The Case Study of National-scale Material Flow Assessment —the Japan Experience

Ecomaterial Design and Process Engineering
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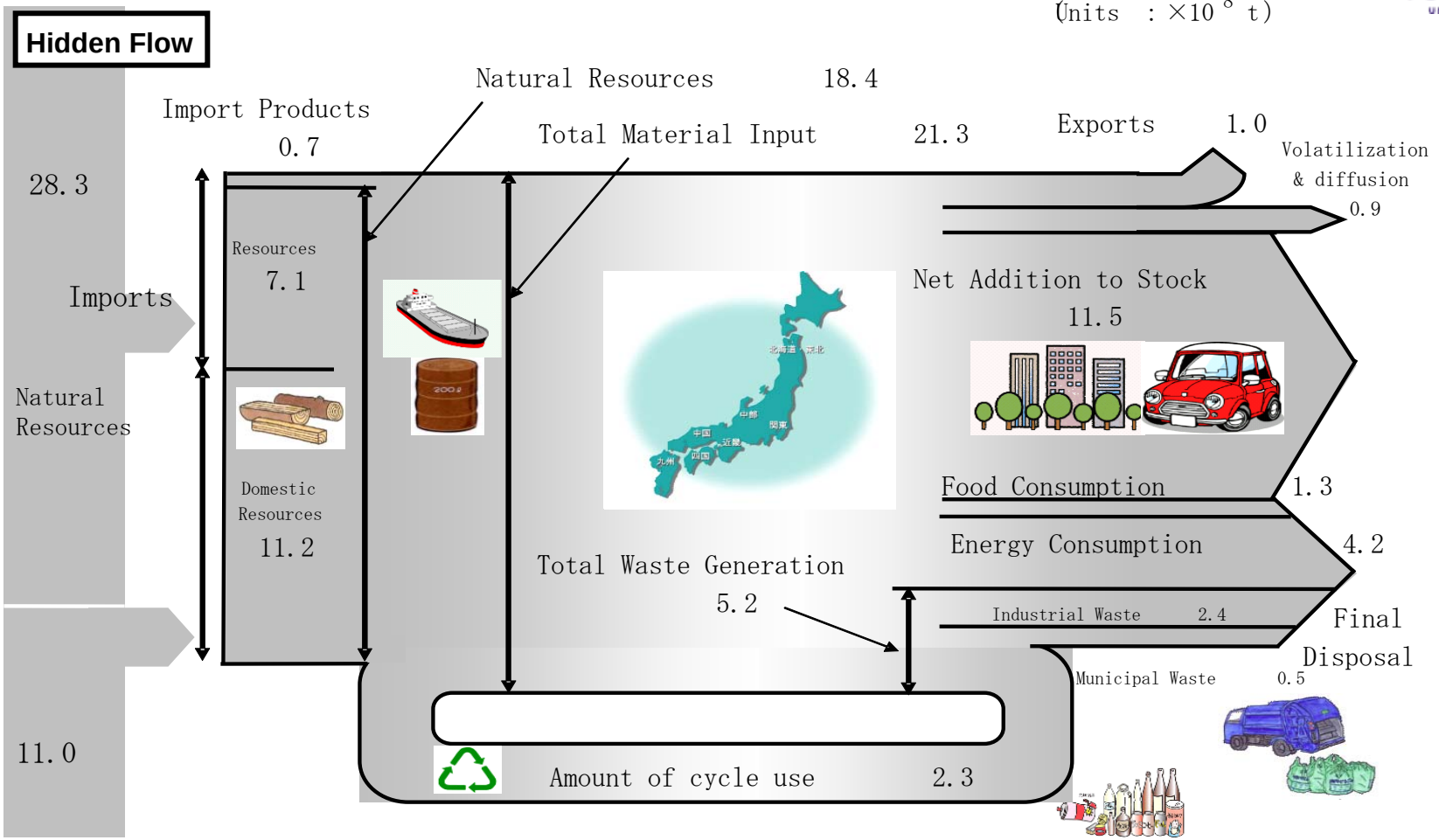
横山 一代　　長坂徹也

17, January, 2007 Environmental & Energy International Conference , Taipei, Taiwan

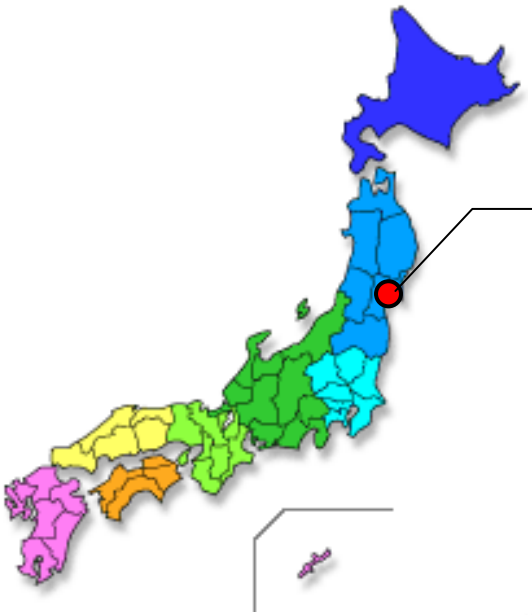
Material flow of Japan (2000year basis)

(Units : $\times 10^8$ t)



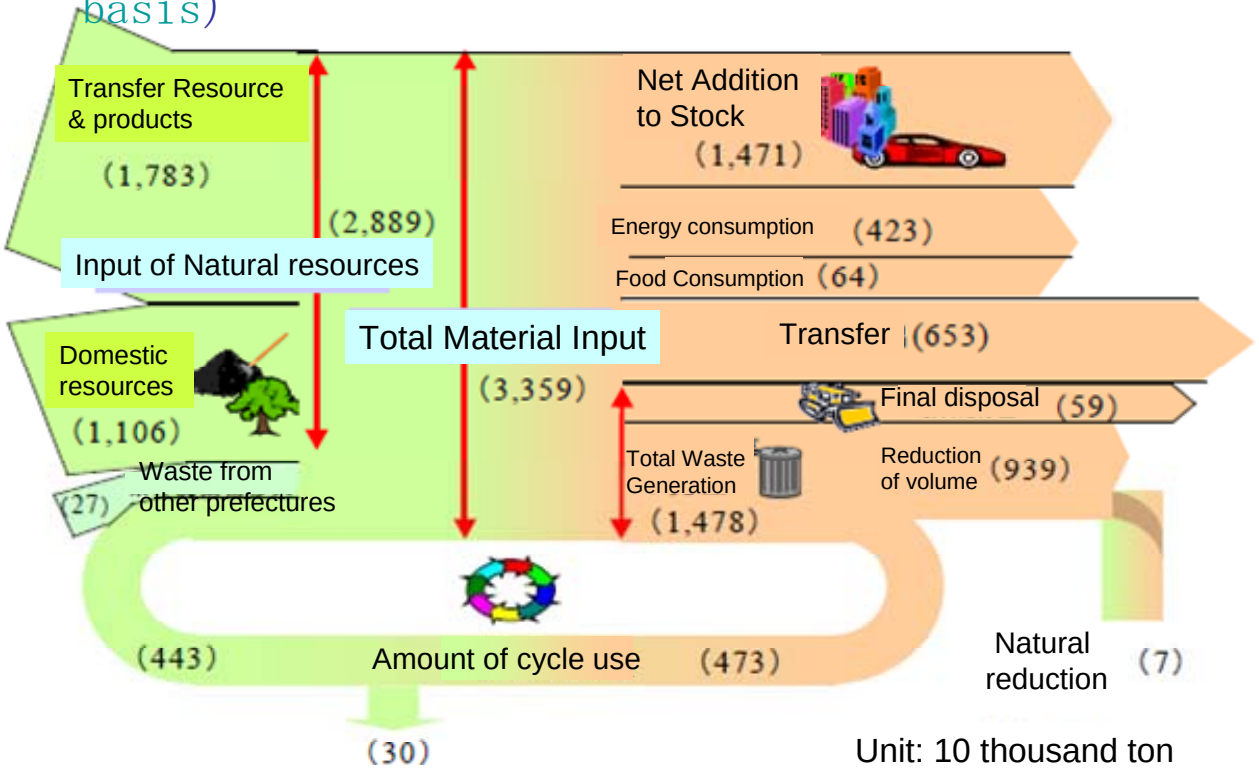
The total land area is approximately 380,000 km^2.

The islands stretch nearly 3,000 km from north to south.
Population = 127 Million



Sendai
仙台

Material flow of Miyagi Prefecture (2003 FY basis)



Unit: 10 thousand ton

- For sound social metabolism, or efficient and sustainable management of resources…
- We need more and more detail information about following questions.
- Where and how much the valuable materials exist in our society?
- When and how we can / should recover the materials from the durable commodities as secondary resources?
- How we should manage valuable materials in our society?

Contents

- “Substance/material flows as sustainability indexes”
  - funded by RISTEX-JST
  - Demand and supply of rare metal in Japan
  - SFA of molybdenum associated with iron and steel cycle in Japan
  - Material flow of Phosphorus in Japan

- “Development of Material Stock Account Framework and Its Application: Strategies for Waste / Resource Management”
  - funded by Ministry of Environment
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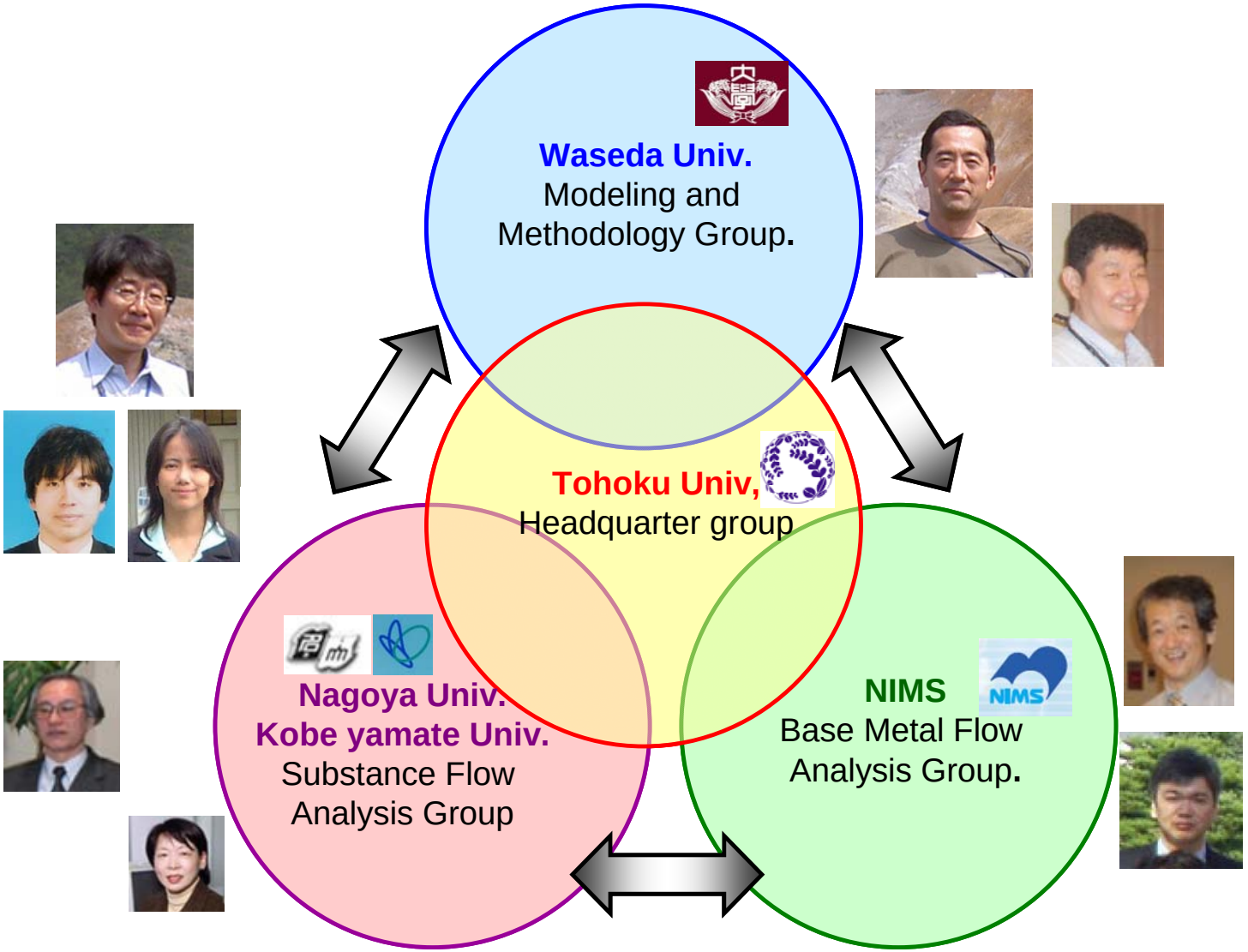
  - Application of MSA and Scenario Analysis

Substance/material flows as sustainability indexes

as a Contract Research Program “The Study on Sustainable Society” funded by RISTEX-JST (Research Institute of Science and Technology for Society - Japan Science and Technology Agency). : 2003~2006



Substance/material flows as sustainability indexes

RISTEX-JST : 2003~2006

Symposium on Advanced Material Flow Analysis for the Sustainable Society

September 25 – 26, 2006

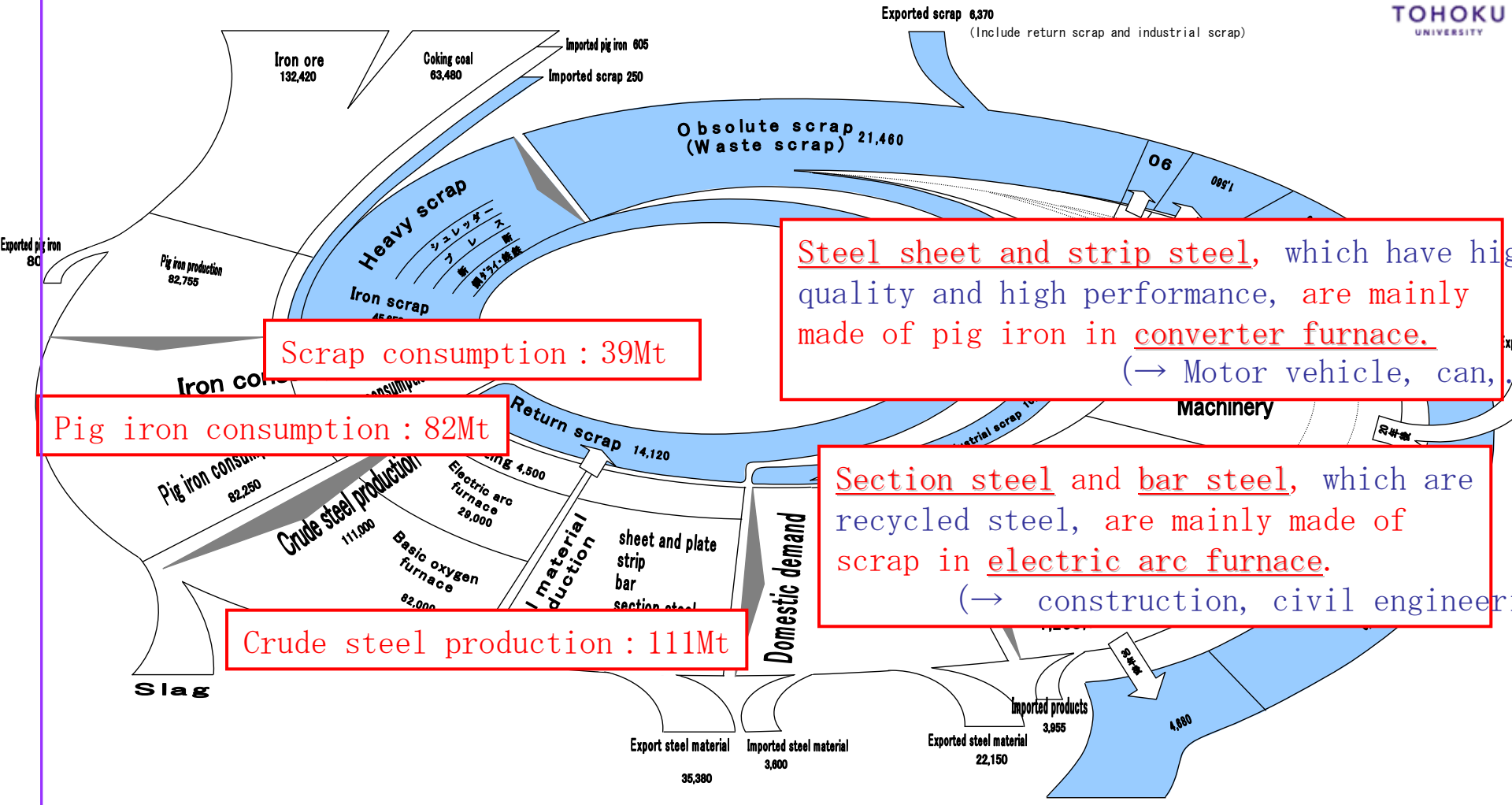
Tohoku University, Sendai, Japan

Sponsored by

RISTEX (Research Institute of Science and Technology for Society),

JST (Japan Science and Technology Agency)

Iron and steel cycle in Japan



Steel sheet and strip steel, which have hig quality and high performance, are mainly made of pig iron in converter furnace.
(→ Motor vehicle, can,

Scrap consumption : 39Mt

Pig iron consumption : 82Mt

Section steel and bar steel, which are recycled steel, are mainly made of scrap in electric arc furnace.
(→ construction, civil engineer

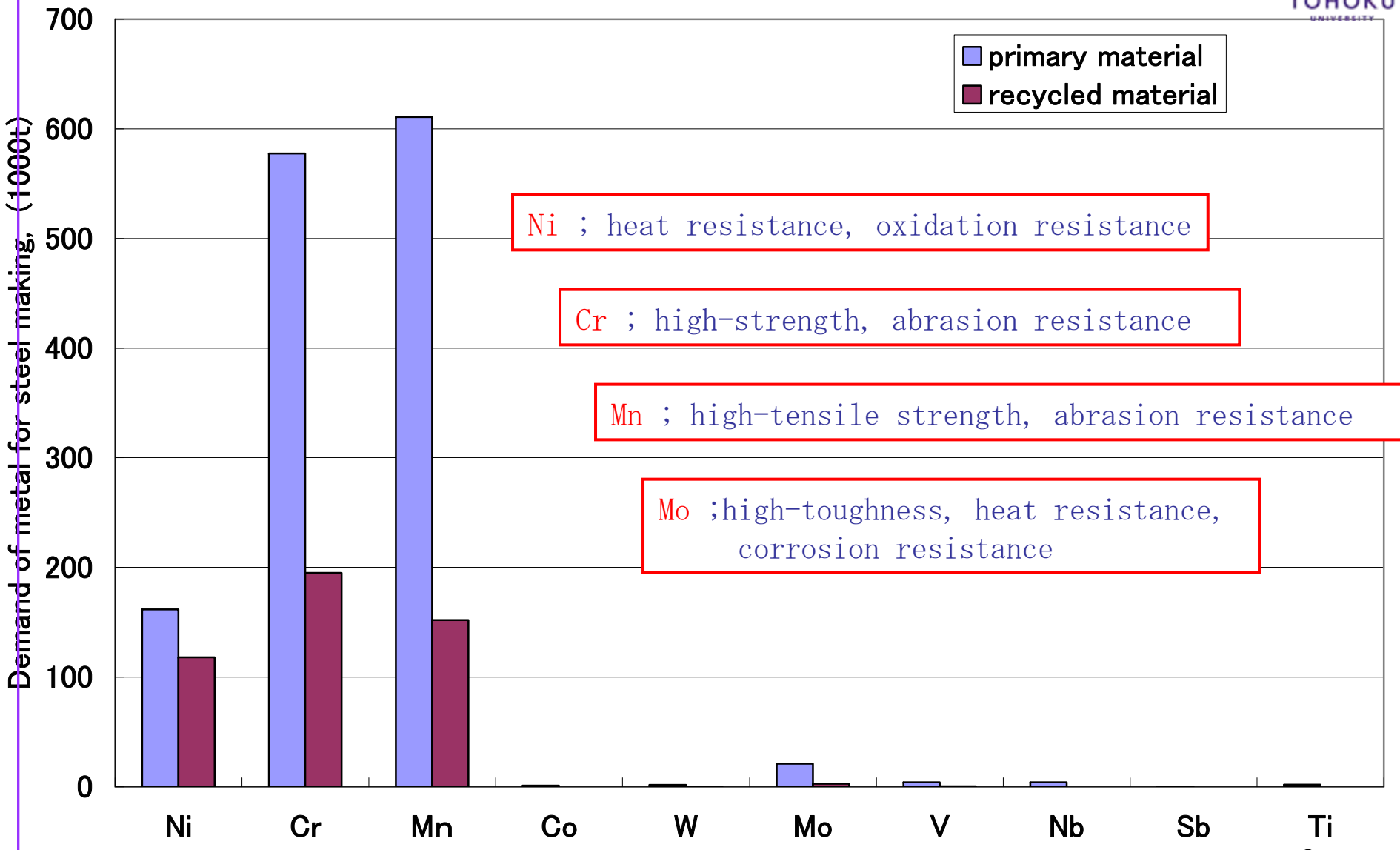
Crude steel production : 111Mt

Iron and steel cycle in Japan (2003fy)
(unit: 1000t)

Data: The Japan ferrous raw materials association

Demand of rare metals in Japan

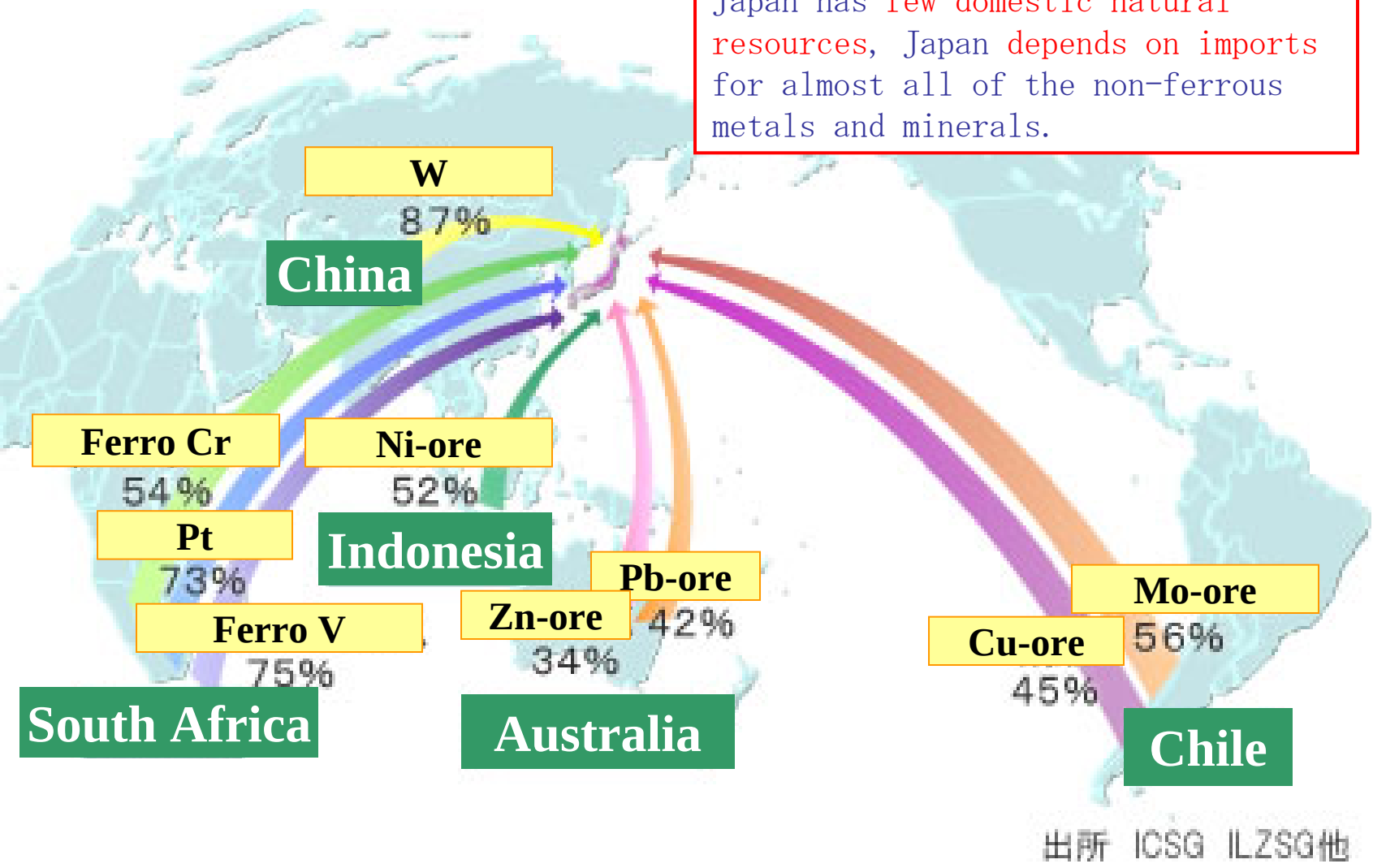
Rare metals (Ni, Cr, Mn, Mo, …etc.) are used for steel making process in order to…



Demand of rare metal for steel making (2003)

Demand of rare metals in Japan (import)

Japan has few domestic natural resources, Japan depends on imports for almost all of the non-ferrous metals and minerals.

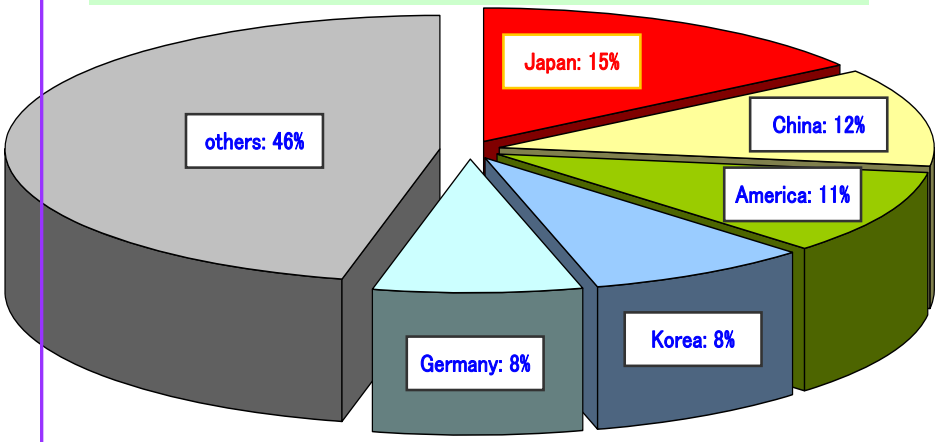


http://www.jogmec.go.jp/j_resourse/index.html

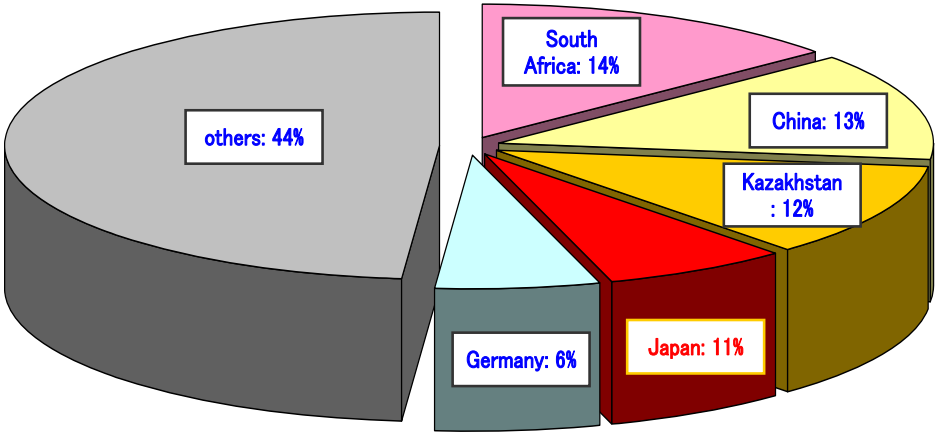
Demand of rare metals in the world

Large amount of rare metals are consumed in Japan. On the other hand, it is expected to increase consumptions of rare metals in other Asian countries (China, Korea…) with industrial development.

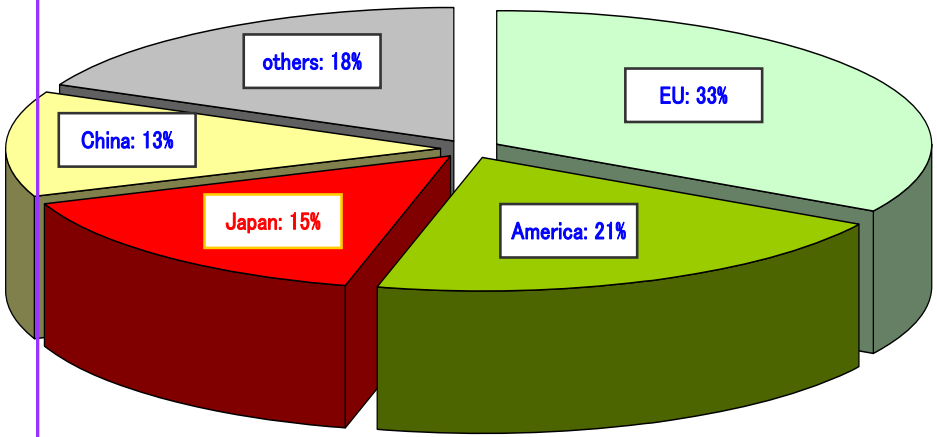
(a)Ni, Consumption(World) :
1,253 $\times 10^3$ Ni-t (2004)



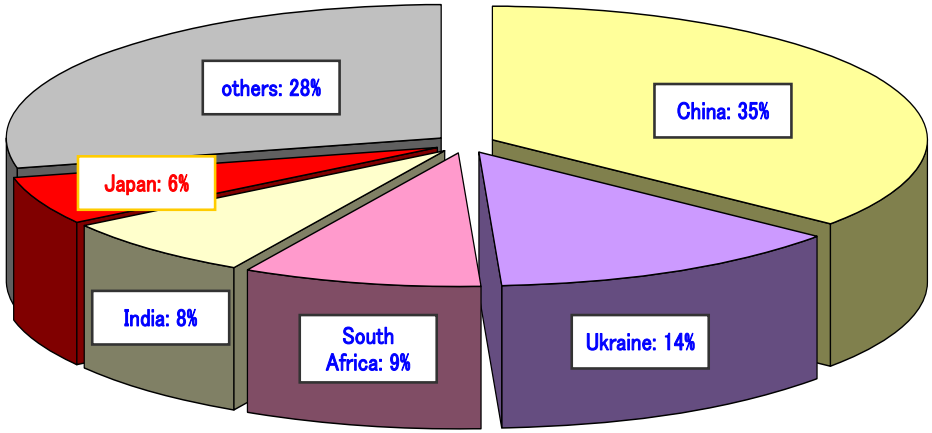
(b)Cr, Consumption(World) :
4,695 $\times 10^3$ Cr-t (2003)



(c)Mo, Consumption(World) :
175 $\times 10^3$ Mo-t (2004)



(d)Mn, Consumption(World) :
19,630 $\times 10^3$ t (2001)



National stockpiling program in Japan

Since 1983, **JOGMEC (Japan Oil, Gas and Metals National Corporation)** has managed the national stockpiling of rare metals to prevent any short-term supply shortage.
At present, JOGMEC stockpiles 7 materials : nickel, chromium, tungsten, cobalt, molybdenum, manganese, and vanadium.


Nickel


Tungsten


Molybdenum


Vanadium


Chromium


Cobalt


Manganese

Stockpiling program of non-ferrous materials in Japan

A management of these metals is important from the viewpoint of the material-cycle and the strategic resource utilization...

Material flow data in Japan

Supply and demand data

1) Ministry of Economy, Trade and Industry

METI: "Yearbook of iron and steel, non-ferrous metals, and fabricated metals statistics", (2005)

Material flow data

2) JOGMEC

JOGMEC: "*Koubutsu Shigen* Material Flow 2004 (in Japanese)", (2005)

3) NIMS, Tohoku Univ., University of Tokyo, and NIES

M.SHIMADA, K.IJIMA, Y.SAWATANI, K.NAKAJIMA, T.NAGASAKA, T.TSUKIHASHI, Y.MORIGUCHI, and K.HALADA: "New Trend of Material Flow in the Era of Globalization", Advance in Ecomaterials, pp.620-633, (2005)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	lantha noid	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	actino id															
lanthanoid		La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	
actinoid		Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr	

JOGMEC[2)]

NIMS et al.[3)]

Target elements (JOGMEC: 44, NIMS et al: 22)

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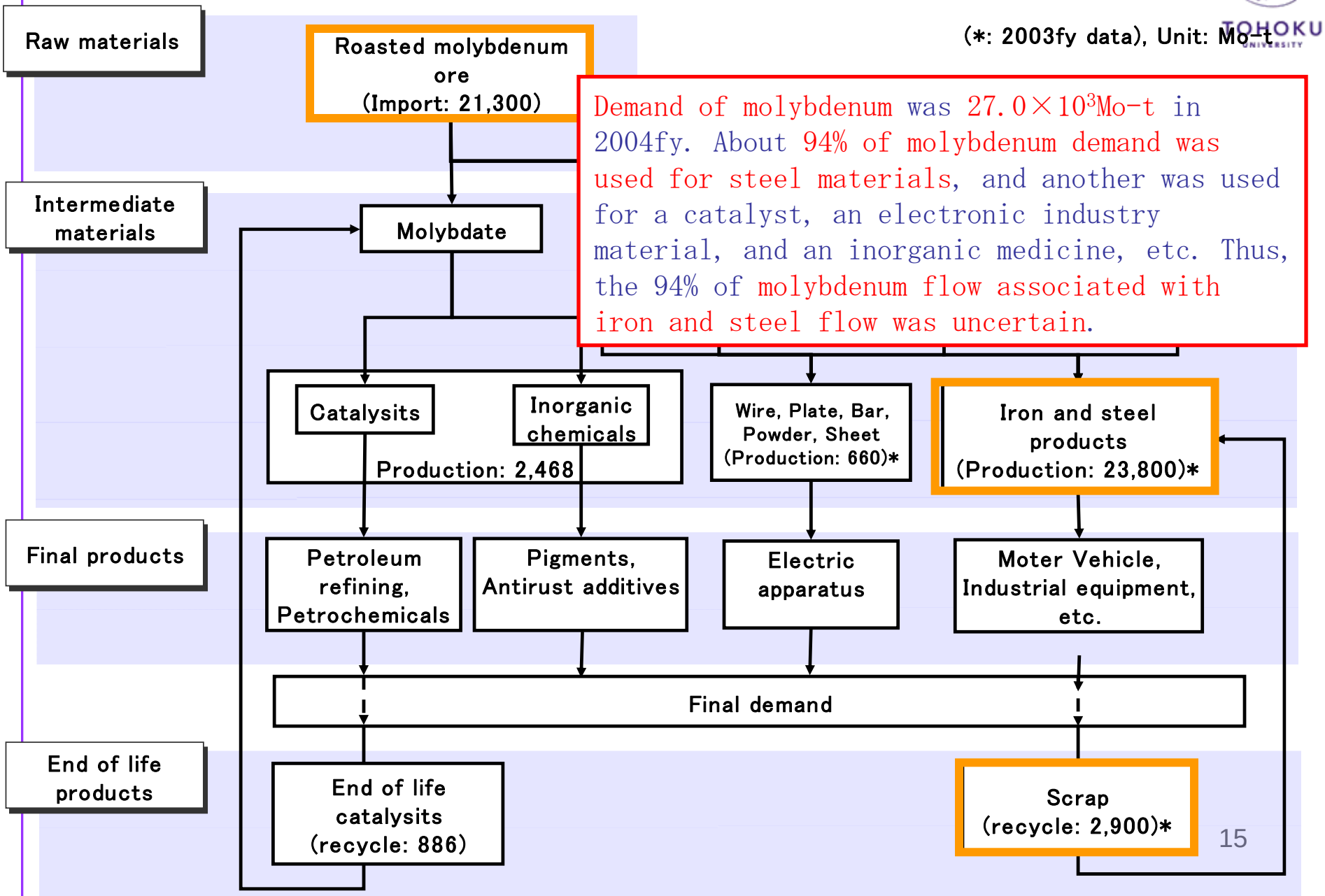
Molybdenum flow in Japan(FY2004)

Data: http://www.jogmec.go.jp

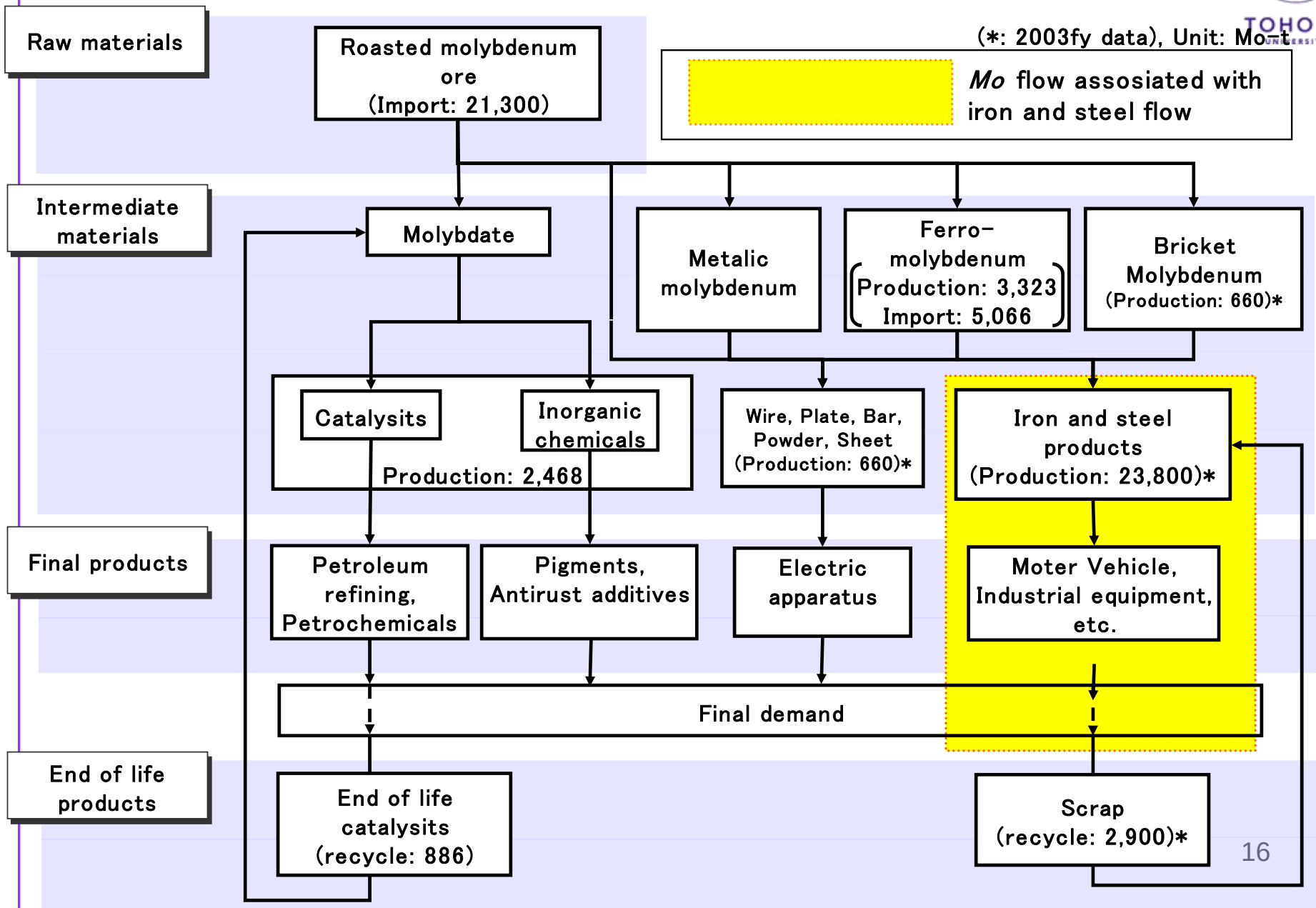
(*: 2003fy data), Unit: Mo-t

Demand of molybdenum was 27.0×10^3Mo-t in 2004fy. About 94% of molybdenum demand was used for steel materials, and another was used for a catalyst, an electronic industry material, and an inorganic medicine, etc. Thus, the 94% of molybdenum flow associated with iron and steel flow was uncertain.

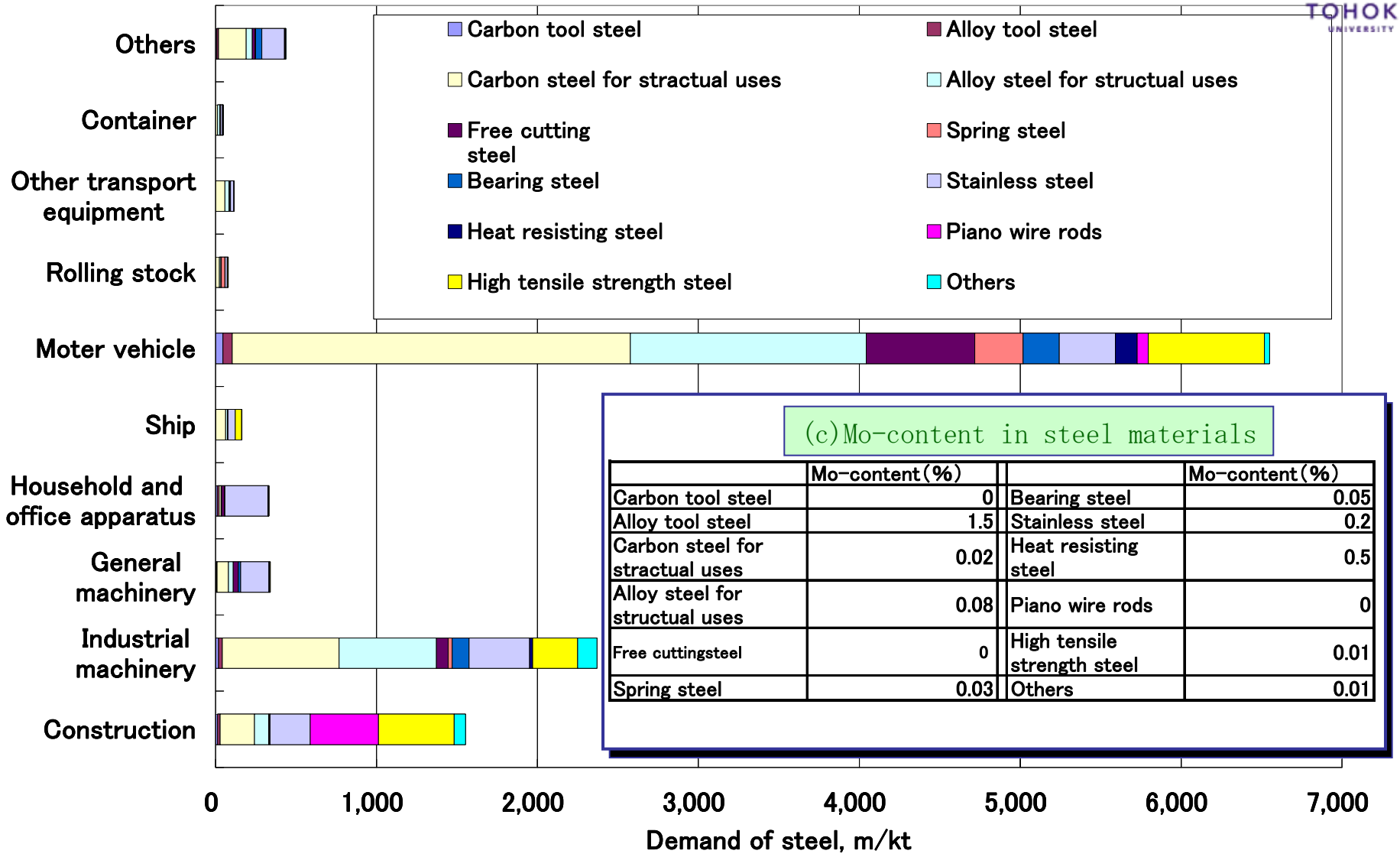


Molybdenum flow in Japan(FY2004)

Data: http://www.jogmec.go.jp



Demand of special steel materials, and Mo-content in steel materials

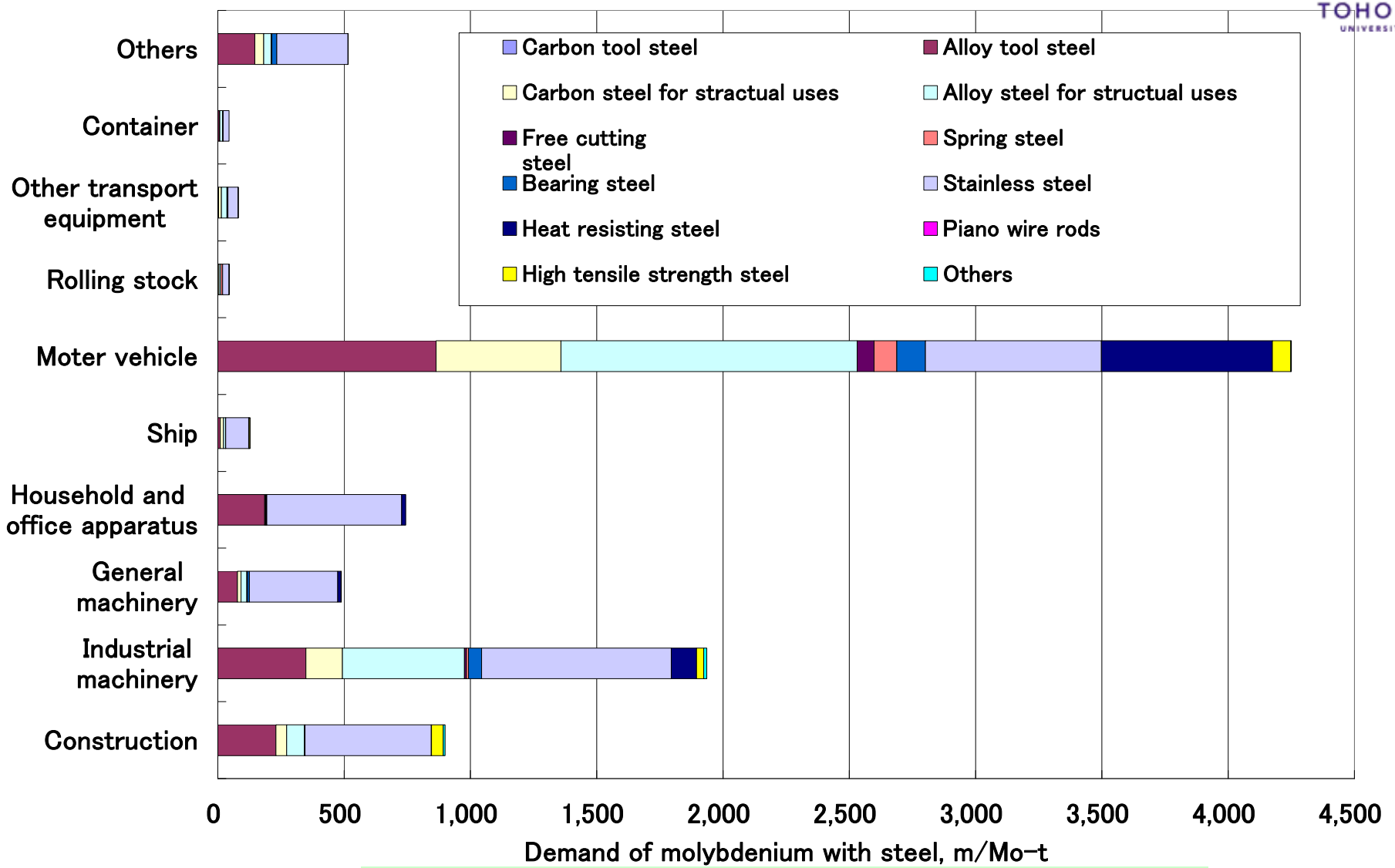


(c)Mo-content in steel materials

	Mo-content(%)		Mo-content(%)
Carbon tool steel	0	Bearing steel	0.05
Alloy tool steel	1.5	Stainless steel	0.2
Carbon steel for stractual uses	0.02	Heat resisting steel	0.5
Alloy steel for structual uses	0.08	Piano wire rods	0
Free cuttingsteel	0	High tensile strength steel	0.01
Spring steel	0.03	Others	0.01

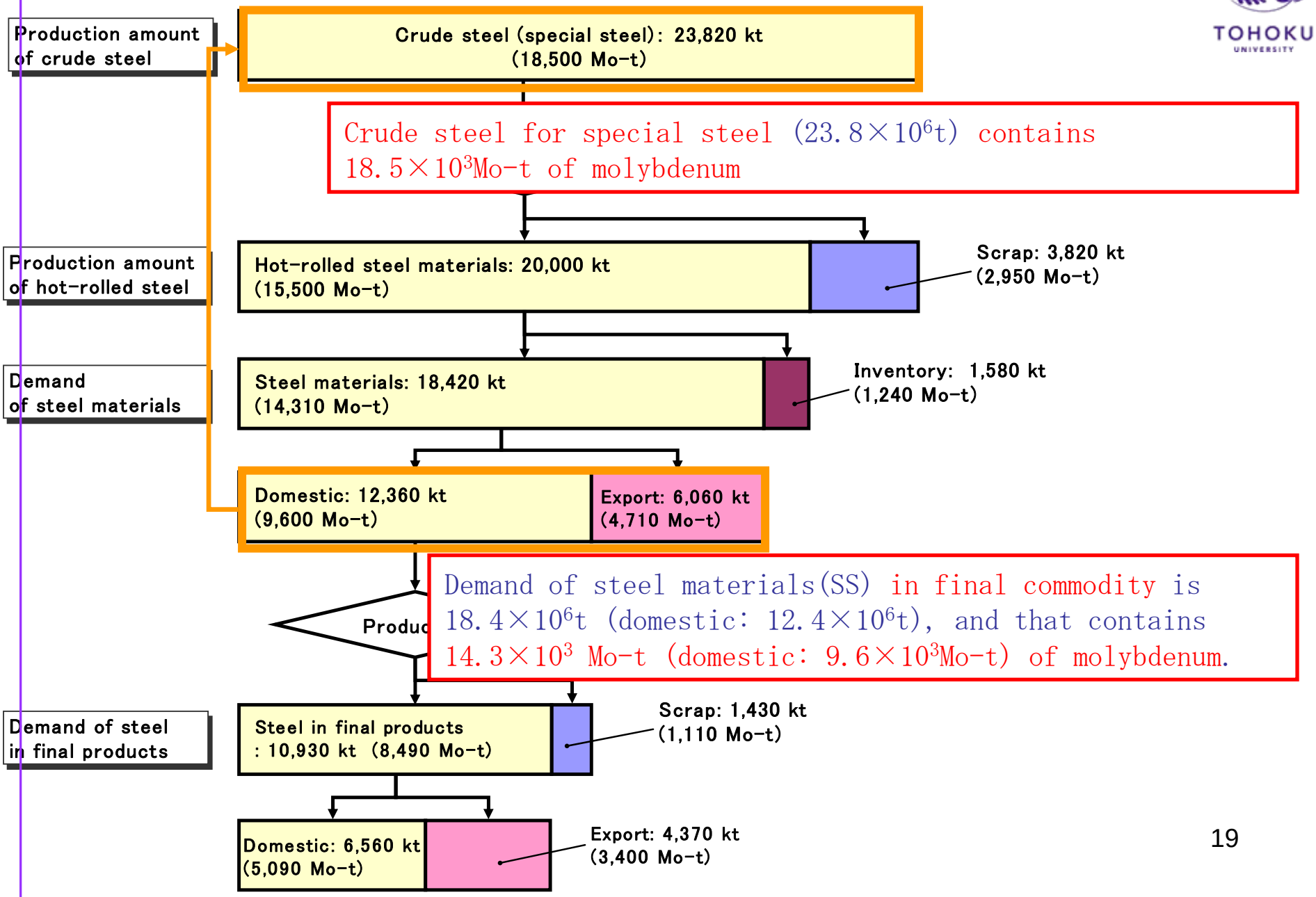
(b) Demand of special steel materials by final commodity production (2004fy)

Demand of *Mo* by final commodity production (Estimated result)



(e) Demand of Mo by final commodity production (originated from special steel) (2004fy)

Demand of Mo associated with iron and steel cycle(2004fy)



Molybdenum parts used in motor vehicle

it seems that a dismantling process to remove automobile parts contains molybdenum is needed in order to promote molybdenum recycling. One of the specific pars is engine valve in automobile whose Mo-content is 0.7%.

Engine valve

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Present status of the world phosphorus resources

- Main use : raw materials for fertilizer
- It completely depends on import.

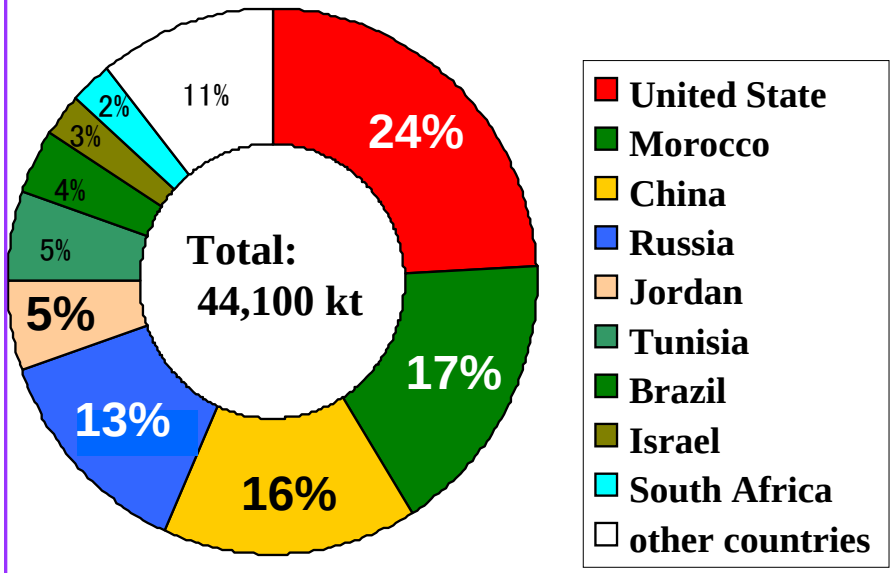


Fig. Phosphate rock production rate in the world. (2002)

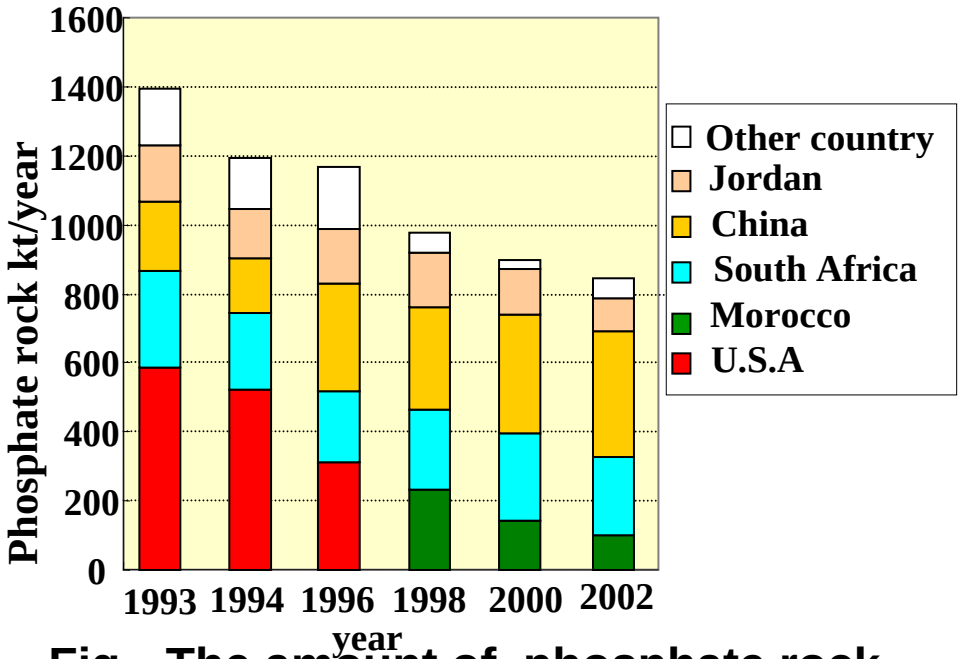


Fig. The amount of phosphate rock imported.

Ministry of finance Japan “Trade Statistics”

Domestic material flow of phosphorus (Conventional type)

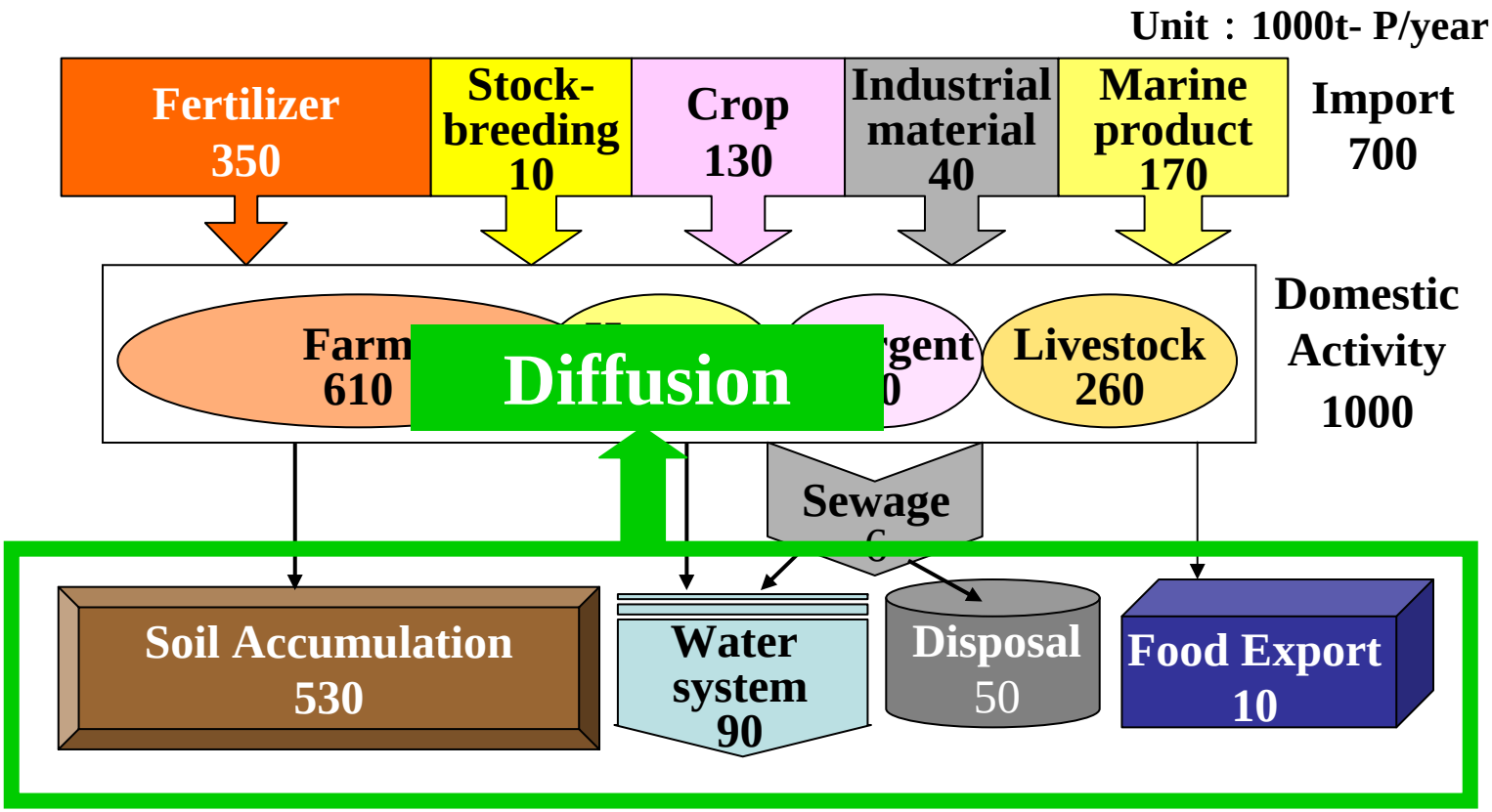


Fig Material flow of phosphorus in Japan, 1993

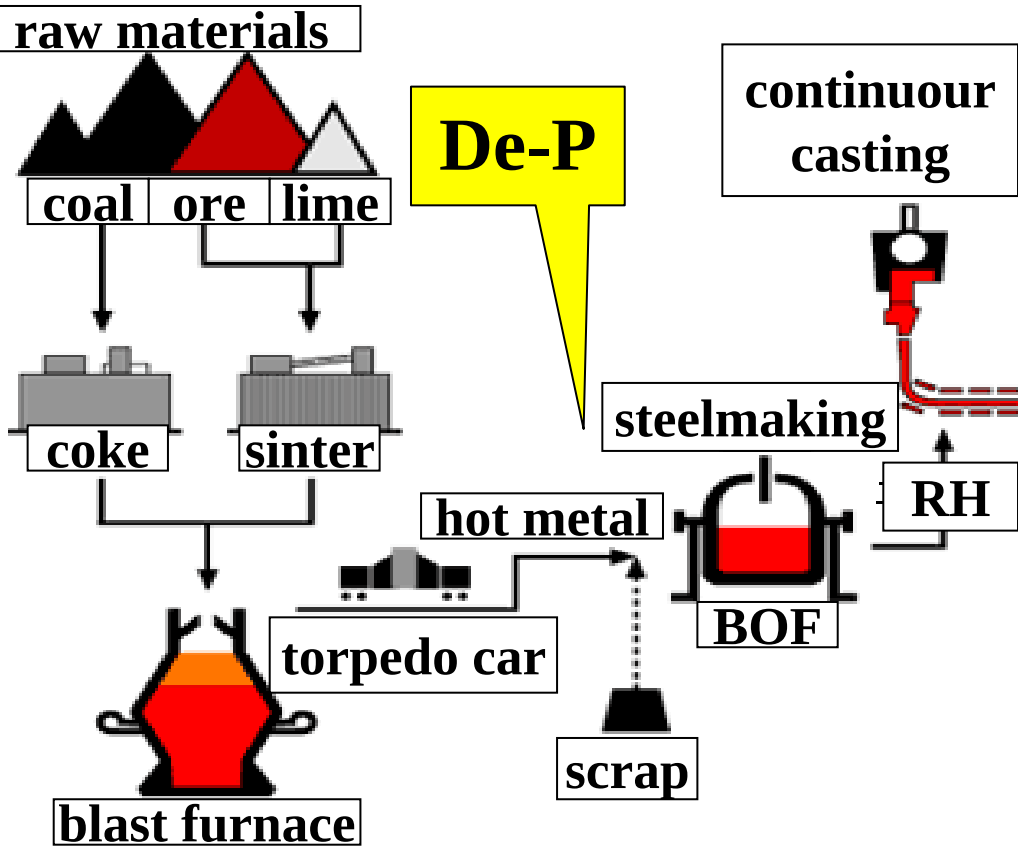
H. Mishina "Saisei to Riyou" Vol. 26 No. 98 2003/1

Dephosphorization of steel with slag

Phosphorus is a natural enemy for steel, because it enhances cold brittleness of steel product.

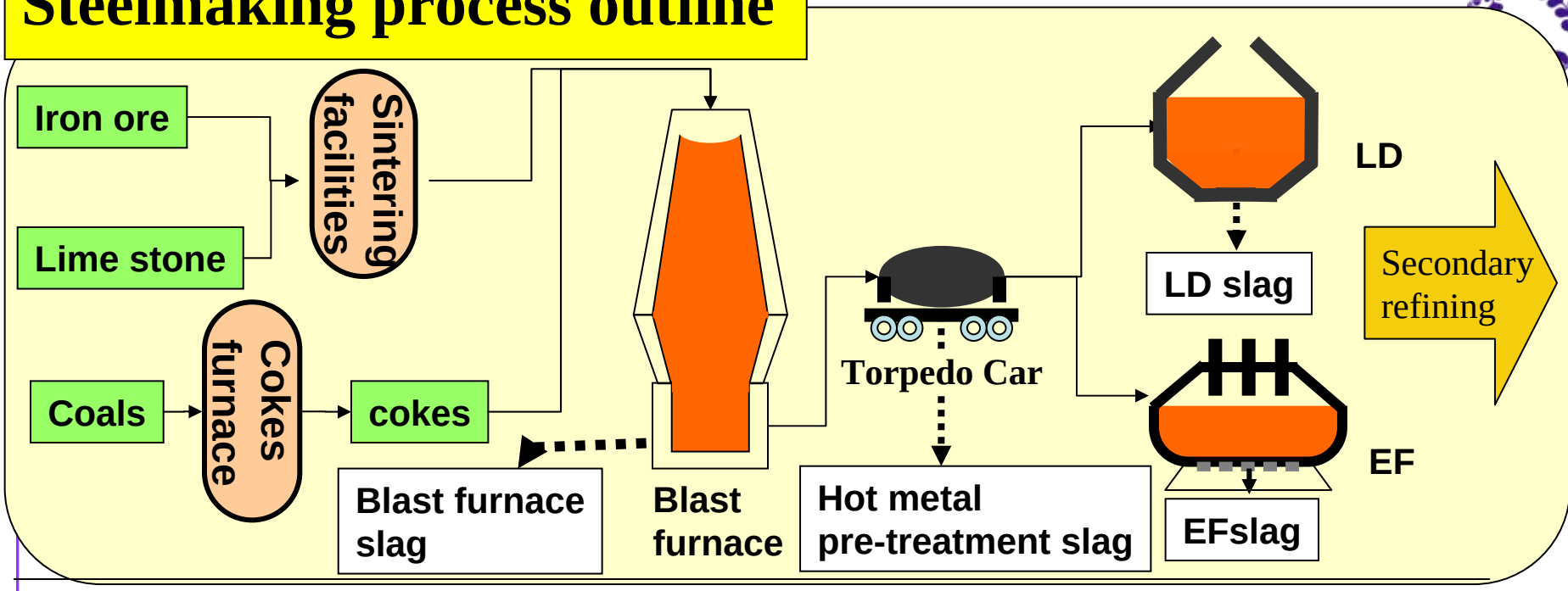
One of the most important roles of steelmaking slag is dephosphorization of molten steel.

The slag after the dephosphorization contains approximately 2 to 10 mass% of P2O5 together with FetO, CaO and SiO2.



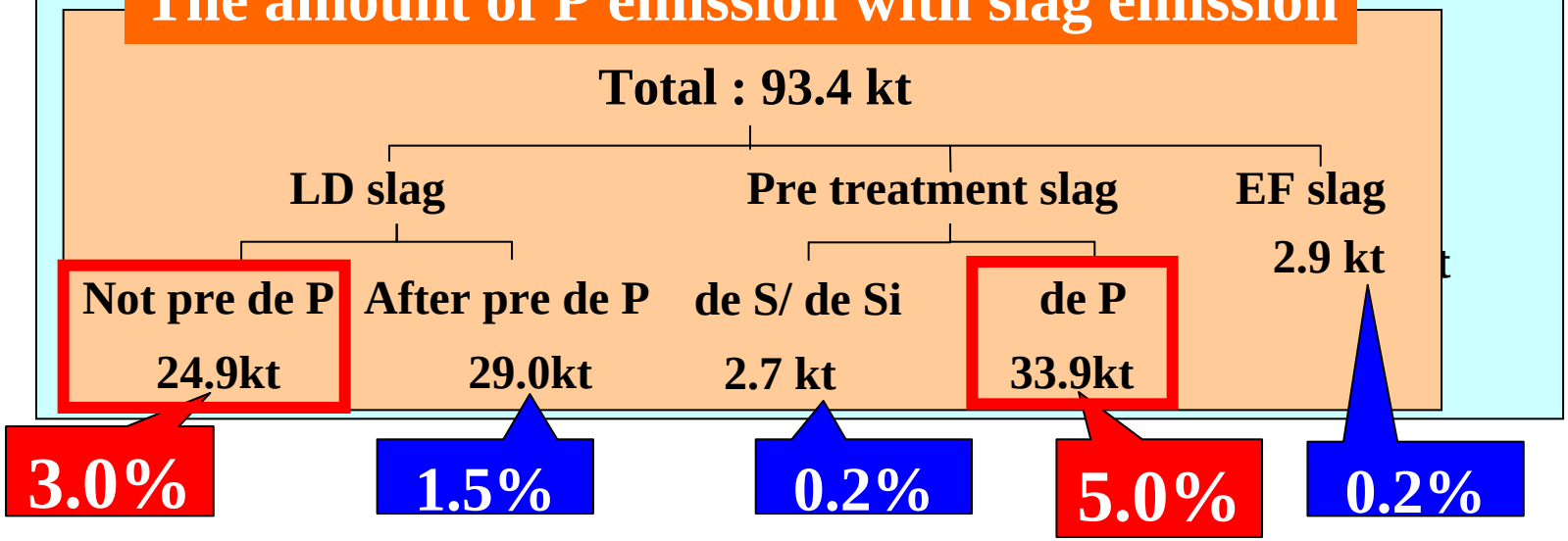
Iron- and steelmaking process

Steelmaking process outline



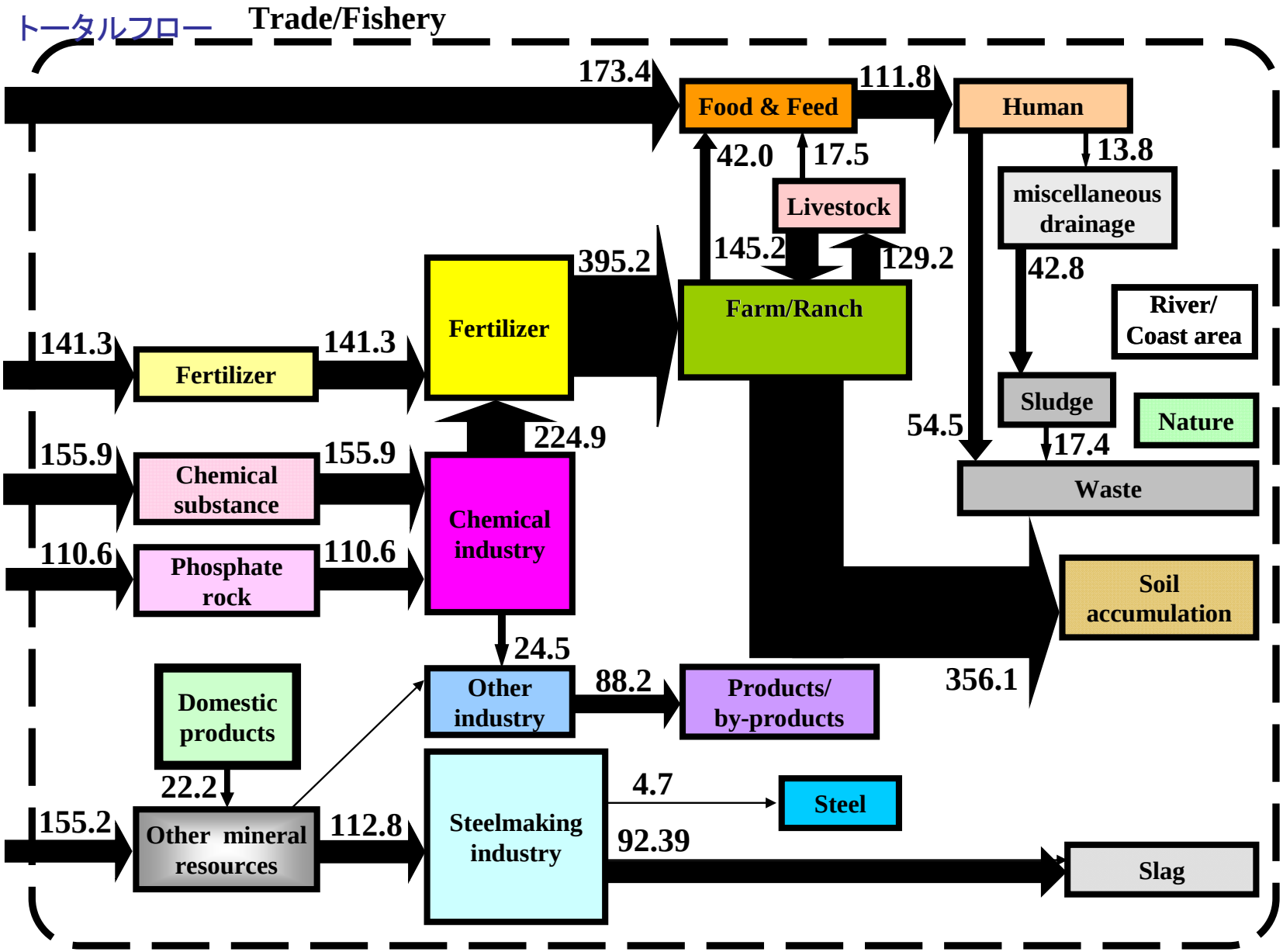
The amount of slag generation based on slag emission intensity

The amount of P emission with slag emission



Material flow of Phosphorus in Japan: Part 1

トータルフロー



Material flow of Phosphorus in Japan: Part 2

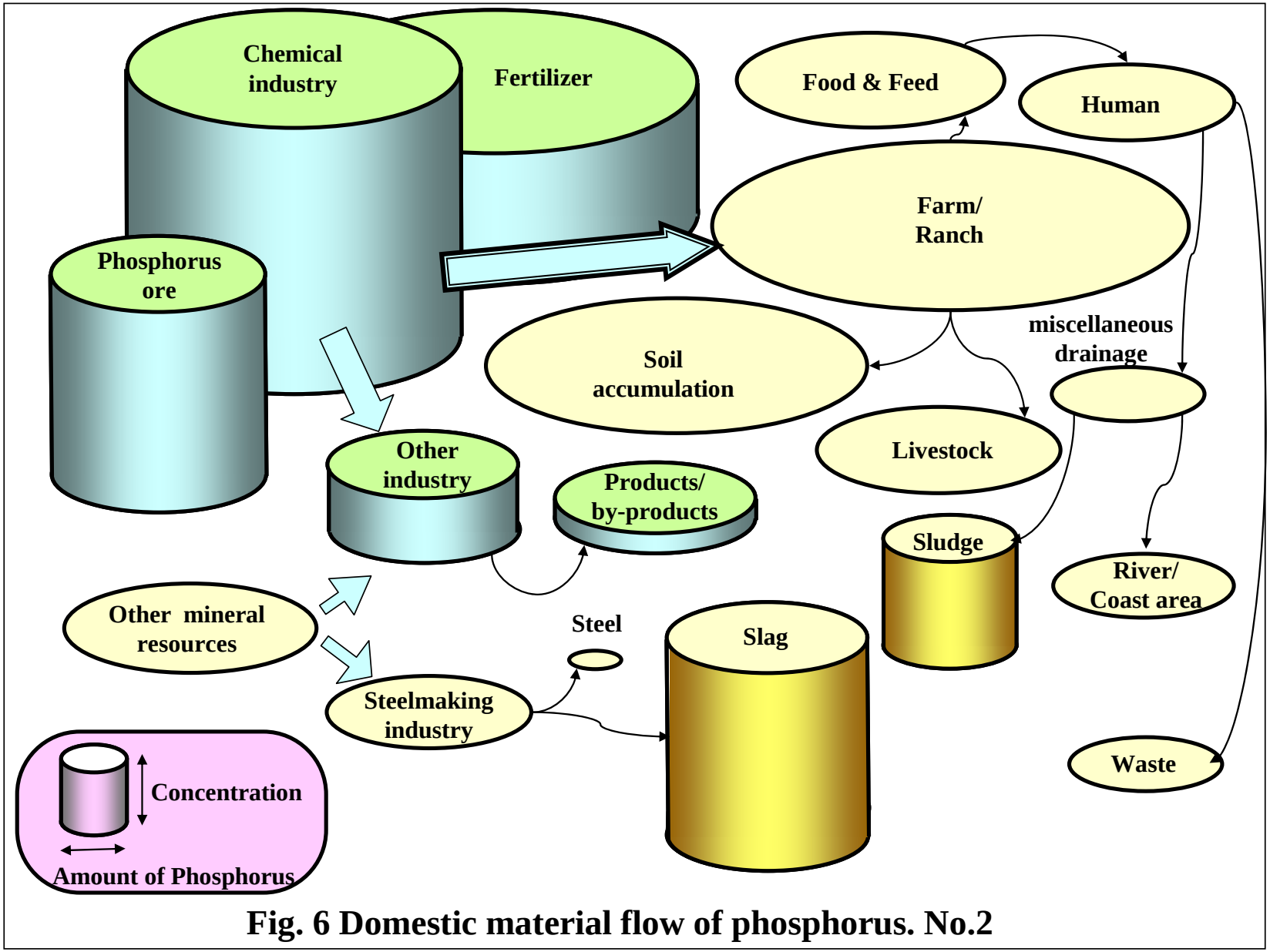


Fig. 6 Domestic material flow of phosphorus. No.2

Substance/material flows as sustainability indexes

RISTEX-JST : 2003~2006

- Our main outcomes are
  - to quantitatively investigate flows of base materials, such as Fe, Al, Cu and associated substances, such as Mo, In, P by using the methods of material flow analysis (MFA), substance flow analysis (SFA), and waste input-output analysis,
  - to develop WIO-MFA model as a mathematical model that enables integrative assessment and analysis of these data from temporal and spatial axes.

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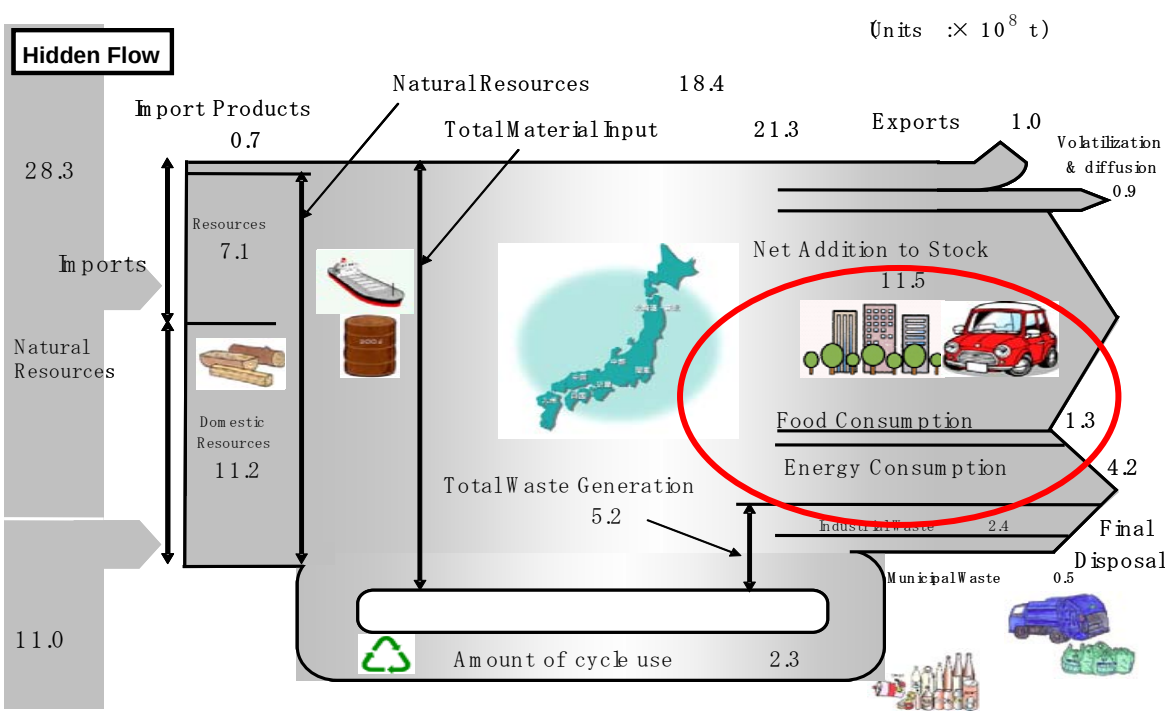
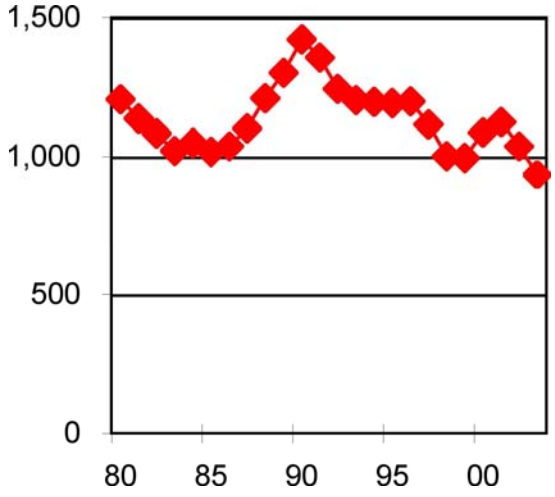
TOHOKU UNIVERSITY

Material flow of Japan (2000 year basis)



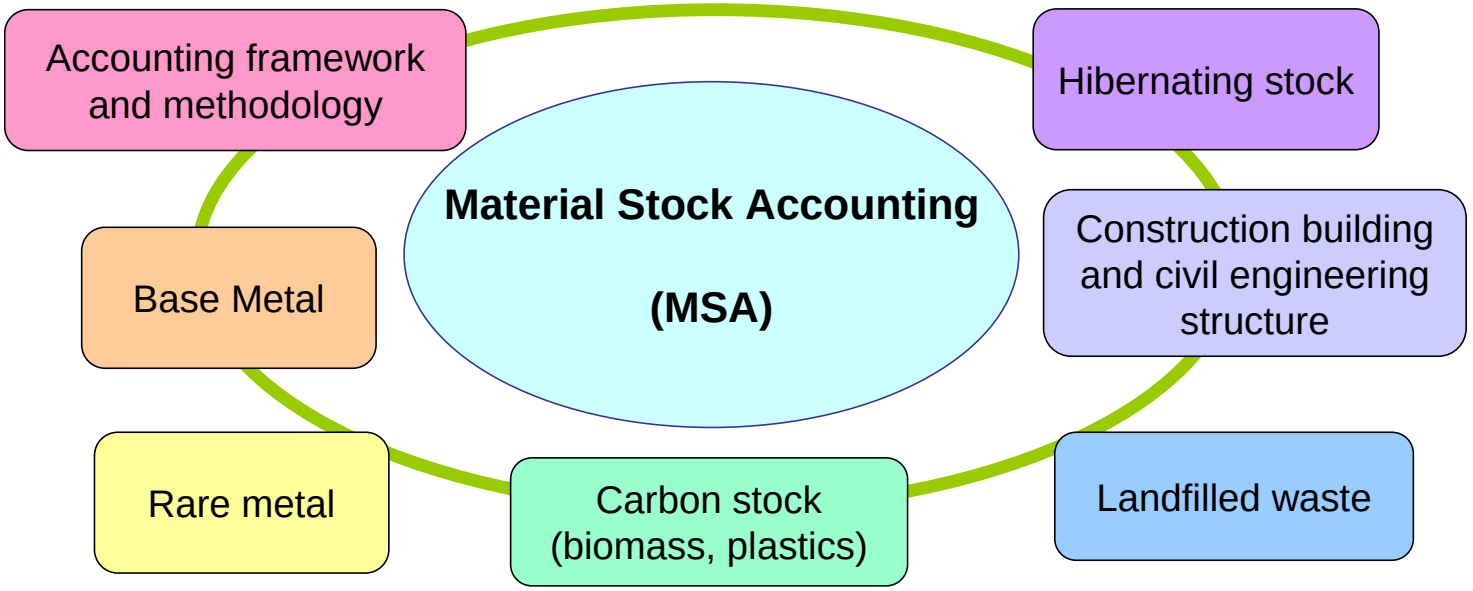


Most materials which have been exploited in the past centuries are still "hibernating" somewhere in the anthroposphere.

Brunner (1999,2004)

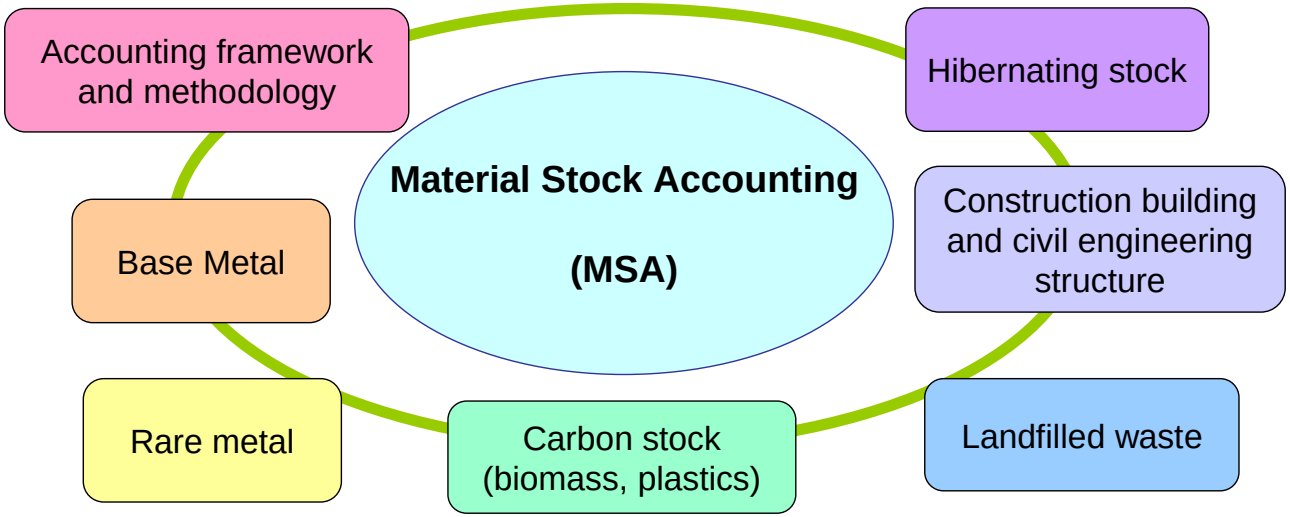
Development of Material Stock Account Framework and Its Application: Strategies for Waste / Resource Management

Grant-in-Aid for Scientific Research for Waste treatment:2006~2008



1. Development of MSA Framework that is consistent with Economy-Wide MFA Framework
2. Application of MSA and Scenario Analysis

Development of Material Stock Account Framework and Its Application: Strategies for Waste / Resource Management



Seiji Hashimoto	National Institute for Environmental Studies
Tomohiro Tasaki	National Institute for Environmental Studies
Shinsuke Murakami	National Institute for Environmental Studies
Osamu Umezawa	Yokohama National University
Hiroki Tanikawa	Wakayama University
Ichiro Daigo	The University of Tokyo
Ken-ichi Nakajima	Tohoku University
Kazuyo Yokoyama	Tohoku University
Masaaki Fuse	National Institute for Advanced Industrial Science and technology
Eiji Yamasue	Kyoto University

What is “material stock”?

Taiwan High Speed Rail

Taipei 101

Unused/left products

Unused infrastructures

Dissipated/left wastes

Landfilled wastes

Unknown export of used products

What is “material stock”?

Taiwan High Speed Rail

Taipei 101

Potential wastes
Potential Resources

What is “material stock”?

Collectability?
Value?
Market?

Unused/left products

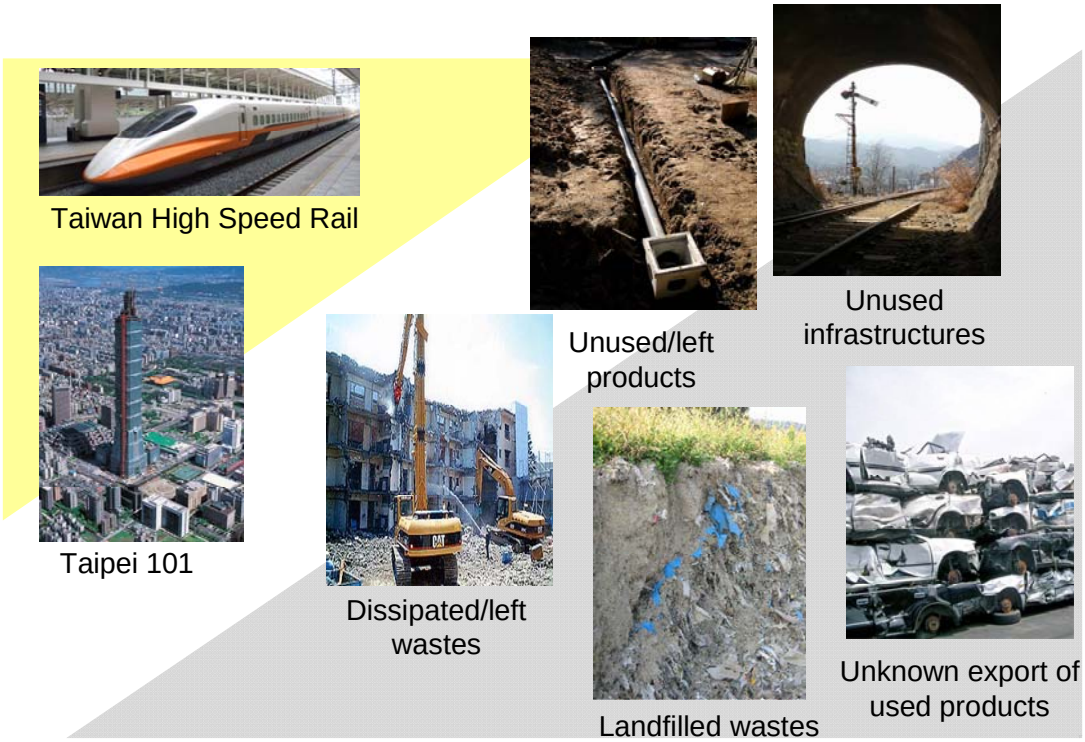
Unused infrastructures

Dissipated/left wastes

Landfilled wastes

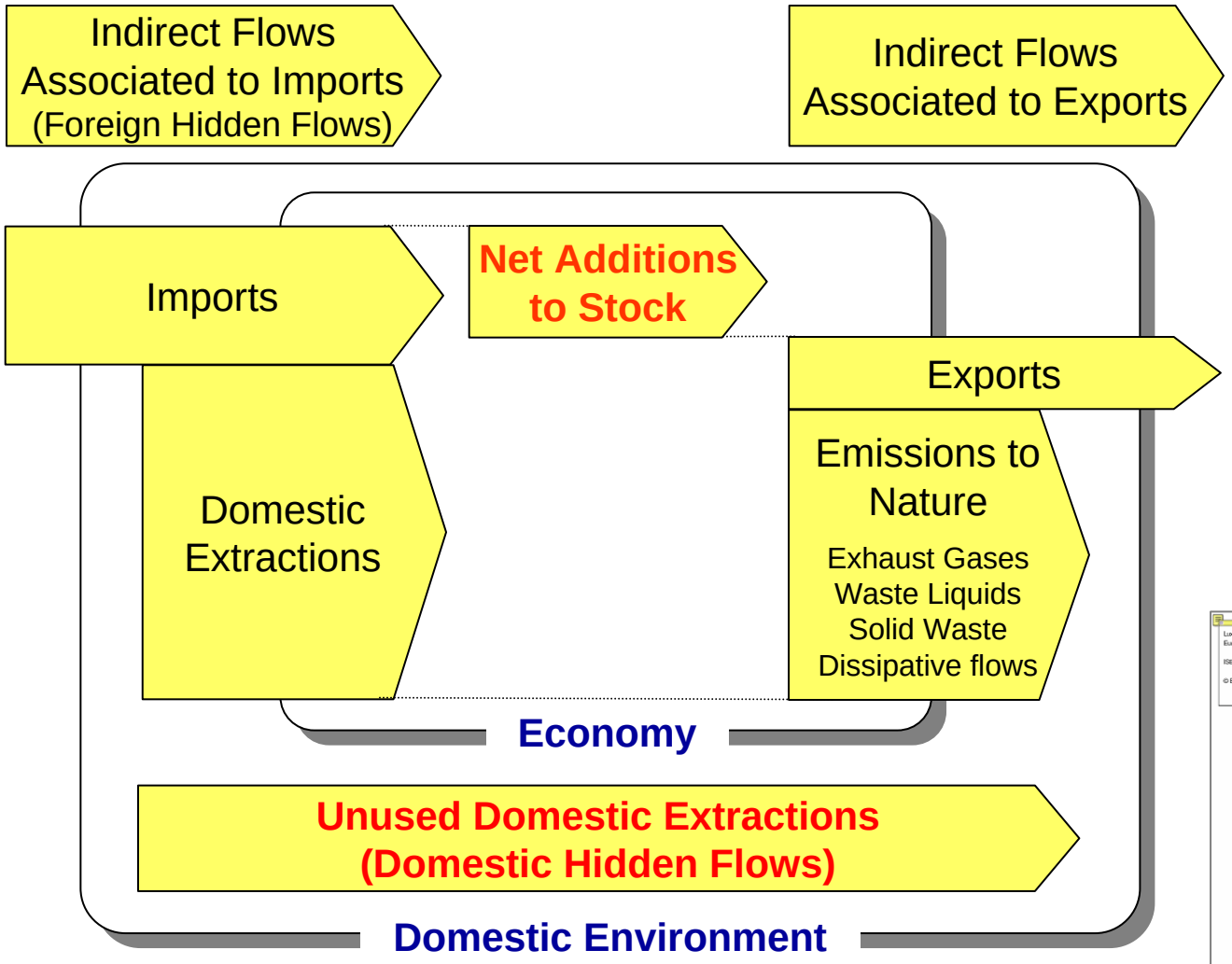
Unknown export of used products

Objective of "Material Stock Accounting"

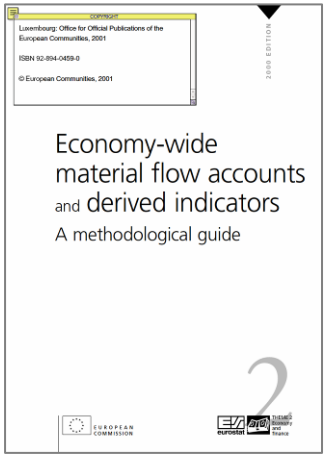


- Accurate estimation of materials that come out of hibernation for
  - Appropriate management of discarded wastes from stocks
  - Improvement of resource productivity through recovery of secondary resources from stocks

Framework of Economy-Wide Material Flow Accounts



Source: Some modifications of Eurostat (2001)



Definition and Categories of Stocked Materials

Stocked materials are defined by

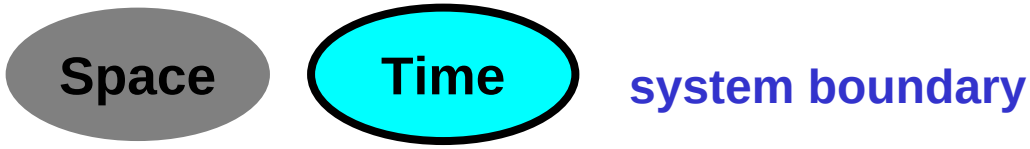
Some vagueness remains in the Economy-Wide MFA. But it is difficult to define the clear boundary between the economy and the environment.

Categorization of stocked materials by condition of usage is useful. This will make a framework of MSA consistent with the framework of Economy-Wide MFA.

Materials now accounted as stock in Economy-Wide MFA		
Within the economy	On boundary between the economy and the environment	In the environment

Definition and Categories of Stocked Materials

Stocked materials are defined by



Considering the objectives of Material Stock Accounts, what have short life spans are not stocked materials that we are concerned with.

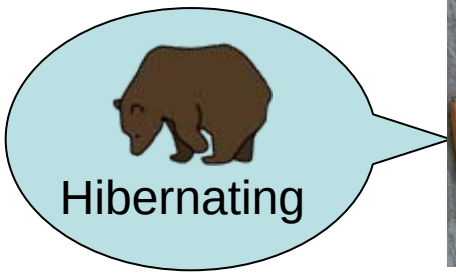
Categorization of stocked materials by condition of usage is useful.

Materials now accounted as stock in Economy-Wide MFA	
< 1 yr life span	> 1 yr life span

Categories of Stocked Materials

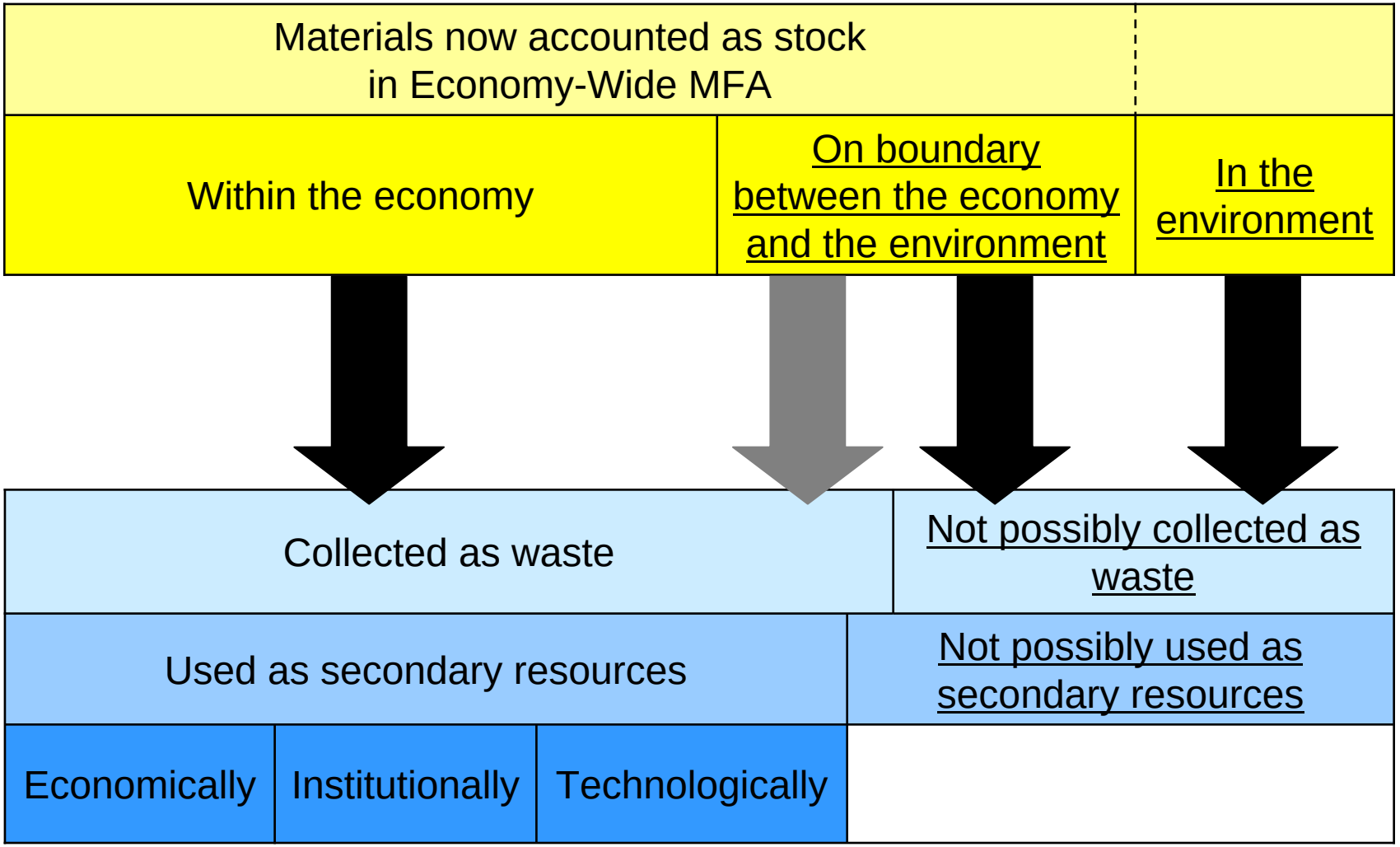
Categorization by condition of usage (tentative)

<table>
<tr><td colspan="5">Materials now accounted as stock
in Economy-Wide MFA</td><td></td></tr>
<tr><td colspan="4">Within the economy</td><td colspan="2">On boundary
between the economy
and the environment</td><td>In the
environment</td></tr>
<tr><td>< 1 yr life span</td><td colspan="3">> 1 yr life span</td><td colspan="2" rowspan="2">Infrastructure,
building foundations,
etc.</td><td rowspan="2">Dissipated/
left
waste</td></tr>
<tr><td>Inventories,
foods at home,
etc.</td><td colspan="3">Buildings,
machineries,
cars, etc.</td></tr>
<tr><td></td><td colspan="2">In use</td><td>Unused/
Dead</td><td>In use</td><td>Unused/
Left</td><td>Dissipated</td></tr>
</table>



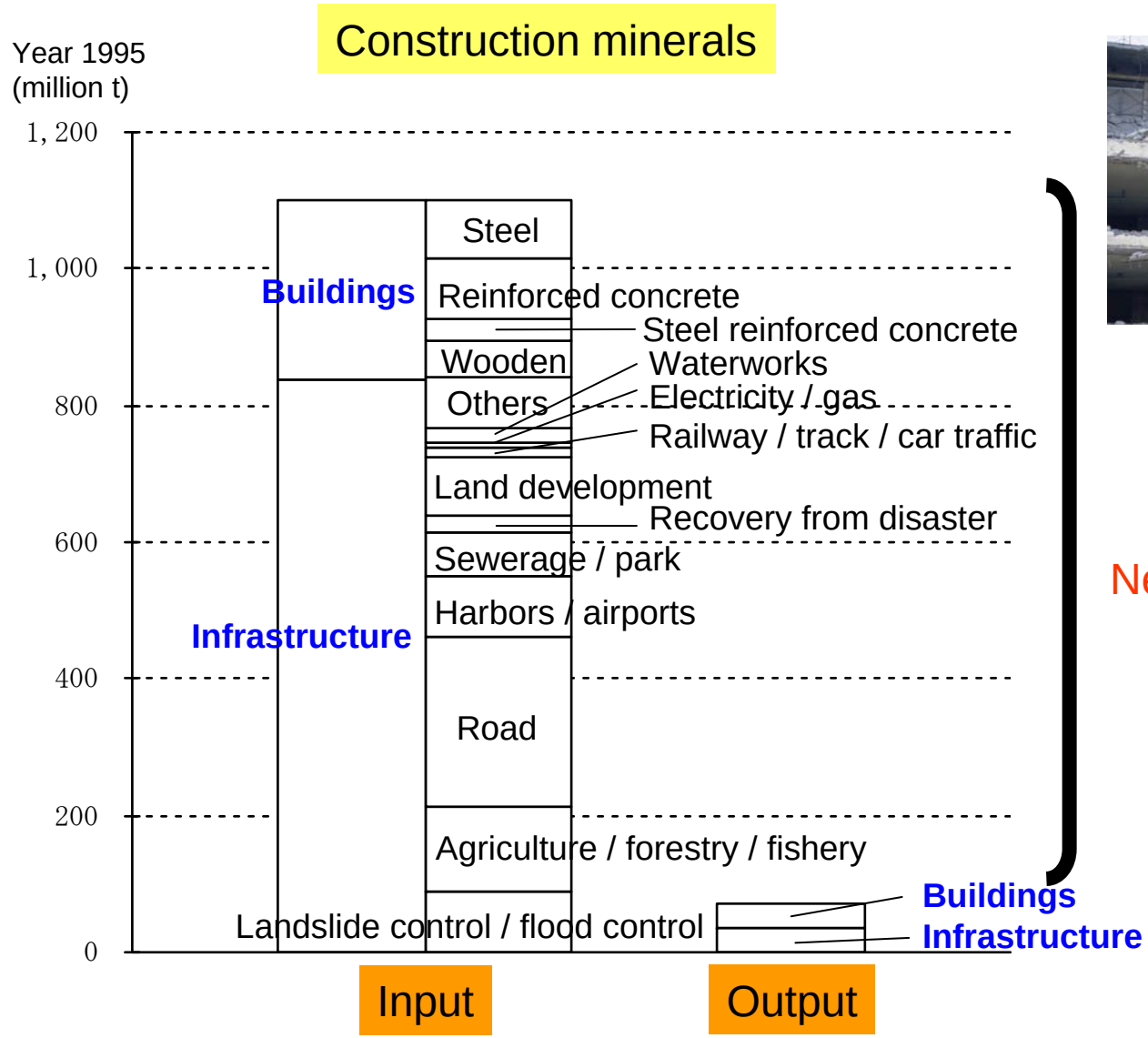
Categories of Stocked Materials

Categorization by condition of usage (tentative)



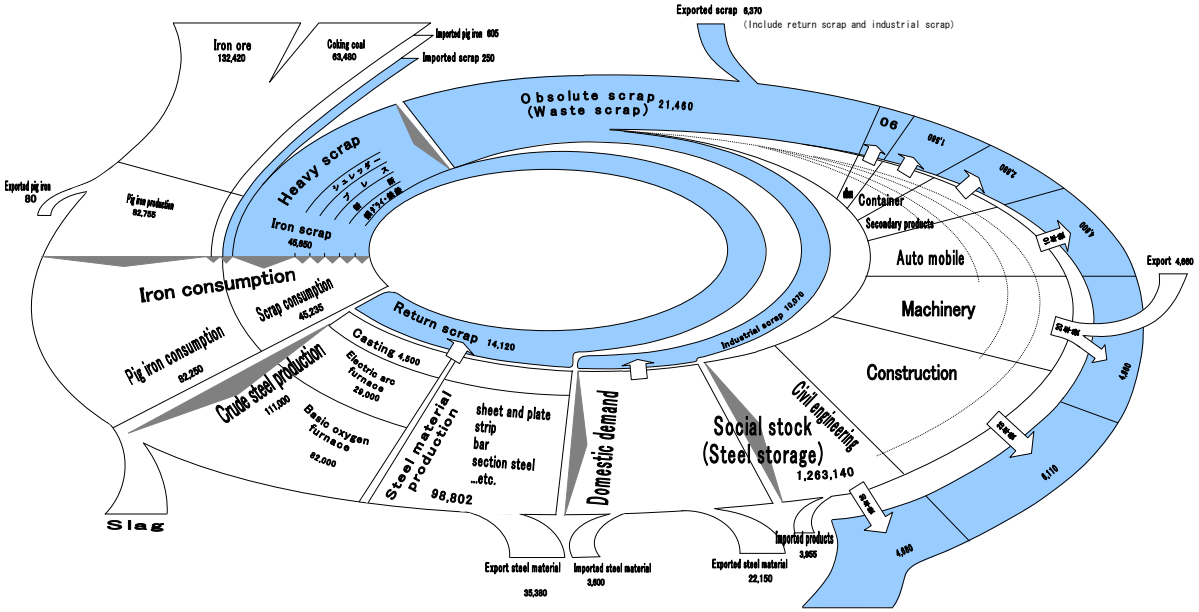
Categorization by possibility of reutilization

How much waste will be generated from stock?



Net Additions to Stock

How much secondary resources can be recovered from stock?



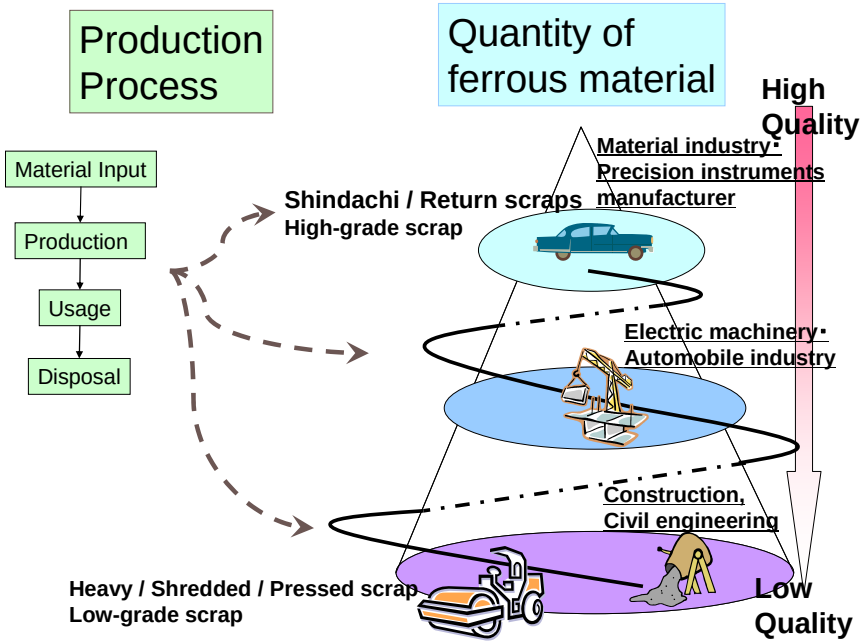
Iron and steelcycle in Japan (2003fy)
(unit:1000t)

Data: The Japan ferrous raw materials association

Steel stock in Japan
1.26 billion tons (2003)
Estimated by the Japan Ferrous Raw Materials Association

How much steel in stock can be reutilized?

How we should manage such secondary resources in future?



System of National Account (SNA) and Material stock Accounting (MSA) Hybrid Accounting sysytem

- System for Integrated Environmental and Economic Accounting(SEEA)
- Physical Input Output Table(PIOT)
- Waste Input Output Table

・・・etc

WIO Table

		Industry			Waste treatment		Final demand	Output
		Agriculture	Materials	Construction	Incineration	Landfilled		
Industry	Agriculture	SNA IO Table (Monetary based table) Extension						
	Materials							
	Construction							
Waste	Garbage	Extension			Physical based table			
	Metal scrap							
	Incineration ash							
	Added value							
	Emission							

Summery

- MFA of Mo:
  - from Upstream
- MFA of P:
  - from Downstream
- Material Stock Accounting:
  - Proposal of new framework

Thank you very much for kind attention.

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