

Taiwan Urban Mining Seminar 111021

Metal Recycling Challenges from Waste Products in Japan

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Metal Recycling Challenges from Waste Products in Japan

1. Backgrounds of Metal Recycling
2. Recycling Potential of Mobile Phones
3. Hazardous Characteristics of E-waste
4. E-Waste Recycling Policies in Japan



1. Backgrounds of Metal Recycling



Securing Policies of Sustainable Mineral Supply

Stable mineral supplies in the medium & long term are secured by exploration/development of minerals, recycling promotion, finding alternative resources for minerals, and by stockpiling of rare metals.

< Promotion of exploration development >

Conduct comprehensive strategies for securing resources exploration among world-wide.

< Promotion of recycling >

Increase collection rate of nonferrous metals contained in collected used-products by technological development.

< Development of alternative sources >

Develop technology for usage reduction of rare metals and find alternative materials.

< Stockpile of rare metals >

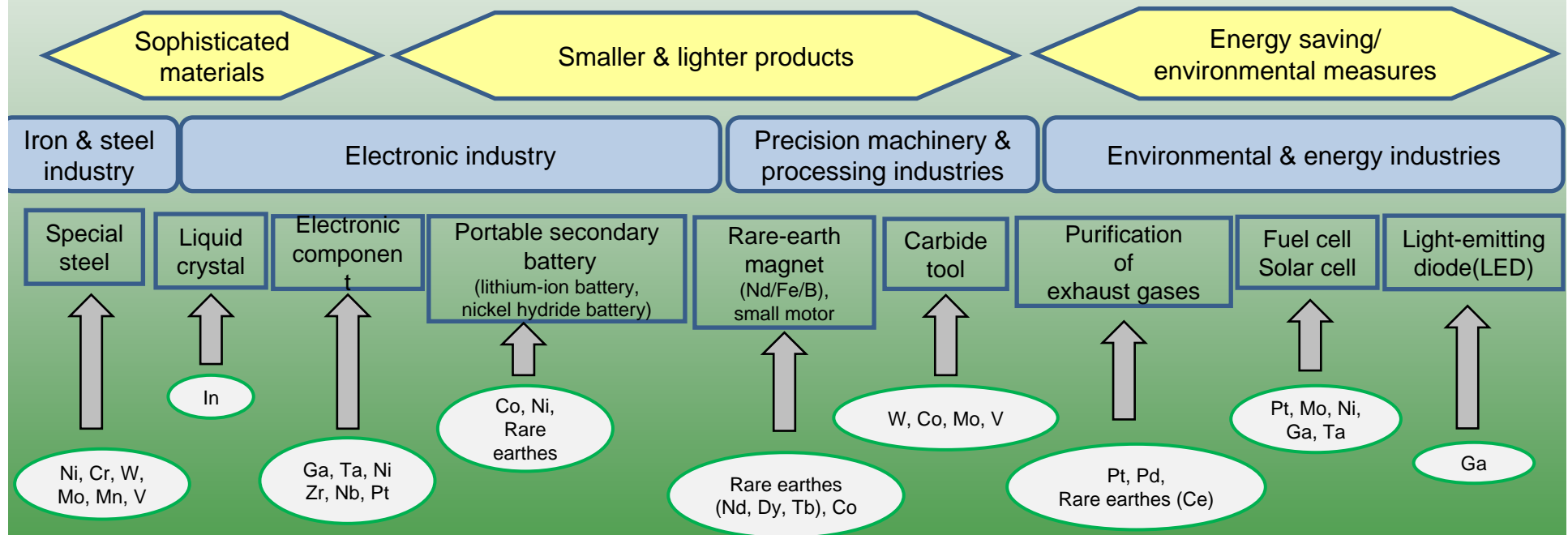
Conduct agile stocking & selling of rare metals on public-private partnership basis.

List of Rare Metals

Lithium	(Li)	Niobium	(Nb)	* Rare earthes
Berylium	(Be)	Molybdenum	(Mo)	Scandium (Sc)
Boron	(B)	Palladium	(Pd)	Yttrium (Y)
Rare earthes	(RE)*	Indium	(In)	Lanthanum (La)
Titanium	(Ti)	Antimony	(Sb)	Cerium (Ce)
Vanadium	(V)	Tellurium	(Te)	Praseodymium (Pr)
Chrome	(Cr)	Cesium	(Cs)	Neodymium (Nd)
Manganese	(Mn)	Barium	(Ba)	Promethium (Pm)
Cobalt	(Co)	Hafnium	(Hf)	Samarium (Sm)
Nickel	(Ni)	Tantalum	(Ta)	Europium (Eu)
Gallium	(Ga)	Tungsten	(W)	Gadolinium (Gd)
Germanium	(Ge)	Rhenium	(Re)	Terbium (Tb)
Selenium	(Se)	Platinum	(Pt)	Dysporosium (Dy)
Rubidium	(Rb)	Thallium	(Tl)	Holmium (Ho)
Strontium	(Sr)	Bismuth	(Bi)	Erbium (Er)
Zirconium	(Zr)			Thulium (Tm)
				Ytterbium (Yb)
				Lutetium (Lu)

Application of rare metals

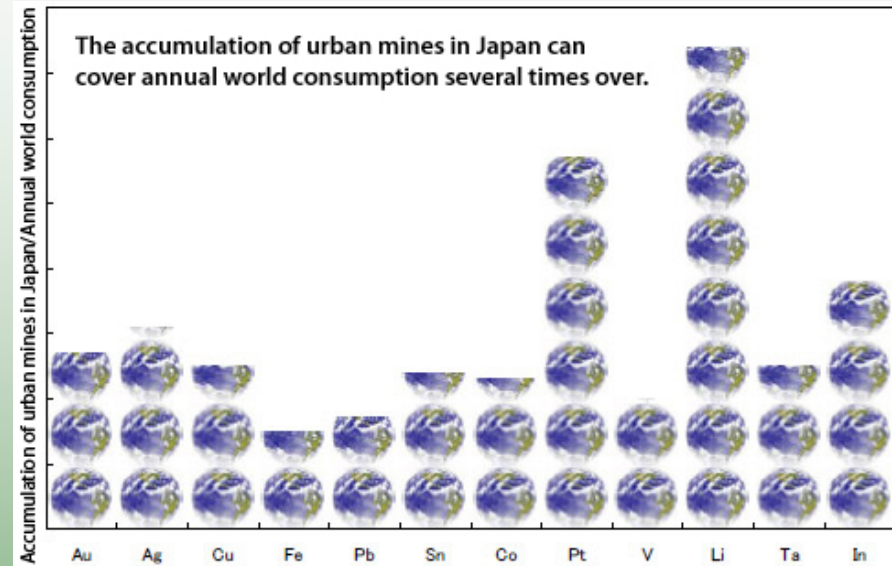
- Rare metals in products are in a small amount; however, they are the backseat players for various industries.



Some modification were made on the ref. erence of Baba, Y.: Metal Resources Report, Vol.35, No2, pp.189-197, 2005

Urban Mining Concept

- The concept of urban mines : introduced by Professor Nanjyo in last 1980s,
- In 2008, National Institute for Materials Science calculated the amount of metals which have been accumulated in Japan to date which are recyclable for use as metal resources in the future. These metals, called “urban mines”, are found in a wide range of products, but are generally not recycled when products are discarded. The results of this study revealed that Japan’s urban mines have reached a scale comparable to natural reserves of the world’s leading resource nations.



According to these calculations, Japan’s urban mines of many metals exceed 10% of world reserves, including Gold; 6,800 tons, or about 16% of the world’s current reserves of 42,000 tons Silver (60,000 tons, or 22%), indium (61%), tin (11%), and tantalum (10%). Many other metals, including platinum, also rank in the top 5 in comparison with reserves by country. (Source: Kohmei Harada)

2. Recycling Potential of Mobile Phones

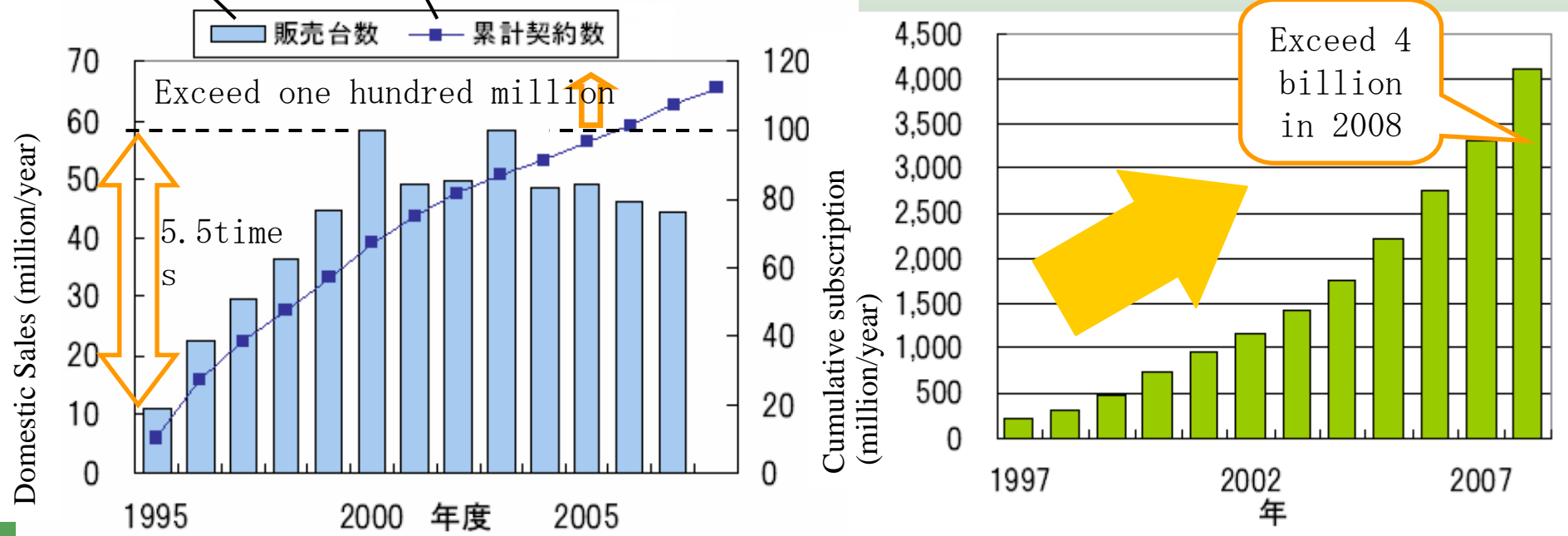


Explosive growth of mobile phone use

- Domestic sales increased by about 5.5 times during 1995-2000.
- In 2006, number of subscription exceeded one hundred million; that is, one for each person on an average
- In 2008, number of subscription across the world exceeded 4 billions.

Domestic sales¹⁾/ number of subscription²⁾
(million/year)

Number of subscription across
the world³⁾ (million/ year)

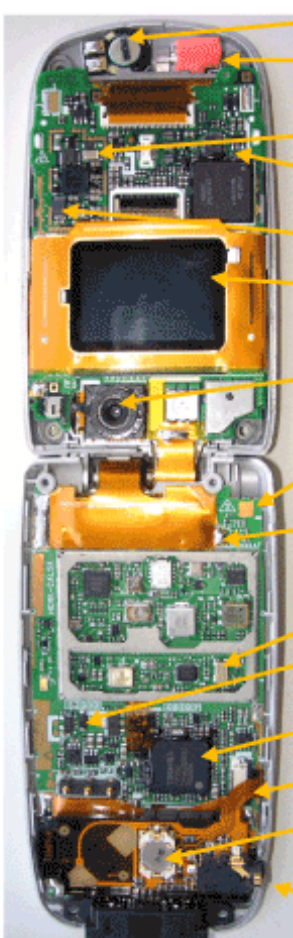


1) Communications and Information network Association of Japan <http://www.ciaj.or.jp/content/info/dat.html>

2) Telecommunications carriers Association <http://www.tca.or.jp/database/index.html>

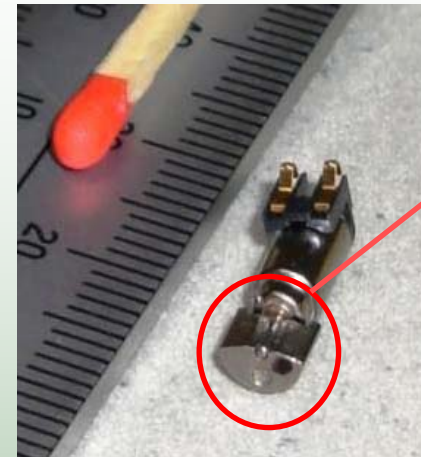
3) International Telecommunication Union http://www.itu.int/ITU-D/ict/statistics/at_glance/KeyTelecom99.html

Metals in Mobile Phone



- Speaker : ferrite
- Vibrating motor: **Nd**
- Ceramic capacitor: **Pd, Ti, Ba, Pb, Ni, Zr**
- Chip resistor: Fe, Ag, **Ni**, Cu, Zn, **Pb**
- Chip coil: Cu
- Crystal display: **In**, Sn
- Camera: Cu, **Ni**, Au
- Glass epoxy board: Cu, SiO₂, (Br)
- Solder: Pb, Sn
- Crystal resonator: Si, Cu, **Ni**
- Tantalum capacitor: **Ta, Ag, Mn**
- IC: Au, Ag, Cu, Si
- Plastic: **Sb**
- Button battery: Ag
- Earphone jack, AC jack: Au
- Contacts :Fe, **Ni**, **Cr**, Au

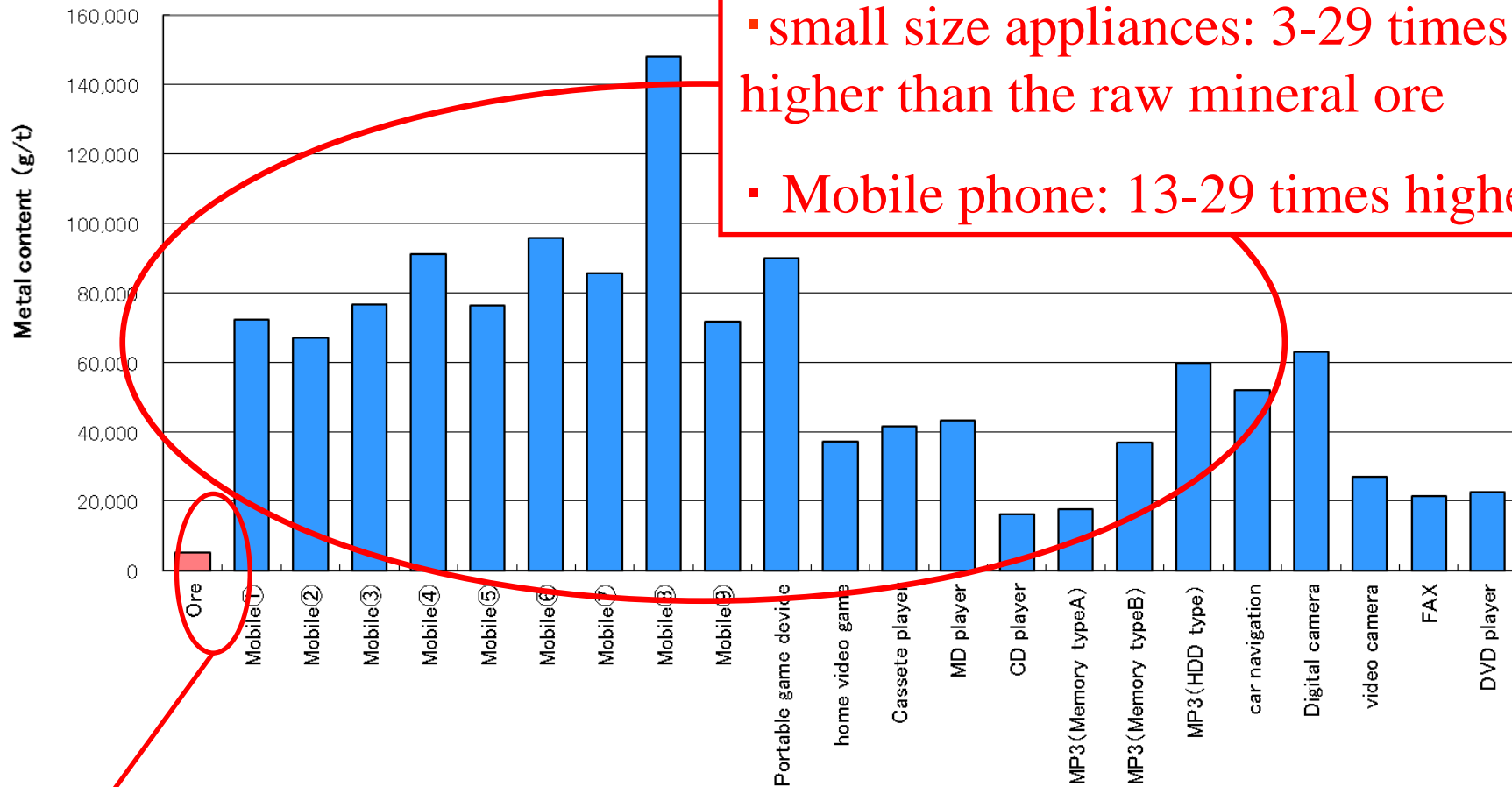
Written in red: rare metal



Motor for mobile phone
W: Tungsten

Contains various useful metals such as rare metals and precious metals

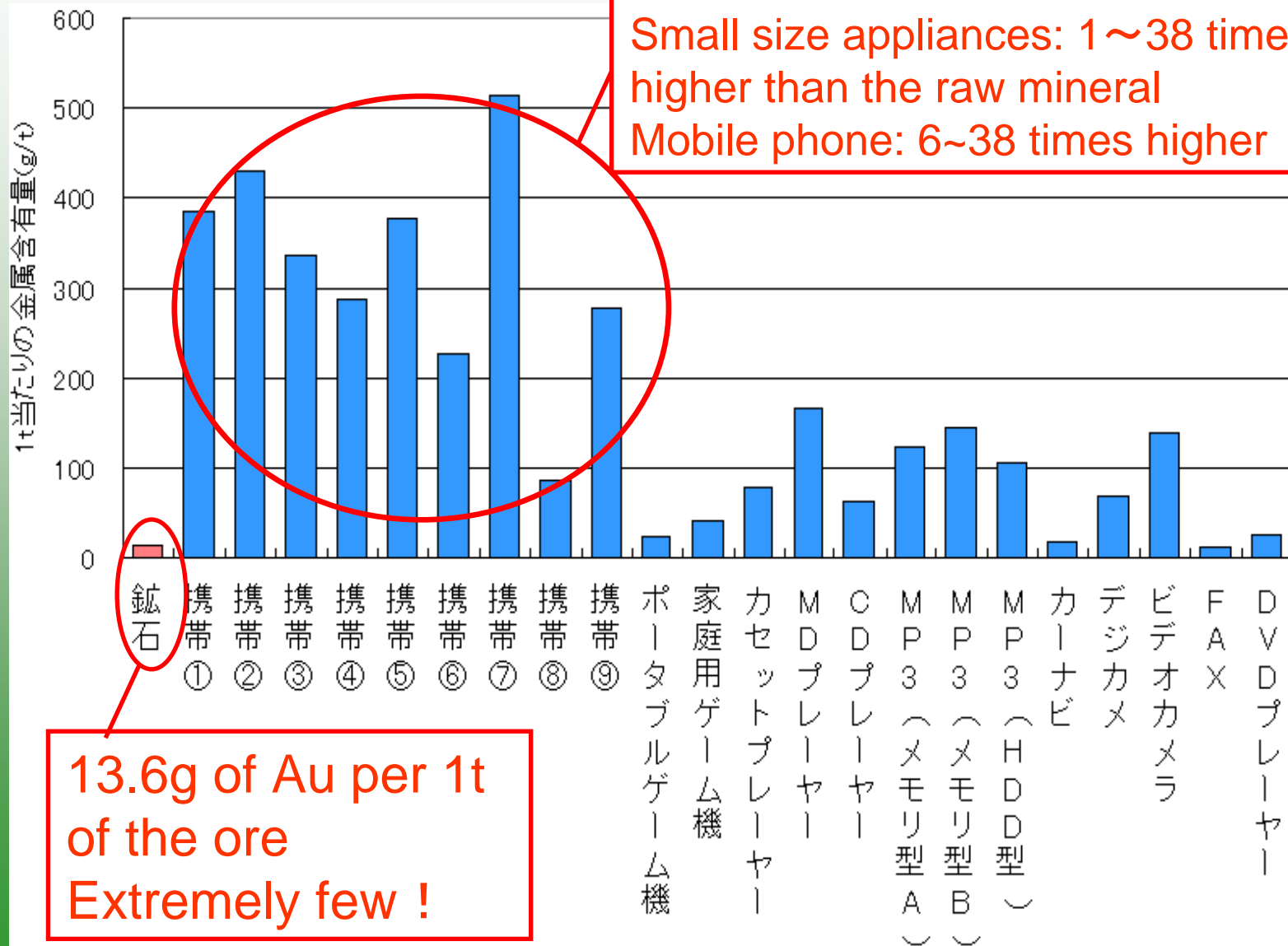
Copper (Cu) in some mobile phones and other end-of-life E/Es (g/ton)



5,171g of Cu per 1t of the ore

- small size appliances: 3-29 times higher than the raw mineral ore
- Mobile phone: 13-29 times higher

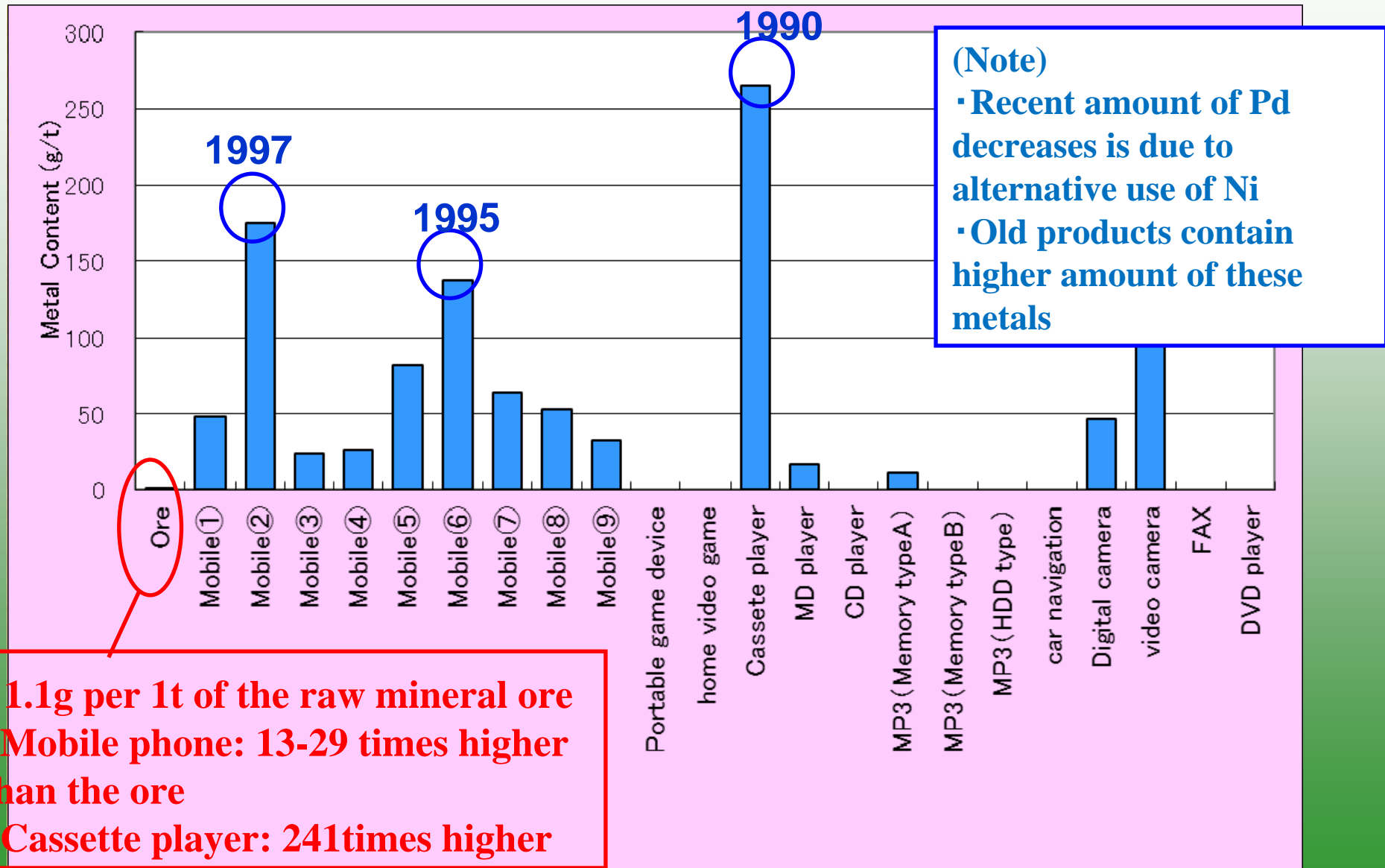
Gold (Au) in some mobile phones and other end-of-life E/Es (g/ton)



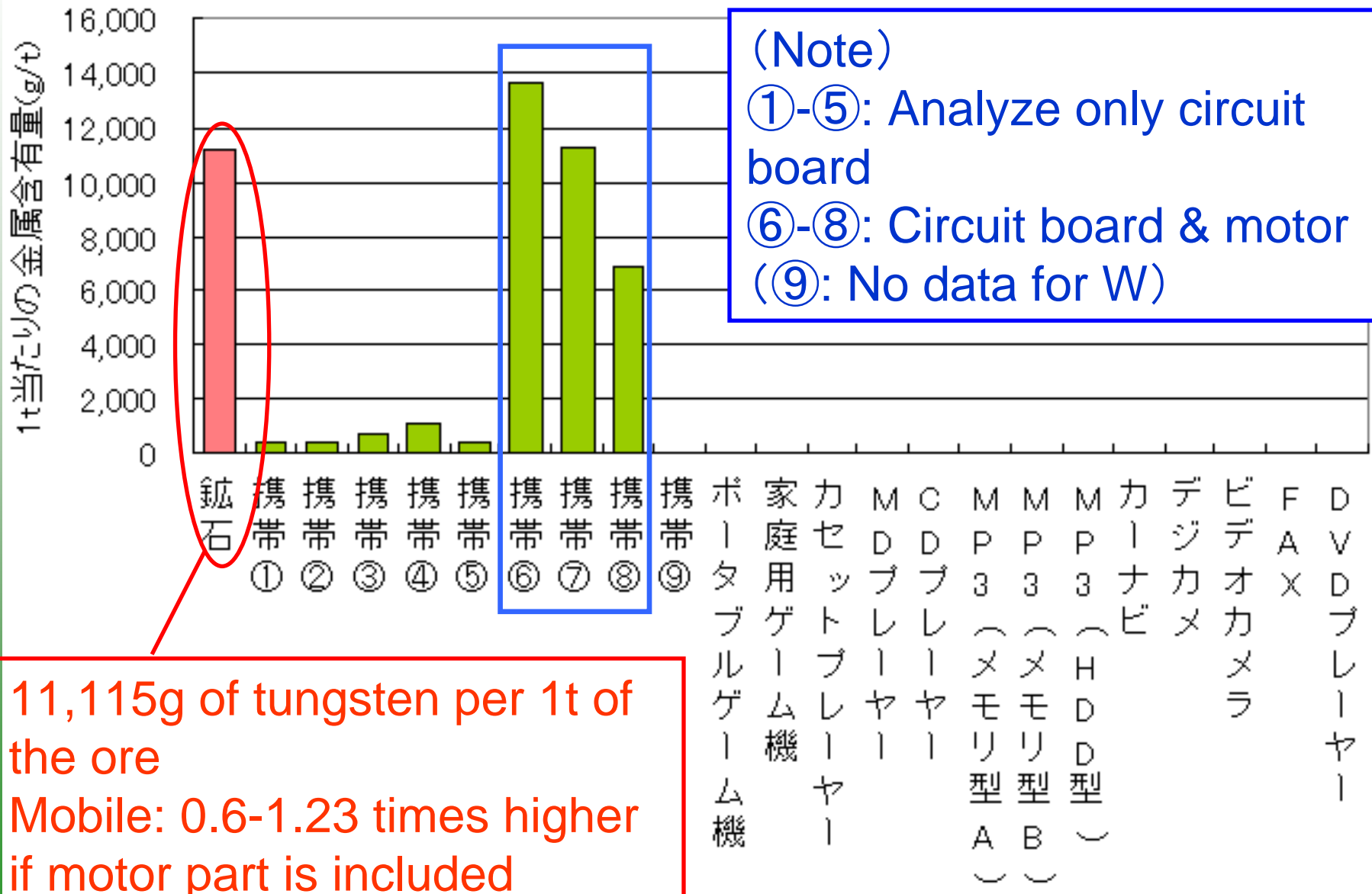
13.6g of Au per 1t of the ore
Extremely few !

Small size appliances: 1~38 times higher than the raw mineral
Mobile phone: 6~38 times higher

Palladium (Pd) in some mobile phones and other end-of-life E/Es (g/ton)

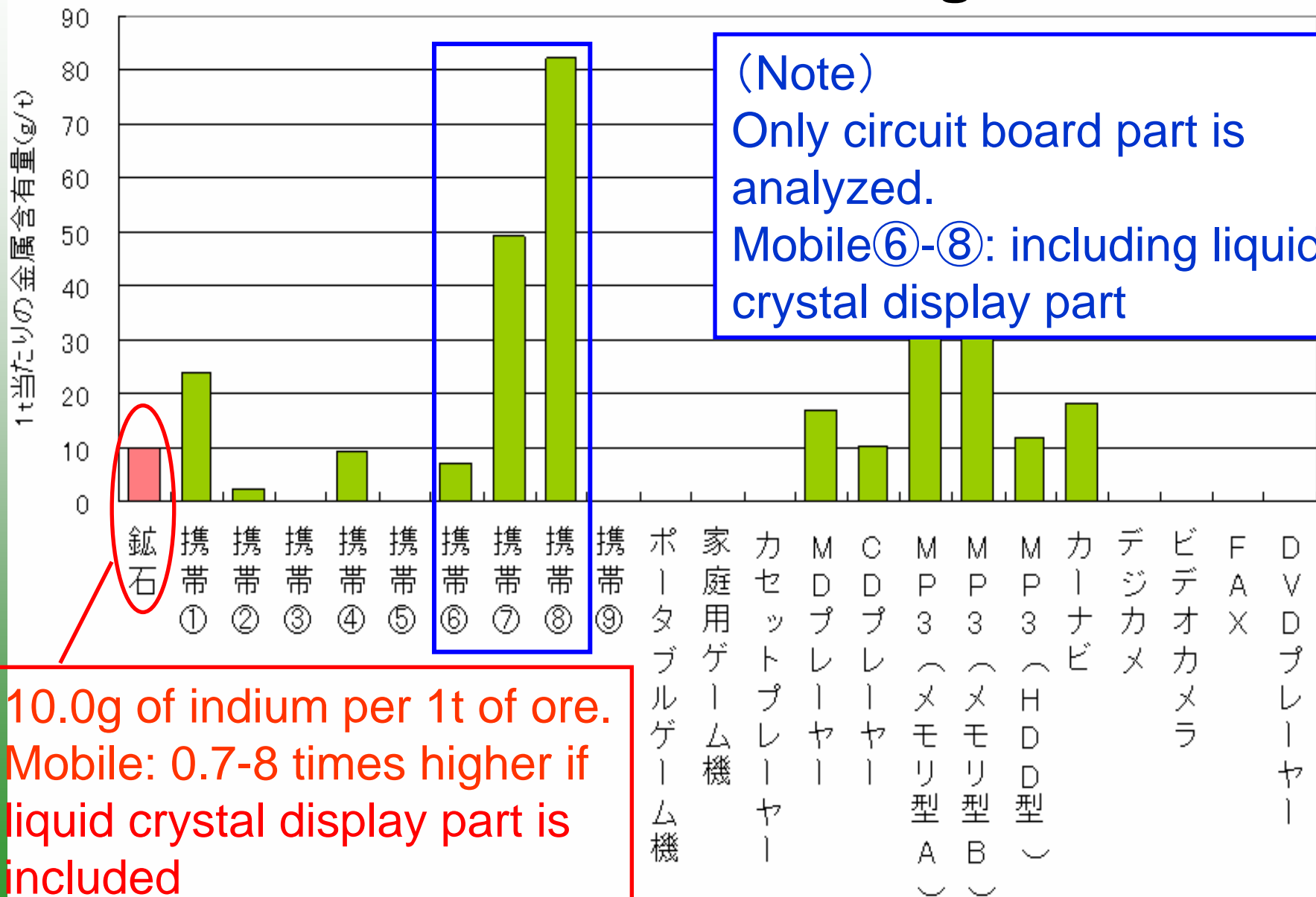


Tungsten (W) in some mobile phones and other end-of-life E/Es (g/ton)



11,115g of tungsten per 1t of the ore
 Mobile: 0.6-1.23 times higher if motor part is included

Indium (In) in some mobile phones and other end-of-life E/Es (g/ton)



(Note)
 Only circuit board part is analyzed.
 Mobile⑥-⑧: including liquid crystal display part

10.0g of indium per 1t of ore.
 Mobile: 0.7-8 times higher if liquid crystal display part is included

3. Hazardous Characteristics of E-waste



Restriction of the use of certain Hazardous Substances in electrical and electronic equipment (RoHS)

- Established in January 27, 2003. Will be applied to products appearing on market after July 1, 2006.
- The purpose is to make common laws on usage restrictions of hazardous substances for electrical and electronic equipment among EU countries and in order to collect & dispose waste electrical and electronic equipment (WEEE) without affecting to human health and to the environment.
- EU nations have started to organize their own domestic laws in response to RoHS.

RoHS Directive of 27 January 2003 preamble (5)

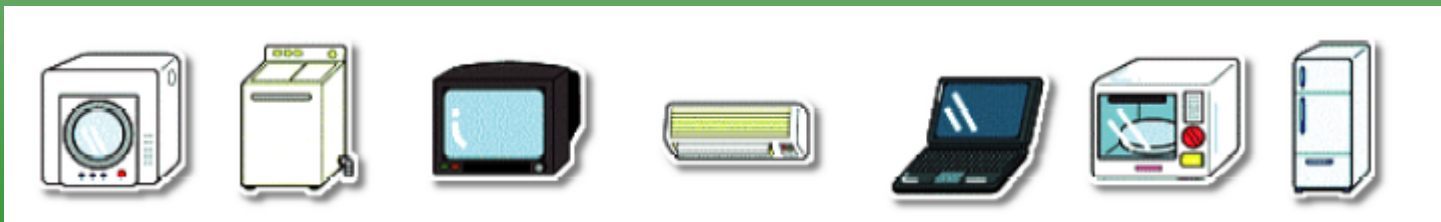
The available evidence indicates that measures on the collection, treatment, recycling and disposal of waste electrical and electronic equipment (WEEE) are necessary to reduce the waste management problems linked to the heavy metals concerned and the flame retardants concerned. In spite of those measures, however, **significant parts of WEEE will continue to be found in the current disposal routes**. Even if WEEE were collected separately and submitted to recycling processes, **its content of mercury, cadmium, lead, chromium VI, PBB and PBDE would be likely to pose risks to health or the environment**.

J-Moss (JIS C0950)

- “The Marking for presence Of the Specific chemical Substances for electrical and electronic equipment”
- “Obligation to provide the information contained” exactly means to show the orange mark of J-Moss and to list the information of the target chemicals on the web.
- In case the contents of these 6 substances are below standard values, marking of the green mark of J-Moss (no contamination) is allowed.

Targeted products that are under obligation of J-Moss by which information about their constituent substances must be reported

- Targeted products
 - ▪ Personal Computer
 - Unit type air conditioner
 - TV
 - Microwave
 - Cloth drier
 - Refrigerator
 - Washing machine



Substances in products such as electric appliances and PC whose information must be reported





◆ Targeted 6 substances and their limit concentrations (if the concentration of these substances is above the level, the examined materials are considered as “contained”)

Chemical substances	Chemical symbols	Targeted substances for calculation	Standard values (wt%)
Lead/lead compound	Pb	Lead	0.1
Mercury/mercury compound	Hg	Mercury	0.1
Cadmium/cadmium compound	Cd	Cadmium	0.01
Hexavalent chromium compound	Cr (VI)	Hexavalent chromium	0.1
Polybromobiphehyl	PBB	Polybromobiphehyl	0.1
Polybrominated dipheny ethers	PBDE	Polybrominated dipheny ethers	0.1

Acute Toxicity Test of Metal Compounds by Oral Exposure to Rat (Yamamoto et al. of National Institute for Materials Science (NIMS))

	1A	2A	3A	4A	5A	6A	7A	8	1B	2B	3B	4B	5B	6B	7B	0		
1	H															He		
2	Li	Be									B	C	N	O	F	Ne		
3	Na	Mg									Al	Si	P	S	Cl	Ar		
4	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
5	Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
6	Cs	Ba	*	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
7	Fr	Ra	**															

R. Yamamoto, Materia Japan, Vol.43, No.8, 639-642(2004)





-  Element with high acute toxicity ($LD_{50} < 10 \text{mg/kg bw}$)
 -  Element with rather high toxicity ($10 < LD_{50} < 100 \text{mg/kg bw}$)
 -  Element with rather low toxicity ($100 < LD_{50} < 1000 \text{mg/kg bw}$)
 -  Element with low toxicity ($1000 \text{mg/kg bw} < LD_{50}$)
- Boldface: rare metals
*lanthanoid
**actinoid

•No data of acute toxicity for 12 elements among 33 rare metals

→ As they have not been used much up until now, so toxicology test was not necessary. Another reason is that those data are difficult to obtain due to high costs of toxicity test and from the viewpoint of consideration for animal care.

**Primary screening based on cytotoxicity assay for metal salts.
(Yamamoto et al. of National Institute for Materials Science (NIMS))**

	1A	2A	3A	4A	5A	6A	7A	8	1B	2B	3B	4B	5B	6B	7B	0		
1	H															He		
2	Li	Be									B	C	N	O	F	Ne		
3	Na	Mg									Al	Si	P	S	Cl	Ar		
4	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
5	Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
6	Cs	Ba	*	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
7	Fr	Ra	**															

-  Elements with high cytotoxicity ($IC_{50} < 10^{-5}$)
-  Element with rather high cytotoxicity ($10^{-5} < IC_{50} < 10^{-4}$)
-  Element with rather low cytotoxicity ($10^{-4} < IC_{50} < 10^{-3}$)
-  Element with low cytotoxicity ($10^{-3} < IC_{50}$)

Boldface: rare metals

*lanthanoid

**actinoid

A. Yamamoto et al. JBMR 39, 331-340, 1998.

Hidden flow means...

Total amount of materials required including rocks and gravels when mining for obtaining a certain amount of minerals. It is also called Ecological Rucksack or Total Material Requirement (TMR)

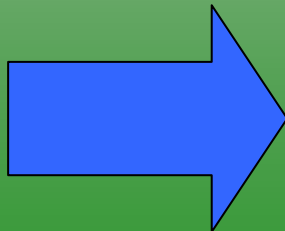


To obtain 1t
of gold . . .



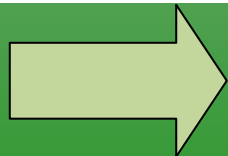
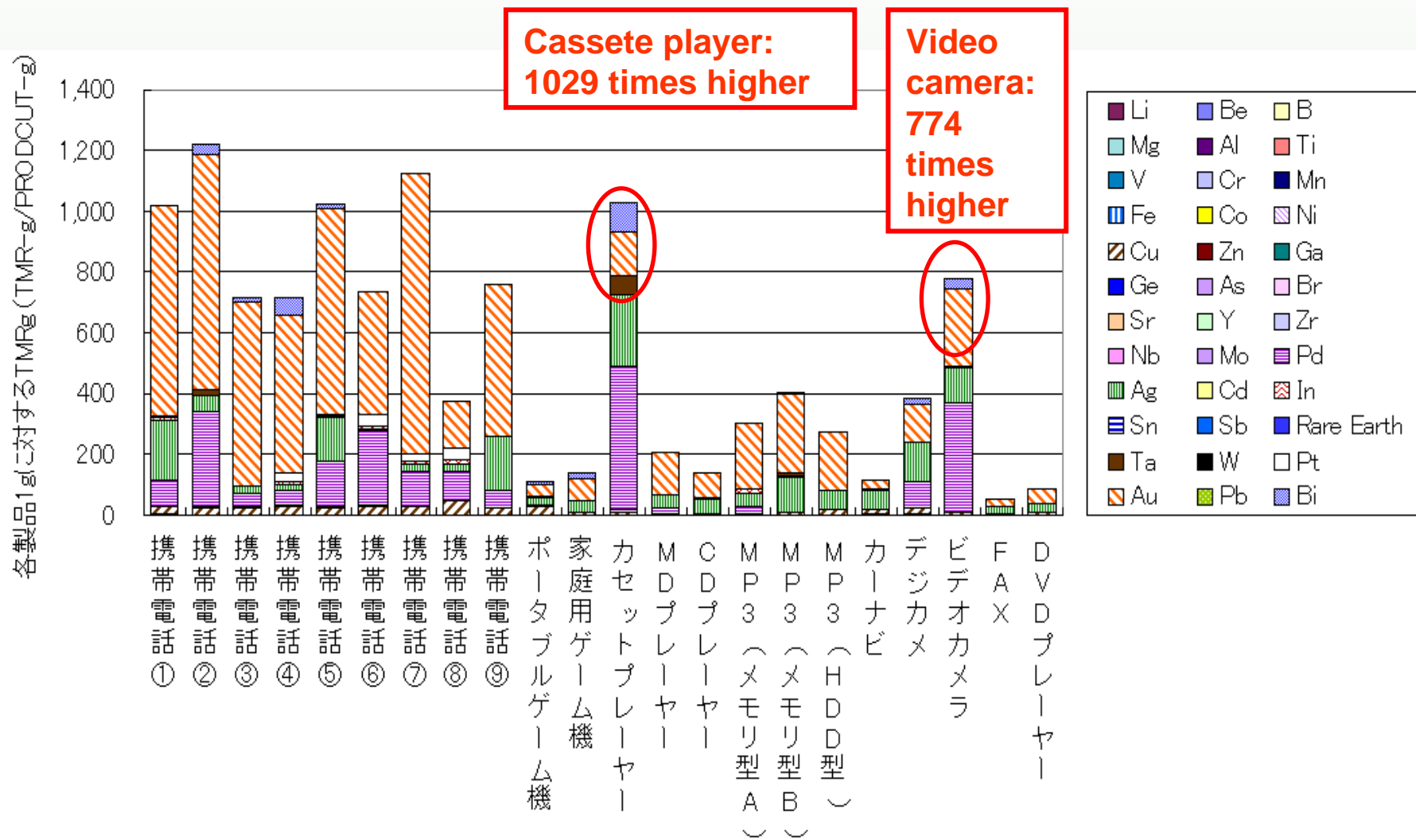
TMR will be over 1
million t.

Though the amount of used mineral itself may be small, we can understand that a very heavy environmental load is produced when considering TMR.



Appeal the importance of “avoiding further mining of minerals” by “long-term use” and “recycling” ways

TMR in some products/ product weight



Indirect but large reduction of environmental burden can be expected by long-term use and recycling of products.

4. E-Waste Recycling Policies in Japan



Recycling Law of Specified Kinds of Home Appliances

Objective

Legally promotion of environmentally sound management of E-waste and efficient use of recyclable resources

Mechanism

Shared responsibilities to all stakeholders:

- End users: payment of recycling fee
- Retailers: collection of used home appliances
- Manufacturers: recycling of collected appliances

Targets

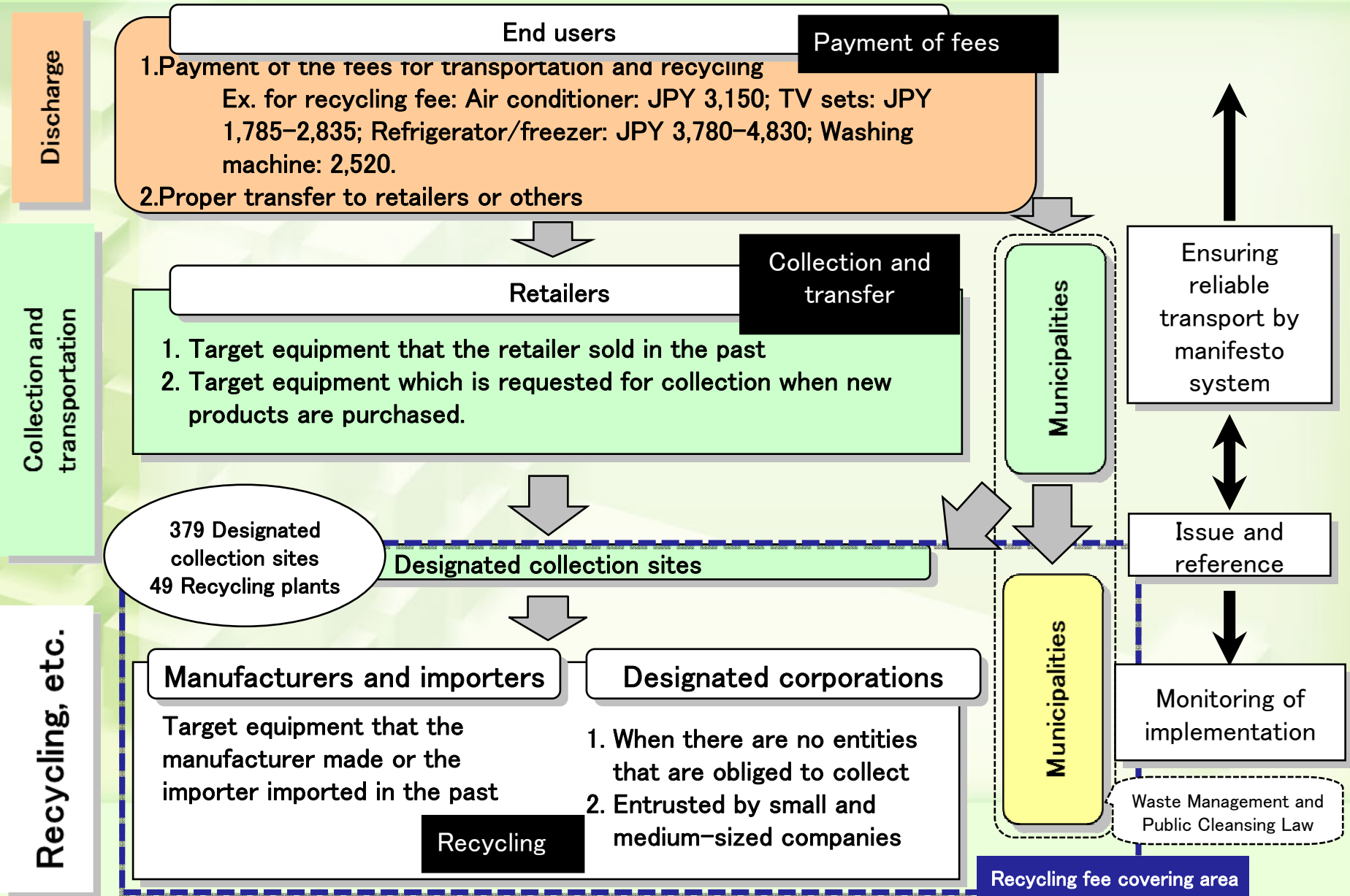
Air conditioners

Televisions (CRTs, LCD/PDP TVs)

Refrigerators and freezers

Washing machines and clothes dryers

Recycling Law of Specified Kinds of Home Appliances



Small appliances & battery collection site in front of an administration office in Kyoto



Dec. 10
2009

Collected mobile phone in the collection site of small appliances in Kyoto



**Feb. 4
2010**

Steps toward Legal Framework for Small Appliances

Potential of other urban mining = Compact digital gadgets

No. of Items 218 million units (45 kinds)/1.4 million tonnes

Potential value Base/precious metals: JPY 30 billion
Rare earth metals: JPY 5 billion

**Available for recovering technology of base/precious metals;
but no legal framework for collection/recovering**



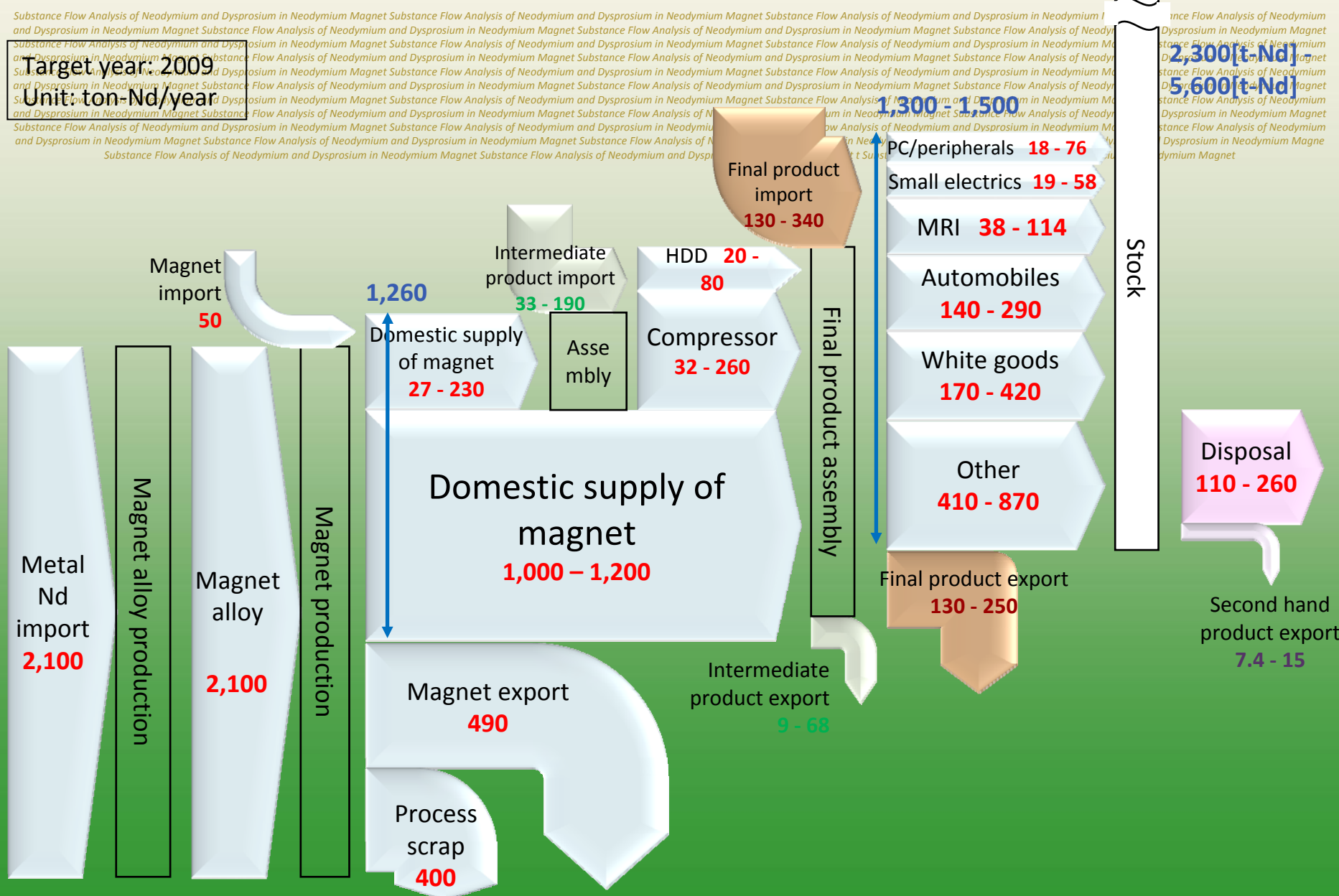
Subcommittee on Compact Digital Equipment Recycling, Central Environment Council

Priority Items Mobile phones, game players, portable CD/MD players, portable digital audio players, digital cameras, automobile navigation system, video cameras, DVD players, etc

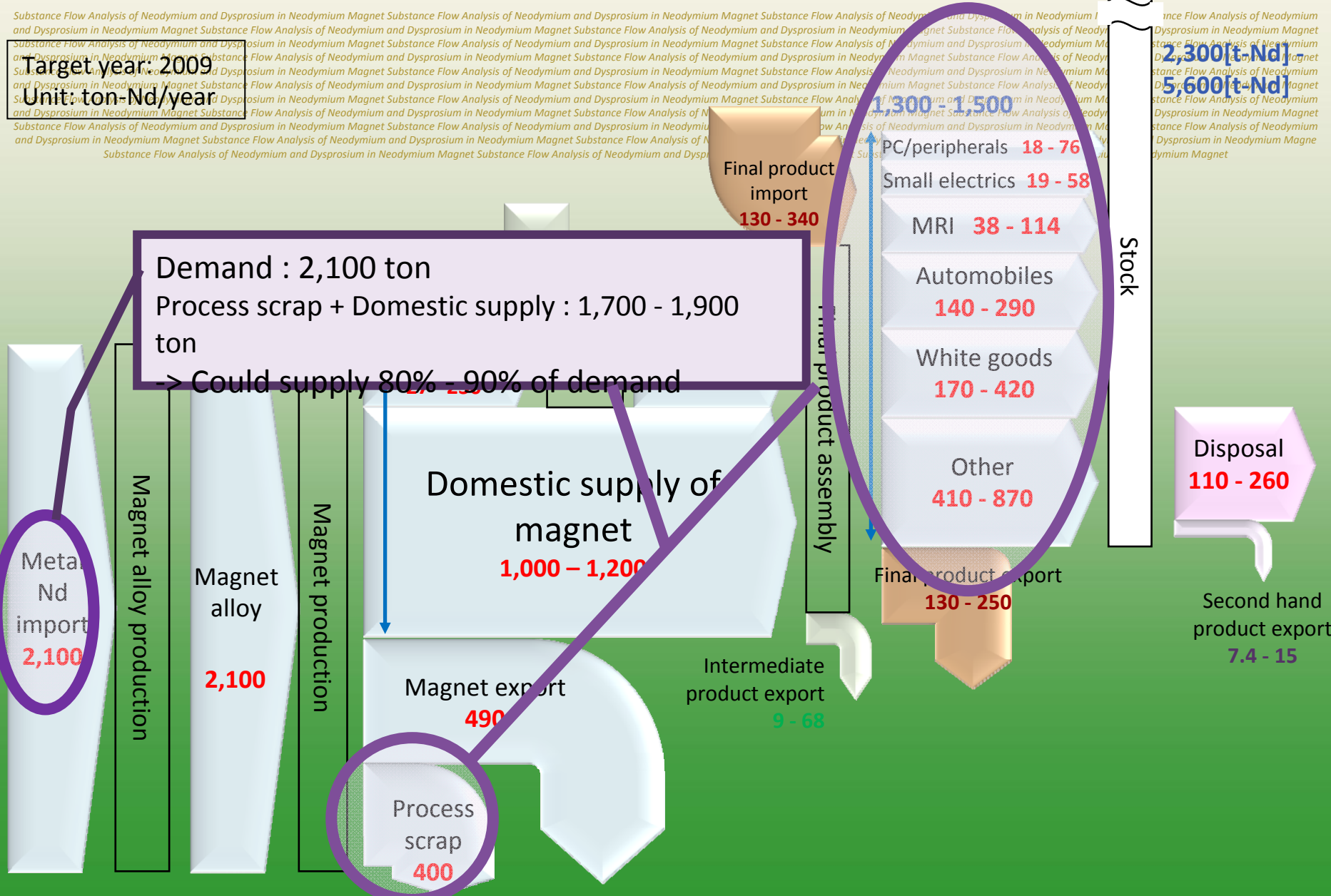
Priority rare earth metals Tungsten, Cobalt, Tantalum, Neodym, Palladium

Option of mechanism Voluntarily mechanism, Utilization of current mechanism, Mandatory mechanism

Result: Nd flow in 2009



Result: Nd flow in 2009



Conclusions

1. Regarding urban cities as urban mines and promotion of metal recycling are essential from the viewpoints of resources and environment conservation. Also, ecological rucksack should be kept in mind at the stage of mining minerals.
2. Not only resource potential, but also adverse harmful effect should be considered. Balanced recycling system considering these two points is expected.
3. In addition to 4 items of home appliances (e.g.: TV and others), recycling policy for small household appliances like mobile phone is under discussion in Japan. Recovery of metal like copper and rare metals like palladium is one of the hot issues.