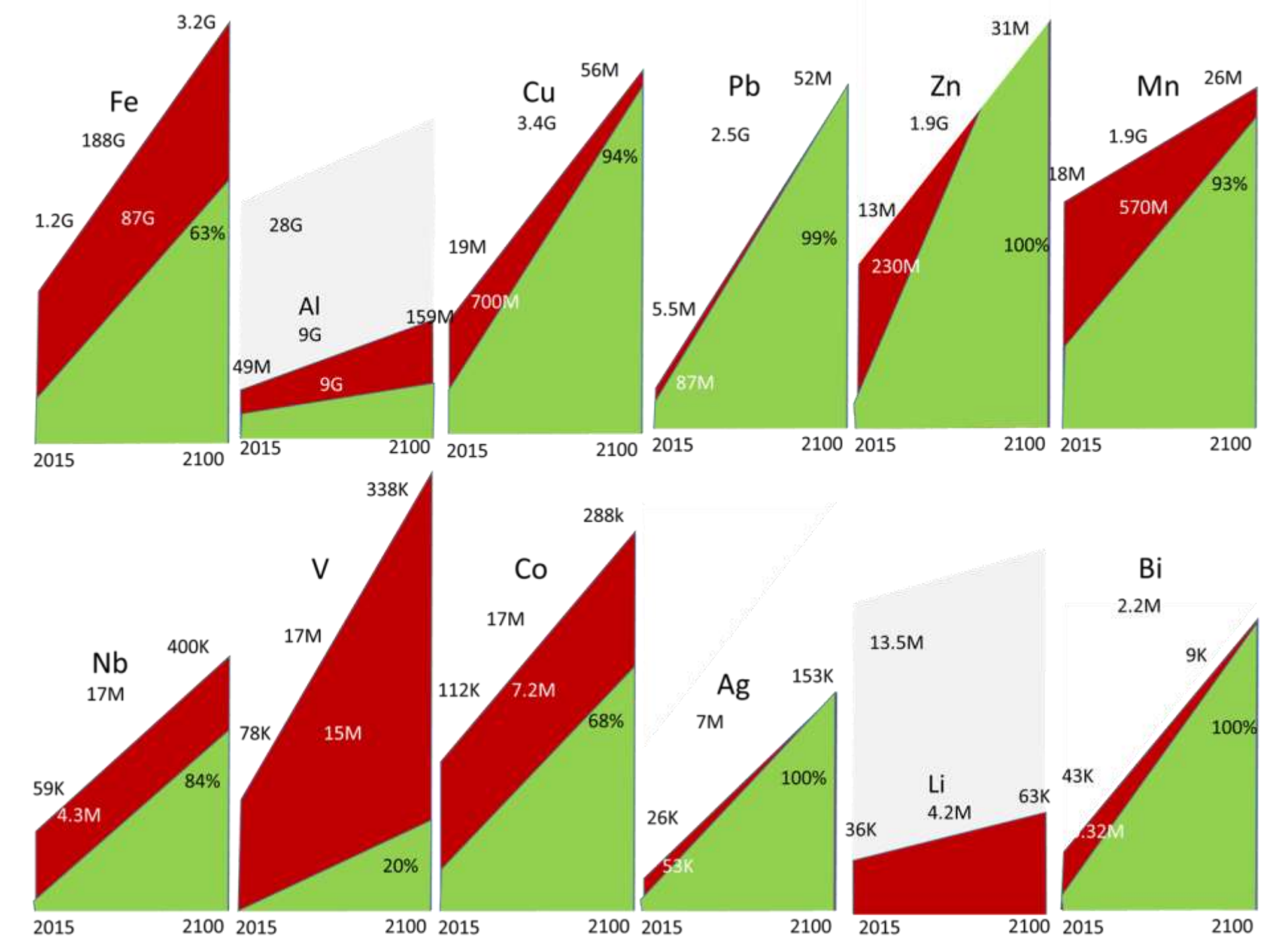
New exploration of natural resource cannot be expected so much.

What can solve it?

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
49M
9G
159M
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
100%
13M
230M
2015
2100
Mn
26M
1.9G
93%
18M
570M
2015
2100
Nb
400K
17M
84%
59K
4.3M
2015
2100
V
338K
17M
78K
15M
20%
2015
2100
Co
288k
17M
112K
7.2M
68%
2015
2100
Ag
153K
7M
100%
26K
53K
2015
2100
Li
13.5M
63K
4.2M
36K
2015
2100
Bi
2.2M
9K
100%
43K
.32M
2015
2100

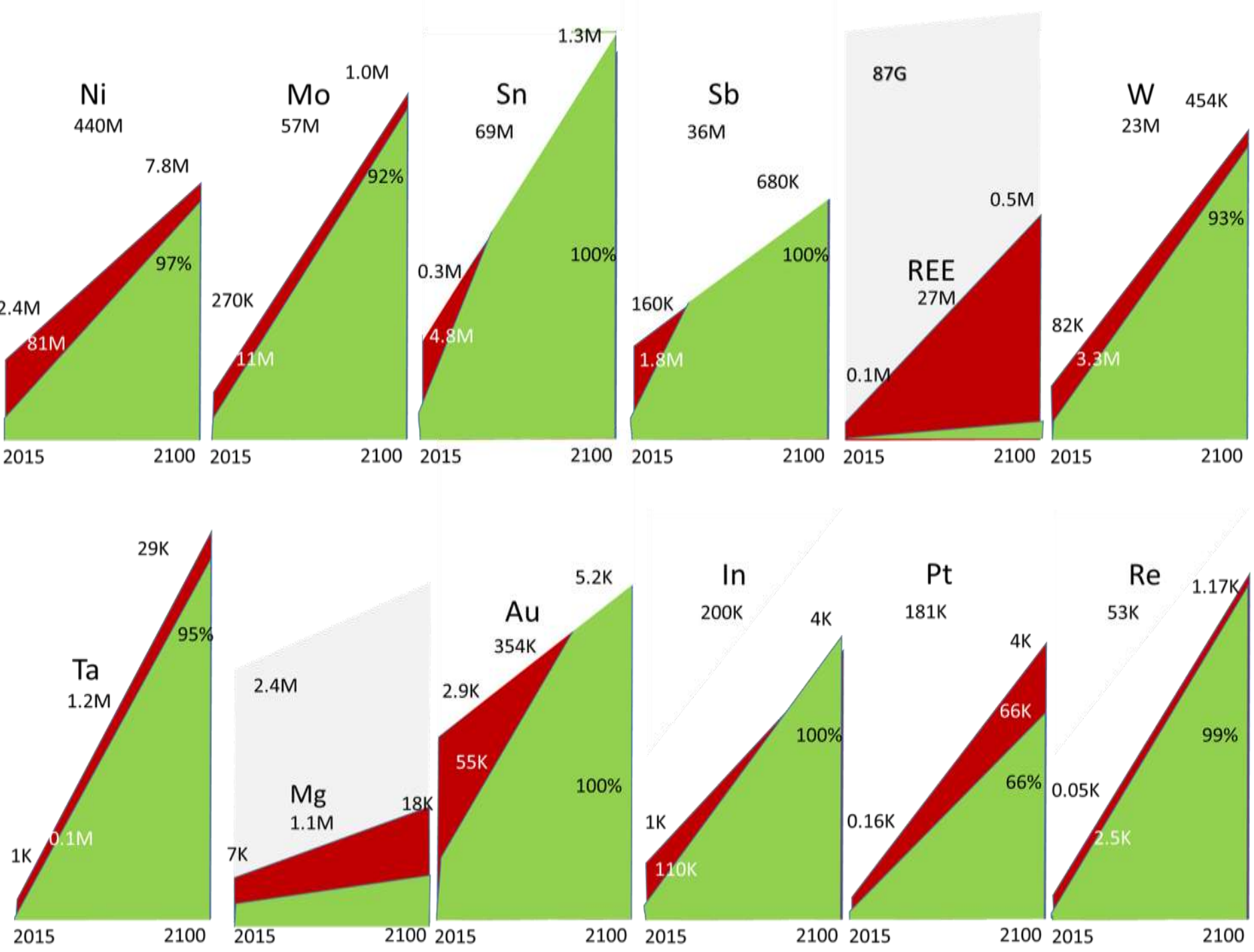
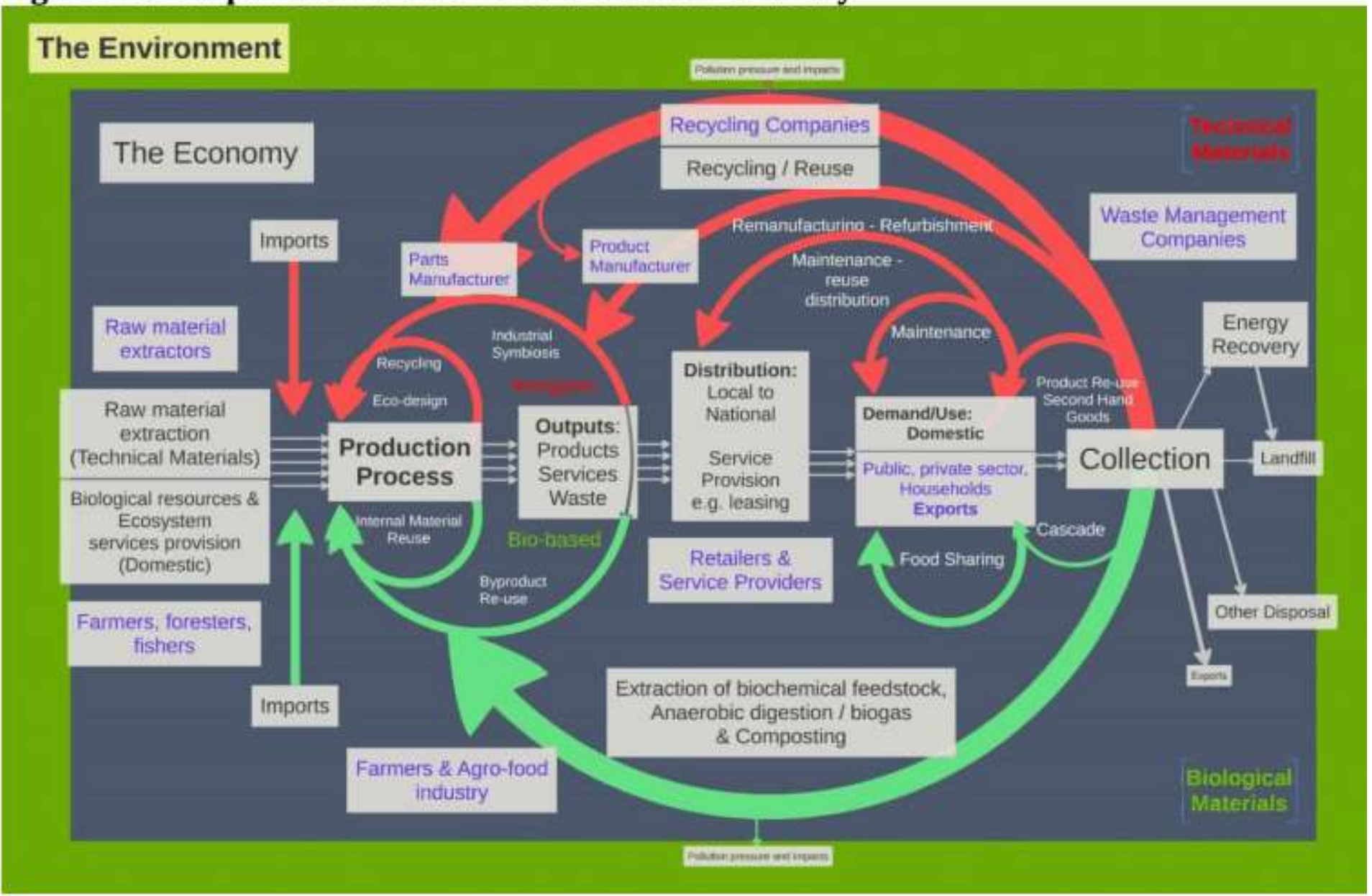
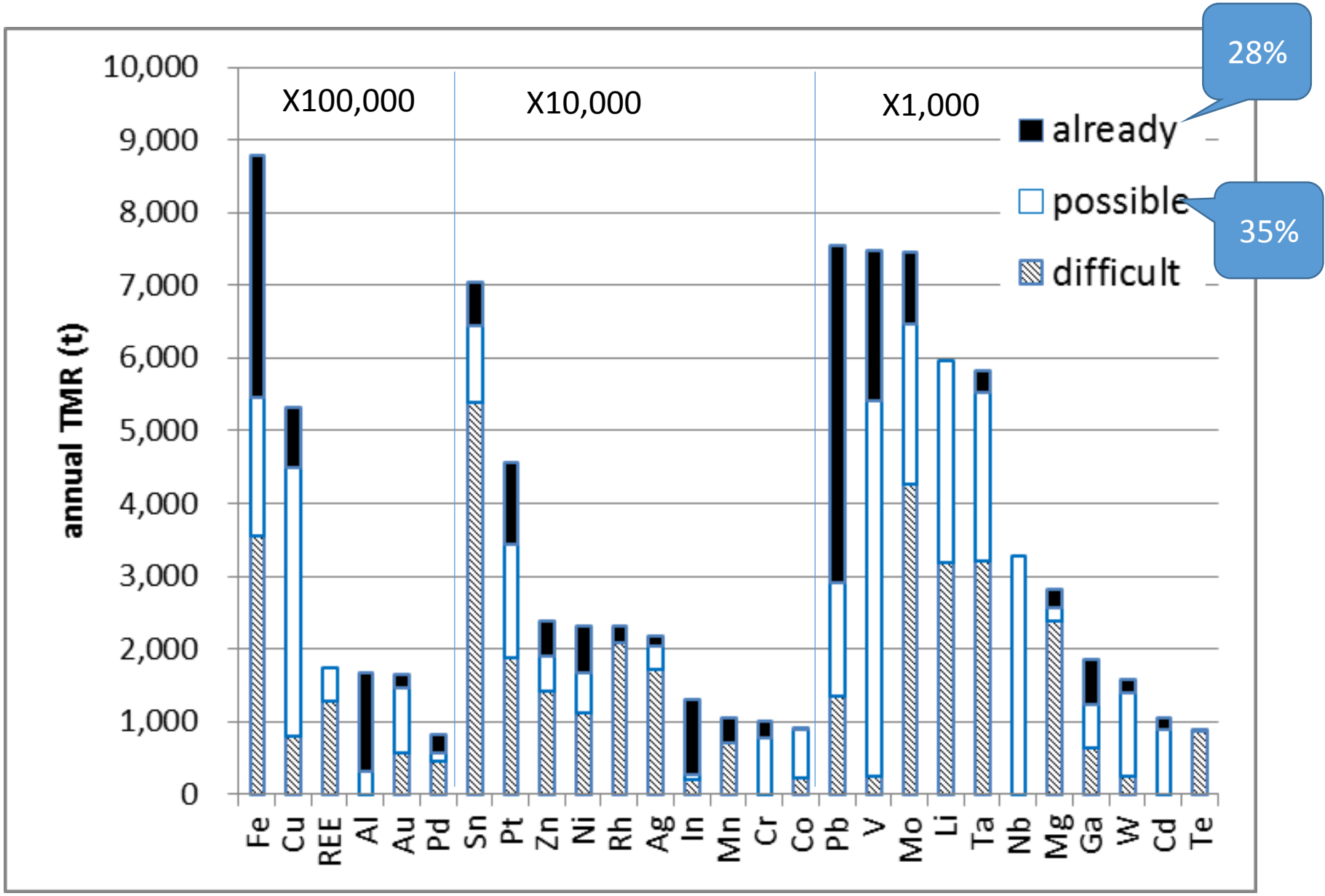
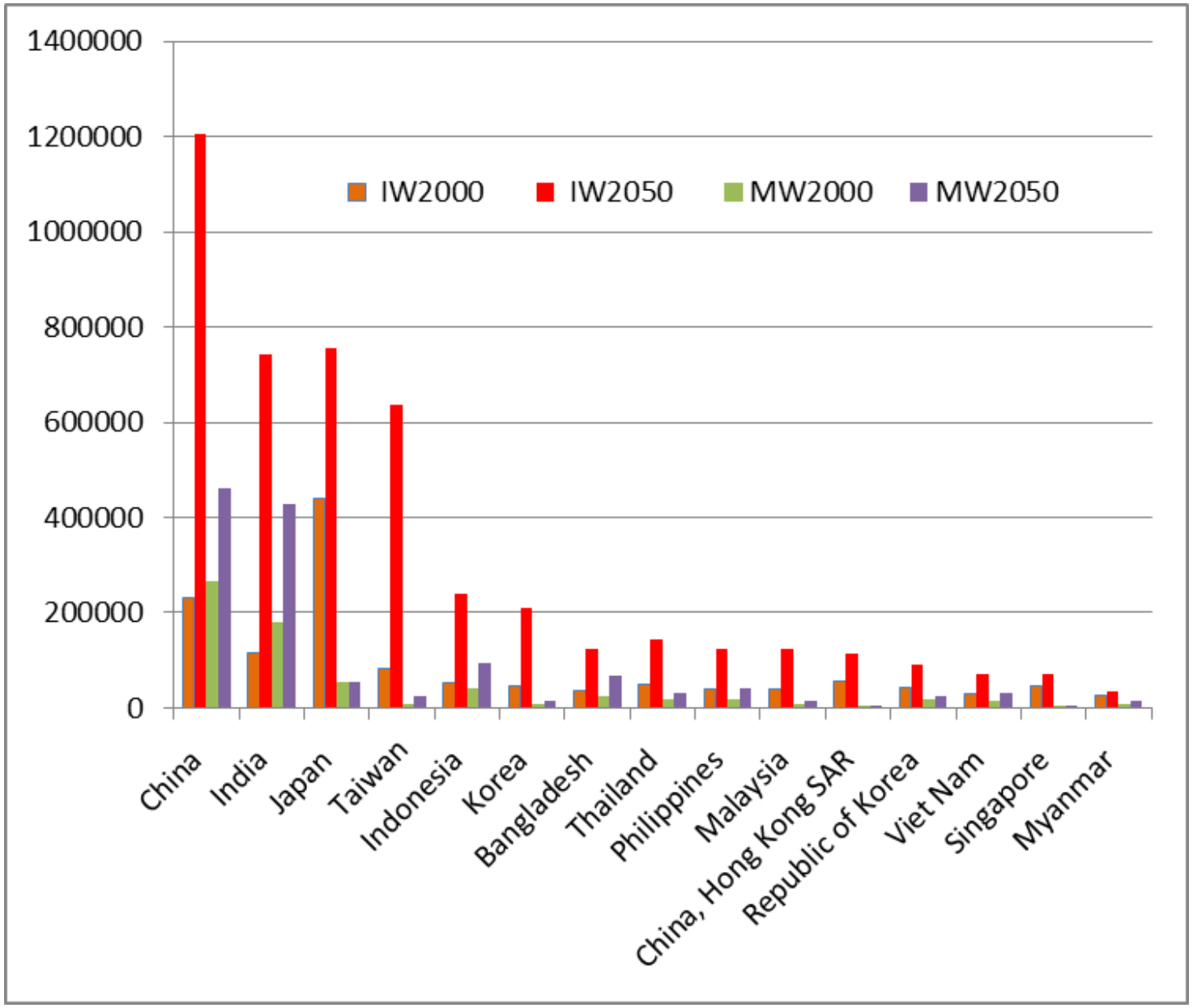

Ni
440M
7.8M
97%
2.4M
81M
2015
2100
Mo
57M
1.0M
92%
270K
11M
2015
2100
Sn
69M
1.3M
100%
0.3M
4.8M
2015
2100
Sb
36M
680K
100%
160K
1.8M
2015
2100
87G
REE
27M
0.5M
0.1M
2015
2100
W
23M
454K
93%
82K
3.3M
2015
2100
Ta
1.2M
29K
95%
1K
0.1M
2015
2100
2.4M
Mg
1.1M
18K
7K
2015
2100
Au
354K
5.2K
2.9K
55K
100%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

Figure E2: Simplified illustration of a circular economy

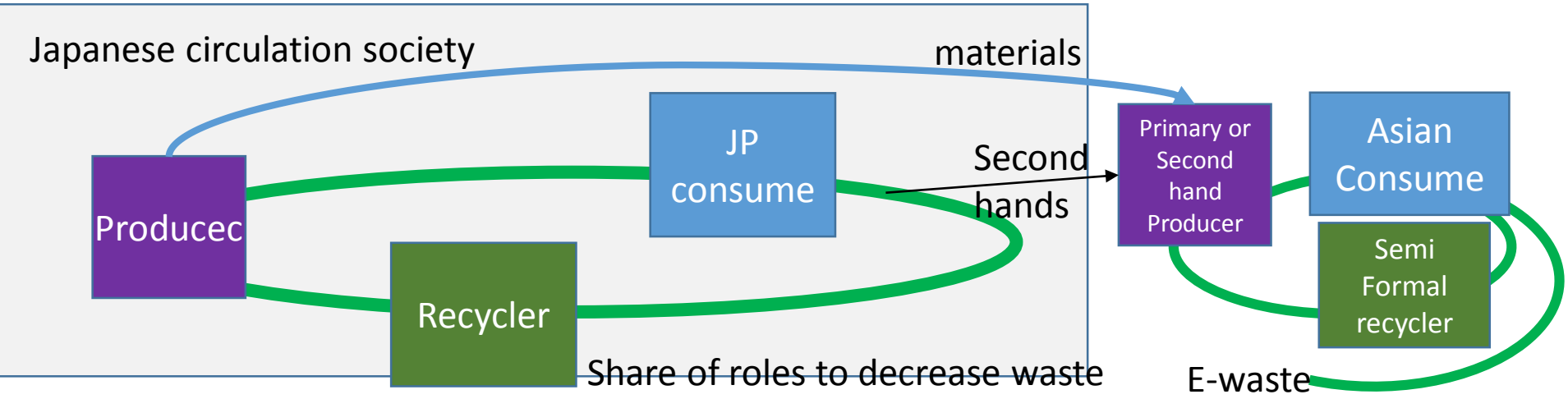


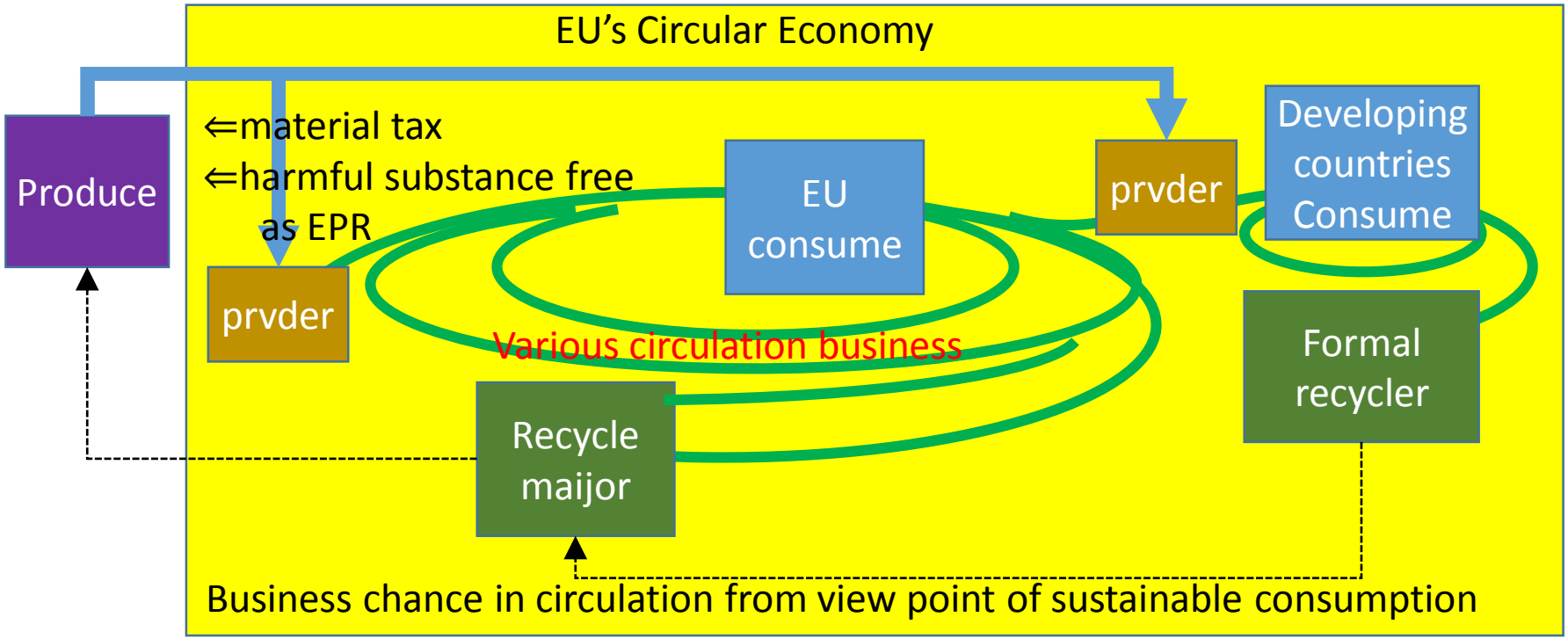
Source: Own representation, P ten Brink, P Razzini, S. Withana and E. van Dijl (IEEP), 2014

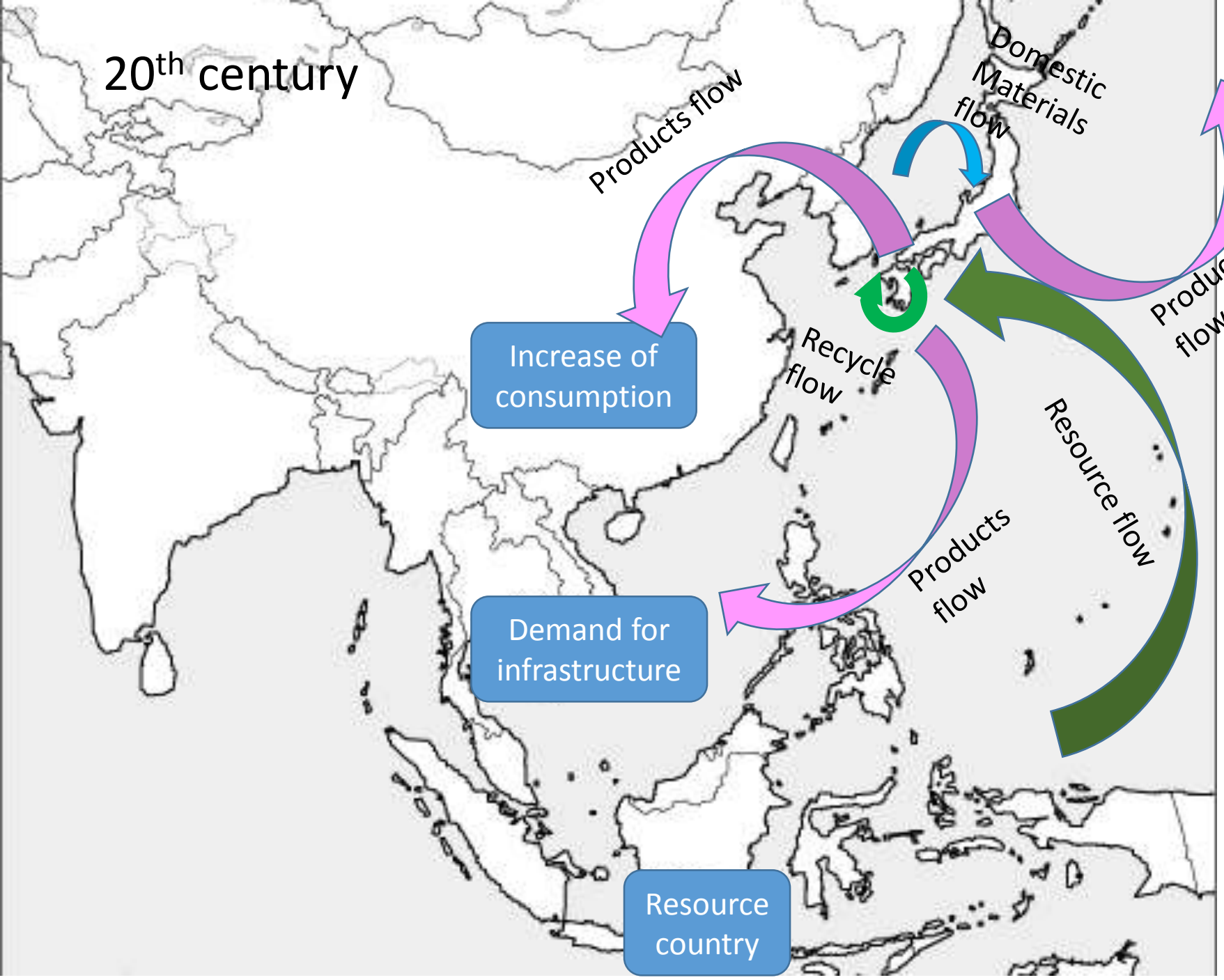

28%
35%
annual TMR (t)
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
X100,000
X10,000
X1,000
already
possible
difficult
Fe
Cu
REE
Al
Au
Pd
Sn
Pt
Zn
Ni
Rh
Ag
In
Mn
Cr
Co
Pb
V
Mo
Li
Ta
Nb
Mg
Ga
W
Cd
Te

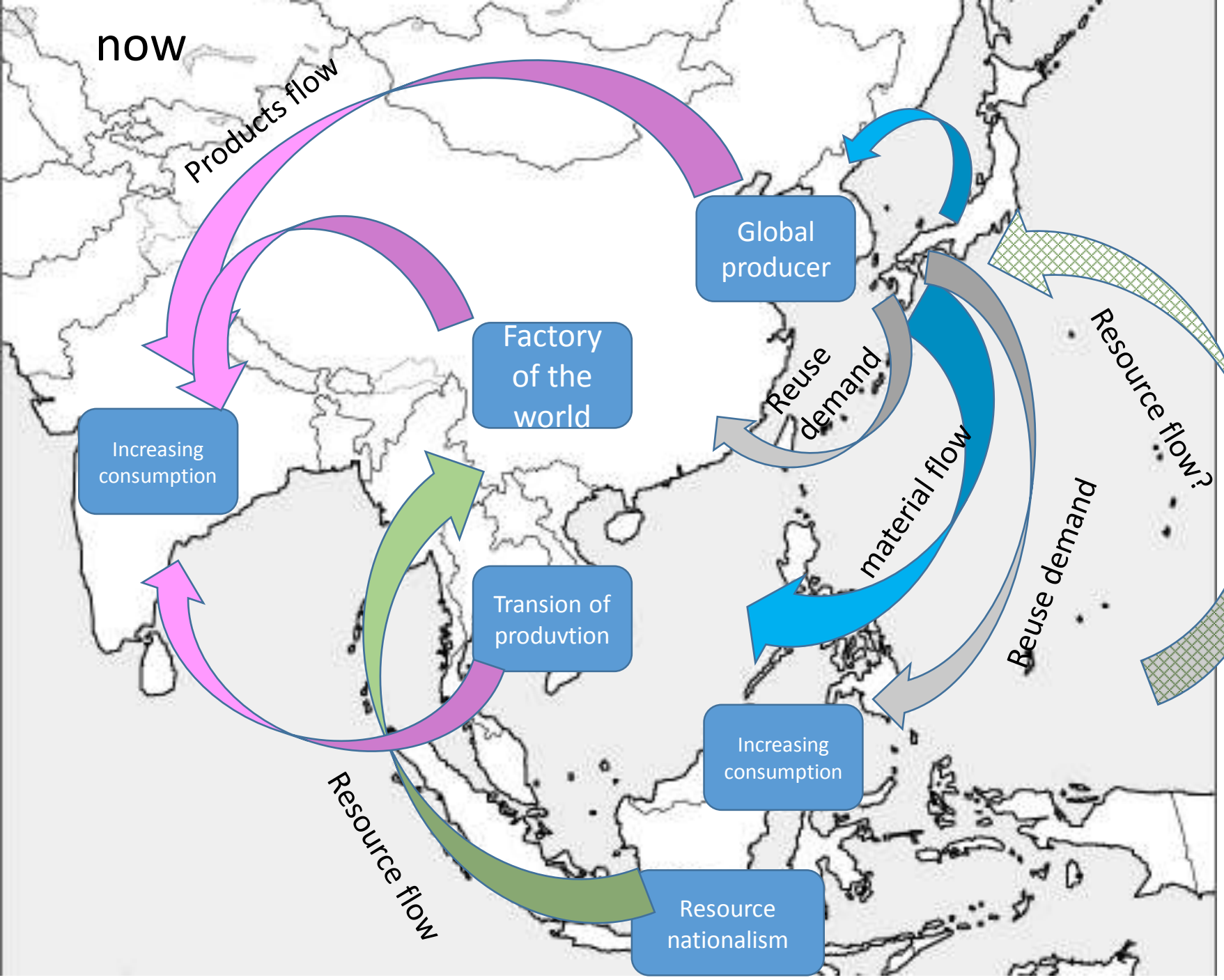

1400000
1200000
1000000
800000
600000
400000
200000
0
IW2000
IW2050
MW2000
MW2050
China
India
Japan
Taiwan
Indonesia
Korea
Bangladesh
Thailand
Philippines
Malaysia
China, Hong Kong SAR
Republic of Korea
Viet Nam
Singapore
Myanmar

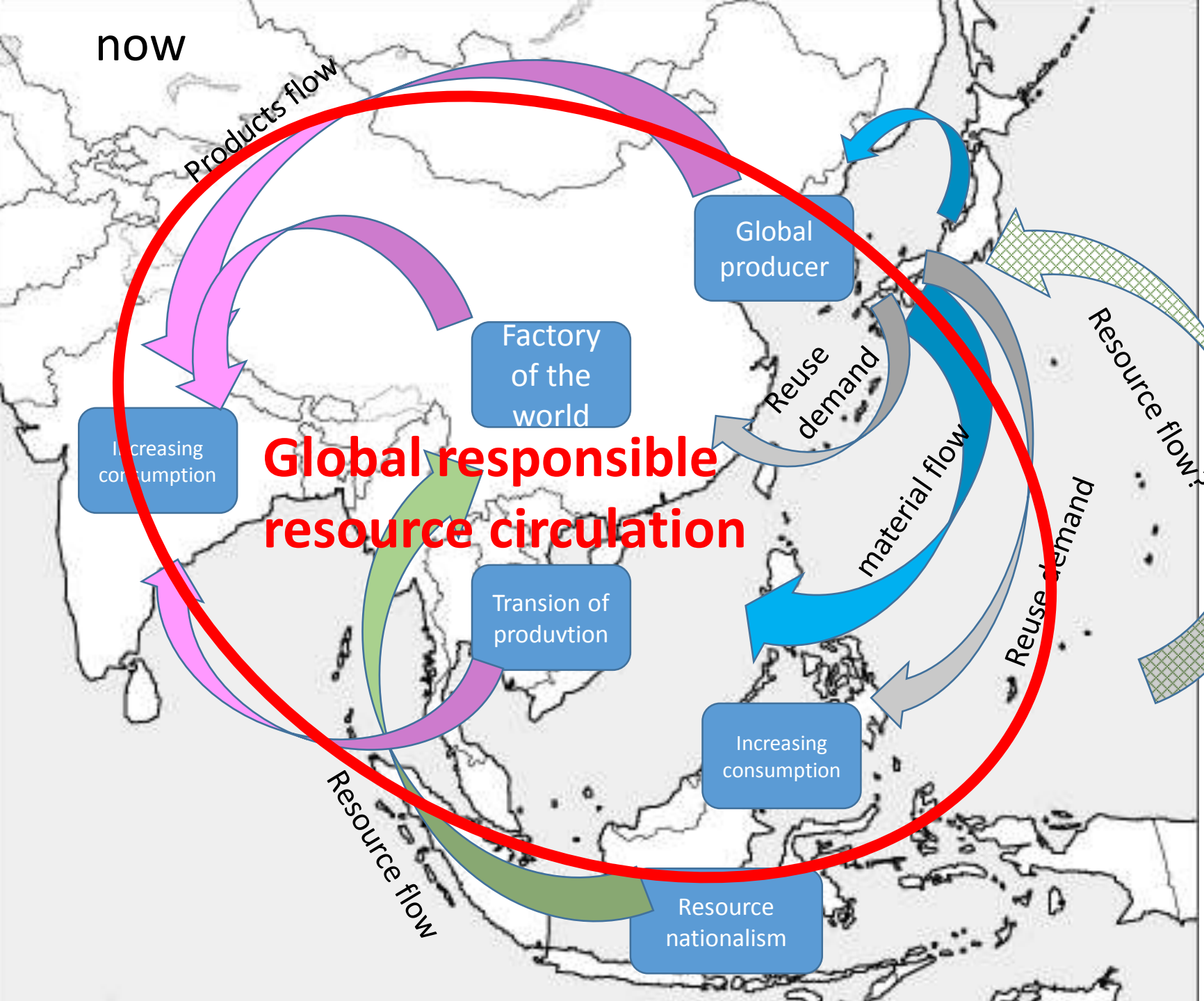
Different circulation society of EU/Africa from JP/Asia

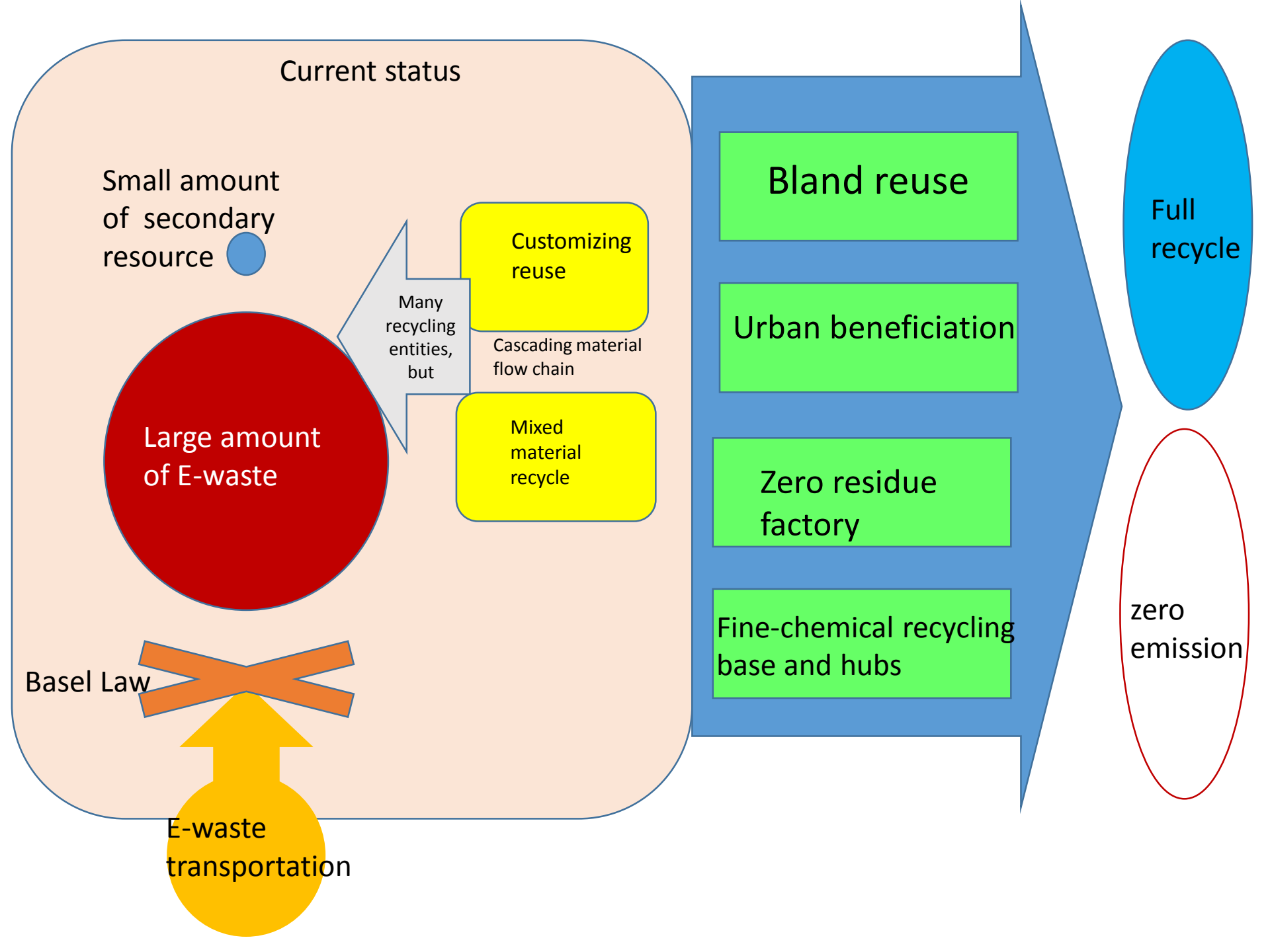


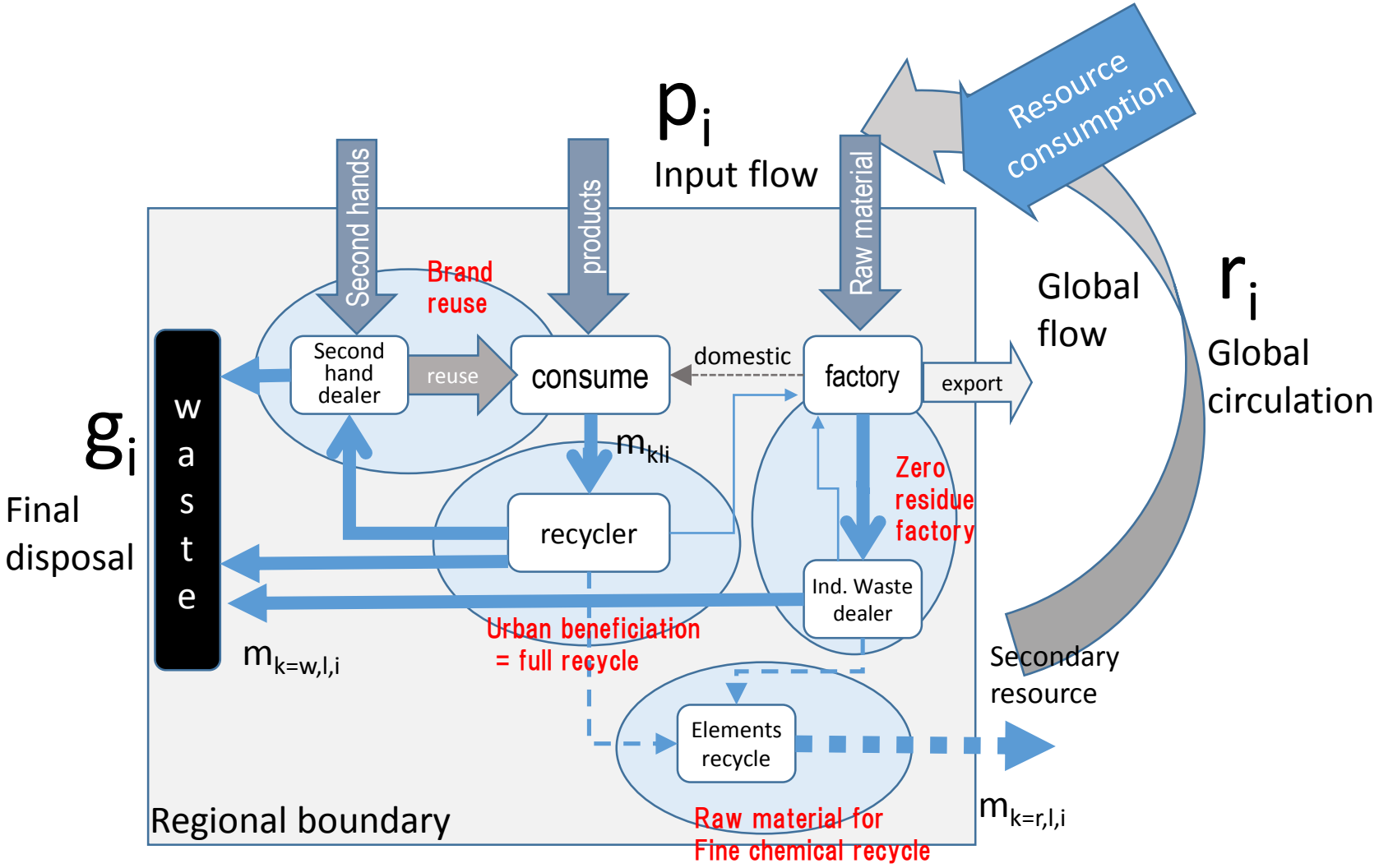



20th century
Products flow
Domestic Materials flow
Products flow
Increase of consumption
Recycle flow
Resource flow
Products flow
Demand for infrastructure
Resource country

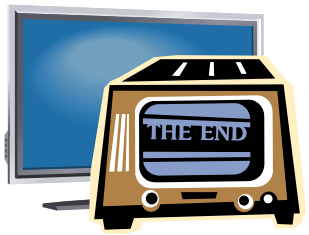

now
Products flow
Global producer
Factory of the world
Increasing consumption
Reuse demand
material flow
Resource flow?
Reuse demand
Transion of produvtion
Increasing consumption
Resource flow
Resource nationalism


now
Products flow
Global producer
Factory of the world
Increasing consumption
Global responsible resource circulation
Transion of produvtion
Increasing consumption
Resource nationalism
Resource flow
Reuse demand
material flow
Reuse demand
Resource flow?


Current status
Small amount of secondary resource
Large amount of E-waste
Many recycling entities, but
Customizing reuse
Cascading material flow chain
Mixed material recycle
Basel Law
E-waste transportation
Bland reuse
Urban beneficiation
Zero residue factory
Fine-chemical recycling base and hubs
Full recycle
zero emission

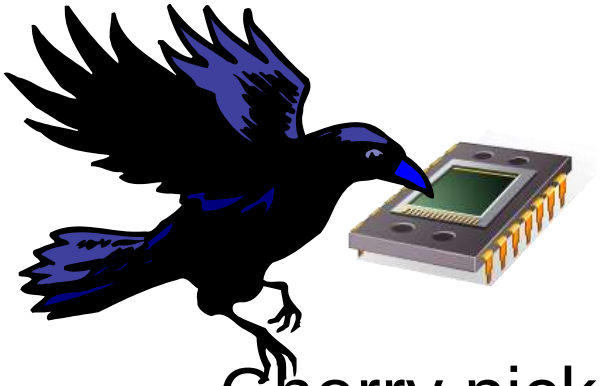

p_i
Input flow
Resource consumption
Second hands
products
Raw material
Brand reuse
Global flow
r_i
Global circulation
Second hand dealer
reuse
consume
domestic
factory
export
g_i
Final disposal
waste
m_{kli}
recycler
Zero residue factory
Ind. Waste dealer
Urban beneficiation = full recycle
$m_{k=w,l,i}$
Secondary resource
Elements recycle
Raw material for Fine chemical recycle
$m_{k=r,l,i}$
Regional boundary

Recycle the
Residue goes as E-waste.
鴉食リサイクル(yashi -recycle) crow-eating recycle



Collect in the
name of Re-use

In hidden place

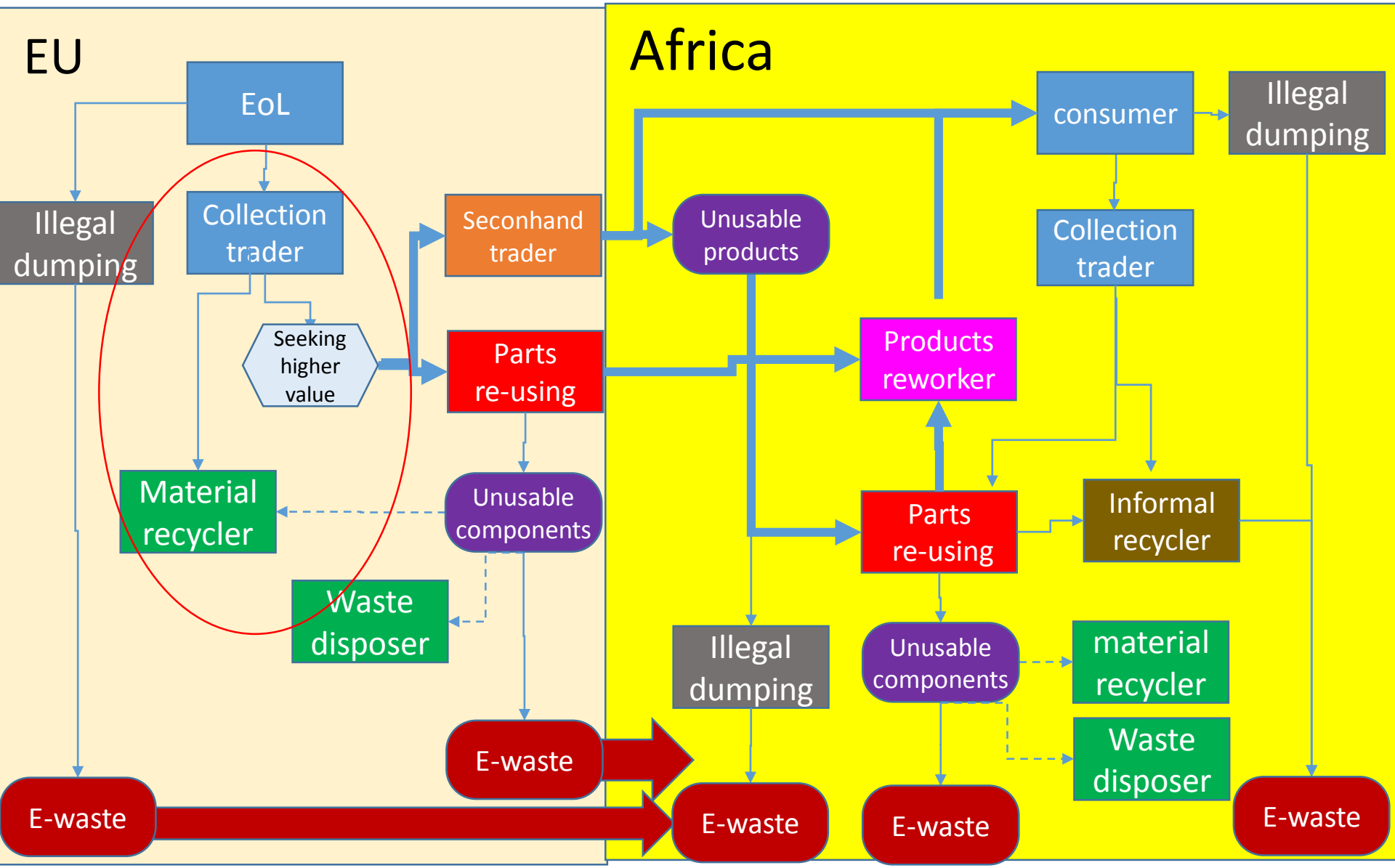


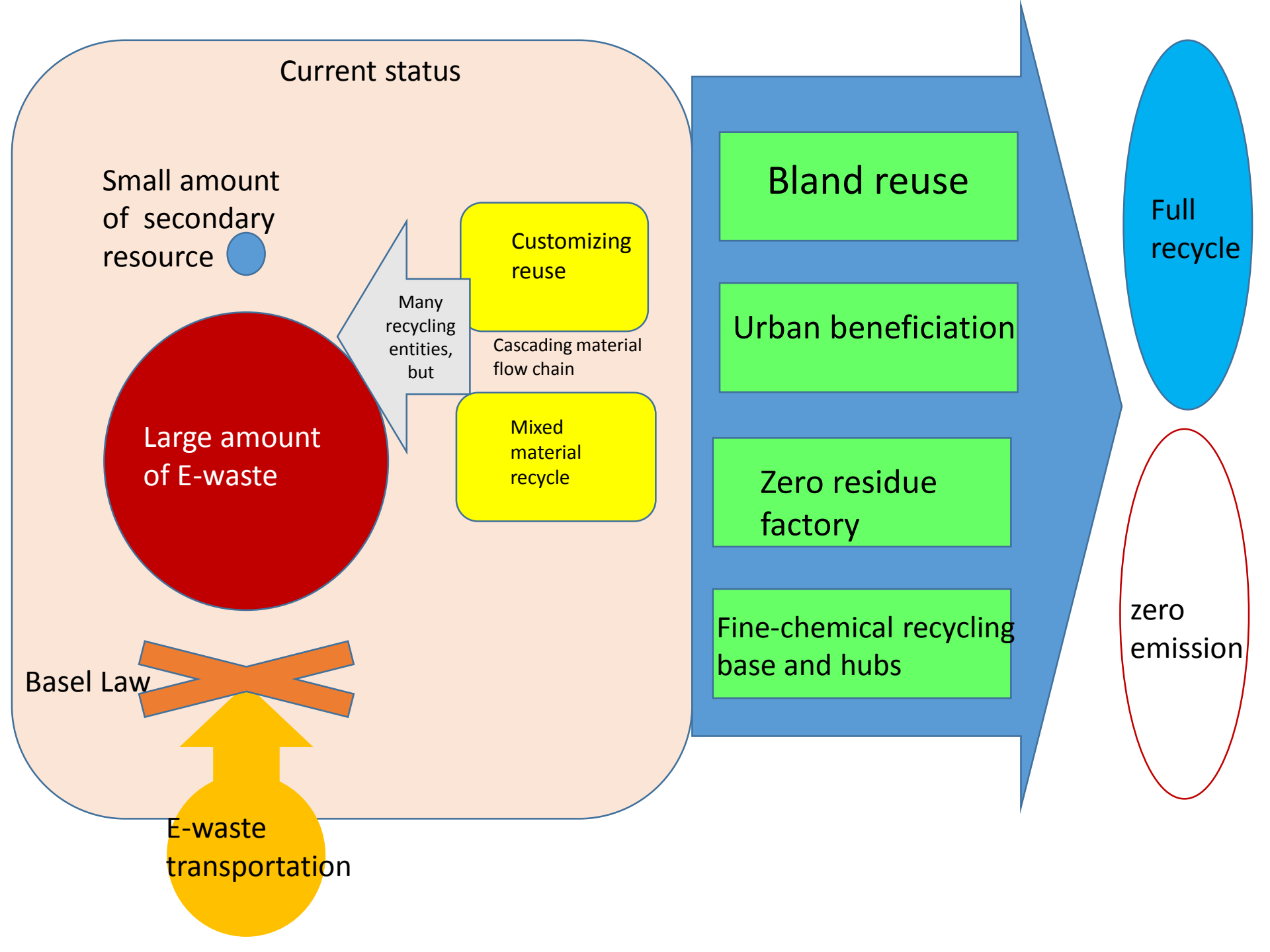
Cherry picking

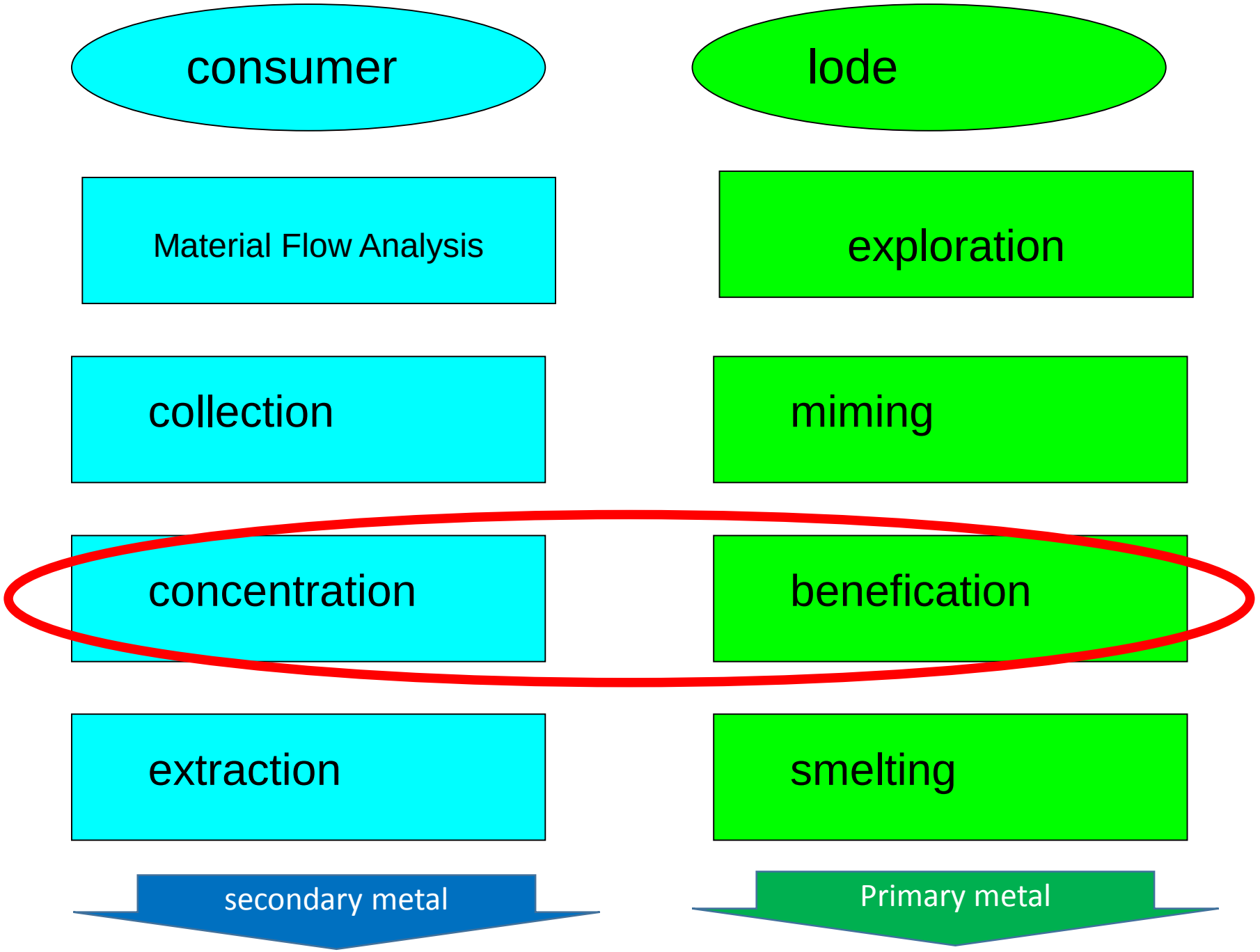
Eat messy.

e-waste

Structure of the issue of E-waste




Current status
Small amount of secondary resource
Large amount of E-waste
Many recycling entities, but
Customizing reuse
Cascading material flow chain
Mixed material recycle
Basel Law
E-waste transportation
Bland reuse
Urban beneficiation
Zero residue factory
Fine-chemical recycling base and hubs
Full recycle
zero emission


consumer
lode
Material Flow Analysis
exploration
collection
miming
concentration
benefication
extraction
smelting
secondary metal
Primary metal

Disassembling, separation and concentrating bring higher value.

Urban Beneficiation (選鉱) rises the value.

To produce Urban Concentration(都市鉱石)

disassemble

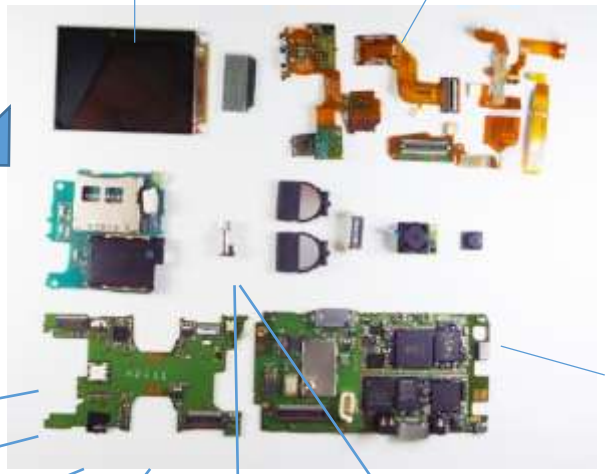
separate

concentrate

(major parts are plastics)

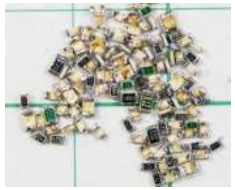
LCD (In)

Cu



Electric board

Au,Pt等



Pd,Ag等

Sn,Ni,Co等

Ta等

W等

Nd等

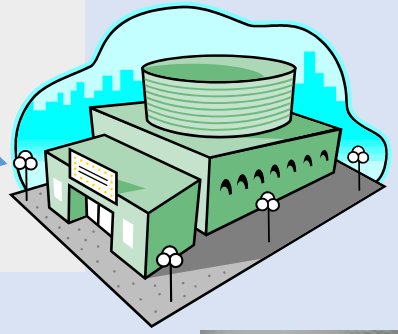
Only 10 seconds

citizen

Carry-on collection

Tsukuba-city model

Local government



technology

NIMS

物材機構
技術指導

recycler

Main selectio

Cu,Au,Ag smelter

Other metal extraction

Crush

Electric board (green & brown)

magnet

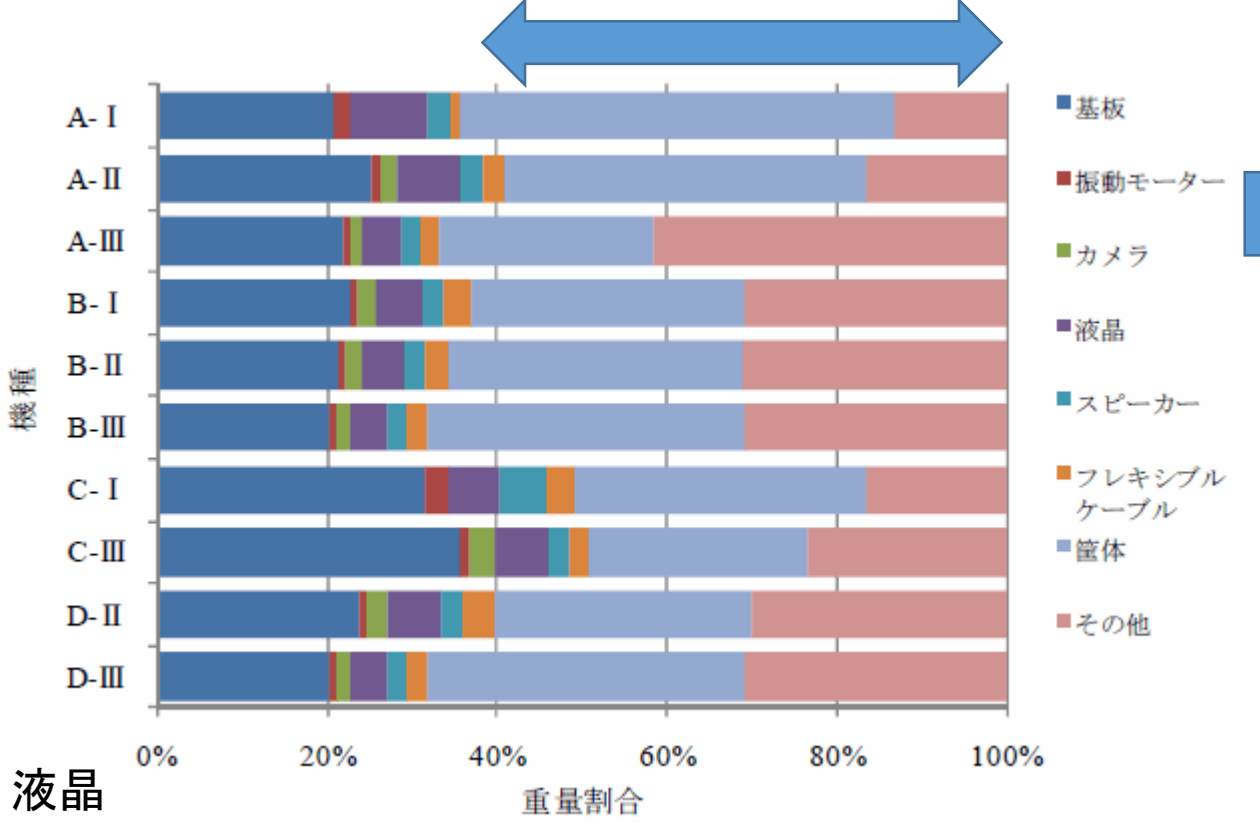
motor

買い取り

W recover

Rough selection (employment measure)

Other waste



スラグ

セメント

液晶

元素	2000-2002 年 A-Ⅰ
Ag	
Al	1～5
As	
Au	
B	1～5
Ba	0.5～3
Ca	0.5～3
Cr	
Cu	0.01～0.1
Fe	
In	0.01～0.1
Mg	0.1～1
Mn	
Mo	
Ni	
Sb	
Si	10～30
Sr	
Ti	0.005～0.05
W	
Zn	

基板

基板	A-Ⅰ
元素	2000-2002 年
Ag	0.262
Au	0.113
Co	0.031
Cu	25.7
Dy	0.014
In	0.008
Nd	0.112
Pd	0.012
Sm	＜0.01
Ta	0.180
W	0.132

Ag 0.05%
Au 0.02%
Co 0.06%
Cu 5%
Dy 0.003%
In 0.0015%
Nd 0.02%
Ta 0.04%
W 0.025%

One container Mobile plant

, which makes the treatment possible where is no facility.

レアメタル（レアアース）リサイクルの技術的・経済的課題

より

河邊　憲次

Thunder birds in the recycling society

This is a factory. WE have waste with rare metals

OK! We'll go and separate it.

Sotrage can be permitted there

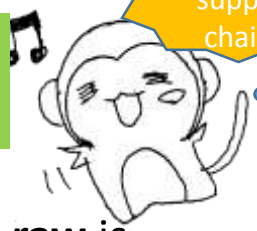
Hazardous substances Are separated there at

No taking with and Less waste

Available metals goes back To the process

Without special facilities

Raw material acquisition



Stable supply chain

Higher function (higher added value)

Requisites raw is Acquired by recycle

Factory scrap

Industrial scrap

consumer scrap

New wave

Electric appliance

Small electric

automobile

Electric appliance

Bottles packaging's

High grade
Less impurity

File chemical

economic

Change money

Cash convert recycling

Valuables are converted Into **Goods**

General ingot

metallurgy

environ ment

Burden share

Robustness, stability

Waste lay off recycling

Bads is salvaged and defused

Construction

Rout of electric appliance recycle

① resource from all over world

②High-tech manufactures

③produce high-tech products

④collect EOLs

⑤partial reuse

⑤dismantle

plastic, iron etc.

⑥full separate
full recycle

Urban cobcen trate

⑦smelt to metal

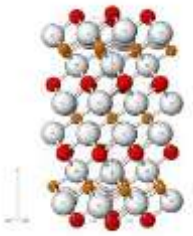
⑧ sold in the market as secondary metal ingot

⑨it should be circulated!!!
as Fine Chemical Recycle

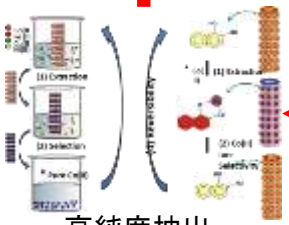
Fine chemical recycle of Co from LiB

Cobalt oxide
約¥9000/kg

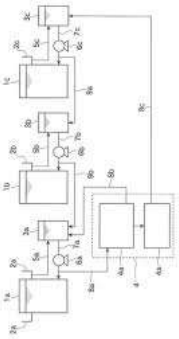
Co LI oxide



Fine Chemical Recycle



高純度抽出



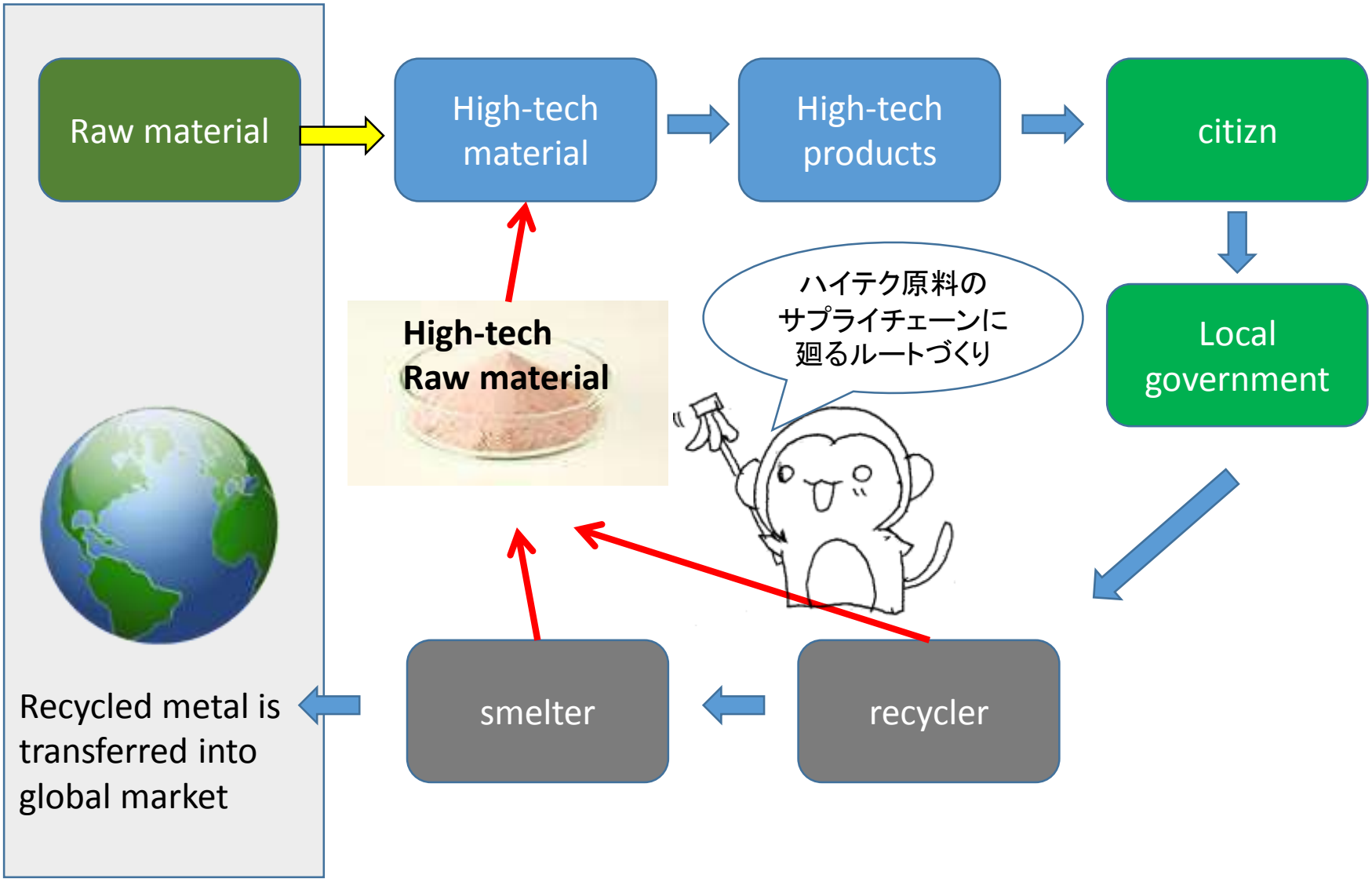
Metallurgical recycle

electrolysis

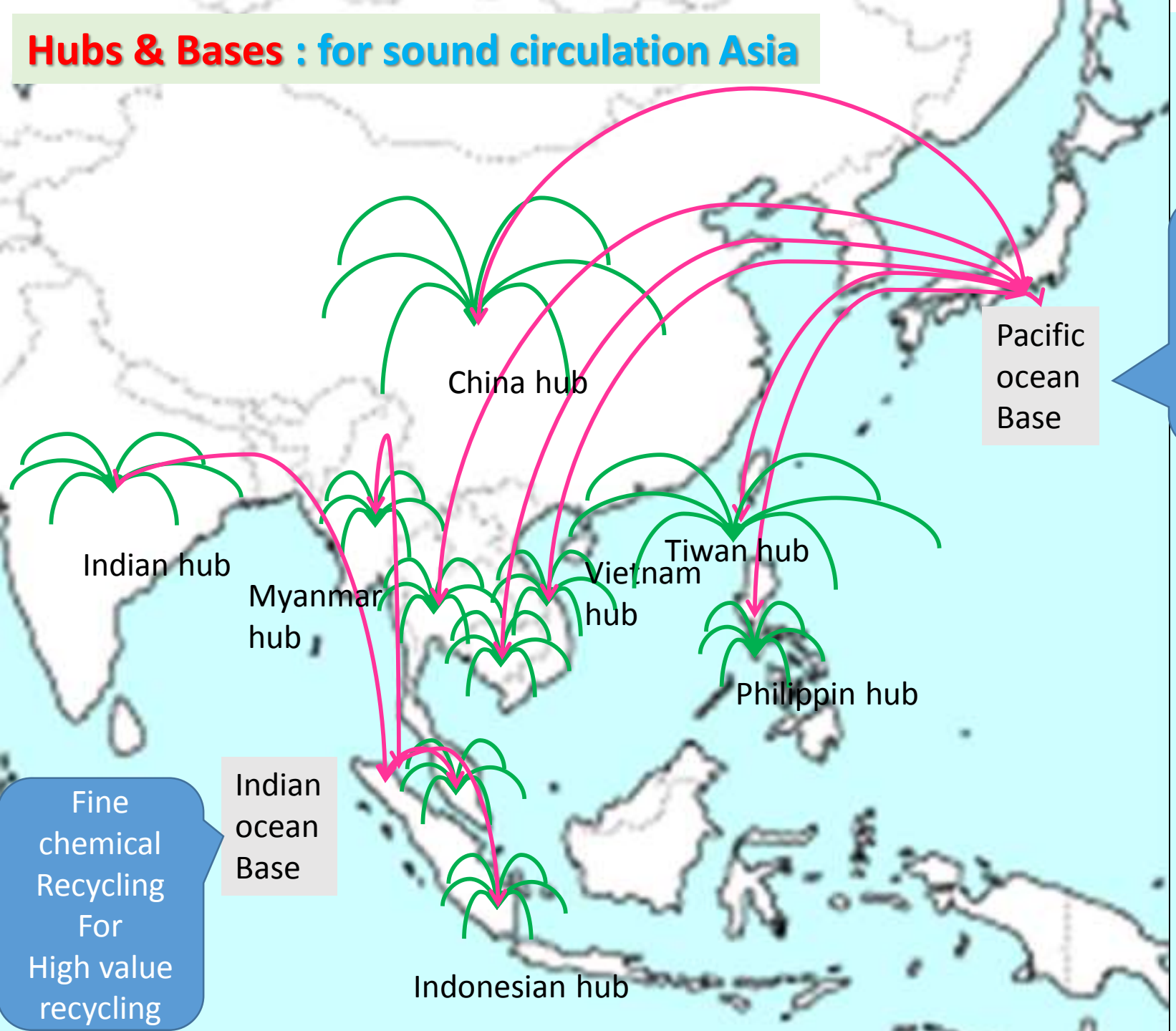
Metallic cobalt
約¥4000/kg

Leaching with containing Na

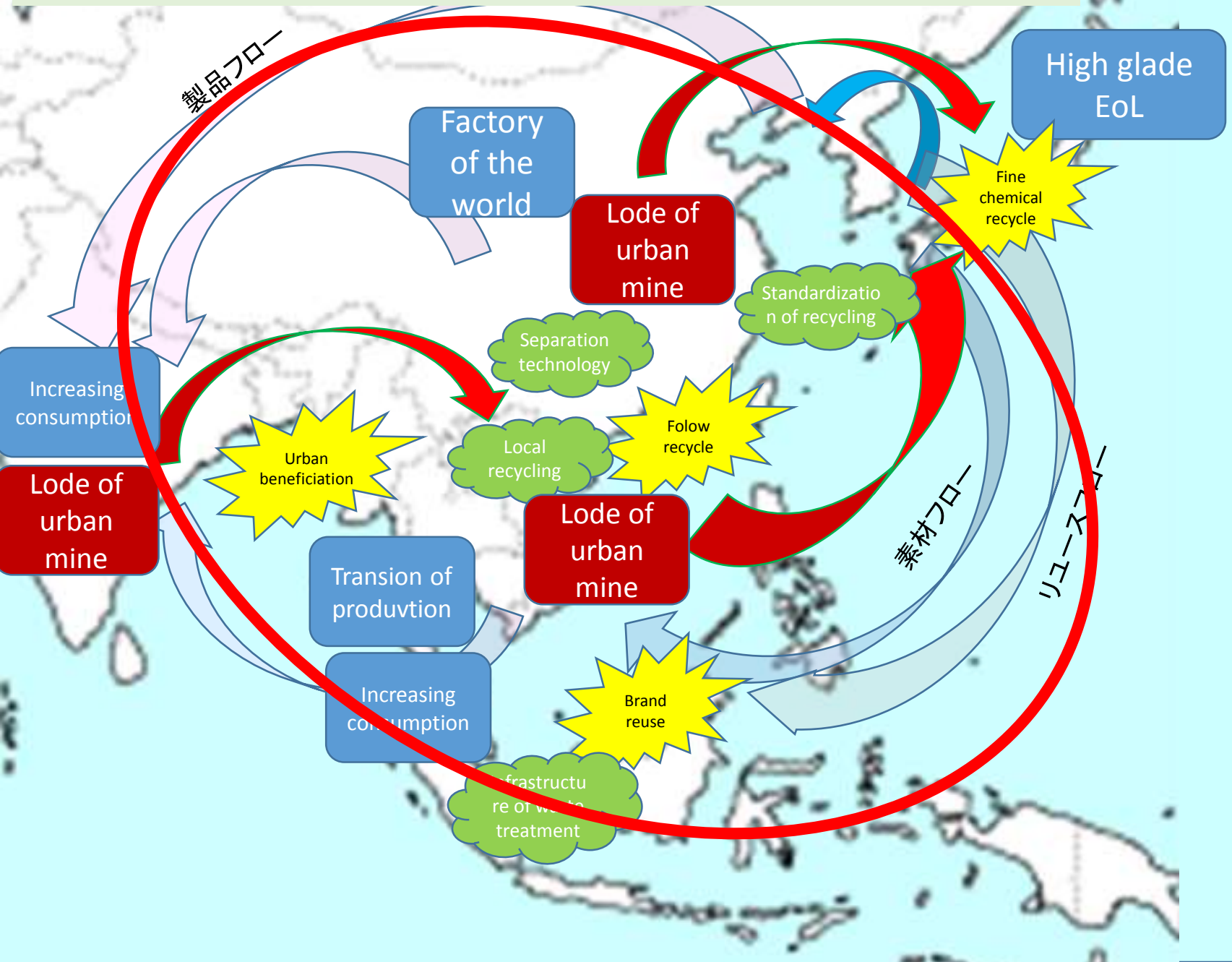
Recycling goes back to supply chain



Hubs & Bases : for sound circulation Asia



Global Urban-Mines : responsible resource circulation



conclusion

- Material consumption has shifting from EU, Us, JP trilateral structure
  to 10billions' universal economy,
  which require a great amount of metals
  and which cannot be supplied by natural resource.

- We have to rush to establish the circulation economy.

- Especially, as Asia area will be the factory of the world,
  it is important to establish sound circulation society
  with international collaboration.

感謝您的關注

Gǎnxiè nín de guānzhù