Sustainable Resource Management Workshop

hosted by CTCI, 5-6 October 2009, Taipei

Course B (for Academic and Research Institute)

Designing and evaluating material cycle systems and related policy / management techniques - Case studies -

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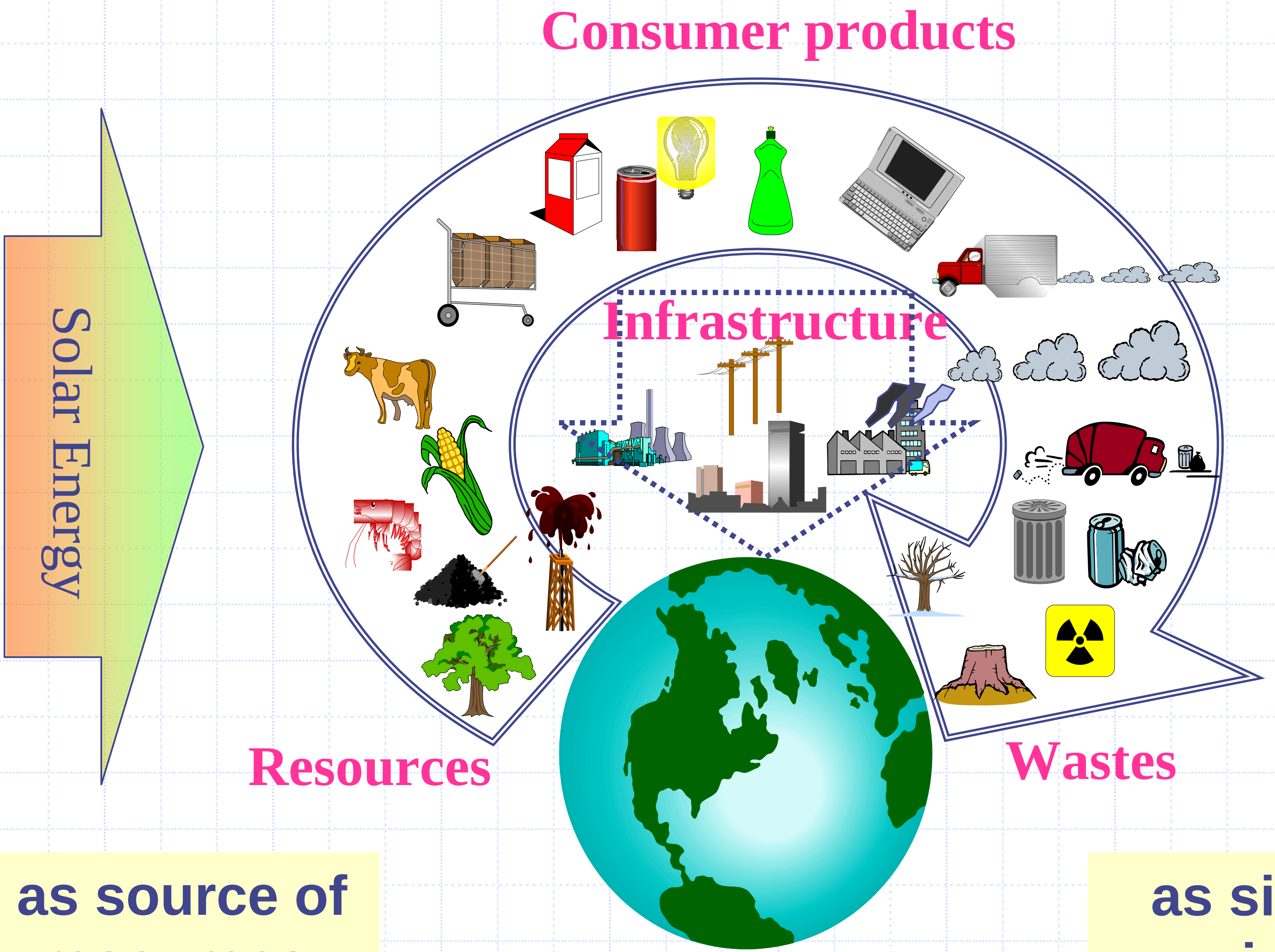
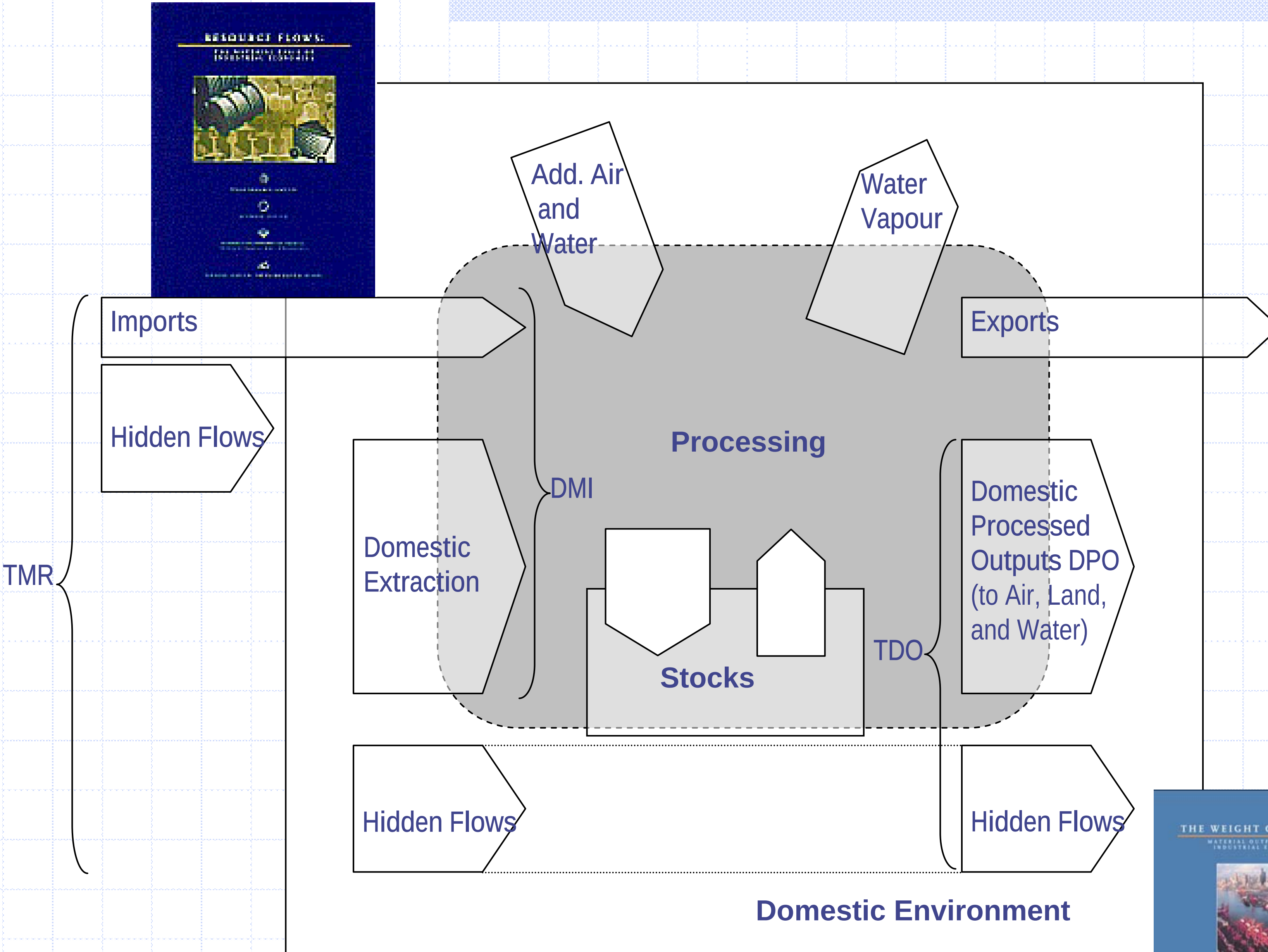
Massive flow of materials on the globe

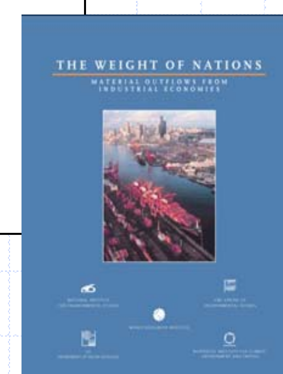


as source of resources

The earth is finite

as sink of residuals

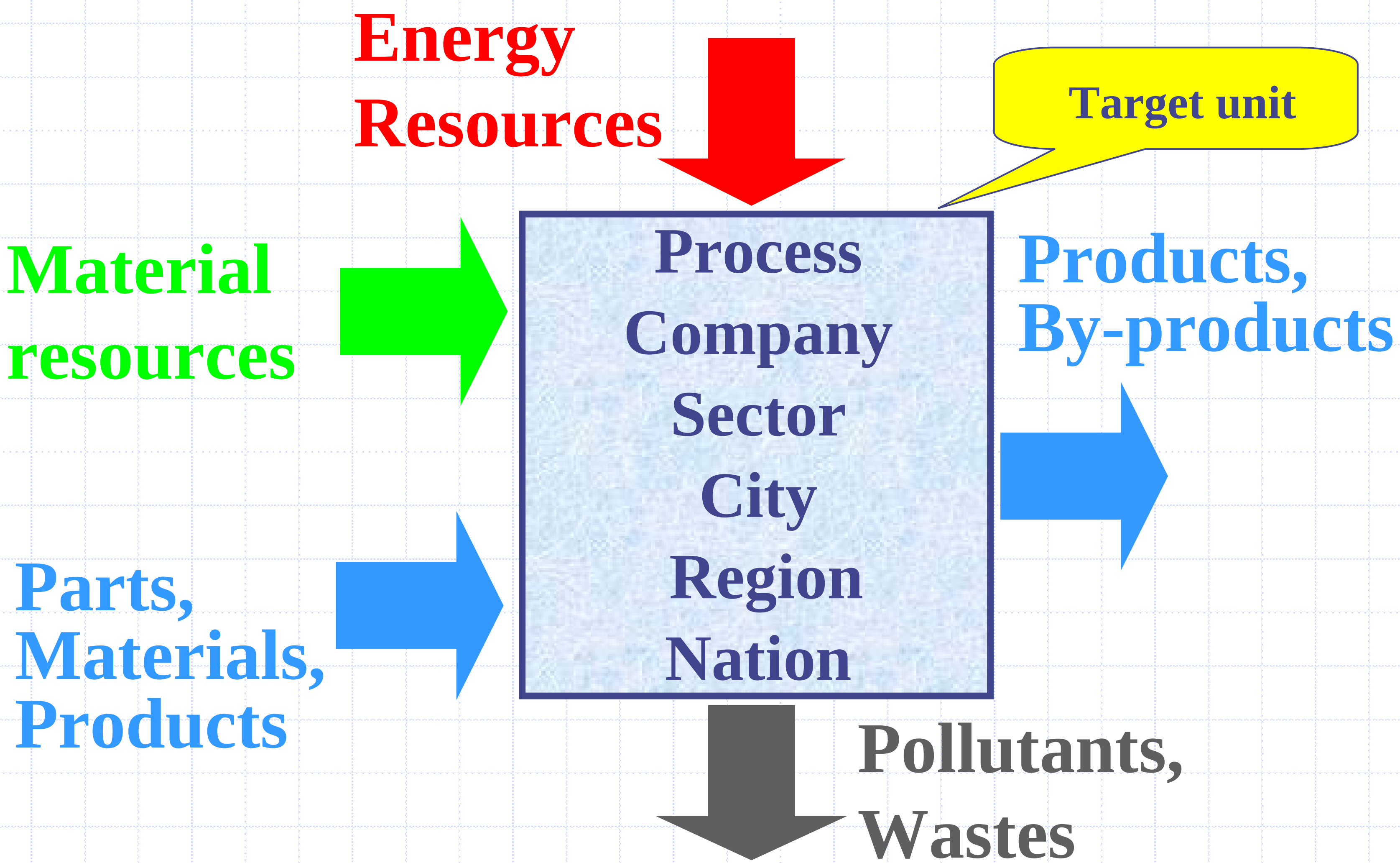




A framework for capturing macroscopic material flows

Source WRI(2000)

General framework of Material Flow Analysis



Material flow related analyses and associated issues of concern

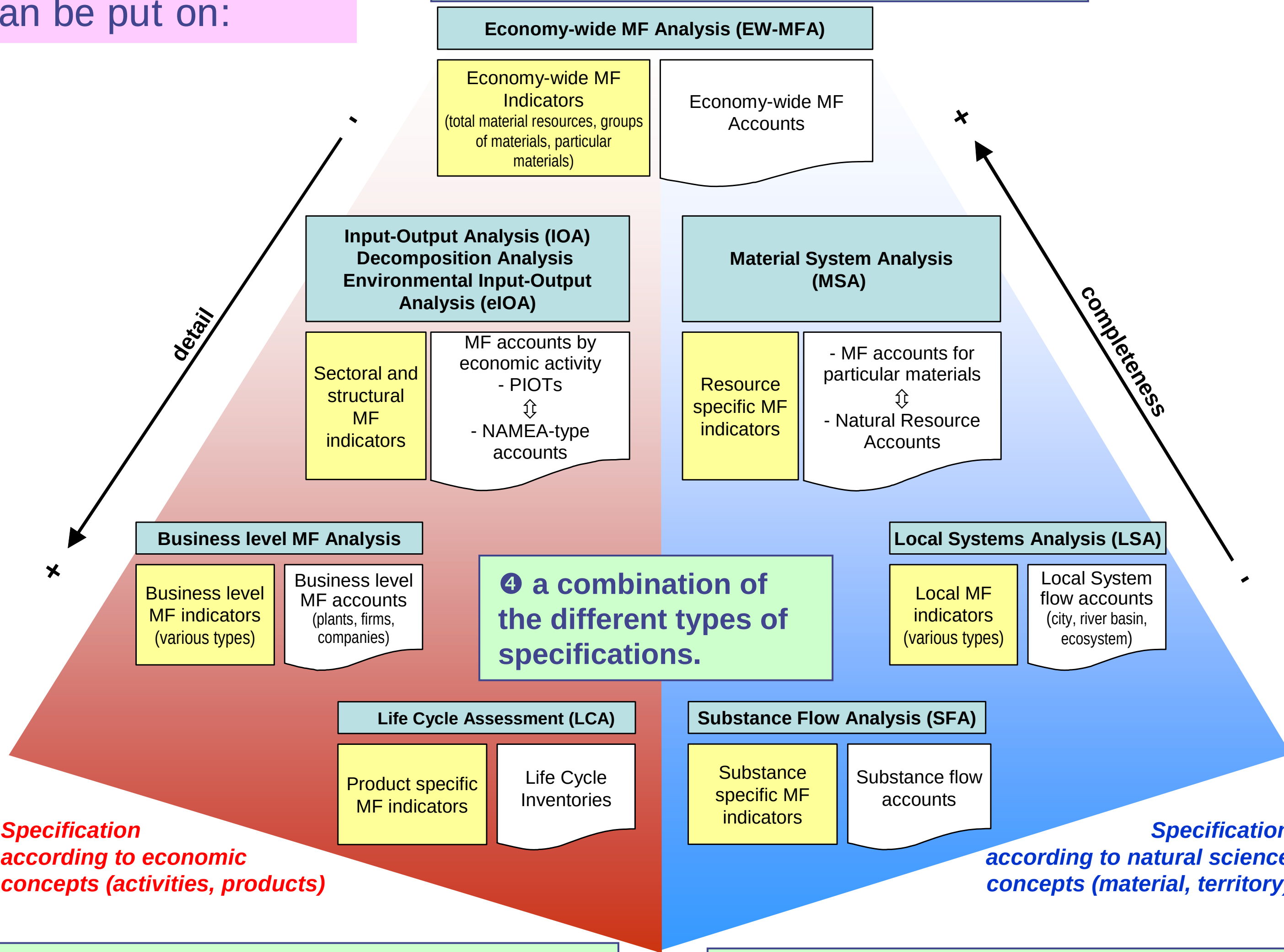
Issues of concern	Specific concerns related to environmental impacts, supply security, technology development			General environmental and economic concerns related to the throughput		
	within certain businesses, economic activities, countries, regions			of substances, materials, manufactured goods		
	associated with			*at the level of*		
Objects of primary interest	Substances	Materials	Manufactured goods	Businesses	Economic activities	Countries, regions
	chemical elements or compounds e.g. Cd, Cl, Pb, Zn, Hg, N, P, C, CO2, CFC	raw materials and semi-finished goods e.g. energy carriers, metals (ferrous, non-ferrous), sand and gravel, timber, plastics	e.g. batteries, cars, computers	e.g. firms, companies, plants, medium sized and big enterprises, MNEs	e.g. production sectors, chemical industry, iron and steel industry, construction, mining	e.g. aggregate mass of materials (& related materials mix), groups of materials, selected materials
Type of analysis	**Ia Substance Flow Analysis**	**Ib Material System Analysis**	**Ic Life Cycle Analysis**	**IIa Business level MF analysis**	**IIb Input-Output Analysis**	**IIc Economy-wide MF Analysis**
	⇳	⇳	⇳	⇳	⇳	⇳
Type of measurement tool	**Substance Flow Accounts**	**Individual Material Flow Accounts ✪**	**Life Cycle Inventories (MF Inventories)**	**Business Material flow accounts**	**Physical Input-Output Tables ✪ ⦿,** NAMEA-type approaches ⦿	**Economy-wide Material Flow Accounts ✪**

✪: MFA tools using the materials balance principle. ⦿: MFA tools using national accounting principles fully in line with the SEEA.
Source: OECD, based on Bringezu and Moriguchi 2002.

Architecture and level of application of MFA tools

When analysing material flows, emphasis can be put on:

❶ all materials entering and leaving the national economy (top of the Figure);



❹ a combination of the different types of specifications.

❷ the industry level, enterprise level, and product level, from product groups down to specific products (left hand side of Figure);

❸ certain material and substance flow systems, from the national down to the local level (right hand side of Figure);

Source: OECD

Key international activities for MFA

Research community

- International Joint Study (AUT,GER,NET,JAP,USA) since 1995
- ConAccount since 1996
- Gordon Conference on Industrial Ecology since 1998
- ISIE(International Society for Industrial Ecology) since 2001
  - Journal of Industrial Ecology, MIT Press, since 1997

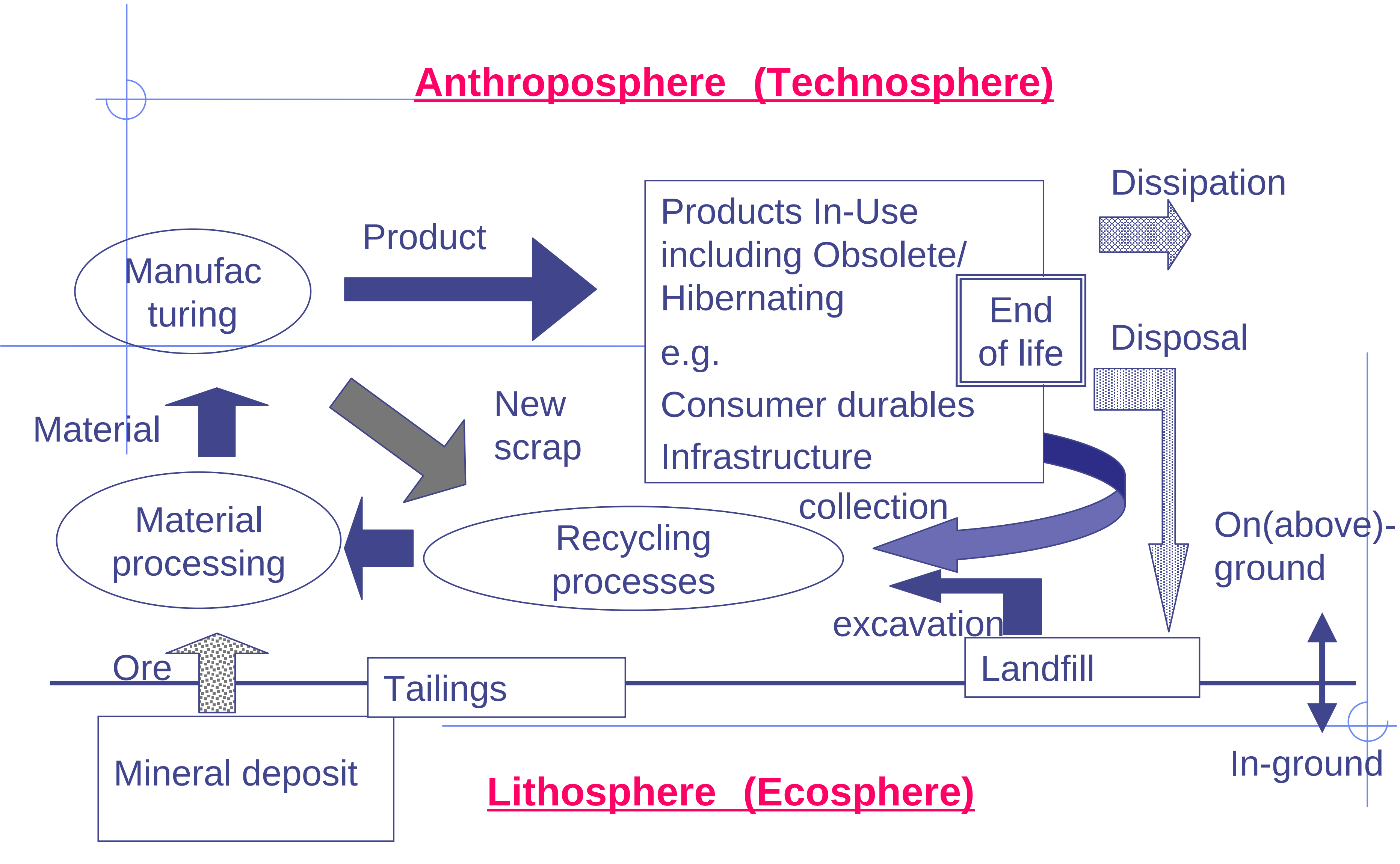
International (intergovernmental) organizations

- OECD(EA, Waste prevention, De-coupling indicator, Council recommendation on MF & RP)
- EUROSTAT: Methodological guide
- EEA/ETCRWM
- UNCEEA (UN Committee of experts on Environmental and Economic Accounting)

OECD, IE, ConAccount and other MFA meetings in last decade

- SCOPE WS on Indicators of SD, November 1995, Wuppertal
- ConAccount Workshop, January 1997, Leiden
- ConAccount Conference, September 1997, Wuppertal
- 1st Gordon Conference on IE, June 1998, New London (NH)
- ConAccount Workshop, November 1998, Amsterdam
- 2nd Gordon Conference on IE, June 2000, New London (NH)
- OECD MFA / WMF-RP seminar, October 2000, Paris
- ConAccount Conference, April 2001, Stockholm
- 1st ISIE Conference, November 2001, Noordwijkerhout
- 3rd Gordon Conference on IE, June 2002, New London (NH)
- 2nd ISIE Conference, June-July 2003, Ann Arbor (MI)
- ConAccount Workshop, October 2003, Wuppertal
- Int'l expert WS on MFA &RP, November 2003, Tokyo
- OECD workshop on MFA, June 2004, Helsinki
- 4th Gordon Conference on IE, August 2004, Oxford
- ConAccount Meeting, October 2004, Zuerich
- OECD workshop on MFA, May 2005, Berlin
- 3rd ISIE Conference, June 2005, Stockholm
- OECD workshop on SMM, November 2005, Seoul
- OECD workshop on MFA, May 2006, Rome
- 5th Gordon Conference on IE, August 2006, Oxford
- ConAccount Meeting, September 2006, Vienna
- 4th ISIE Conference, June 2007, Toronto
- OECD/Japan Seminar on MF/RP, September 2007, Tokyo
- OECD-UNEP Conference on Resource Efficiency, April 2008, Paris
- 6th Gordon Conference on IE, June 2008, New London (NH)
- ConAccount Meeting, September 2008, Prague
- 5th ISIE Conference, June 2009, Lisbon
- ConAccount Meeting, November 2010, Tokyo

Schematic description of stocks and flows



Source : Moriguchi, prepared for Ernst Strüngmann Forum, Frankfurt, Nov. 2008

Presentations at ConAccount 2008 by NIES researchers

- PRODUCT-LEVEL MATERIAL FLOW ANALYSIS OF CONSUMER DURABLES
  Masahiro Oguchi , Takashi Kameya, Tomohiro Tasaki, Noboru Tanikawa

- HIBERNATING STOCKS OF MOBILE PHONES IN JAPAN
  Shinsuke Murakami*, Rie Murakami-Suzuki (* Univ. Tokyo)

- ANALYSIS OF CAUSAL RELATIONSHIP OF CHANGES IN MATERIAL FLOWS: CONTRIBUTION ANALYSIS AND INFLUENCE ANALYSIS
  Tomohiro Tasaki, Aya Yoshida, Yuichi Moriguchi

- MATERIAL FLOW ANALYSIS BASED ON WIO-MFA MODEL: CASE STUDY OF PVC FLOW IN JAPAN
  Kenichi NAKAJIMA,Yoshie YOSHIZAWA, Kazuyo MATSUBAE-YOKOYAMA, Tetusya NAGASAKA, Shinichiro NAKAMURA

- COMPARISON OF APPROACHES TO MATERIAL STOCK AND FLOW ACCOUNTING
  Ichiro Daigo*, Shinsuke Murakami, Yasunari Matsuno, Tomohiro Tasaki, Seiji Hashimoto (* Univ. Tokyo)

- FRAMEWORK FOR DETERMINING POTENTIAL WASTE ACCUMULATED WITHIN AN ECONOMY AND ITS APPLICATION TO CONSTRUCTION MINERALS IN JAPAN
  Seiji Hashimoto, Hiroki Tanikawa, and Yuichi Moriguchi

- MULTI-SCALE ESTIMATION OF MATERIAL STOCK RELATED TO CONSTRUCTION MINERALS OVERTIME
  Hiroki Tanikawa* and Seiji Hashimoto（Nagoya Univ.)

Extracts from presentation at IIOA 2007, Istanbul July 2, 2007

Analysis of material flows by Input-Output framework for environmental and resource issues

by

Yuichi Moriguchi, Dr. Eng.

Director, Research Center for Material Cycles and Waste Management
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Visiting Professor, Graduate School of Frontier Sciences
The University of Tokyo

Ex-Chair, OECD/EPOC/WG on Environmental Information and Outlooks

Background (Demand side)

- Environmental problems associated with massive flows of materials (GHGs, sold waste)

- Recognition of “finiteness” of natural resources and environmental carrying capacity in the context of “sustainability”

- Transition from mass-production, mass-consumption, mass-disposal economy to “Sound material-cycle society” (Japan), “Circular economy” (China)

Background (Supply side)

- Linkage between economic Input-Output analysis and Industrial Ecology studies attracts increasing attention, in relation to;

  LCA (Life Cycle Assessment),

  MFA (Material Flow Analysis/Accounting)

cf. Y. Moriguchi: Symbiosis among Analytical Tools of Industrial Ecology - The Case of MFA, IOA and LCA -, 3rd ISIE Conference, 12-15 June, 2005, Stockholm

“Inter”-action among actors

Inter-disciplinary

- ISIE 2007 Conference, Toronto Canada
June 16-20, 2007
- IIOA 2007 Conference, Istanbul Turkey
July 2-6, 2007

Engineers vs. Economists & Accountants

International

- Academic communities
- International organizations

Researchers vs. Policy makers

Target scale/sector of MFA

- International flows (trade, transportation)
- Total inflows and outflows of national economy
- Inter-regional flows
- Inter-industry flows at national economy (I-O analysis)
- Inter-industry flows at a specific area(Eco-Industrial-Park)
- Emissions of pollutants from the economy and their outflows to the environment
- By-products and waste (valueless outputs)

Application and extension of Input-output framework

1. Extension of the system boundary to incorporate the environment
2. Description of flows of materials with zero or negative value
3. Description of material flows by Physical Input-Output Tables
4. Compilation of empirical database for major environmental and natural resource variables
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The extension of the system boundary to incorporate the environment

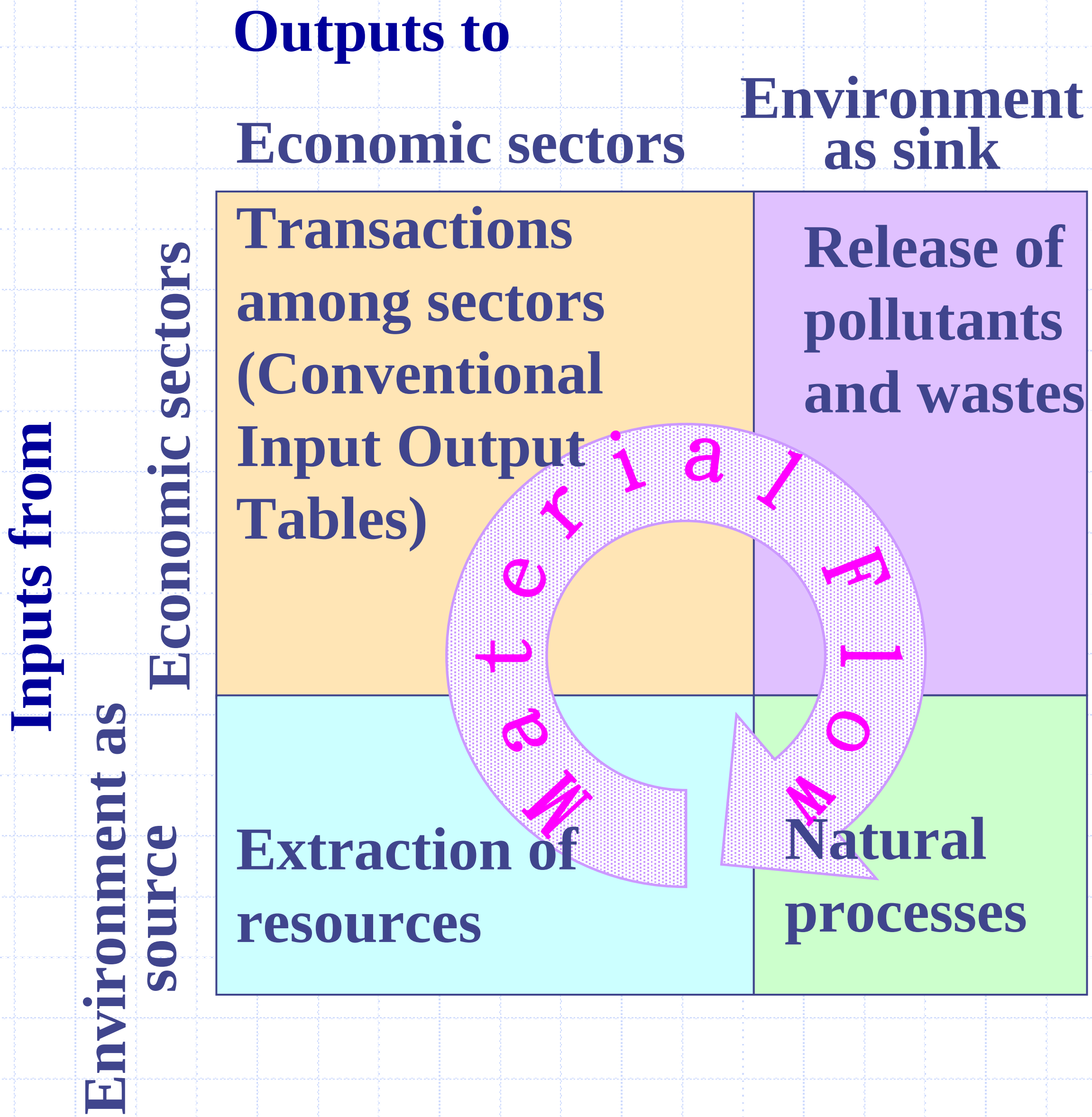
Physical Interpretation

- The Environment as supplier of natural resources to economic activities
- The Environment as recipient of residues from economic activities

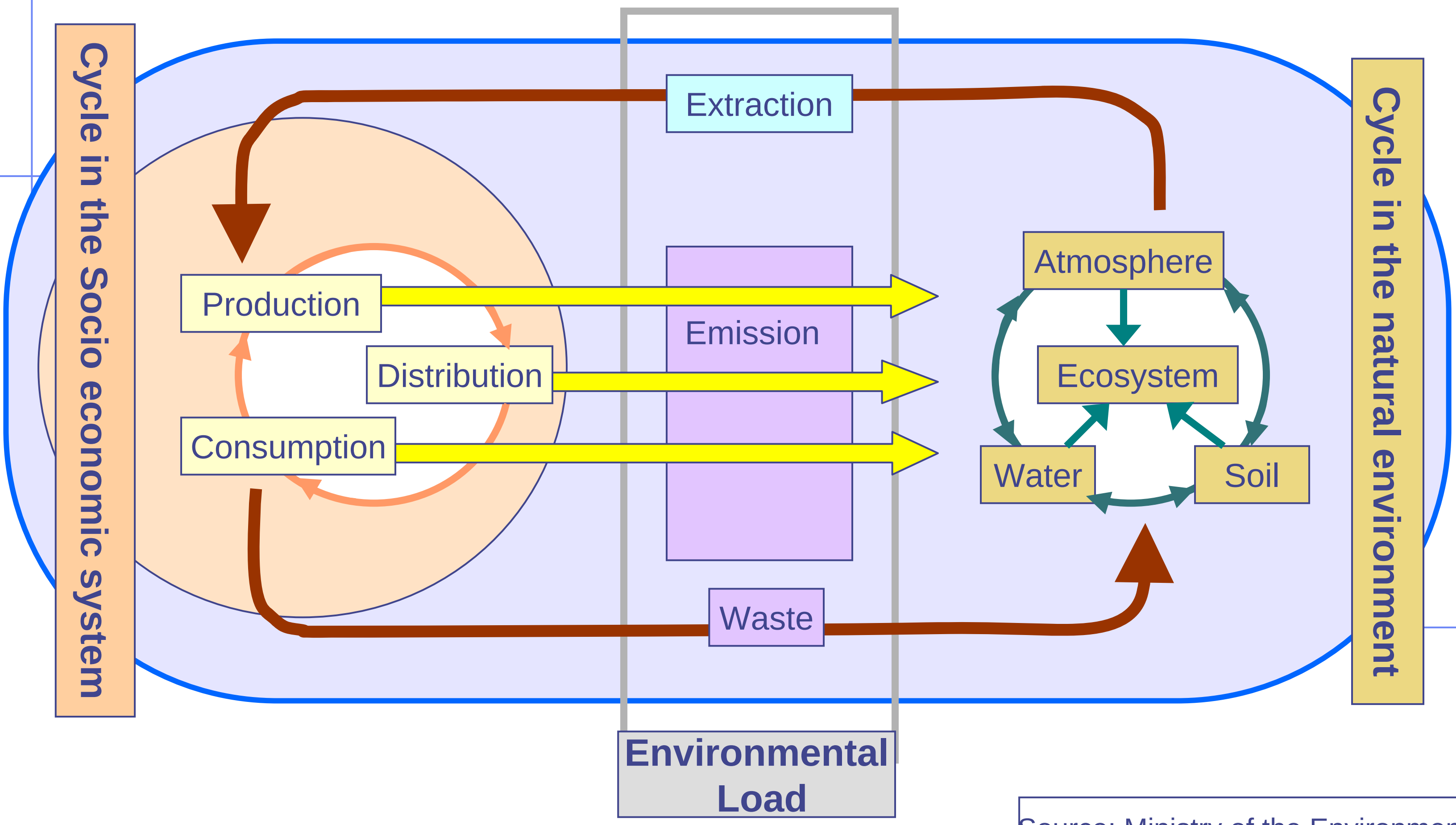
Monetary Interpretation

- Value added is overestimated because the use of natural capital is not evaluated

Extension of Economic Input-Output Tables/Analysis

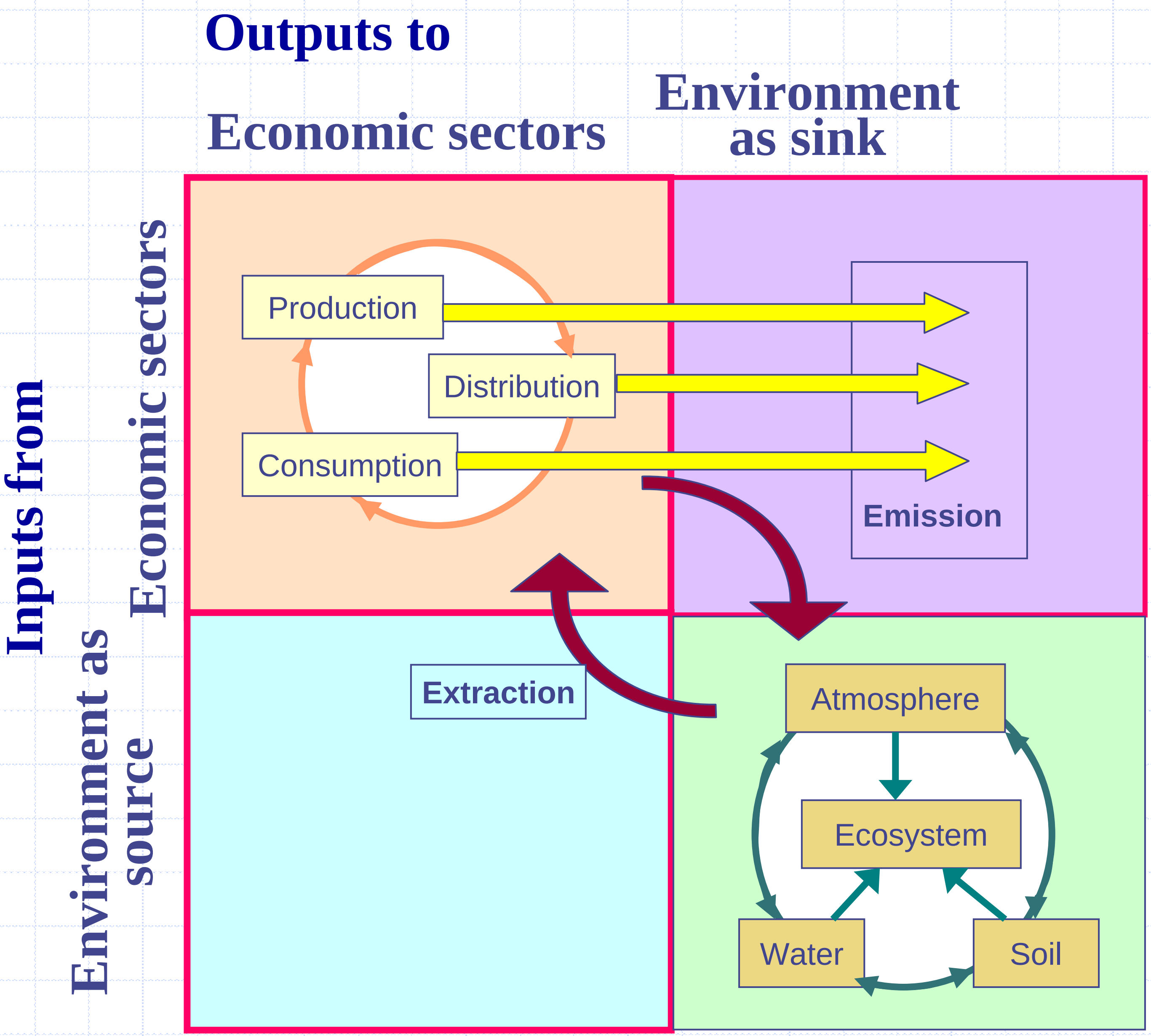


Cycle in the Socio Economic System and Cycle in the Natural Environment

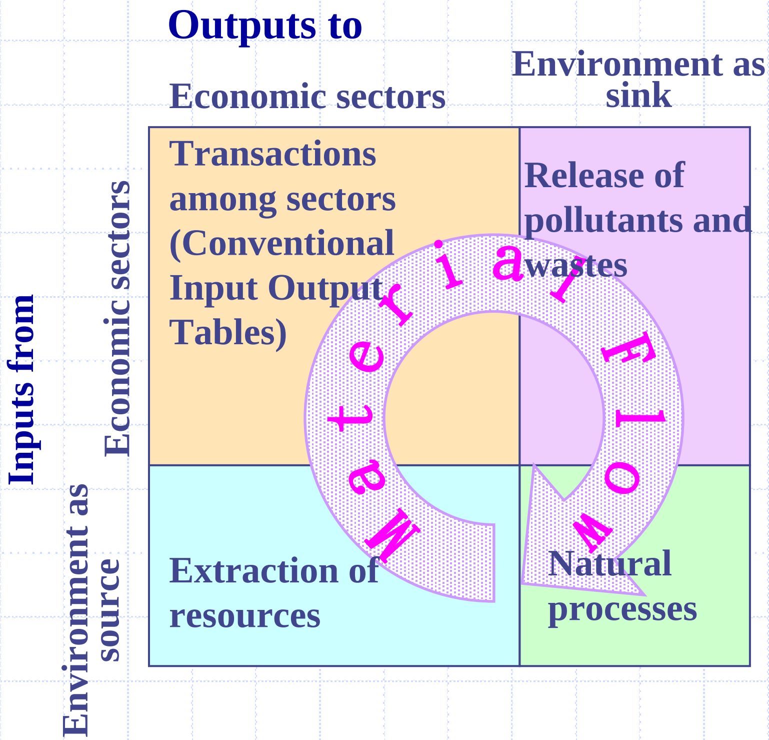


Source: Ministry of the Environment, Japan

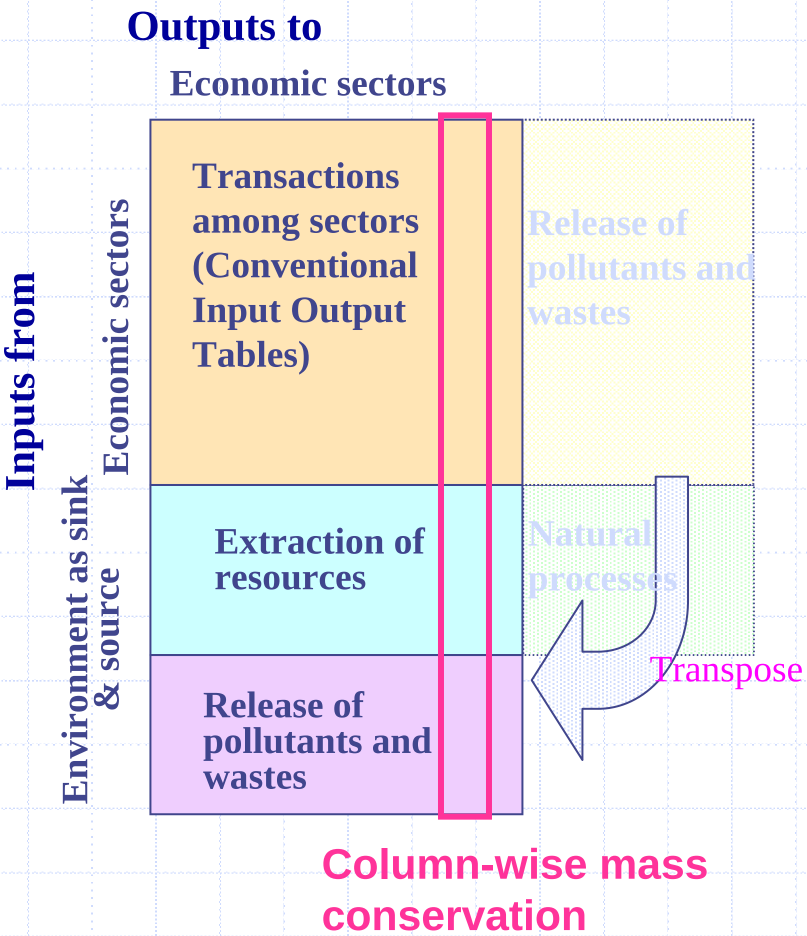
Extension of Economic Input-Output Tables/Analysis



MFA with Input-Output Framework

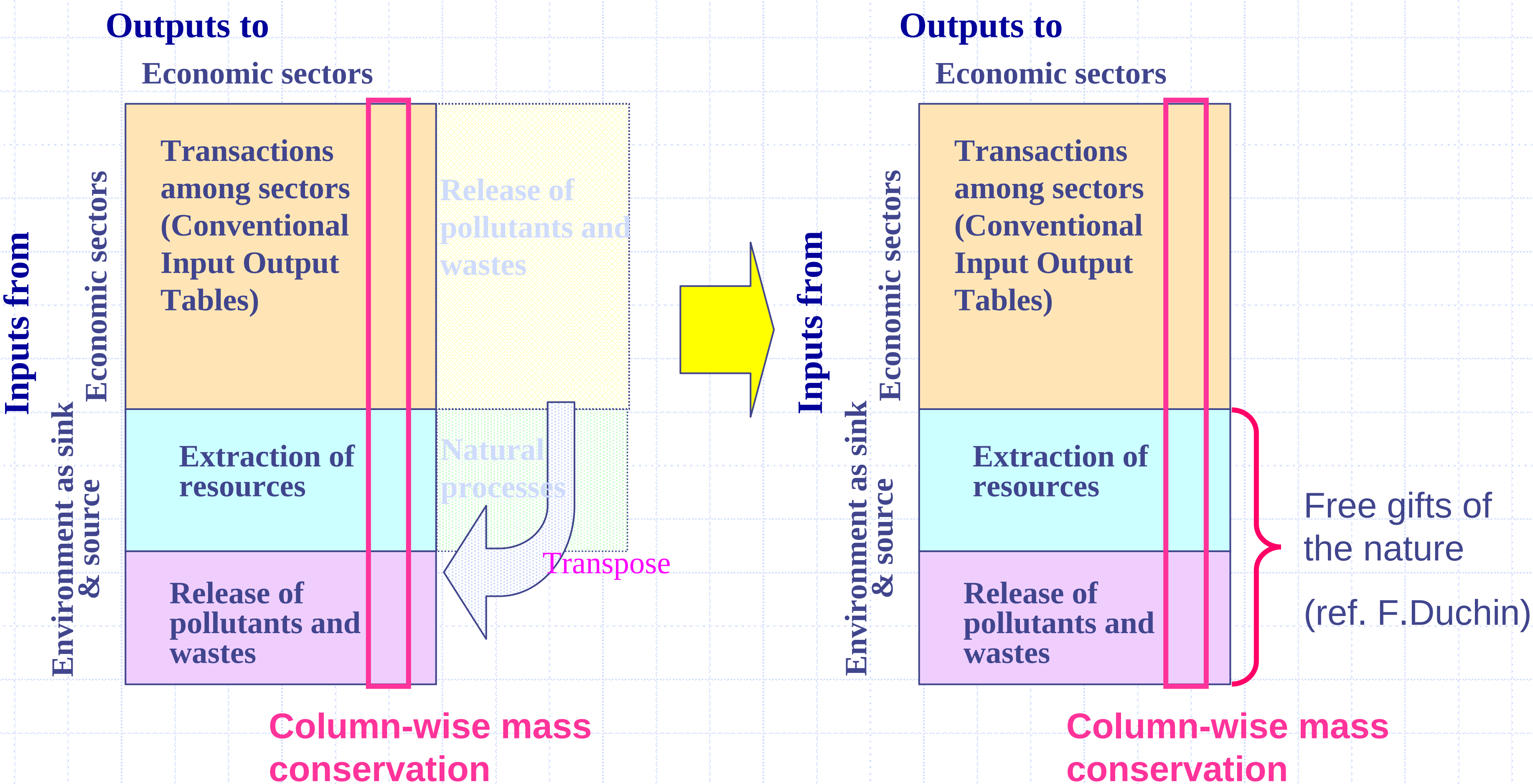


(a) Input-Output relation between economy and the environment



(b) Input-Output table with environmental extension

MFA with Input-Output Framework



(b) Input-Output table with environmental extension

(c) Environment as extra value added

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Empirical data

EIO(3EID)	RIO
Monetary IOT	Monetary IOT (68SNA)
Physical flows From the economy to the nature (Emissions)	Physical flows from the nature to the economy (Resources)
400 sectors	86 -> 17 sectors
1975 to 1990, 1990, 1995, 2000	1980 to 1998
Available on the web	In house (used for MOE)
GHG reduction policy "Hybrid" LCA	Decomposition of RP

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Empirical data: 3 types

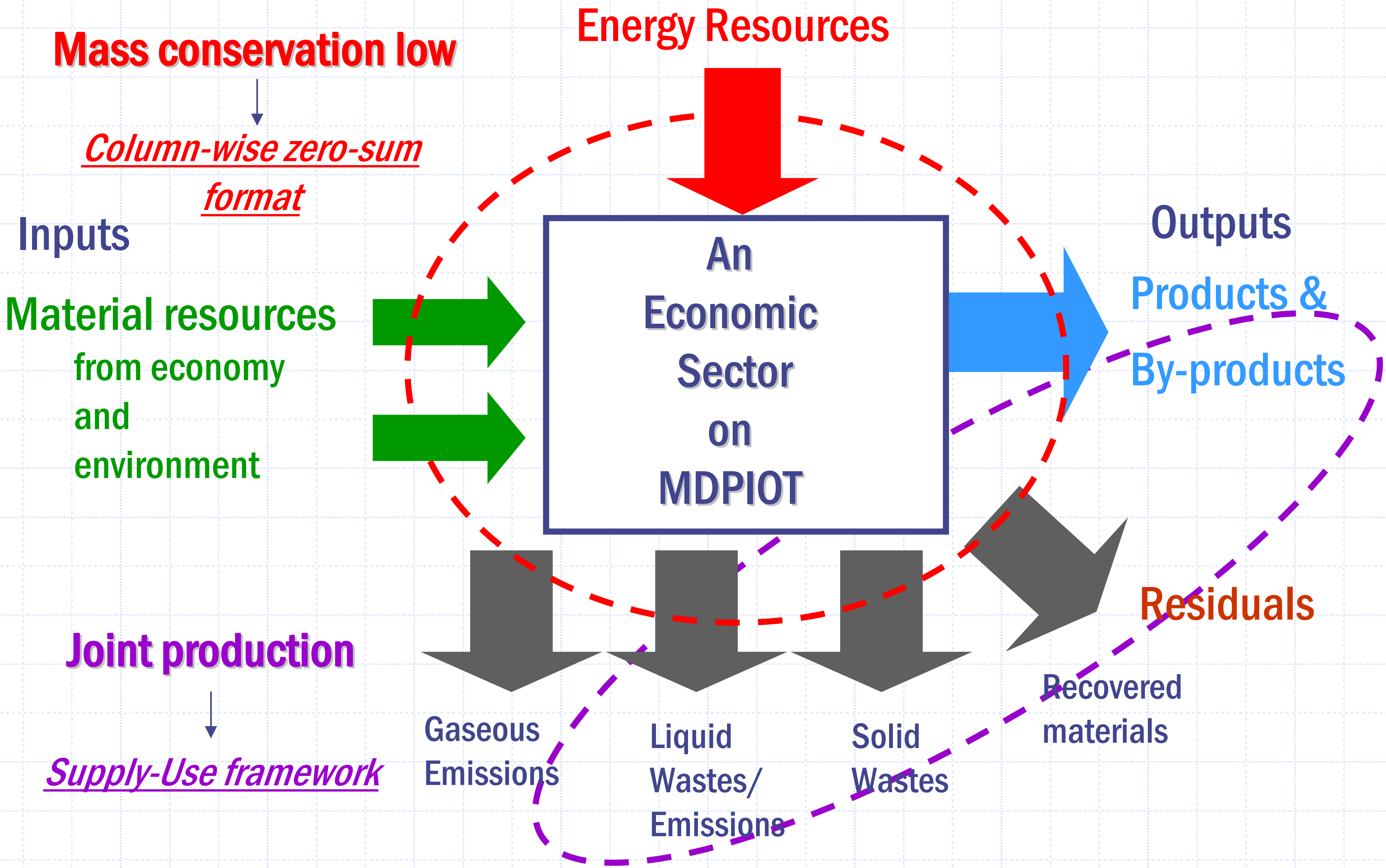
EIO(3EID)	RIO	PIOT
Monetary IOT	Monetary IOT (68SNA)	Physical flows among economic sectors
Physical flows From the economy to the nature (Emissions)	Physical flows from the nature to the economy (Resources)	Physical flows between the economy and the nature
400 sectors	86 -> 17 sectors	146 sectors
1975 to 1990, 1990, 1995, 2000	1980 to 1998	1990, 1995
Available on the web	In house (used for MOE)	In house
GHG reduction policy "Hybrid" LCA	Decomposition of RP	Waste & resource management

What are described by PIOT ?

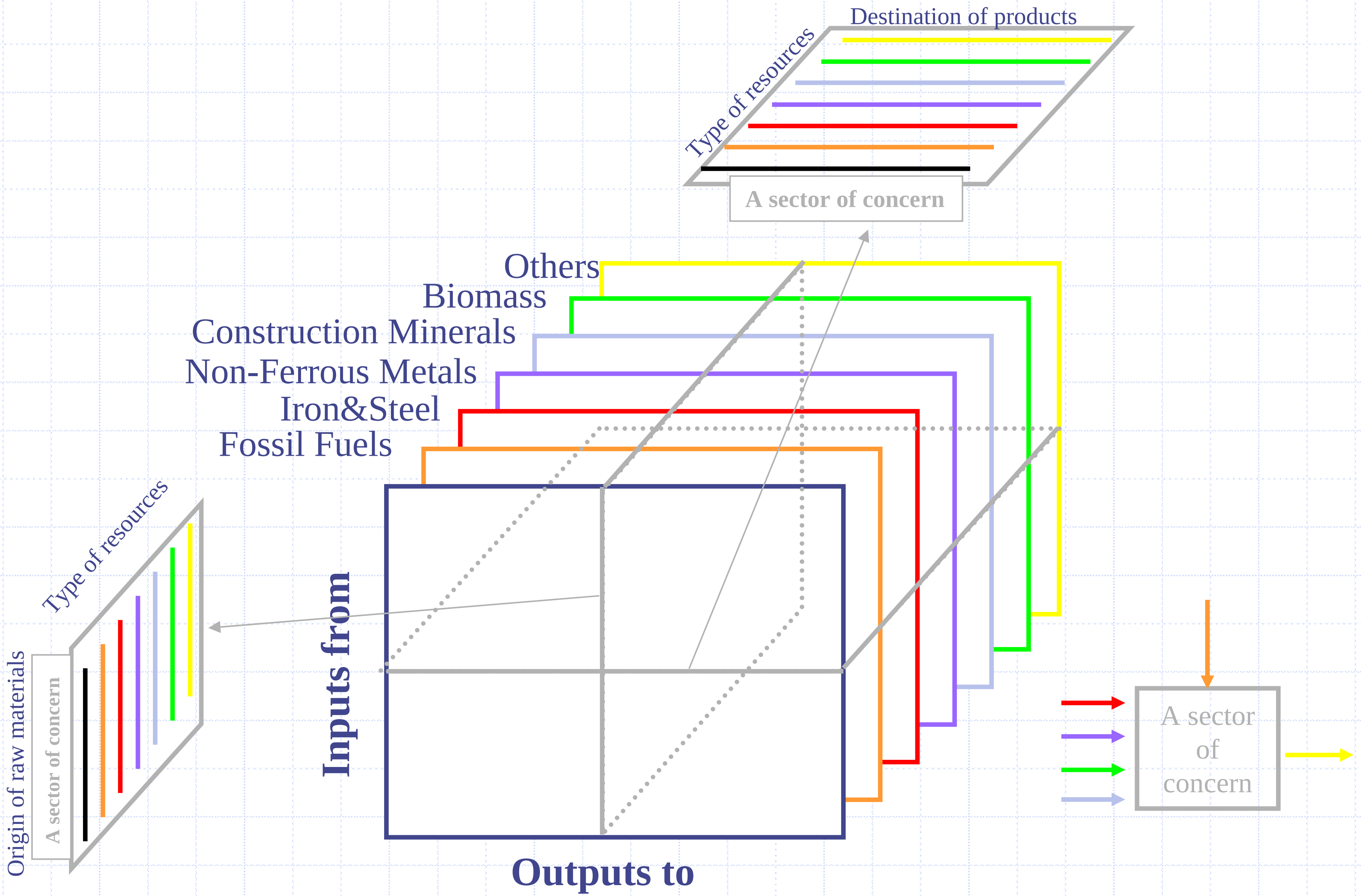
Physical material flows of

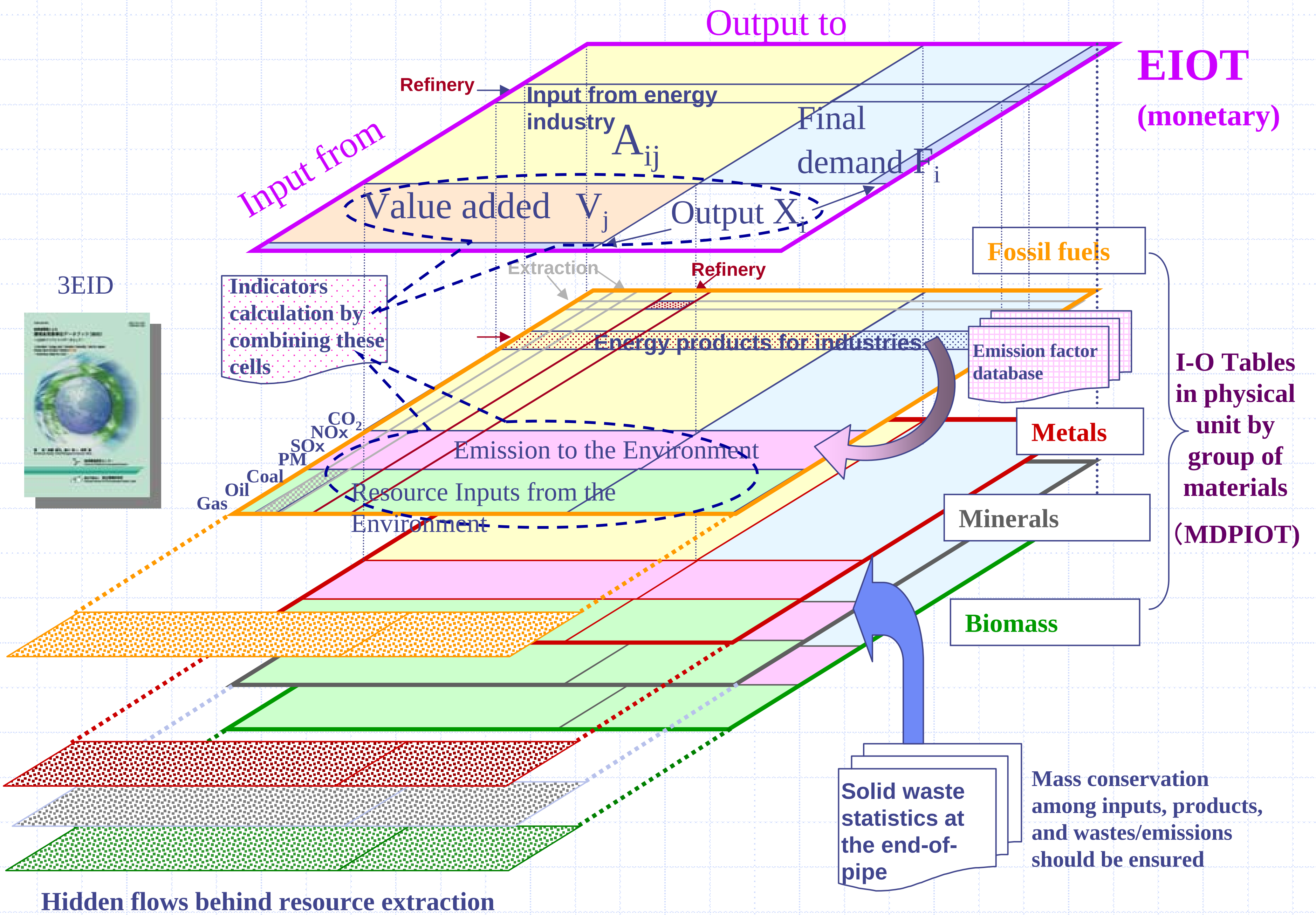
- natural resources from the environment to the economy
- environmental burdens (pollutants and wastes) from the economy to the environment,
- hidden flows associated with these flows,
- commodities (e.g., raw and refined materials, intermediate and final products) among economic sectors.

Data description in MDPIOT

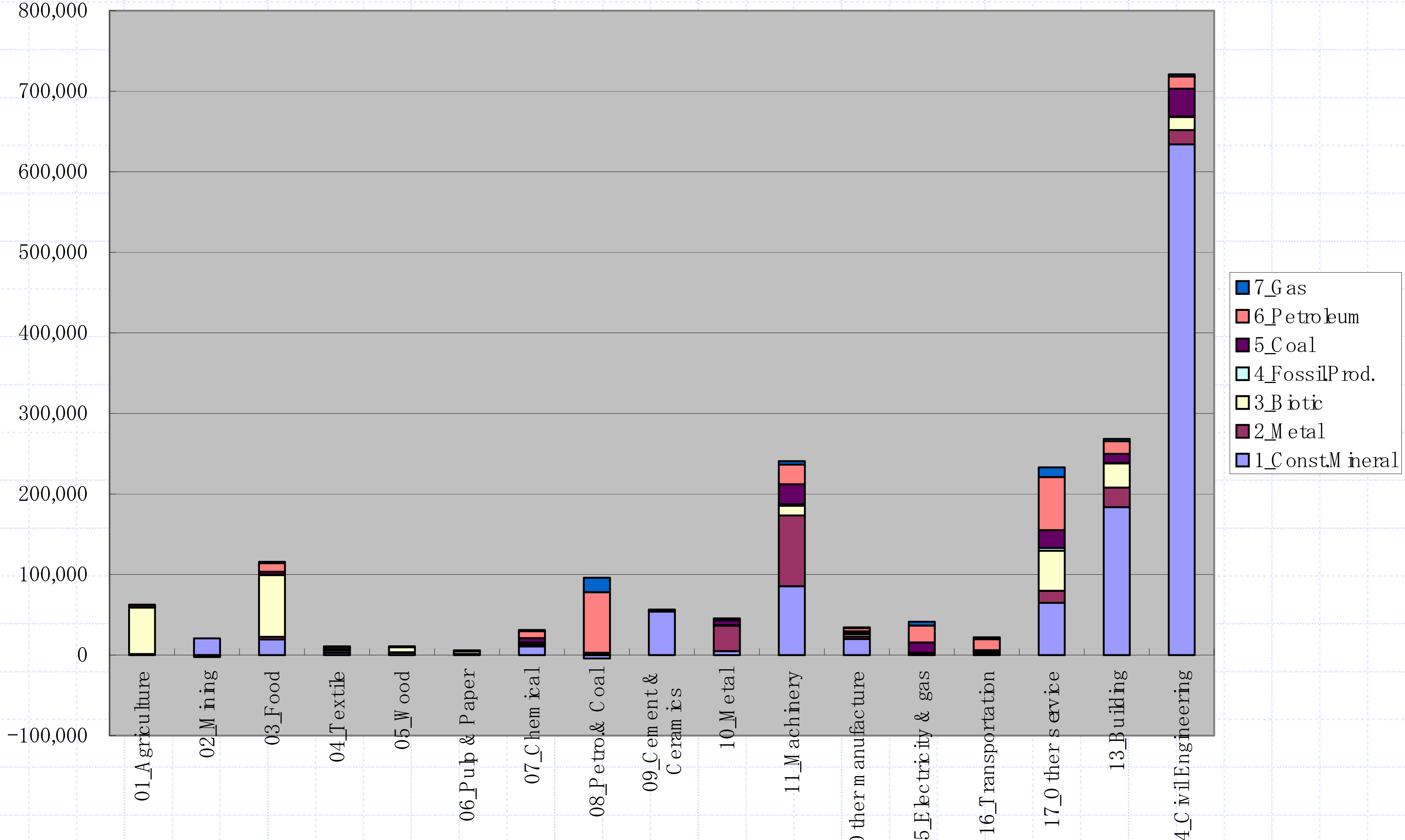


Multi-Dimensional Physical Input Output Tables




Output to
EIOT
(monetary)
Refinery
Input from energy industry
A_{ij}
Final demand F_i
Input from
Value added V_j
Output X_i
3EID
Indicators calculation by combining these cells
Extraction
Refinery
Fossil fuels
Energy products for industries
Emission factor database
CO_2
NOx
SOx
PM
Coal
Oil
Gas
Emission to the Environment
Resource Inputs from the Environment
Metals
Minerals
Biomass
I-O Tables in physical unit by group of materials
(MDPIOT)
Solid waste statistics at the end-of-pipe
Mass conservation among inputs, products, and wastes/emissions should be ensured
Hidden flows behind resource extraction

Material resource inputs induced by final demands



Application and extension of Input-output framework (contd.

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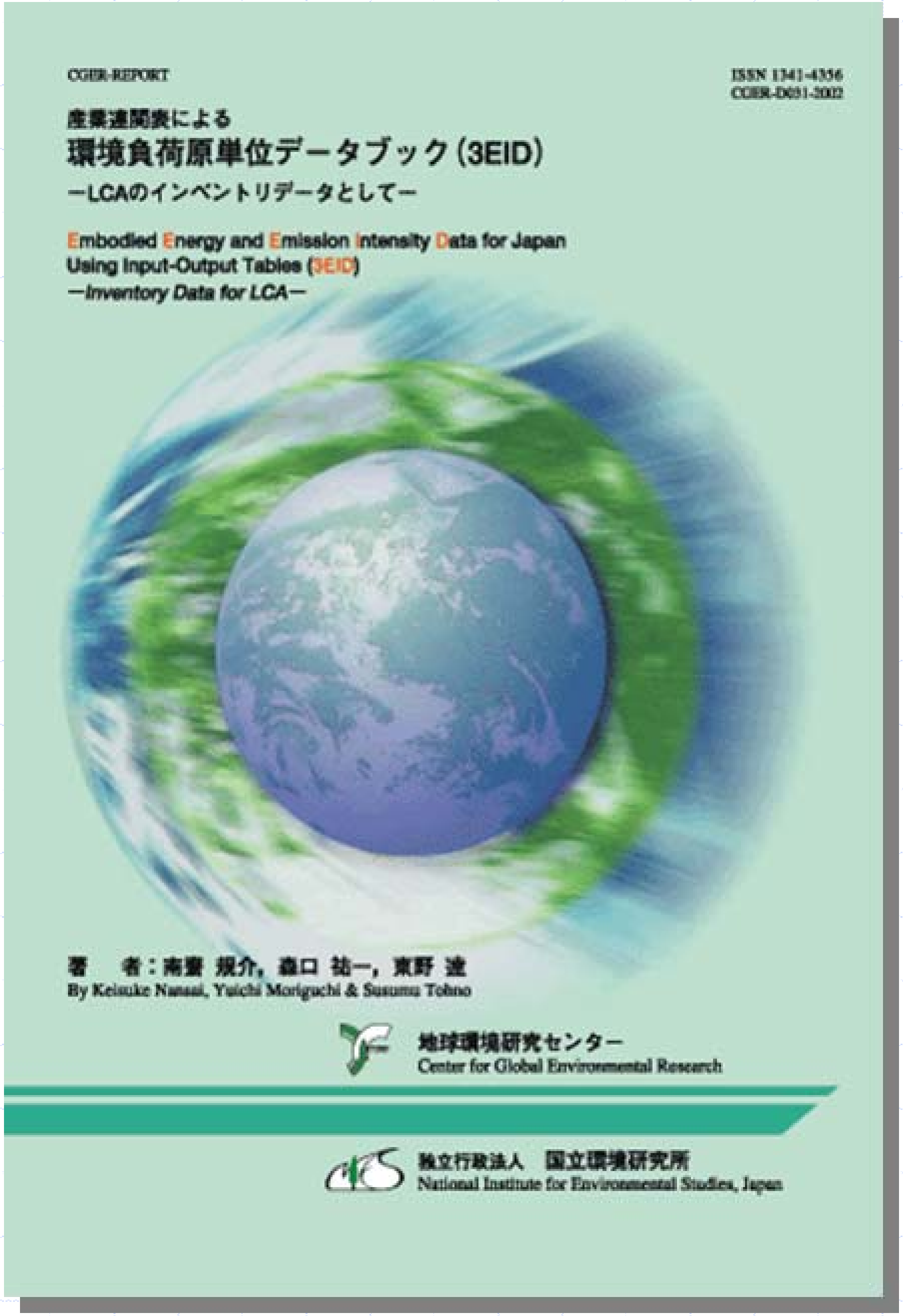


Energy consumption

CO_2

SOx

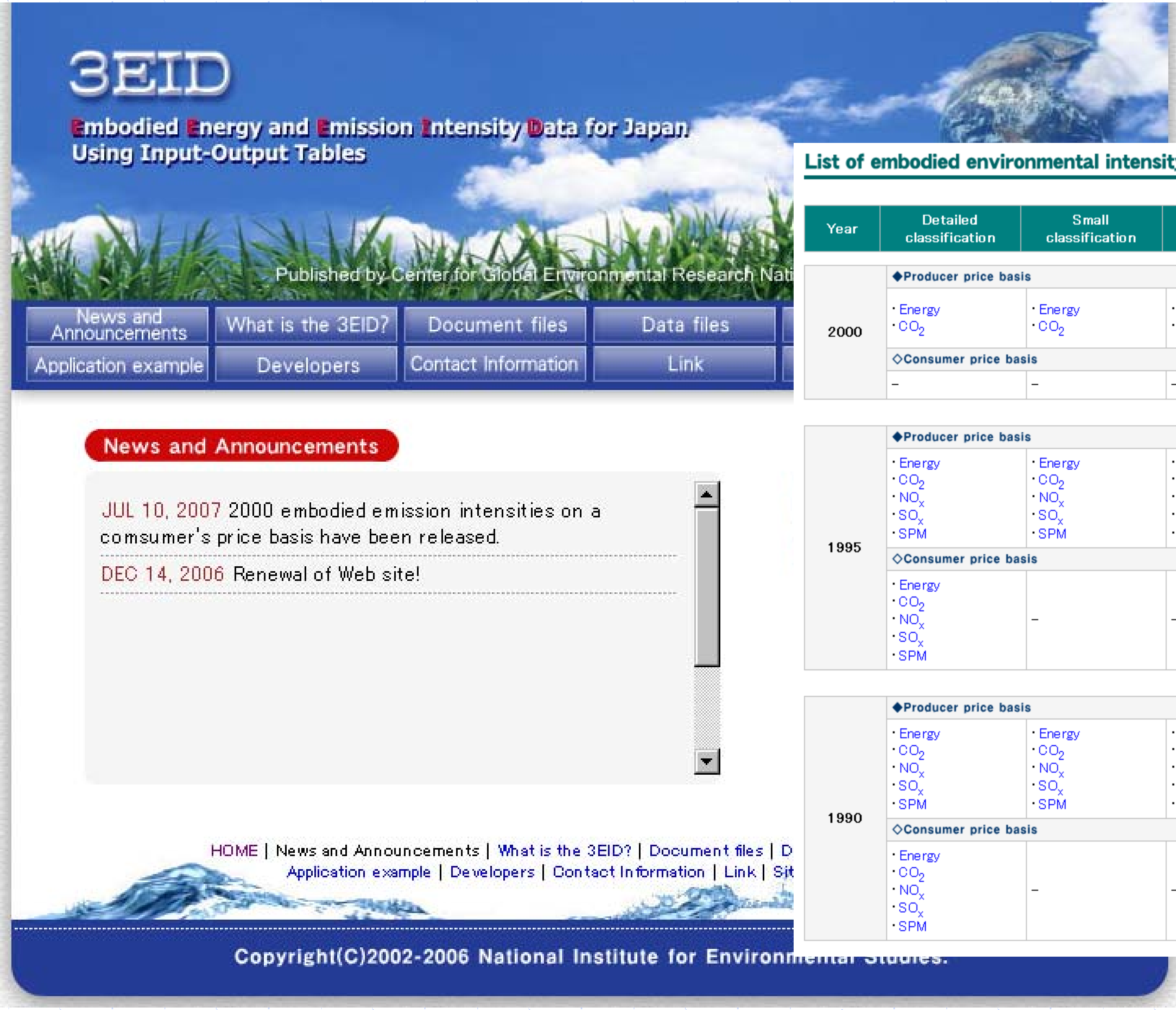
NOx

PM

Emission factor per energy consumption by fuel, by sector and by furnace-type

Emission inventory by each furnace (in total about 100,000 records) for air pollution control policy

3EID Website

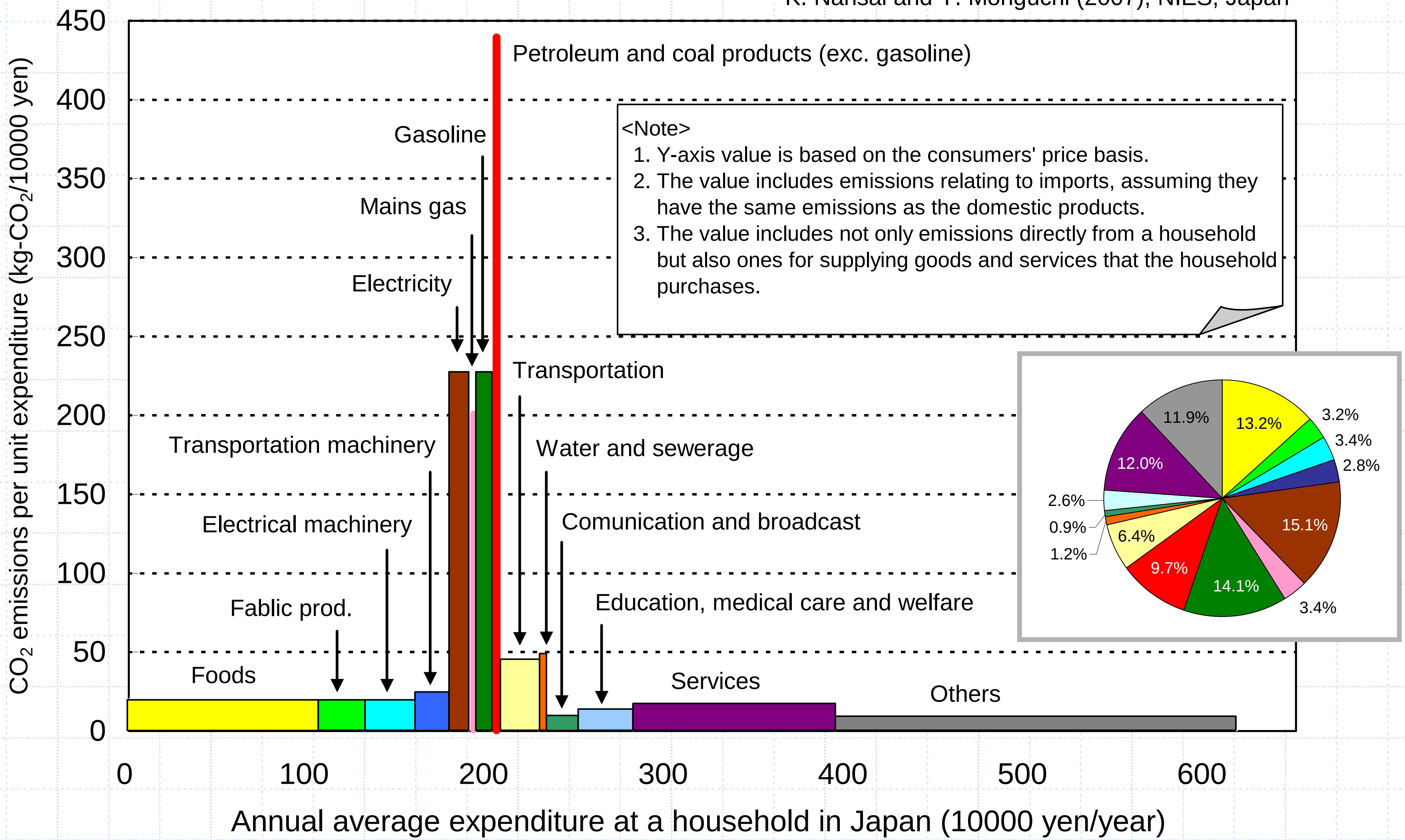


List of embodied environmental intensity

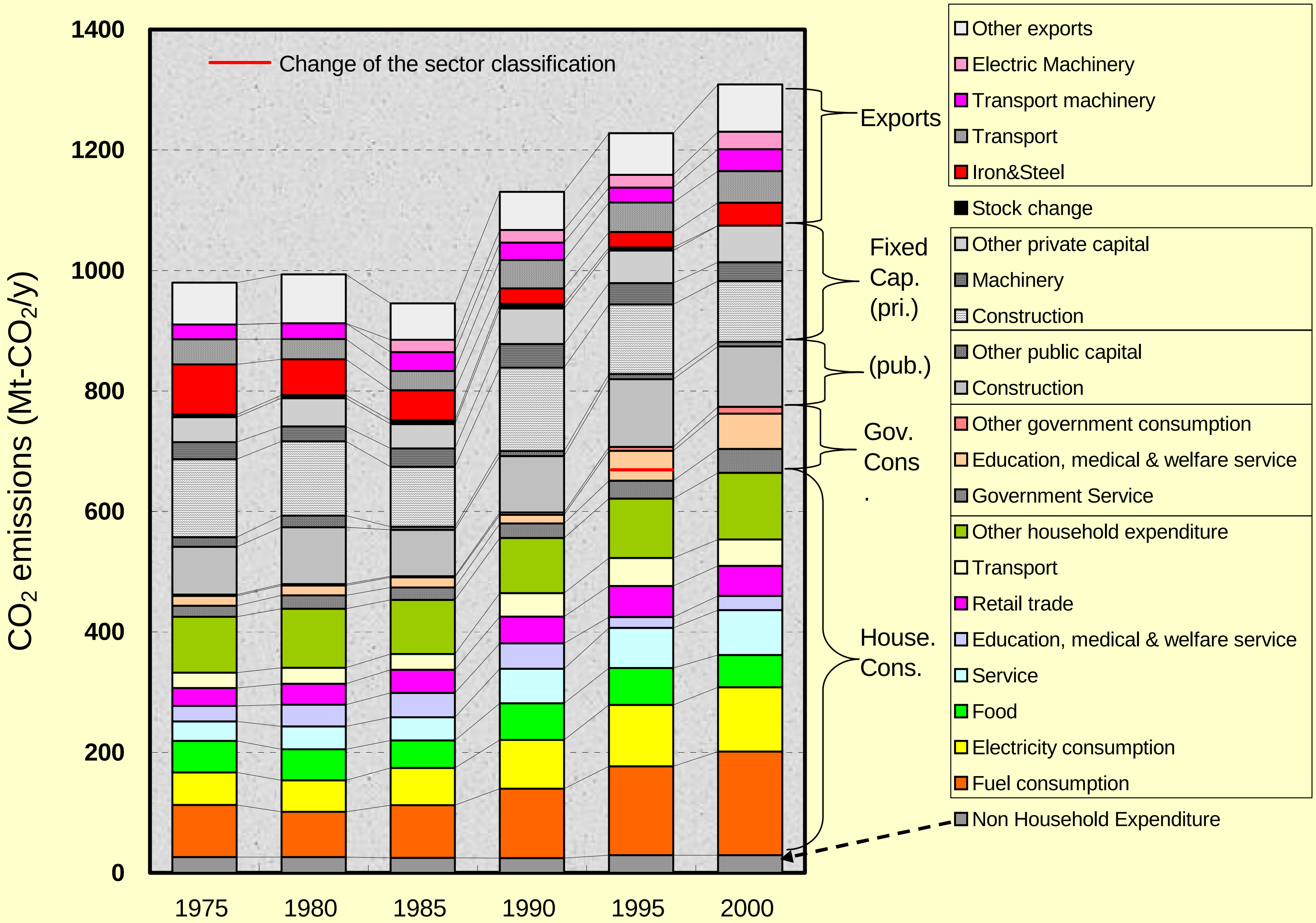
Year	Detailed classification	Small classification	Middle classification	Large classification
2000	◆Producer price basis			
	・Energy ・CO_2	・Energy ・CO_2	・Energy ・CO_2	・Energy ・CO_2
	◇Consumer price basis			
	–	–	–	–
1995	◆Producer price basis			
	・Energy ・CO_2 ・NO_x ・SO_x ・SPM	・Energy ・CO_2 ・NO_x ・SO_x ・SPM	・Energy ・CO_2 ・NO_x ・SO_x ・SPM	・Energy ・CO_2 ・NO_x ・SO_x ・SPM
	◇Consumer price basis			
	・Energy ・CO_2 ・NO_x ・SO_x ・SPM	–	–	–
1990	◆Producer price basis			
	・Energy ・CO_2 ・NO_x ・SO_x ・SPM	・Energy ・CO_2 ・NO_x ・SO_x ・SPM	・Energy ・CO_2 ・NO_x ・SO_x ・SPM	・Energy ・CO_2 ・NO_x ・SO_x ・SPM
	◇Consumer price basis			
	・Energy ・CO_2 ・NO_x ・SO_x ・SPM	–	–	–

Relationship between CO_2 intensities and expenditures of households in Japan

K. Nansai and Y. Moriguchi (2007), NIES, Japan



Japanese CO_2 emissions structure from the viewpoint of final demand (1975-2000)



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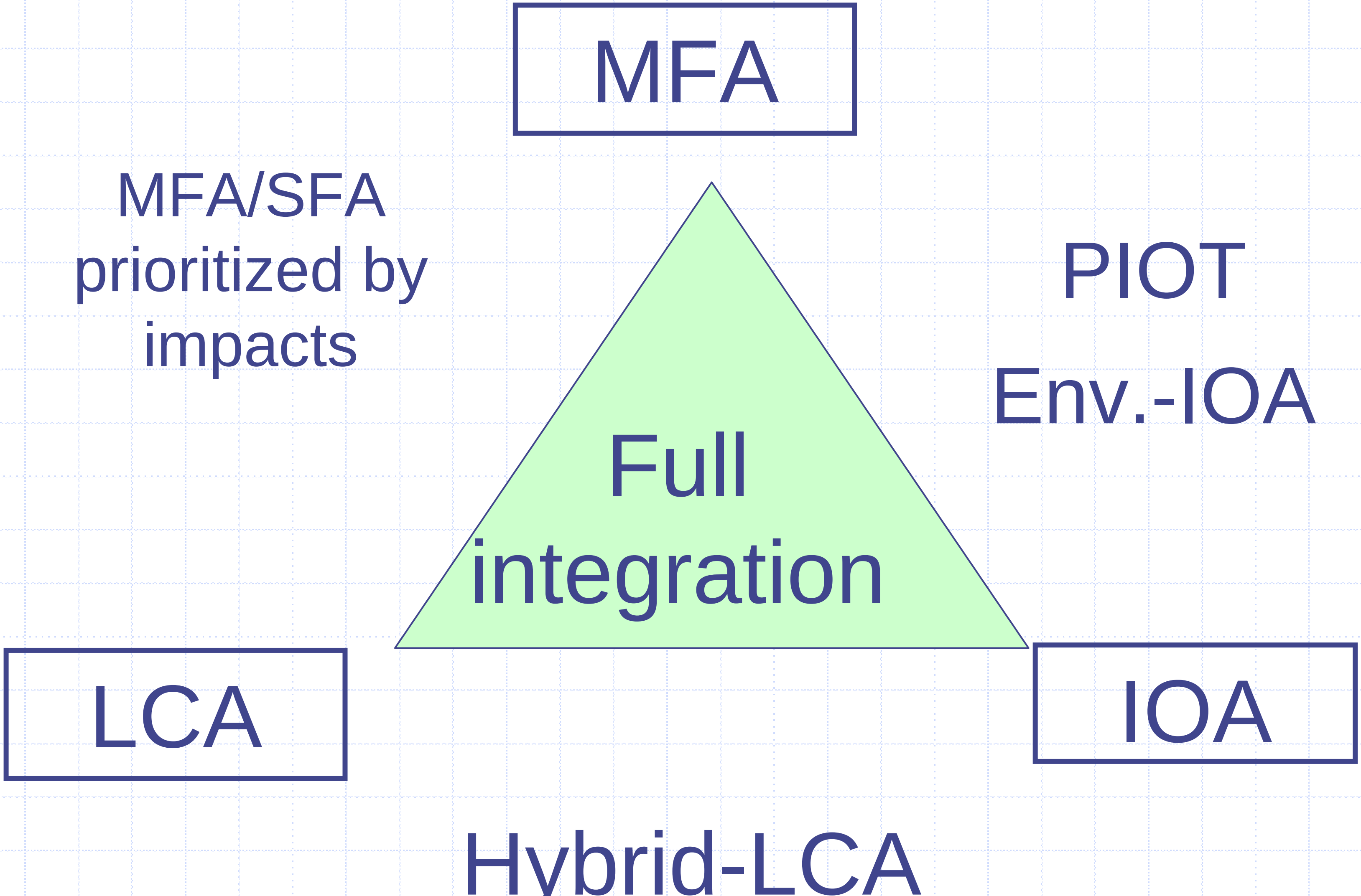
An essence of Industrial Ecology : Symbiosis

- There are a number of players (concepts, approaches, methods, and tools) in the field of industrial ecology.
- Each of them has their own background and has been contributing to the progress in industrial ecology.
- Considering that the "symbiosis" is one of the key concepts of industrial ecology, we may apply this useful concept to the industrial ecology research itself, by linking different tools so that they get mutual benefits.

Actual and potential linkages



Possible combinations/contributions

IOA to LCA ; Hybrid LCA

LCA to IOA ; Impact-based knowledge

MFA to IOA ; Extension of system boundary

IOA to MFA ; PIOT, Consistent accounting framework

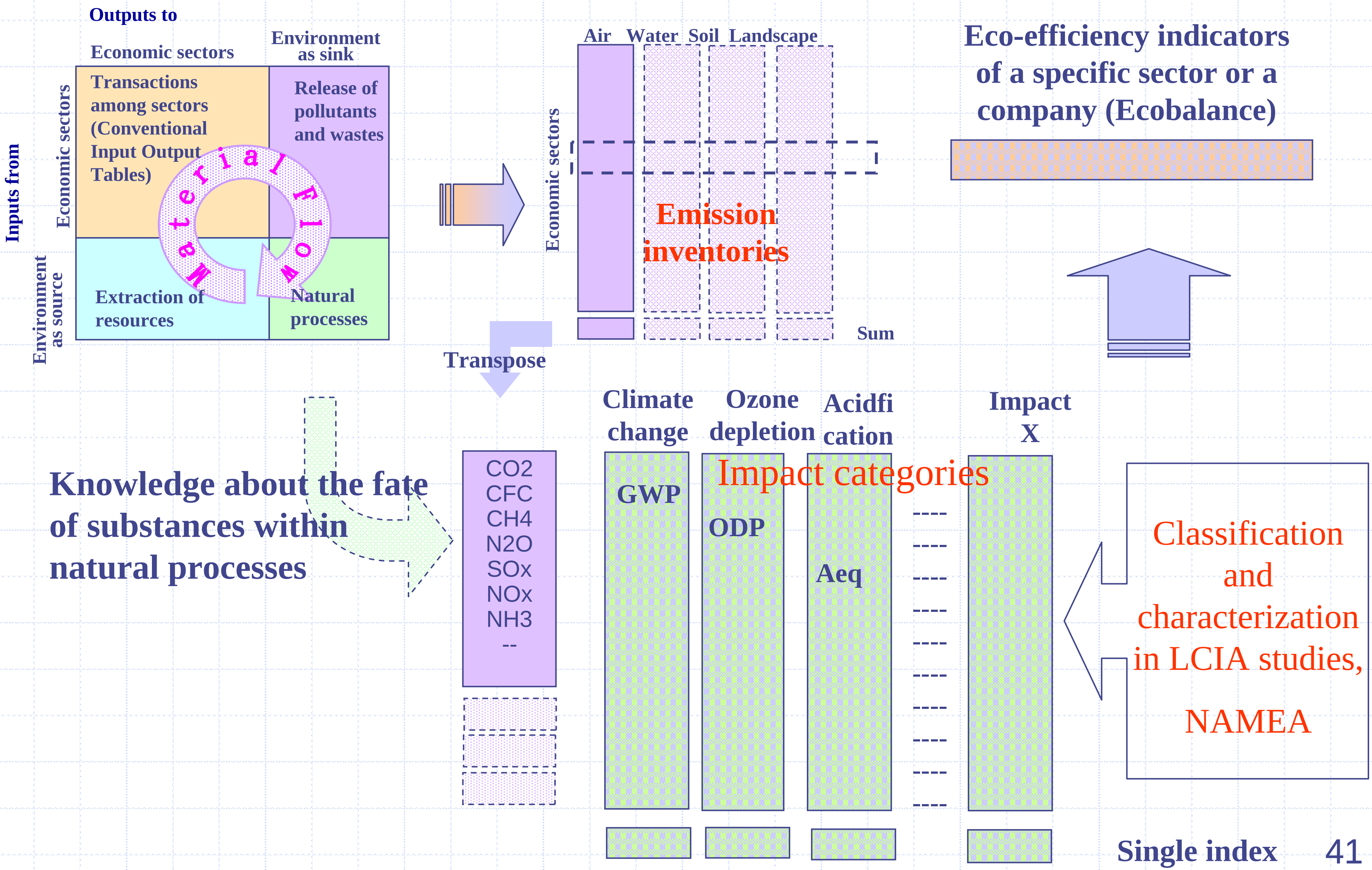
MFA to LCA ; LCA of meso, macro systems

LCA to MFA ; Impact-based MFA

MFA, IOA to LCA: LCA of whole economic activities

LCA to MFA, IOA: PIOT weighted by impacts

Matrix to describe relationships between pressures and impacts (learning from LCIA methodologies)



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Hybrid method

Rationale

- Leontief inverse in IOA and matrix method in LCA are mathematically identical
- Combination of top-down statistics and bottom-up technology data has mutual benefits
- Bottom-up of technology data can be compiled as I-O matrix

	Advantages	Disadvantages
Top-down I-O tables	➢Completeness in coverage and consistent system boundary	➢Delayed, costly data compilation ➢Aggregation error
Bottom-up Process data	➢Detailed resolution ➢Timely data for current and new technology	➢Incomplete system boundary ➢More costly to cover many sectors

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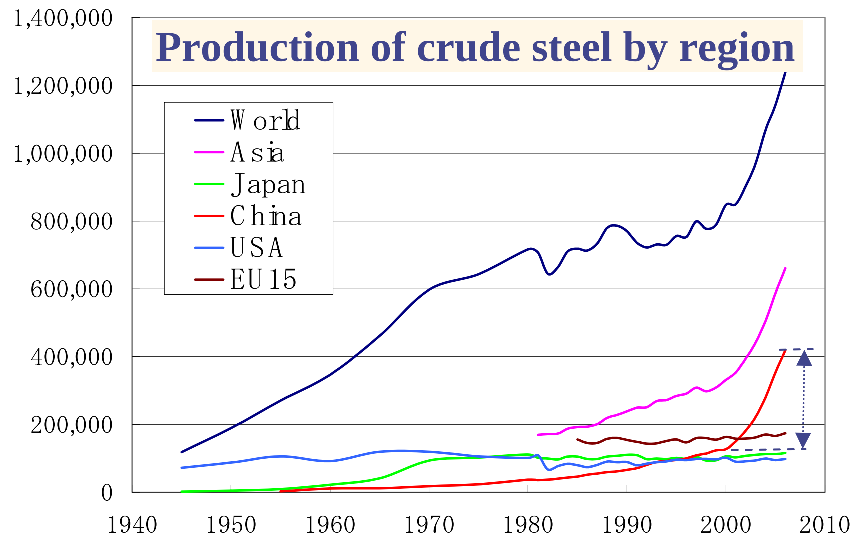
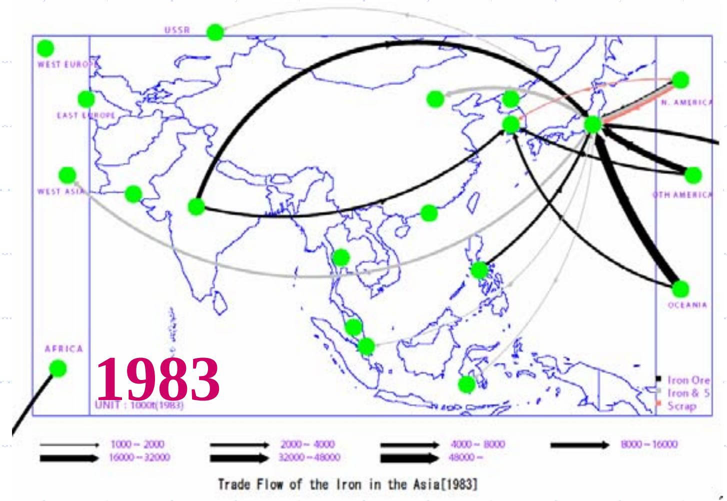
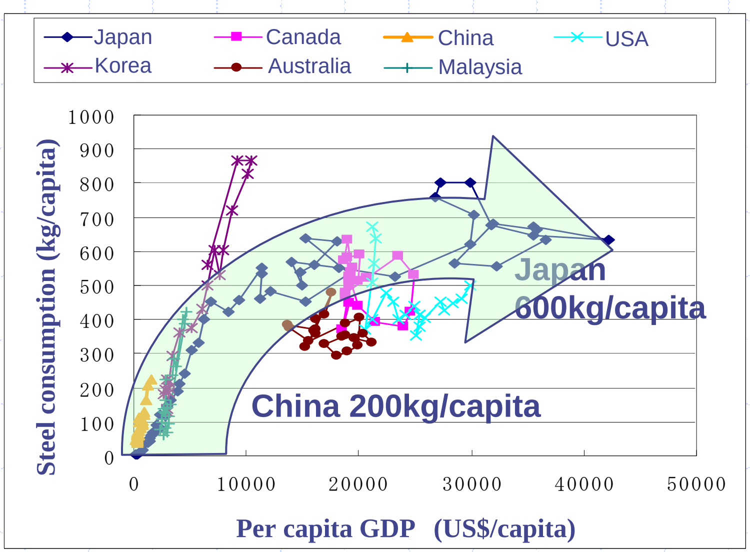
Scenario analysis: A case of steel production and consumption in Japan and China

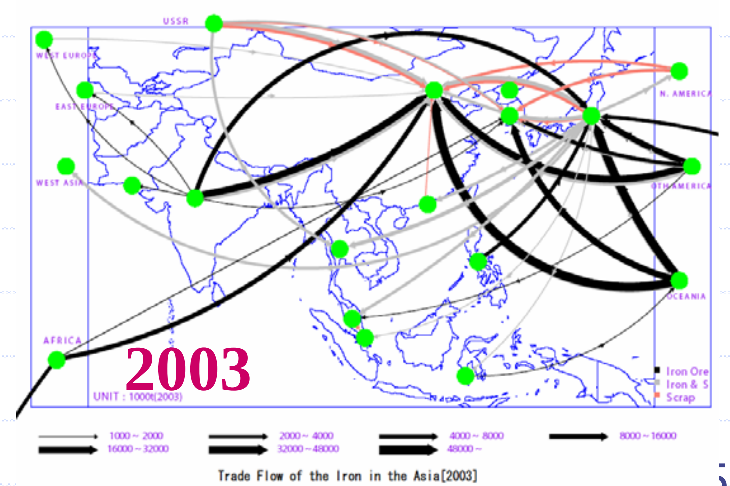




Increasing resource flows to developing economies

Growth of material consumption vs. GDP





Scenario analysis: A case of steel production and consumption in Japan and China

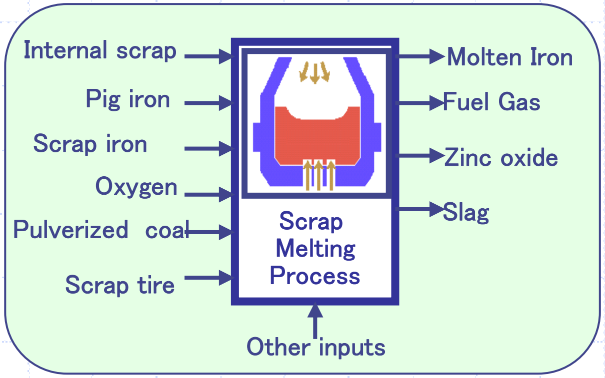
Assumptions

	Population	High grade steel/capita	Low grade steel/capita	Total consump-tion	Total Production
Japan	100 million	300kg/year	200kg/year	50Mt	50-150Mt
China	1,400 million (Urban 600) (Rural 800)	 300kg/year 100kg/year	 200kg/year 150kg/year	500Mt (300Mt) (200Mt)	400-500Mt

Key processes

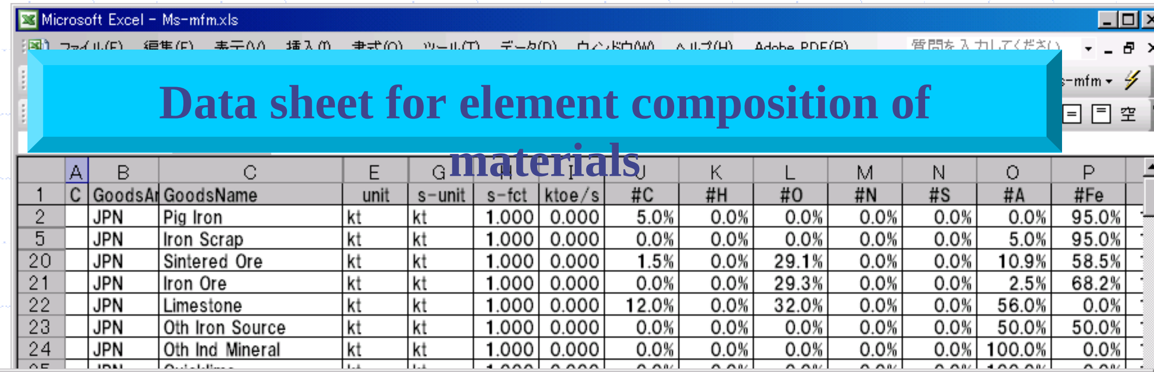
- Coke Oven
- Blast furnace& converter
- SMP: Scrap Melting Process
- Electric arc furnace
- Electric power generation

Database installed in Material Flow Model



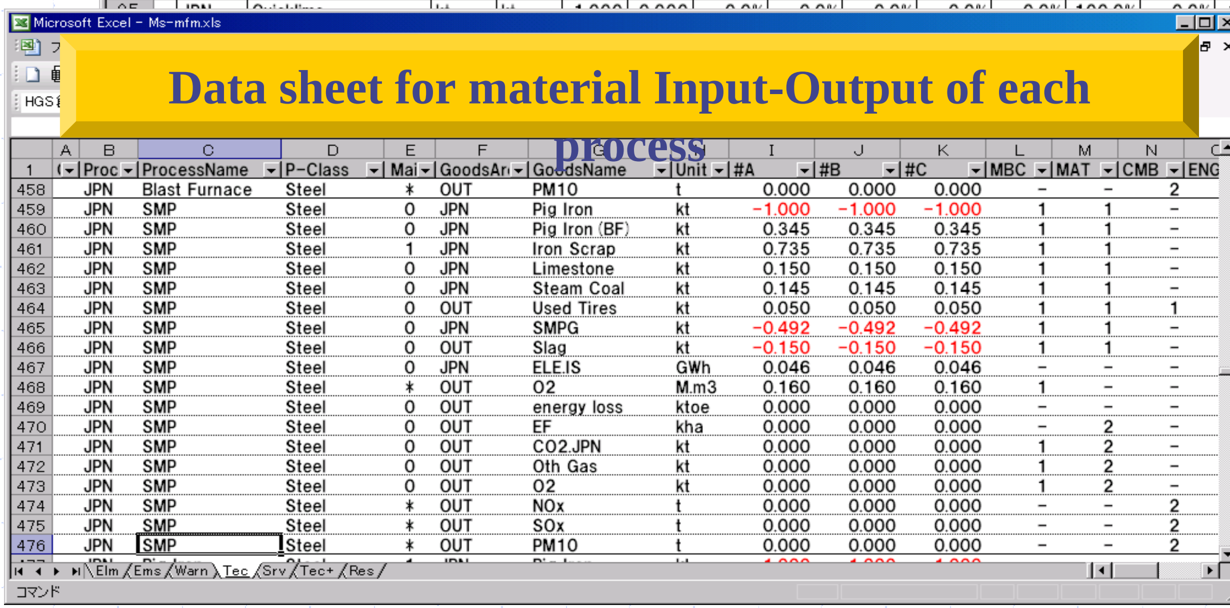
Typical processes

- •Coal mining in Australia
- •Coal mining in China
- •Iron ore mining in Australia
- •Shipping from Australia to Japan
- •Coke Oven in Japan
- •Blast furnace in Japan
- •Scrap Melting Process
- •Electric furnace in Japan
- •Blast furnace in China
- •Electric furnace in China
- •Power generation in Japan
- •Power generation in China



Data sheet for element composition of materials

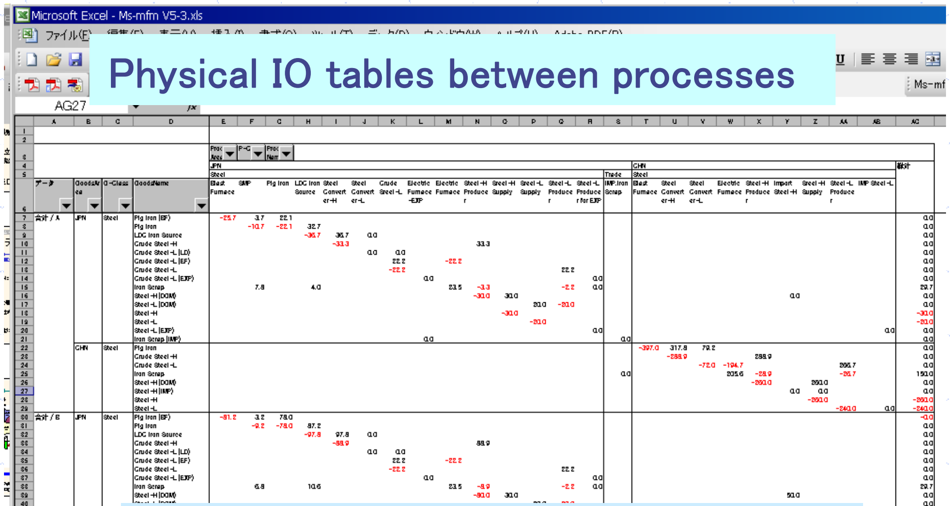
	A	B	C	E	G	H	I	J	K	L	M	N	O	P
1	C	GoodsAr	GoodsName	unit	s-unit	s-fct	ktoe/s	#C	#H	#O	#N	#S	#A	#Fe
2		JPN	Pig Iron	kt	kt	1.000	0.000	5.0%	0.0%	0.0%	0.0%	0.0%	0.0%	95.0%
5		JPN	Iron Scrap	kt	kt	1.000	0.000	0.0%	0.0%	0.0%	0.0%	0.0%	5.0%	95.0%
20		JPN	Sintered Ore	kt	kt	1.000	0.000	1.5%	0.0%	29.1%	0.0%	0.0%	10.9%	58.5%
21		JPN	Iron Ore	kt	kt	1.000	0.000	0.0%	0.0%	29.3%	0.0%	0.0%	2.5%	68.2%
22		JPN	Limestone	kt	kt	1.000	0.000	12.0%	0.0%	32.0%	0.0%	0.0%	56.0%	0.0%
23		JPN	Oth Iron Source	kt	kt	1.000	0.000	0.0%	0.0%	0.0%	0.0%	0.0%	50.0%	50.0%
24		JPN	Oth Ind Mineral	kt	kt	1.000	0.000	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%	0.0%

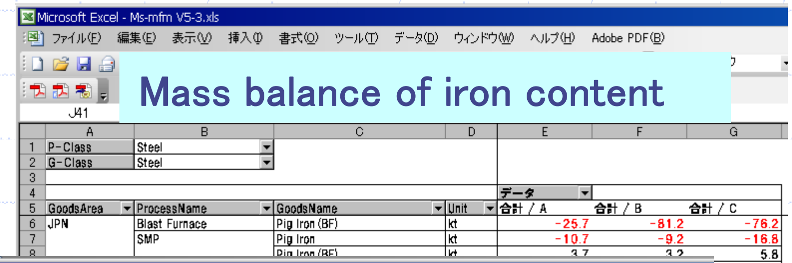


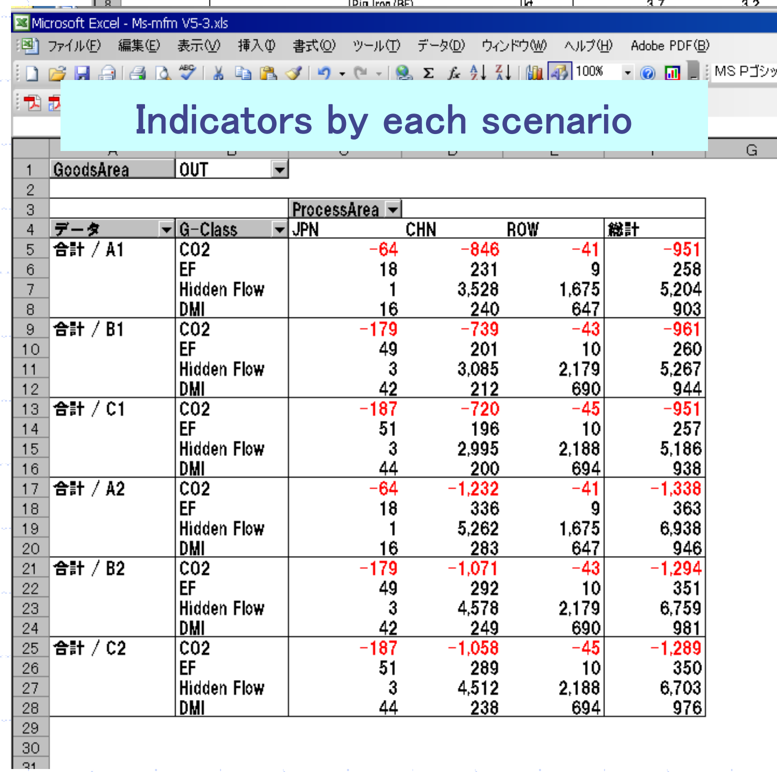
Data sheet for material Input-Output of each process

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	(	Proc	ProcessName	P-Class	Mai	GoodsAr	GoodsName	Unit	#A	#B	#C	MBC	MAT	CMB
458		JPN	Blast Furnace	Steel	*	OUT	PM10	t	0.000	0.000	0.000	–	–	2
459		JPN	SMP	Steel	0	JPN	Pig Iron	kt	-1.000	-1.000	-1.000	1	1	–
460		JPN	SMP	Steel	0	JPN	Pig Iron (BF)	kt	0.345	0.345	0.345	1	1	–
461		JPN	SMP	Steel	1	JPN	Iron Scrap	kt	0.735	0.735	0.735	1	1	–
462		JPN	SMP	Steel	0	JPN	Limestone	kt	0.150	0.150	0.150	1	1	–
463		JPN	SMP	Steel	0	JPN	Steam Coal	kt	0.145	0.145	0.145	1	1	–
464		JPN	SMP	Steel	0	OUT	Used Tires	kt	0.050	0.050	0.050	1	1	1
465		JPN	SMP	Steel	0	JPN	SMPG	kt	-0.492	-0.492	-0.492	1	1	–
466		JPN	SMP	Steel	0	OUT	Slag	kt	-0.150	-0.150	-0.150	1	1	–
467		JPN	SMP	Steel	0	JPN	ELE.IS	GWh	0.046	0.046	0.046	–	–	–
468		JPN	SMP	Steel	*	OUT	O2	M.m3	0.160	0.160	0.160	1	–	–
469		JPN	SMP	Steel	0	OUT	energy loss	ktoe	0.000	0.000	0.000	–	–	–
470		JPN	SMP	Steel	0	OUT	EF	kha	0.000	0.000	0.000	–	2	–
471		JPN	SMP	Steel	0	OUT	CO2.JPN	kt	0.000	0.000	0.000	1	2	–
472		JPN	SMP	Steel	0	OUT	Oth Gas	kt	0.000	0.000	0.000	1	2	–
473		JPN	SMP	Steel	0	OUT	O2	kt	0.000	0.000	0.000	1	2	–
474		JPN	SMP	Steel	*	OUT	NOx	t	0.000	0.000	0.000	–	–	2
475		JPN	SMP	Steel	*	OUT	SOx	t	0.000	0.000	0.000	–	–	2
476		JPN	SMP	Steel	*	OUT	PM10	t	0.000	0.000	0.000	–	–	2

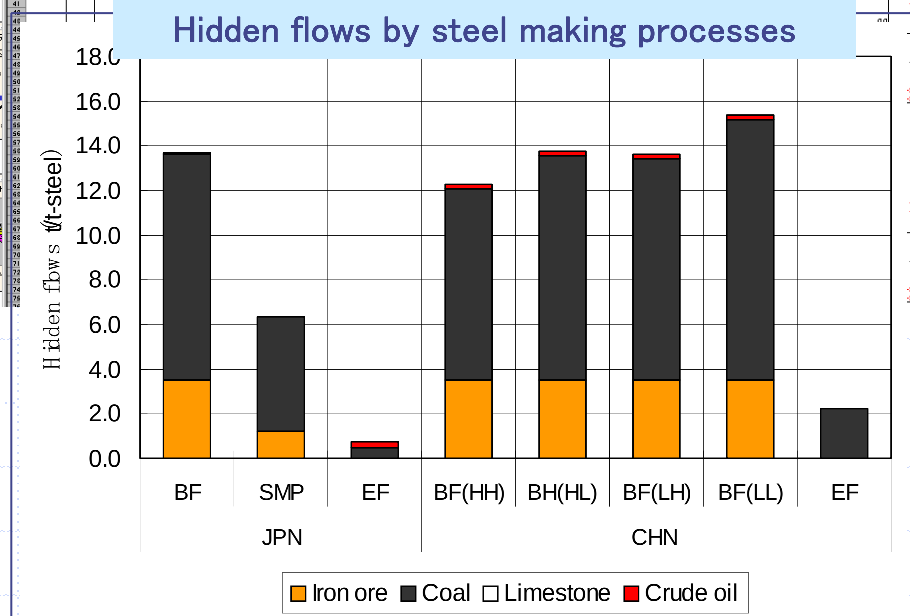
Outputs from Material Flow Model







GoodsArea	OUT				
		ProcessArea			
データ	G-Class	JPN	CHN	ROW	総計
合計 / A1	CO2	-64	-846	-41	-951
	EF	18	231	9	258
	Hidden Flow	1	3,528	1,675	5,204
	DMI	16	240	647	903
合計 / B1	CO2	-179	-739	-43	-961
	EF	49	201	10	260
	Hidden Flow	3	3,085	2,179	5,267
	DMI	42	212	690	944
合計 / C1	CO2	-187	-720	-45	-951
	EF	51	196	10	257
	Hidden Flow	3	2,995	2,188	5,186
	DMI	44	200	694	938
合計 / A2	CO2	-64	-1,232	-41	-1,338
	EF	18	336	9	363
	Hidden Flow	1	5,262	1,675	6,938
	DMI	16	283	647	946
合計 / B2	CO2	-179	-1,071	-43	-1,294
	EF	49	292	10	351
	Hidden Flow	3	4,578	2,179	6,759
	DMI	42	249	690	981
合計 / C2	CO2	-187	-1,058	-45	-1,289
	EF	51	289	10	350
	Hidden Flow	3	4,512	2,188	6,703
	DMI	44	238	694	976



WIO and WIO-MFA by Prof. Shinichiro Nakamura

- Next several slides are provided by the courtesy of Prof. Shinichiro Nakamura, Waseda University, in order to introduce an outline of WIO and WIO-MFA.

MFA, Mass Conservation and IOA

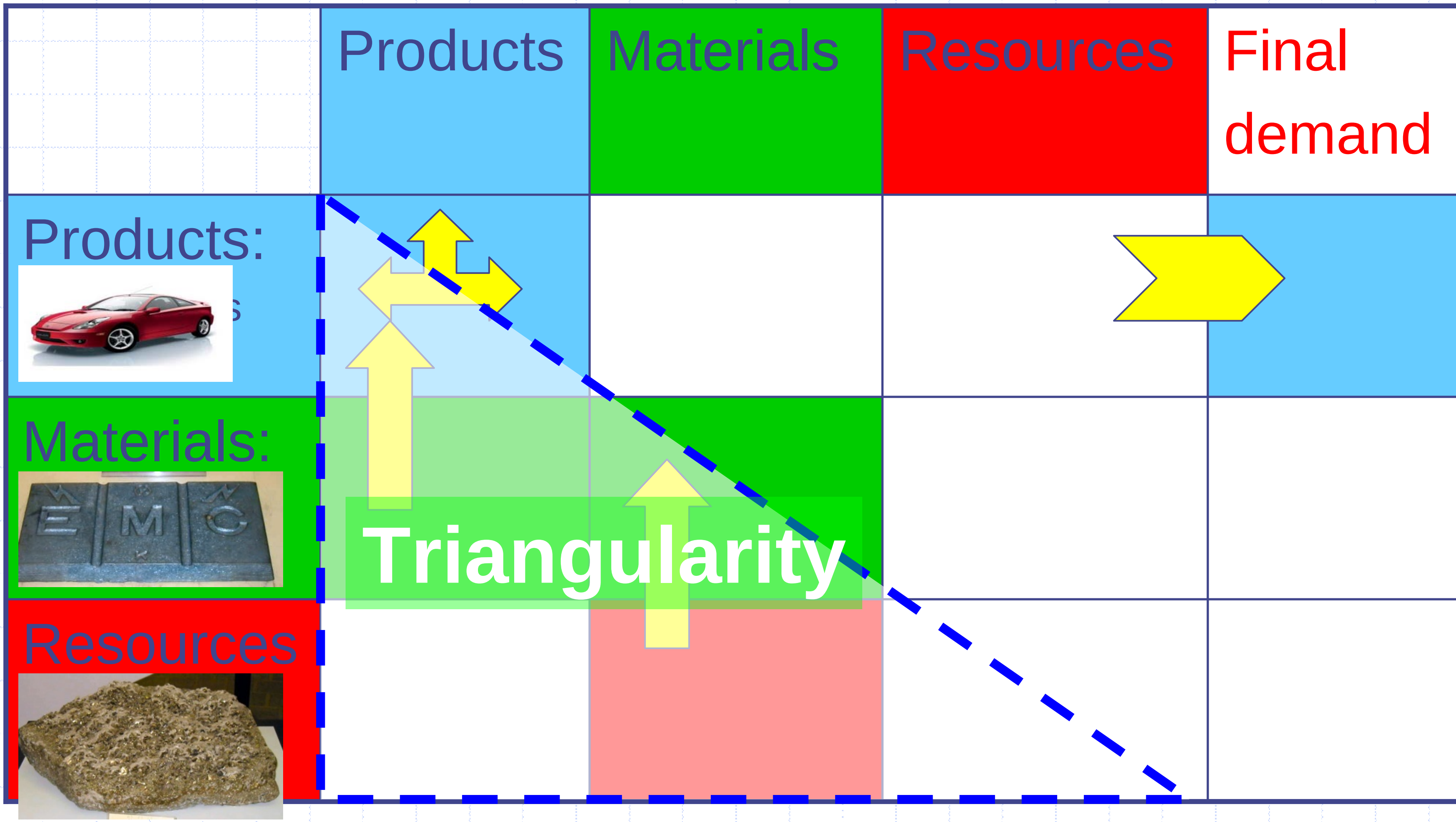
- Mass balance principle: the core of MFA (Voet, HBIE 2001)
- Waste flow must be properly taken into account
  - Yields of input cannot be 100%.
    - Input = Output + Waste
  - The conventional IOA does (Strassert, HBIE 2001):
    - *Not* consider the flow of waste, and
    - *Not* meet the mass balance principle.
- Double counting must be avoided:
  - A clear definition of *materials* in MFA needed!
  - There is *no* general consensus on a methodological framework for MF accounting and analysis (Bringezu and Moriguchi, HBIE 2001)

Source: Prof. S. Nakamura, Waseda University

WIO-MFA: a model of MFA based on WIO:
(Nakamura and Nakajima, Mater. Trans. 48-12, 2005)

- Advantages of using WIO:
  - explicit consideration of the flow of waste.
  - not only descriptive, but provides analytical model as well.
- WIO—MFA
  - A physical WIO that meets the mass balance principle.
  - An analytical model of MFA
  - An explicit definition of *materials* that avoids double counting
  - Estimate the material content of product that makes possible
    - conversion of a MIOT into an MF accounting (PIOT): fully consistent with the concept of MIOT, which may not be the case for a PIOT that is made from scratch (Weisz and Duchin, 2006)
    - a simultaneous estimation of MF accounting for an arbitrary number of materials

A schematic representation of triangularity between ***Resources***, ***Materials***, and ***Products***



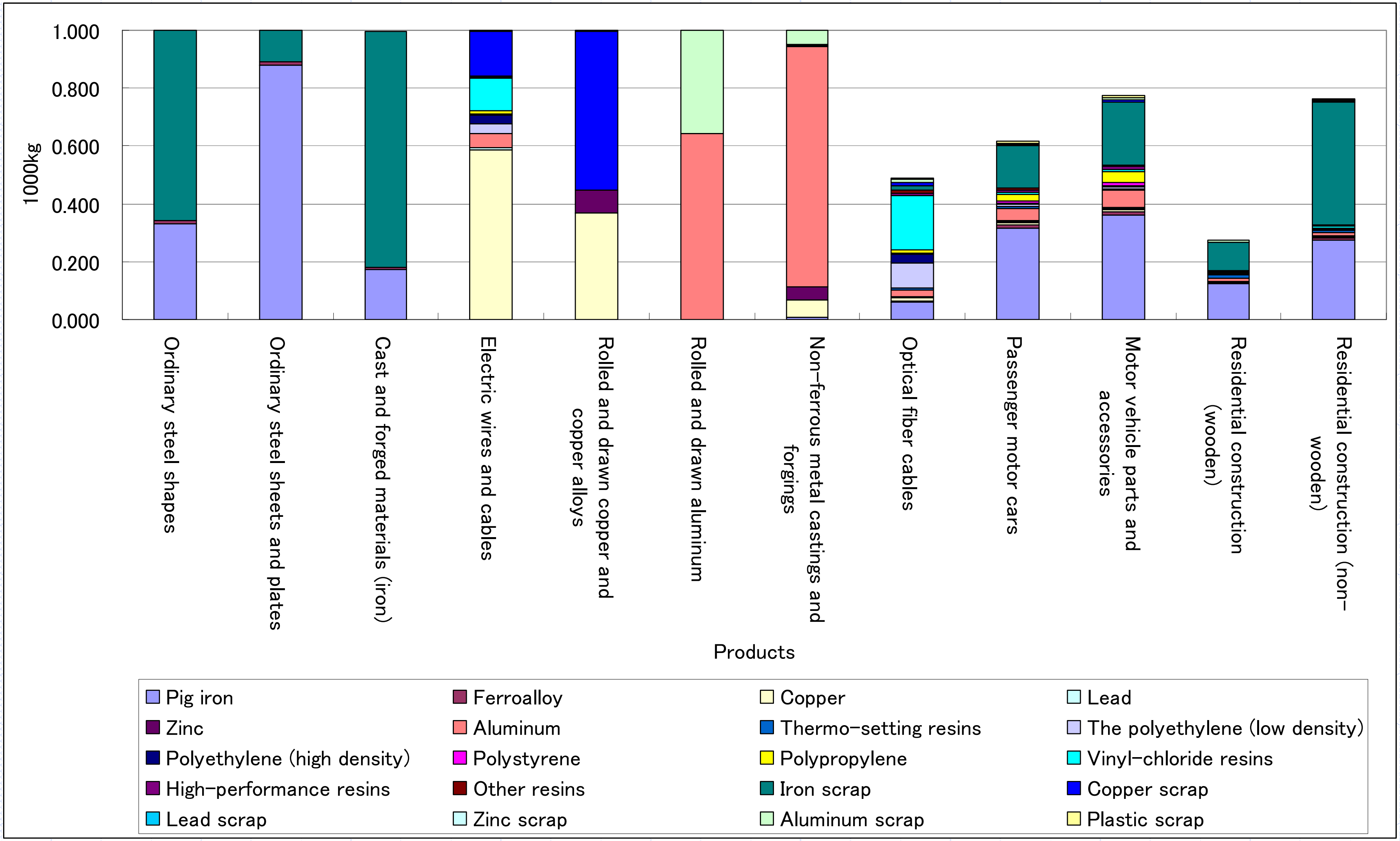
Source: Prof. S. Nakamura, Waseda University

Implementation: Japanese WIO (2000)

- Materials (10^3kg):
  - 11 metal types
    1. Iron
    2. Aluminum
    3. Copper
    4. Lead
    5. Zinc
    6. Ferro alloy
    7. Iron scrap
    8. Aluminum scrap
    9. Copper scrap
    10. Lead scrap
    11. Zinc scrap
- Materials (10^3kg):
  - 9 plastic types
    1. Thermo-setting resins
    2. Polyethylene (low density)
    3. Polyethylene (high density)
    4. Polystyrene
    5. Polypropylene
    6. Vinyl-chloride resins
    7. High-performance resins
    8. Other resins
    9. Waste plastic
- Resources: 12 types
- Products: 408 types

Source: Prof. S. Nakamura, Waseda University

Metal & plastic composition of products



Source: Prof. S. Nakamura, Waseda University