Integrative Approaches towards Sustainability

Rüdiger Kühr &
Motoyuki Suzuki
(eds.)

Proceedings of a
German-Japanese Workshop

organised by the
United Nations University,
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GERMAN-JAPANESE WORKSHOP ON INTEGRATED APPROACHES TOWARDS SUSTAINABILITY

Friday, 29 September 2000
Fraunhofer - Gesellschaft, Leonrodstrasse 54, 80636 Munich, Germany

Organisers:
Fraunhofer - Gesellschaft, Munich
United Nations University, Zero Emissions Forum, Contact Point Europe, Berlin

Programme

9.00-09.15 Welcome and Opening Remarks

Dr. Dieter R. Fuchs, Director Int. Co-operation, Fraunhofer Society
Prof. Motoyuki Suzuki, Vice-Rector, United Nations University

Session: Economy & Social

09.20-09.40 Prof. Yuzuru Miyata (Toyohashi University of Technology)
"Zero Emissions Oriented Regional Economic System"
09.45-10.05 Prof. Helge Majer (University of Stuttgart)
"Sustainable production - The holistic view"
10.10-10.40 Discussion
10.40-11.00 Coffee Break

Session: The Zero Emission Concept

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"Zero Emissions Activities in Japan"
11.20-11.40 Marc-Andree Wolf (IKP)
"Zero Emission as the integrated approach towards a sustainable society"
11.45-12.30 Discussion
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3. Session: Technology

a)

13:15-13:30 Dr. Manfred Schuckert (Daimler-Evobus):
"Fuel cells as efficient and marketable energy conversion system in transport systems"

13:30-13:45 Mr. Toyoharu Morita (Ebara Research Co.,Ltd.)
"Approaches to Zero Emissions in Japanese Industries"

13:45-14:15 Discussion

b)

14:15-14:30 Prof. Akiyoshi Sakoda (University of Tokyo)
"Physicochemical Conversions of Biomass"

14:30-14:45 Prof. Walter Trösch (Fraunhofer IGB)
"Environmental Biotechnology – the Challenge of Biomimetics"

14:45-15:15 Discussion

Excurse: Education

15:15-15:30 Dr. Christa Henze (University of Essen)
"Sustainability in teacher-training courses at universities - an investigation of higher education in North-Rhine-Westphalia"

15:30-15:45 Prof. Sachihiko Harashina, (Tokyo Institute of Technology):
"Citizen Participation System"

15:45-16:15 Discussions

16:15-16:30 Coffee Break

16:30-16:45 Mr. Helmut Schulz (Head of Division, Clean Technologies and Sustainable Products, Federal Ministry of Education and Research (BMBF)) "Research and Activities in the field of sustainable Management in Germany"

16:45-17:00 Discussion & Closing Remarks

A General Equilibrium Analysis of Environmental and Economic Interaction with Material Circulation - A CGE-modeling Approach –

Yuzuru MIYATA & Xiaojin PANG

Toyohashi University of Technology, Department of Socio-economic Planning, Tempaku, Toyohashi

Introduction

Waste has been throwing a serious issue to our present society. To cope with this issue, a terminology "zero-emissions" has very often been used at various phases. As this name suggests, the concept of zero-emissions implies a social system where no waste is discharged ultimately. This concept was initially advocated by United Nations University in 1995 (Capra and Pauli, 1995), and since its initiation, study of zero-emissions has attracted many researchers, in particular, in Japan (Suzuki, 2000).

Looking at the current study situation , however, it has still stayed at an initial stage. For example, studies have been concentrated on the kind of materials used, or the kind of waste generated in a specific production system (Suzuki, 2000).

Besides the natural science or engineering approach, study of zero-emissions has been a considerably unexplored field in environmental economics despite the fact of potentially attractive and important theme. For example, it would be significantly worth examined how the economic impacts of promotion and realization of a zero-emissions oriented society would be. But there have been little attempts for this topic in environmental economics.

Taking these backgrounds into account, this article aims to extend the authors' previous study concerning this field (Miyata and Pang, 1999a and 1999b), and then to evaluate the possibility and economic impacts of the zero-emissions oriented society taking Aichi Prefecture in Japan as a study region. More concretely, this paper emphasizes a *CGE*-modeling approach to evaluate the following contents: reduction in the volume of final unused materials due to improvement of recycling rates resulting from technological progress, changes in the scale of waste recycling and abatement activities, industrial structural change towards a zero-emissions society, and impacts of environmental subsidies for promotion of a zero-emissions oriented society.

Economic and Material Circulation Accounting Matrix

The authors have already proposed an economic-waste accounting matrix in their previous studies (Miyata and Pang, 1999a and 1999b). Instead of the former concept, the present paper introduces a significantly extended new accounting matrix. The structure of this new matrix is illustrated in Table 2. In the new accounting matrix, waste generated by each industry is classified into more detailed categories i.e. 26 types. And then recycling, internal and external abatements are considered for each type of waste of each industry.

Table 1 Classification of Recycled Commodities

recycled commodities	abbreviation	corresponding waste	6 digit classification in I/O table	2 digit classification in I/O table
recycled construction materials Ⅰ	RC Ⅰ	cinder and slag	other non-metallic ore	mining
recycled construction materials Ⅱ	RC Ⅱ	organic sludge, inorganic sludge, and construction waste	gravel and quarrying	mining
recycled construction materials Ⅲ	RC Ⅲ	soot and dust	other non-metallic ore	mining
compost	COM	animal waste	organic fertilizers	beverage and feed
recycled organic fertilizers	ROF	organic sludge	organic fertilizers	beverage and feed
recycled organic fertilizers and feeds	ROFF	animal and vegetable residue	organic fertilizers and feeds	beverage and feed
recycled fiber	RF	waste fiber	fabrics	fabric and textile
recycled wooden products	RW	waste wood	timber, plywood, and wooden chip	wooden product
recycled pulp and paper	RPP	waste paper	pulp and paper	pulp and paper
recycled chemical fertilizers	RCF	cinder, inorganic sludge	chemical fertilizer	chemical
recycled acid and alkali	RAA	waste acid and alkali	inorganic chemicals basic products	chemical
recycled oils	RO	waste oil	petroleum refinery products	petroleum refinery and coal
recycled plastics	RP	waste plastic	plastic products	plastic
recycled tires	RT	waste tire	tires and inner tubes	rubber
recycled rubber	RR	waste rubber	rubber products	rubber
recycled glass and construction materials Ⅳ	RG	waste glass and porcelain	glass, and miscellaneous ceramic, stone and clay products	ceramic, stone, and clay
recycled iron	RI	slag and waste metal	crude steel	iron and steel
recycled non-ferrous metals	RNF	slag and waste metal	non-ferrous metals	non-ferrous metal

Moreover, waste recycling , internal and external abatement activities are explicitly specified with their factor inputs, i.e. intermediate, labor, and capital inputs. Recycled materials are discriminated from virgin commodities, being in turn used as intermediate and final goods. Table 1 depicts the classification of recycled materials.

Table 3 shows an estimation result of the new economic and material circulation accounting matrix in anaggregate format. The original format of this matrix is composed of 34 industries, 18 recycling activities (*R*-activities), 34 internal waste abatement activities (*S*-activities), one external waste abatement activity (*C*-activity), the government, aggregate household, capital, labor, capital account, and the external sector. Industries, *R*- and *S*-activities are aggregated into respective sectors yielding Table 3. Here, *C*-activity is defined as an aggregate activity that is composed of waste abatement firms and public waste abatement activities.

From this table, one can see that industries in Aichi Prefecture totally produce 66 trillion and 75.95 billion yen of output in 1994, generating 16.84 million tons of waste (including industrial general waste). Households earn 26 trillion and 63.04 billion yen of income, consume 15 trillion and 16.23 billion yen, and discharge 2.14 million tons of waste.

2.80 million tons of industrial waste is disposed by *S*-activities at the cost of 3.9 billion yen. 5.92

million tons of industrial and household waste is treated by *C*-activities at the cost of 16.1 million yen. Finally, 10.25 million tons of waste is recycled costing 24.02 million yen.

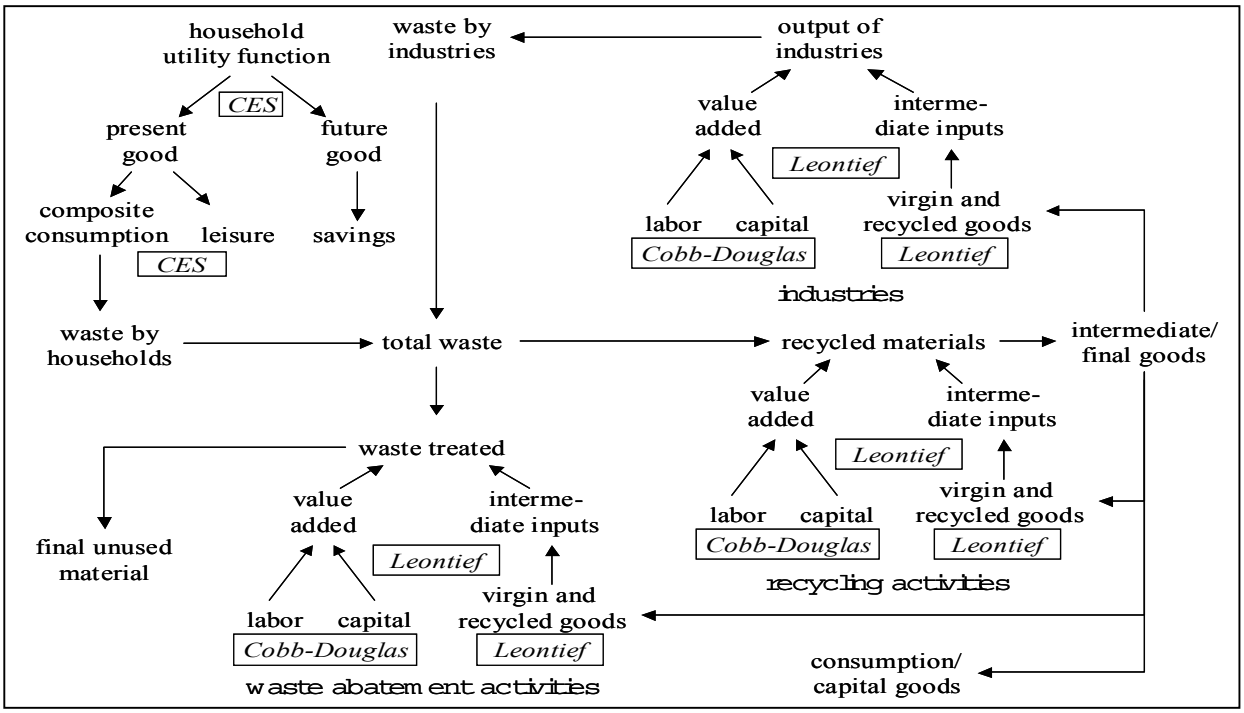

Figure 1 Hierarchical Structure of the Economic and Material Circulation CGE Model

		production activities	recycling activities	waste abatement activities		final demand	total
		34 industries	recycled construction materials ・ recycled metals	self-abatement	consigned abtement		
production activities	34 industries	intermediate inputs in industries	intermediate inputs in recycling	intermediate inputs in waste abatement			demand for virgin goods
		recycled goods	virgin goods				
recycling activities	recycled construction materials : recycled metals	purchase of recycled goods	supply of recycled goods	purchase of recycled goods			demand for recycled goods
waste abatement activities	self-abatement	???????? waste	material transformation	?		household waste	demand for waste abatement
	consigned abtement	payment to waste abatement					
value added							
total		supply of virgin goods	supply of recycled goods	total waste abated		total	

Table 2 Structure of Economic-Material Circulation Accounting Matrix

Table 3 Estimated Economic and Material Circulation Accounting Matrix of 1994 Aichi's Economy

		production activities	recycling activities	waste abatement activities		institution		production factors		capital accumulation	external sector	total
		34 industries	18 recycling activies	self-abatement	consigned abatement	government	households	capital	labor			
production activities	34 industries	35,476,581	172,849	2,669	29,541	1,962,981	15,162,063	0	0	7,337,704	6,615,136	66,759,524
recycling activies	18 recycling activies	239,846	55	0	8	0	227	0	0	31	0	240,167
waste abatement activities	self-abatement	3,875	0	0	0	0	0	0	0	0	0	3,875
	consigned abatement	96,280	0	0	0	57,085	7,643	0	0	0	0	161,008
institution	government	2,285,022	9,166	0	3,152	0	6,118,189	0	0	0	1,324,915	9,740,444
	households	0	0	0	0	2,149,822	0	8,008,547	16,197,355	0	274,696	26,630,420
production factors	capital	7,518,146	28,719	91	13,483	0	0	0	0	0	448,107	8,008,547
	labor	16,672,090	17,411	629	103,499	0	0	0	0	0	253,257	17,046,886
capital finance		4,467,684	11,967	486	11,324	1,753,243	5,342,298	0	0	0	232,738	11,819,740
external sector		0	0	0	0	3,817,313	0	0	849,531	4,482,005	0	9,148,849
total		66,759,525	240,167	3,875	161,008	9,740,444	26,630,420	8,008,547	17,046,886	11,819,740	9,148,849	149,559,461
waste generation /recycling/abatement		16,837	−10,250	−2,800	−5,923	0	2,136	0	0	0	0	0

Note: Figures in transaction of economic sectors are in million yen, while waste generation/recycling/abatement are in thousand tons

The Model

The proposed model in this study is static one similar to our previous model. Figure 1 graphically illustrates its hierarchical structure. This section explains details of the model.

A. Main Assumptions of the Model

Main assumptions made for the model are summarized here, however, there are many additional assumptions made in the model. Those will be explained at appropriate places to avoid unnecessary complexity.

(1) 1994 Aichi's economy is examined. Economic agents are households, 34 industries, 18 *R*-activities, 34 *S*-activities, *C*-activity, the government, and the external sector. Waste discharged by industries and households are classified into 26 types.

(2) *R*-activities process a part of industries' and households' waste, and supply recycled goods as intermediate and final commodities. *R*-activities are assumed to take firm's behavior.

(3) Each industry is equipped with its own *S*-activity. Each *S*-activity is assumed to abate only waste which is discharged by its associated industry. Operation of each *S*-activity is managed by its industry.

(4) *C*-activity is composed of public and private abatement activities, and disposes of industrial and household wastes that are neither recycled nor self-abated. *C*-activity is assumed to take firm's behavior.

(5) Recycled goods are discriminated from virgin goods.

(6) 55 markets are considered in the model. They are 34 virgin commodity, 18 recycled commodity, one external waste abatement service, labor, and capital markets. These are assumed to be perfectly competitive, and in equilibrium in 1994.

Table 4 Classification of Industries

industry	abbreviation	Industry	abbreviation
1. agriculture and forestry	AF	18. metal product	MT
2. fishery	FS	19. general machinery	GM
3. mining	MI	20. electric machinery	EM
4. food	FO	21. transportation equipment	TE
5. beverage and feed	BF	22. precision machinery	PM
6. fabric and textile	FT	23. other manufacturing	OM
7. wooden product	WD	24. construction	CO
8. furniture	FU	25. electric power	EP
9. pulp and paper	PP	26. gas, steam, and hot water supply	GS
10. chemical	CH	27. water supply and sewage disposal	WS
11. petroleum refinery and coal	PC	28. trade	TR
12. plastic	PL	29. financial service, insurance, and real estate	FI
13. rubber	RB	30. land transport	LT
14. leather	LE	31. other transport	OT
15. ceramic, stone, and clay	CS	32. communication and broadcasting	CB
16. iron and steel	IS	33. car repairing	CR
17. non-ferrous metal	NF	34. other services	OS

B. Industries and Waste Self-abatement Activities

Each industry produces its commodities inputting intermediate goods, labor, and capital, while it generates waste. Waste is recycled by *R*-activities, disposed by the industry itself employing its associated *S*-activity, and treated by *C*-activity. Portions of wastes recycled, internally and externally abated to the total waste generated by each industry and household are fixed. Each industry pays internal and external waste abatement costs.

Leontief technology is assumed in intermediate inputs, while *Cobb-Douglas* technology is applied in labor and capital inputs. Constant returns to scale are assumed in the technology of each industry. The technology in *S*-activities is also *Leontief* and *Cobb-Douglas* with respect to intermediate inputs, and labor and capital inputs, respectively, with constant returns to scale.

Profit maximization in industry's behavior becomes cost minimization given its output, due to linear homogeneity in the production technology. Note that each intermediate input in each industry is specified as a composite of virgin and recycled goods considerably differing from our previous study. In what follows, every intermediate input is specified as a composite of virgin and recycled commodities for general expression. For notational convenience, virgin and recycled goods are abbreviated by *V*- and

R-goods, respectively, and a composite of *V*- and *R*-commodities by *V*/*R*-composite hereafter.

$$\begin{aligned} &min \quad \sum_{i=1}^{34} p_{ij}^{V} x_{ij}^{V} + (1+tp_{Vj})(w \cdot L_{Vj} + r \cdot K_{Vj}) + \sum_{i=1}^{34} p_{ij}^{T} x_{ij}^{T} + (1+tp_{Tj})(w \cdot L_{Tj} + r \cdot K_{Tj}) + q_C WC_j \\ &with\ respect\ to \quad x_{ij}^{V}, L_{Vj}, K_{Vj}, x_{ij}^{T}, L_{Tj}, K_{Tj}, WC_j \qquad (j = 1,...,34) \end{aligned} \tag{1}$$

subject to

$$X_j = min\ \{\frac{1}{a_{V0j}} f_{Vj}(L_{Vj}, K_{Vj}),\ \frac{x_{1j}^{V}}{a_{1j}^{V}}, ..., \frac{x_{34j}^{V}}{a_{34j}^{V}}\} \tag{2}$$

$$x_{ij}^{V} \equiv x_{Vij}^{\alpha_{Vij}} \prod_{k=1}^{18} z_{Vkij}^{\alpha_{Vkij}} \quad (\alpha_{Vij} + \sum_{k=1}^{18} \alpha_{Vkij} = 1) \tag{3}$$

$$WG_{kj} \equiv \varsigma_{kj} X_j \quad (k = 1,...,26,\ j = 1,...,34) \tag{4}$$

$$WT_j \equiv \sum_{k=1}^{26} \eta_{kj} WG_{kj} \tag{5}$$

$$WT_j = min\ \{\frac{1}{a_{T0j}} f_{Tj}(L_{Tj}, K_{Tj}),\ \frac{x_{1j}^{T}}{a_{1j}^{T}}, ..., \frac{x_{34j}^{T}}{a_{34j}^{T}}\} \tag{6}$$

$$x_{ij}^{T} \equiv x_{Tij}^{\alpha_{Tij}} \prod_{k=1}^{18} z_{Tkij}^{\alpha_{Tkij}} \quad (\alpha_{Tij} + \sum_{k=1}^{18} \alpha_{Tkij} = 1) \tag{7}$$

$$WC_j \equiv \sum_{k=1}^{26} \theta_{kj} WG_{kj} \tag{8}$$

$$f_{Vj}(L_{Vj}, K_{Vj}) \equiv A_{Vj} L_{Vj}^{\alpha_{Vj}} K_{Vj}^{1-\alpha_{Vj}} \tag{9}$$

$$f_{Tj}(L_{Tj}, K_{Tj}) \equiv A_{Tj} L_{Tj}^{\alpha_{Tj}} K_{Tj}^{1-\alpha_{Tj}} \tag{10}$$

where

p^{V}_{ij}: price index of intermediate input of *V*/*R*-composite *i* in industry *j*

x^{V}_{ij}: intermediate input of *V*/*R*-composite *i* in industry *j*

tp_{Vj}: net indirect tax rate on industry *j*

w: wage rate

L_{Vj}: labor input in industry *j*

r: capital return rate

K_{Vj}: capital input in industry *j*

p^{T}_{ij}: price index of intermediate input of *V*/*R*-composite *i* in *S*-activity *j*

x^T_{ij} : intermediate *V*/*R*-composite input *i* in *S*-activity *j*

tp_{Tj} : net indirect tax rate on *S*-activity *j*

L_{Tj} : labor input in *S*-activity *j*

K_{Tj} : capital input in *S*-activity *j*

q_C : price of service of *C*-activity

WC_j : volume of waste discharged by industry *j* and disposed by *C*-activity

X_j : output of industry *j*

a_{V0j} : value added rate in industry *j*

a^V_{ij} : intermediate input coefficient of *V*/*R*-composite *i* in industry *j*

x_{Vij} : virgin commodity *i* in intermediate *V*/*R*-composite *i* in industry *j*

α_{Vij} : share parameter on virgin commodity *i* in intermediate *V*/*R*-composite *i* in industry *j*

z_{Vkij} : recycled commodity *k* in intermediate *V*/*R*-composite *i* in industry *j*

α_{Vkij} : share parameter on recycled good *k* in intermediate *V*/*R*-composite *i* in industry *j*

WG_{kj} : volume of waste of type *k* discharged by industry *j*

ζ_{kj} : marginal waste discharge of type *k* in industry *j*

WT_j : volume of waste disposed by *S*-activity *j*

η_{kj} : rate of internal abatement on waste of type *k* discharged by industry *j*

a_{T0j} : value added rate in industry *j*

a^T_{ij} : intermediate input coefficient of *V*/*R*-composite *i* in *S*-activity *j*

x_{Tij} : virgin commodity *i* in intermediate *V*/*R*-composite *i* in *S*-activity *j*

α_{Tij} : share parameter on virgin commodity *i* in intermediate *V*/*R*-composite *i* in *S*-activity *j*

z_{Tkij} : recycled commodity *k* in intermediate *V*/*R*-composite *i* in *S*-activity *j*

α_{Tkij} : share parameter on recycled commodity *k* in intermediate *V*/*R*-composite *i* in *S*-activity *j*

θ_{kj} : rate of external abatement on waste of type *k* discharged by industry *j*

A_{Vj} : efficiency parameter in industry *j*'s production function

α_{Vj} : share parameter on labor input in industry *j*'s production function

A_{Tj} : efficiency parameter in *S*-activity *j*'s production function

α_{Tj} : share parameter on labor input in *S*-activity *j*'s production function

Solving cost minimization problem expressed by equations (1) to (10) given an output X_j, conditional demands for intermediate goods, labor, and capital are derived with price indices of intermediate *V*/*R*-composites.

Conditional demands for intermediate goods, labor, and capital, and price indices of intermediate *V*/*R*-composites.

$$x_{ij}^{V} = a_{ij}^{V} X_j$$

$$z_{Vkij} = x_{ij}^{V} \frac{\alpha_{Vkij}}{p_{Rk}} \left[\frac{p_{Vi}}{\alpha_{Vij}} \right]^{\alpha_{Vij}} \prod_{l=1}^{18} \left[\frac{p_{Rl}}{\alpha_{Vlij}} \right]^{\alpha_{Vlij}}$$

$$x_{Vij} = x_{ij}^{V} \frac{\alpha_{Vij}}{p_{Vi}} \left[\frac{p_{Vi}}{\alpha_{Vij}} \right]^{\alpha_{Vij}} \prod_{l=1}^{18} \left[\frac{p_{Rl}}{\alpha_{Vlij}} \right]^{\alpha_{Vlij}}$$

$$L_{Vj} = \left[\frac{a_{Vj} r}{(1 - a_{Vj}) w} \right]^{1-\alpha_{Vj}} \frac{a_{V0j} X_j}{A_{Vj}}$$

$$K_{Vj} = \left[\frac{(1 - a_{Vj}) w}{a_{Vj} r} \right]^{\alpha_{Vj}} \frac{a_{V0j} X_j}{A_{Vj}}$$

$$x_{Tij} = a_{ij}^{T} WT_j$$

$$x_{Tij} = x_{ij}^{T} \frac{\alpha_{Tij}}{p_{Vi}} \left[\frac{p_{Vi}}{\alpha_{Tij}} \right]^{\alpha_{Tij}} \prod_{l=1}^{18} \left[\frac{p_{Rl}}{\alpha_{Tlij}} \right]^{\alpha_{Tlij}}$$

Conditional demands for intermediate goods, labor, and capital, and price indices of intermediate *V*/*R*-composites.

$$x_{ij}^{V} = a_{ij}^{V} X_j$$

$$z_{Vkij} = x_{ij}^{V} \frac{\alpha_{Vkij}}{p_{Rk}} \left[\frac{p_{Vi}}{\alpha_{Vij}} \right]^{\alpha_{Vij}} \prod_{l=1}^{18} \left[\frac{p_{Rl}}{\alpha_{Vlij}} \right]^{\alpha_{Vlij}}$$

$$x_{Vij} = x_{ij}^{V} \frac{\alpha_{Vij}}{p_{Vi}} \left[\frac{p_{Vi}}{\alpha_{Vij}} \right]^{\alpha_{Vij}} \prod_{l=1}^{18} \left[\frac{p_{Rl}}{\alpha_{Vlij}} \right]^{\alpha_{Vlij}}$$

$$L_{Vj} = \left[\frac{a_{Vj} r}{(1 - a_{Vj}) w} \right]^{1-\alpha_{Vj}} \frac{a_{V0j} X_j}{A_{Vj}}$$

$$K_{Vj} = \left[\frac{(1 - a_{Vj}) w}{a_{Vj} r} \right]^{\alpha_{Vj}} \frac{a_{V0j} X_j}{A_{Vj}}$$

$$x_{Tij} = a_{ij}^{T} WT_j$$

$$x_{Tij} = x_{ij}^{T} \frac{\alpha_{Tij}}{p_{Vi}} \left[\frac{p_{Vi}}{\alpha_{Tij}} \right]^{\alpha_{Tij}} \prod_{l=1}^{18} \left[\frac{p_{Rl}}{\alpha_{Tlij}} \right]^{\alpha_{Tlij}}$$

$$z_{Tkij} = x_{ij}^{T} \frac{\alpha_{Tkij}}{p_{Rk}} \left[\frac{p_{Vi}}{\alpha_{Tij}} \right]^{\alpha_{Tij}} \prod_{l=1}^{18} \left[\frac{p_{Rl}}{\alpha_{Tlij}} \right]^{\alpha_{Tlij}}$$

$$L_{Tj} = \left[\frac{\alpha_{Tj} r}{(1-\alpha_{Tj}) w} \right]^{1-\alpha_{Tj}} \frac{a_{T0j} WT_{j}}{A_{Tj}}$$

$$K_{Tj} = \left[\frac{(1-\alpha_{Tj}) w}{\alpha_{Tj} r} \right]^{\alpha_{Tj}} \frac{a_{T0j} WT_{j}}{A_{Tj}}$$

$$p_{ij}^{V} = \left[\frac{p_{Vi}}{\alpha_{Vij}} \right]^{\alpha_{Vij}} \prod_{k=1}^{18} \left[\frac{p_{Rk}}{\alpha_{Vkij}} \right]^{\alpha_{Vkij}}$$

$$p_{ij}^{T} = \left[\frac{p_{Vi}}{\alpha_{Tij}} \right]^{\alpha_{Tij}} \prod_{k=1}^{18} \left[\frac{p_{Rk}}{\alpha_{Tkij}} \right]^{\alpha_{Tkij}}$$

where
p_{Vi} : price of virgin commodity i
p_{Rk} : price of recycled commodity k

Free entry assumption ensures zero profit condition in every industry, yielding a supply function.

$$p_{Vj} X_j = \sum_{i=1}^{34} p_{Vi} x_{Vij} + \sum_{i=1}^{34} \sum_{k=1}^{18} p_{Rk} z_{Vkij} + (1+tp_{Vj})[w \cdot L_{Vj} + r \cdot K_{Vj}]$$

$$+ \sum_{i=1}^{34} p_{Vi} x_{Tij} + \sum_{i=1}^{34} \sum_{k=1}^{18} p_{Rk} z_{Tkij} + (1+tp_{Tj})[w \cdot L_{Tj} + r \cdot K_{Tj}] + q_C WC_j$$

The shadow price of S-activity j's service, q_j, is calculated from the *Lagrangian* multiplier associated with the technological constraint (6).

$$q_j = \sum_{i=1}^{34} p_{Vi} a_{Tij} + \sum_{i=1}^{34} \sum_{k=1}^{18} p_{Rk} c_{Tkij} + w \cdot l_{Tj} + r \cdot k_{Tj}$$

$a_{Tij} \equiv \partial x_{Tij} / \partial WT_j$, $c_{Tkij} \equiv \partial z_{Tkij} / \partial WT_j$,
$l_{Tj} \equiv \partial L_{Tj} / \partial WT_j$, $k_{Tj} \equiv \partial K_{Tj} / \partial WT_j$

where
q_j : shadow price of S-activity j's service

C. External Waste Abatement Activity

C-activity actually disposes of both industrial and household waste. In the model, *C*-activity is assumed to abate waste which is neither self-treated nor recycled. The technology in *C*-activity is assumed to be the same as that in *S*-activities, but this activity is supposed to take firm's behavior. That is, cost minimizing is the optimal behavior of *C*-activity under given industries' and households' waste to be reduced.

$$min \sum_{i=1}^{34} p_i^C x_i^C + (1+tp_C)(w \cdot L_C + r \cdot K_C) \tag{26}$$

with respect to x^C_i, L_C, K_C

subject to

$$WC \equiv \sum_{j=1}^{34}\sum_{k=1}^{26} \theta_{kj} WG_{kj} + (1-\sum_{k=1}^{26}\mu_k)WH \tag{27}$$

$$WC = min\{\frac{1}{a_{C0}} f_C(L_C, K_C), \frac{x_1^C}{a_1^C}, ..., \frac{x_{34}^C}{a_{34}^C}\} \tag{28}$$

$$f_C(L_C, K_C) \equiv A_C L_C^{\alpha_C} K_C^{1-\alpha_C} \tag{29}$$

$$x_i^C \equiv x_{Ci}^{\alpha_{Ci}} \prod_{k=1}^{18} z_{Cki}^{\alpha_{Cki}} \qquad (\alpha_{Ci} + \sum_{k=1}^{18} \alpha_{Cki} = 1) \tag{30}$$

where

p^C_i: price index of intermediate input of *V*/*R*-composite *i* in *C*-activity

x^C_i: intermediate input of *V*/*R*-composite *i* in *C*-activity

tp_C: net indirect tax rate on *C*-activity

L_C: labor input in *C*-activity

K_C: capital input in *C*-activity

WC: total volume of waste disposed by *C*-activity

μ_k: recycling rate on household waste of type *k*

WH: household waste

a_{C0}: value added rate in *C*-activity

a^C_i: intermediate input coefficient of *V*/*R*-composite *i* in *C*-activity

A_C: efficiency parameter in production function in *C*-activity

α_C: share parameter on labor input in production function in *C*-activity

x_{Ci}: virgin commodity *i* in intermediate *V*/*R*-composite *i* in *C*-activity

α_{Ci}: share parameter on virgin commodity *i* in intermediate *V*/*R*-composite *i* in *C*-activity

z_{Ckj} : recycled commodity *k* in intermediate *V*/*R*-composite *i* in *C*-activity

α_{Cki} : share parameter on recycled good *k* in intermediate *V*/*R*-composite *i* in *C*-activity

From the above-stated optimization problem, we obtain conditional demands for intermediate goods, labor, and capital with the price indices of intermediate *V*/*R*-composites.

$$x_i^C = a_i^C WC \tag{31}$$

$$x_{Ci} = x_i^C \frac{\alpha_{Ci}}{p_{Vi}} \left[\frac{p_{Vi}}{\alpha_{Ci}} \right]^{\alpha_{Ci}} \prod_{l=1}^{18} \left[\frac{p_{Rl}}{\alpha_{Cli}} \right]^{\alpha_{Cli}} \tag{32}$$

$$z_{Cki} = x_i^C \frac{\alpha_{Cki}}{p_{Rk}} \left[\frac{p_{Vi}}{\alpha_{Ci}} \right]^{\alpha_{Ci}} \prod_{l=1}^{18} \left[\frac{p_{Rl}}{\alpha_{Cli}} \right]^{\alpha_{Cli}} \tag{33}$$

$$L_C = \left[\frac{\alpha_C r}{(1-f_{2C})w} \right]^{1-\alpha_C} \frac{a_{C0} WC}{A_C} \tag{34}$$

$$K_C = \left[\frac{(1-\alpha_C)w}{\alpha_C r} \right]^{\alpha_C} \frac{a_{C0} WC}{A_C} \tag{35}$$

$$p_i^C = \left[\frac{p_{Vi}}{\alpha_{Ci}} \right]^{\alpha_{Ci}} \prod_{k=1}^{18} \left[\frac{p_{Rk}}{\alpha_{Cki}} \right]^{\alpha_{Cki}} \tag{36}$$

Zero profit condition is also realized in equilibrium yielding a supply function of *C*-activity.

$$q_C WC = \sum_{i=1}^{34} p_{Vi} x_{Ci} + \sum_{i=1}^{34} \sum_{k=1}^{18} p_{Rk} z_{Cki} + (1+tp_C)[w \cdot L_C + r \cdot K_C] \tag{37}$$

D. Recycling Activities

R-activities process a part of industrial and household wastes, and supply recycled goods. It is assumed that waste transformed by *R*-activities is purchased free of cost from industries and households, but the quantity of waste inputted in *R*-activities imposes a technological constraint on the quantity of recycled commodities produced by *R*-activities.

R-activities are also assumed to take firm's behavior implying cost minimization of production costs under a given volume of waste to be recycled.

$$min \sum_{i=1}^{34} p_{ij}^R x_{ij}^R + (1+tp_{Rj})(w \cdot L_{Rj} + r \cdot K_{Rj}) \qquad (j = 1,\ldots,18) \tag{38}$$

with respect to x^R_{ij}, L_{Rj}, K_{Rj}

subject to

$$Z_j = min\{\frac{1}{a_{R0j}} f_R(L_{Rj}, K_{Rj}), \frac{x^R_{1j}}{a^R_{1j}}, \cdots, \frac{x^R_{34j}}{a^R_{34j}}, \frac{WZ_j}{a^R_{Zj}}\} \tag{39}$$

$$WR_k \equiv \sum_{j=1}^{34} \xi_{kj} \varsigma_{kj} X_j + \mu_k \cdot \kappa \cdot CC \tag{40}$$

$$WZ_j \equiv \sum_{k=1}^{26} \phi_{jk} WR_k \tag{41}$$

$$f_{Rj}(L_{Rj}, K_{Rj}) \equiv A_{Rj} L_{Rj}^{\alpha_{Rj}} K_{Rj}^{1-\alpha_{Rj}} \tag{42}$$

$$x^R_{ij} \equiv x_{Rij}^{\alpha_{Rij}} \prod_{k=1}^{26} z_{Rkij}^{\alpha_{Rkij}} \quad (\alpha_{Rij} + \sum_{k=1}^{18} \alpha_{Rkij} = 1) \tag{43}$$

where

p^R_{ij}: price index of intermediate input of *V*/*R*-composite *i* in *R*-activity *j*

x^R_{ij}: intermediate input of *V*/*R*-composite *i* in *R*-activity *j*

tp_{Rj}: net indirect tax rate on *R*-activity *j*

L_{Rj}: labor input in *R*-activity *j*

K_{Rj}: capital input in *R*-activity *j*

Z_j: recycled good supplied by *R*-activity *j*

a_{R0j}: value added rate in *R*-activity *j*

a^R_{ij}: intermediate input coefficient of *V*/*R*-composite *i* in *R*-activity *j*

WZ_j: waste input in *R*-activity *j*

a^R_{Zj}: waste input coefficient in *R*-activity *j*

WR_{kj}: waste recycled of type *k* discharged by industry *j*

ξ_{kj}: recycling rate on waste of type *k* discharged by industry *j*

κ: household marginal waste generation

CC: household composite consumption

ϕ_{jk}: proportion of waste of type *k* inputted to recycling activity *j*

A_{Rj}: efficiency parameter in production function in *R*-activity *j*

α_{Rj}: share parameter on labor input in production function in *R*-activity *j*

x_{Rij}: virgin commodity *i* in intermediate *V*/*R*-composite *i* in *R*-activity *j*

α_{Rij}: share parameter on virgin commodity *i* in intermediate *V*/*R*-composite *i* in *R*-activity *j*

z_{Rkij}: recycled commodity *k* in intermediate *V*/*R*-composite *i* in *R*-activity *j*

α_{Rkij}: share parameter on recycled good *k* in intermediate *V*/*R*-composite *i* in *R*-activity *j*

Conditional demands for intermediate, labor, capital, and waste inputs associated with the supply of recycled good Z_j are derived from the optimization problem described by equations (38) to (43). Similar to the other activities, price indices of intermediate *V*/*R*-composites and zero profit condition are also obtained.

$$x_{ij}^R = a_{ij}^R Z_j \quad @ \tag{44}$$

$$x_{Rij} = x_{ij}^R \frac{\alpha_{Rij}}{p_{Vi}} \left[\frac{p_{Vi}}{\alpha_{Rij}} \right]^{\alpha_{Rij}} \prod_{l=1}^{18} \left[\frac{p_{Rl}}{\alpha_{Rlij}} \right]^{\alpha_{Rlij}} \tag{45}$$

$$z_{Rkij} = x_{ij}^R \frac{\alpha_{Rkij}}{p_{Rk}} \left[\frac{p_{Vi}}{\alpha_{Rij}} \right]^{\alpha_{Vij}} \prod_{l=1}^{18} \left[\frac{p_{Rl}}{\alpha_{Rlij}} \right]^{\alpha_{Rlij}} \tag{46}$$

$$L_{Rj} = \left[\frac{a_{Rj} r}{(1 - a_{Rj}) w} \right]^{1-\alpha_{Rj}} \frac{a_{R0j} Z_j}{A_{Rj}} \tag{47}$$

$$K_{Rj} = \left[\frac{(1 - a_{Rj}) w}{a_{Rj} r} \right]^{\alpha_{Rj}} \frac{a_{R0j} Z_j}{A_{Rj}} \tag{48}$$

$$WZ_j = a_{Zj}^R Z_j \quad @ \tag{49}$$

$$p_{ij}^R = \left[\frac{p_{Vi}}{\alpha_{Rij}} \right]^{\alpha_{Rij}} \prod_{k=1}^{18} \left[\frac{p_{Rk}}{\alpha_{Rkij}} \right]^{\alpha_{Rkij}} \tag{50}$$

$$p_{Rj} Z_j = \sum_{i=1}^{34} p_{Vi} x_{Rij} + \sum_{i=1}^{34} \sum_{k=1}^{18} p_{Rk} z_{Rkij} + (1 + tp_{Rj})[w \cdot L_{Rj} + r \cdot K_{Rj}] \tag{51}$$

Note that the volume of waste processed in producing recycled goods (49) must coincide with the volume of waste in generation side (41). This point will be referred again in a later part.

E. Households

Households are assumed to be homogeneous with the fixed number of households. Thus one can consider that households share an aggregate single utility function. Households share a *CES* utility function of the present and future goods. Here, the present good is defined as a *CES* composite of present consumption goods and leisure time, while the future good is derived from saving.

Households choose a bundle of the present and future goods so as to maximize the utility function with a budget constraint. Then the present good is divided into a composite consumption good and a leisure time, being further disaggregated into virgin and recycled commodities. Household behavior is now described as follows:

$$\max_{G,H} u(G,H) \equiv \{\alpha^{1/\nu_1} G^{(\nu_1-1)/\nu_1} + (1-\alpha)^{1/\nu_1} H^{(\nu_1-1)/\nu_1}\}^{\nu_1/(\nu_1-1)} \quad (52)$$

subject to

$$p_G \cdot G + p_H \cdot H = (1-ty)FI - TrHO \quad (53)$$

$$FI \equiv (1-l_o)w \cdot E + LI + (1-k_o)(1-k_r)r \cdot KS + KI + TrGH + TrOH \quad (54)$$

where

G: household present consumption

H: household future consumption

α: share parameter in utility function

ν_1: elasticity of substitution between present and future goods

p_G: price index of present good

p_H: price index of future good

ty: direct tax rate on households

FI: household full income

$TrHO$: current transfers from households to the external sector

l_o: rate of labor income transferred to the external sector

E: household initial labor endowment

LI: labor income transfers from the external sector to households (exogenous variable)

k_o: rate of capital income transferred to the external sector

k_r: capital depreciation rate

KS: initial capital stock endowed by households

KI: property income transferred from the external sector (exogenous variable)

$TrGH$: government current transfers to households

$TrOH$: current transfers from the external sector to households

Solving this utility maximization problem, demand functions for present and future goods are obtained yielding a household saving function.

$$G = \frac{\alpha[(1-ty)FI - TrHO]}{p_G^{\nu_1} \cdot \Delta} \quad (55)$$

$$H = \frac{(1-\alpha)[(1-ty)FI - TrHO]}{p_H^{v_1} \cdot \Delta} \tag{56}$$

$$S = p_H H / p_s \tag{57}$$

$$\Delta \equiv \alpha p_G^{1-v_1} + (1-\alpha) p_H^{1-v_1} \tag{58}$$

where

S: household real saving

p_s: price of saving good

Then maximizing the demand for present good (55) with a budget constraint yields a composite consumption and a leisure demand functions.

$$\max_{CC,F} \; G \equiv \{\beta^{1/v_2} CC^{(v_2-1)/v_2} + (1-\beta)^{1/v_2} F^{(v_2-1)/v_2}\}^{v_2/(v_2-1)} \tag{59}$$

subject to

$$p \cdot CC + (1-ty)(1-l_o)w \cdot F = (1-ty)FI - TrHO - SH \tag{60}$$

$$SH \equiv P_S \cdot S \tag{61}$$

where

β: share parameter in sub-utility function

v_2: elasticity of substitution between composite consumption and leisure time

F: leisure time

p: price index of composite consumption good

SH: household nominal savings

$$CC = \frac{\beta[(1-ty)FI - TrHO - SH]}{p^{v_2} \cdot \Omega} \tag{62}$$

$$F = \frac{(1-\beta)[(1-ty)FI - TrHO]}{[(1-ty)(1-l_o)w]^{v_2} \cdot \Omega} \tag{63}$$

$$LS = E - F \tag{64}$$

$$f \equiv \beta p^{(1-v_2)} + (1-\beta)[(1-ty)(1-l_o)w]^{(1-v_2)} \tag{65}$$

where LS : household labor supply

Substituting composite consumption (62) and leisure time (63) into (59), the price index of the present good is derived as follows:

$$p_G = \{\beta\ p^{1-v_2} + (1-\beta)[(1-ty)(1-l_o)w]^{1-v_2}\}^{1/(v_2-1)} \tag{66}$$

Moreover, the composite consumption is disaggregated into *V/R*-composites by type through maximizing a *Cobb-Douglas* sub-sub utility function given household income and leisure time.

$$max\ CC \equiv \prod_{i=1}^{34} C_i^{C\gamma_i} \qquad (\sum_{i=1}^{34} \gamma_i = 1) \tag{67}$$

subject to

$$\sum_{i=1}^{34} p_i^D \cdot C_i^C = (1-ty)Y - TrHO - SH \tag{68}$$

$$Y \equiv (1\text{-}l_0)w \cdot LS + LI + (1\text{-}k_0)(1\text{-}k_r)r \cdot KS + KI + TrGH + TrOH \tag{69}$$

where

C^C_i: household consumption of *V/R*-composite good *i*

γ_i: share parameter in sub-sub-utility function

p^D_i: price index of *V/R*-composite consumption good *i*

Y: household income

From this optimization problem, *V/R*-composites by type are derived with the price index of *CC*.

$$C_i^C = \frac{\gamma_i}{p_i^D}[(1-ty)Y - TrHO - SH], \quad p \equiv \prod_{i=1}^{34} [\frac{p_i^D}{\gamma_i}]^{\gamma_i} \tag{70}$$

Finally, *V/R*-composites are further disaggregated into virgin and recycled goods with a budget constraint.

$$max\ C_i^C \equiv C_i^{\alpha_i} \prod_{k=1}^{18} Z_{Cki}^{\alpha_{ki}} \qquad (\alpha_i + \sum_{k=1}^{18} \alpha_{ki} = 1) \tag{71}$$

subject to

$$p_i^D C_i^C = p_{Vi} C_i + \sum_{k=1}^{18} p_{Rk} Z_{Cki} \tag{72}$$

where

C_i: household consumption of virgin good *i*

α_i: share parameter on virgin good *i* in *V/R*-composite *i*

Z_{Cki} : household consumption of recycled good k

α_{ki} : share parameter on recycled good k in V/R-composite i

Therefore we have;

$$C_i = C_i^C \frac{\alpha_i}{p_{Vi}} \left[\frac{p_{Vi}}{\alpha_i} \right]^{\alpha_i} \prod_{k=1}^{18} \left[\frac{p_{Rk}}{\alpha_{ki}} \right]^{\alpha_{ki}} \tag{73}$$

$$Z_{Cki} = C_i^C \frac{\alpha_{ki}}{p_{Rk}} \left[\frac{p_{Vi}}{\alpha_i} \right]^{\alpha_i} \prod_{l=1}^{18} \left[\frac{p_{Rl}}{\alpha_{li}} \right]^{\alpha_{li}} \tag{74}$$

$$p_i^D = \left[\frac{p_{Vi}}{\alpha_i} \right]^{\alpha_{Rij}} \prod_{k=1}^{18} \left[\frac{p_{Rk}}{\alpha_{ki}} \right]^{\alpha_{Rkij}} \tag{75}$$

F. The Government, the External Sector, and Saving/Investment Balance

These are specified as the following balances of payments.

government sector

$$\begin{aligned} & ty \cdot Y + \sum_{j=1}^{34} tp_{Vj} (w \cdot L_{Vj} + r \cdot K_{Vj}) + \sum_{k=1}^{18} tp_{Rk} (w \cdot L_{Rk} + r \cdot K_{Rk}) \\ & + \sum_{j=1}^{34} tp_{Tj} (w \cdot L_{Tj} + r \cdot K_{Tj}) + tp_C (w \cdot L_C + r \cdot K_C) + TrOG \\ & = \sum_{i=1}^{34} p_{Vi} \cdot CG_i + \sum_{k=1}^{18} p_{Rk} \cdot Z_{Gk} + TrGH + WTC + TrGO + SG \end{aligned} \tag{76}$$

$$WTC \equiv q_C \sum_{k=1}^{26} (1 - \mu_k) WH \tag{77}$$

where

$TrOG$: current transfers from the external sector to the government (exogenous variable)

CG_i : government consumption of virgin good i

Z_{Gk} : government consumption of recycled good k

$TrGH$: government current transfers to households

WTC : government expenditures on C-activity

$TrGO$: government current transfers to the external sector

SG : government nominal savings

external sector

$$\sum_{i=1}^{34} p_i \cdot EM_i + TrHO + TrGO + KIO + LIO = \sum_{i=1}^{34} p_i \cdot EX_i + TrOH + TrOG + KI + LI + SO \quad (78)$$

$$LIO \equiv l_o \cdot w \cdot LS, \quad KIO \equiv k_o \cdot r \cdot KS \quad (79)$$

where

EM_i : import of virgin commodity i

KIO : property income transfers from households to the external sector

LIO : labor income transfers from households to the external sector

EX_i : export of virgin commodity i (exogenous variable)

KI : property income transfers from the external sector to households (exogenous variable)

LI : labor income transfers from the external sector to households (exogenous variable)

SO : savings of the external sector (= - prefectural current surplus)

balance of saving and investment

$$SH + SG + SO + \sum_{j=1}^{34} DR_{Vj} + \sum_{k=1}^{18} DR_{Rk} + \sum_{j=1}^{34} DR_{Tj} + DR_C = \sum_{i=1}^{34} p_{Vi} \cdot I_i + \sum_{k=1}^{18} p_{Rk} \cdot Z_{Ik} \quad (80)$$

where

DR_{Vi} : capital depreciation in industry j

DR_{Ri} : capital depreciation in R-activity j

DR_{Ti} : capital depreciation in S-activity j

R_C : capital depreciation in C-activity

I_i : virgin good i used in investment

Z_{Ik} : recycled good k used in investment

In the above specifications, nominal government consumption expenditures, $p_{Vi} \cdot CG_i$ and $p_{Rk} \cdot Z_{Gk}$, current transfers from the government to households, *TrGH*, and current transfers from the government to the external sector, *TrGO*, are assumed to be proportional to the government total revenue. Proportions of virgin and recycled goods in government consumption expenditures and capital investment are fixed at nominal term.

Exports of each commodity are fixed at a real value, while imports are assumed to be proportional to prefectural domestic demand for each good. Exports and imports are assumed to exclude recycled commodities since this study emphasizes intraregional material circulation.

G. Supply Functions

Differentiating the zero profit conditions in industries, *R*-activities, and *C*-activity with respect to supply quantity, supply functions are respectively derived. Industries' and *R*-activities' supply functions can be expressed by matrix representation as in equation (81).

$$
\begin{bmatrix} p_{V1} \\ \vdots \\ p_{V34} \\ p_{R1} \\ \vdots \\ p_{R18} \end{bmatrix} = \left[\begin{array}{ccc|ccc} a_{V11} & \cdots & a_{V341} & c_{V11} & \cdots & c_{V181} \\ \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ a_{V134} & \cdots & a_{V3434} & c_{V134} & \cdots & c_{V1834} \\ \hline b_{R11} & \cdots & b_{R341} & d_{R11} & \cdots & d_{R181} \\ \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ b_{R118} & \cdots & b_{R3418} & d_{R118} & \cdots & d_{R1818} \end{array}\right] \begin{bmatrix} p_{V1} \\ \vdots \\ p_{V34} \\ p_{R1} \\ \vdots \\ p_{R18} \end{bmatrix}
$$

$$
+ \left[\begin{array}{ccc|c} \sum_{k=1}^{26}\eta_{k1}\zeta_{k1} & \cdots & 0 & \\ \vdots & \ddots & \vdots & 0 \\ 0 & \cdots & \sum_{k=1}^{26}\eta_{k34}\zeta_{k34} & \\ \hline & 0 & & 0 \end{array}\right] \left[\begin{array}{ccc|ccc} a_{T11} & \cdots & a_{T341} & c_{T11} & \cdots & c_{T181} \\ \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ a_{T134} & \cdots & a_{T3434} & c_{T134} & \cdots & c_{T1834} \\ \hline & 0 & & & 0 & \end{array}\right] \begin{bmatrix} p_{V1} \\ \vdots \\ p_{V34} \\ p_{R1} \\ \vdots \\ p_{R18} \end{bmatrix}
$$

$$
+ \left[\begin{array}{ccc|c} \sum_{k=1}^{26}\theta_{k1}\zeta_{k1} & \cdots & 0 & \\ \vdots & \ddots & \vdots & 0 \\ 0 & \cdots & \sum_{k=1}^{26}\theta_{k34}\zeta_{k34} & \\ \hline & 0 & & 0 \end{array}\right] \left[\begin{array}{ccc|ccc} a_{C1} & \cdots & a_{C35} & c_{C1} & \cdots & c_{C18} \\ \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ a_{C1} & \cdots & a_{C35} & c_{C1} & \cdots & c_{C18} \\ \hline & 0 & & & 0 & \end{array}\right] \begin{bmatrix} p_{V1} \\ \vdots \\ p_{V34} \\ p_{R1} \\ \vdots \\ p_{R18} \end{bmatrix} \tag{81}
$$

$$
+ \begin{bmatrix} (1+tp_{V1})(w\cdot l_{V1}+r\cdot k_{V1})+(1+tp_{T1})(w\cdot l_{T1}+r\cdot k_{T1})+(1+tp_{C})(w\cdot l_{C}+r\cdot k_{C}) \\ \vdots \\ (1+tp_{V34})(w\cdot l_{V34}+r\cdot k_{V34})+(1+tp_{T34})(w\cdot l_{T34}+r\cdot k_{T34})+(1+tp_{C})(w\cdot l_{C}+r\cdot k_{C}) \\ (1+tp_{R1})(w\cdot l_{R1}+r\cdot k_{R1}) \\ \vdots \\ (1+tp_{R18})(w\cdot l_{R18}+r\cdot k_{R18}) \end{bmatrix}
$$

$$a_{Vij} \equiv \frac{\partial x_{Vij}}{\partial X_j} = \frac{\alpha_{Vij}}{p_{Vi}} \left[\frac{p_{Vi}}{\alpha_{Vij}} \right]^{\alpha_{Vij}} \prod_{k=1}^{18} \left[\frac{p_{Rk}}{\alpha_{Vkij}} \right]^{\alpha_{Vkij}} a_{ij}^{V} \tag{82}$$

$$b_{Rij} \equiv \frac{\partial x_{Rij}}{\partial X_j} = \frac{\alpha_{Rij}}{p_{Vi}} \left[\frac{p_{Vi}}{\alpha_{Rij}} \right]^{\alpha_{Rij}} \prod_{k=1}^{18} \left[\frac{p_{Rk}}{\alpha_{Rkij}} \right]^{\alpha_{Rkij}} a_{ij}^{R} \tag{83}$$

$$c_{Vkj} \equiv \sum_{i=1}^{34} \frac{\partial z_{Vkij}}{\partial X_j} = \sum_{i=1}^{34} \frac{\alpha_{Vkij}}{p_{Rk}} \left[\frac{p_{Vi}}{\alpha_{Vij}} \right]^{\alpha_{Vij}} \prod_{l=1}^{18} \left[\frac{p_{Rl}}{\alpha_{Vlij}} \right]^{\alpha_{Vlij}} a_{ij}^{V} \tag{84}$$

$$d_{Rkj} \equiv \sum_{i=1}^{34} \frac{\partial z_{Rkij}}{\partial Z_j} = \sum_{i=1}^{34} \frac{\alpha_{Rkij}}{p_{Rk}} \left[\frac{p_{Vi}}{\alpha_{Rij}} \right]^{\alpha_{Vij}} \prod_{l=1}^{18} \left[\frac{p_{Rl}}{\alpha_{Rlij}} \right]^{\alpha_{Rlij}} a_{ij}^{R} \tag{85}$$

$$a_{Tij} \equiv \frac{\partial x_{Tij}}{\partial WT_j} = \frac{\alpha_{Tij}}{p_{Vi}} \left[\frac{p_{Vi}}{\alpha_{Tij}} \right]^{\alpha_{Tij}} \prod_{l=1}^{18} \left[\frac{p_{Rl}}{\alpha_{Tlij}} \right]^{\alpha_{Tlij}} a_{ij}^{T} \tag{86}$$

$$c_{Tkj} \equiv \sum_{i=1}^{34} \frac{\partial z_{Tkij}}{\partial WT_j} = \sum_{i=1}^{34} \frac{\alpha_{Tkij}}{p_{Rk}} \left[\frac{p_{Vi}}{\alpha_{Tij}} \right]^{\alpha_{Vij}} \prod_{l=1}^{18} \left[\frac{p_{Rl}}{\alpha_{Tlij}} \right]^{\alpha_{Tlij}} a_{ij}^{T} \tag{87}$$

$$a_{Ci} \equiv \frac{\partial x_{Ci}}{\partial WC} = \frac{\alpha_{Ci}}{p_{Vi}} \left[\frac{p_{Vi}}{\alpha_{Ci}} \right]^{\alpha_{Ci}} \prod_{l=1}^{18} \left[\frac{p_{Rl}}{\alpha_{Cli}} \right]^{\alpha_{Cli}} a_{i}^{C} \tag{88}$$

$$c_{Ck} \equiv \sum_{i=1}^{34} \frac{\partial z_{Cki}}{\partial WC} = \sum_{i=1}^{34} \frac{\alpha_{Cki}}{p_{Rk}} \left[\frac{p_{Vi}}{\alpha_{Ci}} \right]^{\alpha_{Ci}} \prod_{l=1}^{18} \left[\frac{p_{Rl}}{\alpha_{Cli}} \right]^{\alpha_{Cli}} a_{i}^{C} \tag{89}$$

$$l_{Vj} \equiv \partial L_{Vj} / \partial X_j \ , \ k_{Vj} \equiv \partial K_{Vj} / \partial X_j \ , \ l_{Tj} \equiv \partial L_{Tj} / \partial WT_j \ , \ k_{Tj} \equiv \partial K_{Tj} / \partial WT_j \tag{90}$$

$$l_C \equiv \partial L_C / \partial WC \ , \ k_C \equiv \partial K_C / \partial WC \ , \ l_{Rj} \equiv \partial L_{Rj} / \partial Z_j \ , \ k_{Rj} \equiv \partial K_{Rj} / \partial Z_j \tag{91}$$

The supply function of *C*-activity is given by the following equation.

$$q_C = \sum_{i=1}^{34} p_{Vi} a_{Ci} + \sum_{k=1}^{18} p_{Rk} c_{Ck} + (1 + tp_C)[w \cdot L_C + r \cdot K_C] \tag{92}$$

Therefore given a price system satisfying equations (81) and (92), all the demands including demands for virgin and recycled commodities, and production factors are determined. Then outputs of industries, *R*-, and *C*-activities are determined to meet the respective demand levels.

Equilibrium Conditions

Summarizing the demand and supply functions mentioned above, the equilibrium conditions in the present model are described as follows:

virgin and recycled commodity market equilibrium

$$
\begin{bmatrix} X_1 \\ \vdots \\ X_{34} \\ Z_1 \\ \vdots \\ Z_{18} \end{bmatrix} + \begin{bmatrix} EM_1 \\ \vdots \\ EM_{34} \\ 0 \\ \vdots \\ 0 \end{bmatrix} = \left[\begin{array}{ccc|ccc} a_{V11} & \cdots & a_{V134} & b_{R11} & \cdots & b_{R118} \\ \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ a_{V341} & \cdots & a_{V3434} & b_{R341} & \cdots & b_{R3418} \\ \hline c_{V11} & \cdots & c_{V134} & d_{R11} & \cdots & d_{R118} \\ \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ c_{V181} & \cdots & c_{V1834} & d_{R181} & \cdots & d_{R1818} \end{array}\right] \begin{bmatrix} X_1 \\ \vdots \\ X_{34} \\ Z_1 \\ \vdots \\ Z_{18} \end{bmatrix}
$$

$$
+ \left[\begin{array}{ccc|c} a_{T11} & \cdots & a_{T134} & 0 \\ \vdots & \ddots & \vdots & \\ a_{T341} & \cdots & a_{T3434} & \\ \hline c_{T11} & \cdots & c_{T134} & 0 \\ \vdots & \ddots & \vdots & \\ c_{T181} & \cdots & c_{T1834} & \end{array}\right] \left[\begin{array}{ccc|c} \sum_{k=1}^{26}\eta_{k1}\zeta_{k1} & \cdots & 0 & \\ \vdots & \ddots & \vdots & 0 \\ 0 & \cdots & \sum_{k=1}^{26}\eta_{k34}\zeta_{k34} & \\ \hline & 0 & & 0 \end{array}\right] \begin{bmatrix} X_1 \\ \vdots \\ X_{34} \\ Z_1 \\ \vdots \\ Z_{18} \end{bmatrix}
$$

$$
+ \left[\begin{array}{ccc|c} a_{C1} & \cdots & a_{C1} & 0 \\ \vdots & \ddots & \vdots & \\ a_{C35} & \cdots & a_{C35} & \\ \hline c_{C1} & \cdots & c_{C1} & 0 \\ \vdots & \ddots & \vdots & \\ c_{C18} & \cdots & c_{C18} & \end{array}\right] \left[\begin{array}{ccc|c} \sum_{k=1}^{26}\theta_{k1}\zeta_{k1} & \cdots & 0 & \\ \vdots & \ddots & \vdots & 0 \\ 0 & \cdots & \sum_{k=1}^{26}\theta_{k34}\zeta_{k34} & \\ \hline & 0 & & 0 \end{array}\right] \begin{bmatrix} X_1 \\ \vdots \\ X_{34} \\ Z_1 \\ \vdots \\ Z_{18} \end{bmatrix} \tag{93}
$$

$$
+ \begin{bmatrix} a_{C1} \\ \vdots \\ a_{C35} \\ c_{C1} \\ \vdots \\ c_{C18} \end{bmatrix} (1-\sum_{k=1}^{26}\mu_k)\cdot\kappa\cdot CC + \begin{bmatrix} C_1 \\ \vdots \\ C_{34} \\ Z_{C1} \\ \vdots \\ Z_{C18} \end{bmatrix} + \begin{bmatrix} CG_1 \\ \vdots \\ CG_{34} \\ Z_{G1} \\ \vdots \\ Z_{G18} \end{bmatrix} + \begin{bmatrix} I_1 \\ \vdots \\ I_{34} \\ Z_{I1} \\ \vdots \\ Z_{I18} \end{bmatrix} + \begin{bmatrix} EX_1 \\ \vdots \\ EX_{34} \\ 0 \\ \vdots \\ 0 \end{bmatrix}
$$

waste recycling equilibrium

$$Z_i = \sum_{k=1}^{26} \phi_{ik} \left(\sum_{j=1}^{34} \xi_{kj} \cdot \zeta_{kj} \cdot X_j + \mu_k \cdot CC \right) @ \quad (i = 1,...,18) \tag{94}$$

waste self-abatement equilibrium

$$WT_j = \sum_{k=1}^{26} \eta_{ki} \cdot \zeta_{kj} \cdot X_j \quad (j = 1,...,34) \tag{95}$$

waste external consigned abatement equilibrium

$$WC = \sum_{j=1}^{34} \sum_{k=1}^{26} \theta_{kj} \cdot \zeta_{kj} \cdot X_j + (1 - \sum_{k=1}^{26} \mu_k) \cdot \kappa \cdot CC \tag{96}$$

labor market equilibrium

$$LS = \sum_{j=1}^{34} L_{Vj} + \sum_{j=1}^{18} L_{Rj} + \sum_{j=1}^{34} L_{Tj} + L_C \tag{97}$$

capital market equilibrium

$$\overline{KS} = \sum_{j=1}^{34} K_{Vj} + \sum_{j=1}^{18} K_{Rj} + \sum_{j=1}^{34} K_{Tj} + K_C \tag{98}$$

In these conditions, commodities are supplied to meet the demand, and waste abatement services are provided to treat wastes described by equations (95) and (96). However, the volume of waste to be recycled, Z_i, is determined by equation (93) derived from waste demand side as well as by the condition (94) imposed by waste generation side. To realize both the conditions, in this study, net indirect tax rates on *R*-activities, tp_{Ri}, are adjusted to satisfy equation (94) from waste demand side, while recycling rates, ξ_{kj} and μ_k, are adjusted from waste generation side.

In addition, the above-mentioned equilibrium conditions are, of course, insufficient to solve the model implying that all the equations in the model are necessary. However if equation (94) is satisfied, the *Walras* law, that is, *value of excess demand for labor* + *value of excess demand for capital* = 0 will be realized. This implies that if either labor or capital market is cleared, the equilibrium solution of the model can be obtained.

Thus letting labor be a numeraire (w=1), capital return rate is computed to clear the capital rental market by using *Newton-Raphson* method. Moreover, net indirect tax rates on *R*-activities, tp_{Ri}, or recycling rates, ξ_{kj} and μ_k, are calibrated feedbacking a gap in equation (94) to obtain the full equilibrium solution.

Parameter Setting

For numerical experiment, it is necessary to estimate parameters in functions specified in the model. Since the technological parameters in the production functions in industries, *R*-, *S*-, and *C*-activities are specified as *Leontief-Cobb-Douglas* type, they can easily be estimated by applying the economic and

material balance accounting matrix as a benchmark dataset in a usual *CGE*-modeling framework (Shoven and Whalley, 1992). The detailed results of parameter estimation is beyond the scope of this paper, therefore, they are skipped here.

For the parameters in the utility function, estimation of them is made in a standard way with results shown in Table 4 though the description of the estimation method is skipped as well.

Marginal waste generations, waste recycling rates, and waste abatement rates were estimated by employing Research Report on Industrial Waste in Aichi Prefecture (1996). Waste is expressed in physical term in this study, but recycled goods are modeled in both physical and monetary terms. Prices of recycled commodities are estimated by applying Japan's I/O Tables (1999) and Research Report on Cost of Waste Disposal (1998).

Table 4 Parameters in Utility Function

Commodities	share parameter
present goods	0.77824
future goods	0.22176
composite consumption	0.58506
leisure time	0.41494
elasticity of substitution between present and future goods	1.11908
elasticity of substitution between composite consumption and leisure time	1.07054

Simulation Analysis

A. Simulation Cases

As described in the model specification, optimization is made to derive the demand and supply equilibrium of virgin commodities, implying that virgin commodity equilibrium is a result of economic agent purposive behavior. But the demand and supply of recycled materials are linked to by-products of industries, implying that disequilibrium in recycled commodity market is prone and inevitable under fixed parameters relating to recycling. Figure 2 graphically illustrates this situation.

Therefore if some waste program is to be implemented, the following conditions must hold to equilibrate the demand and supply of virgin and recycled goods.

(1) Recycling rates must rise when the demand for recycled goods is intended to increase.

(2) Prices of recycled goods must decline when the supply of recycled commodities is intended to increase. Taking these conditions into account, 6 cases presented in Table 5 will be simulated and comparatively examined. Exgogenous changes in parameters in cases 1 to 3 are shown in Tables 6 and 7, which are set up referring to targets made by the government or some industrial associations (National Environmental Planning Agency, 1993) .

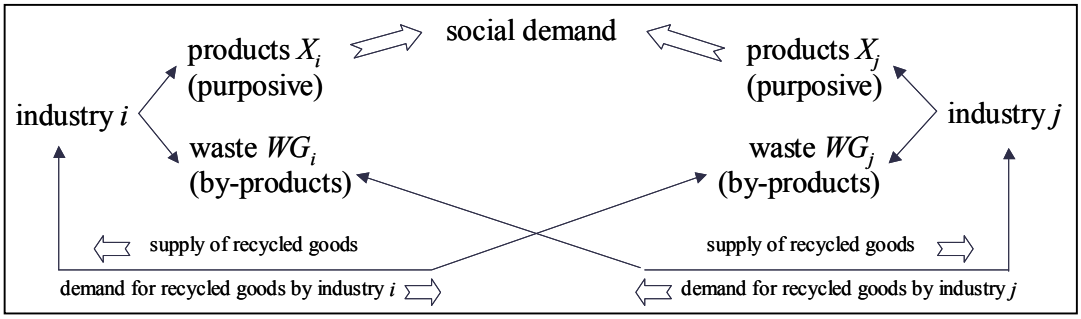

Figure 2 Concept of Simulation Analysis

Table 5 Simulation Cases

case	description
base case	Business as usual case.
case 1	Recycling of waste is expanded in demand side by rising share parameters on recycled goods in intermediate *V*/*R*-composite inputs in industries, *R*-, *S*-, and *C*- activities. To equilibrate demand for and supply of recycled goods, recycling rates are endogenously calibrated. Rates of increase in share parameters are shown in Table 6.
case 2	Recycling of waste is promoted in supply side by increasing recycling rates. *R*-activities are subsidized by the government to equilibrate demand and supply of recycled goods through lowering prices of recycled goods. Rates of increase in recycling rates are presented in Table 7.
case 3	In addition to case 2, additional government subsidies are equivalently financed by rising household direct tax rate.
case 4	Recycling rate on every waste is increased to 100%. Similar to case 2, additional government subsidies for *R*-activities are considered.
case 5	In addition to case 4, household direct tax rate is internalized to equivalently compensate the additional government subsidies in case 4.

Table 6 Assumed Rates of Increase in Share Parameters on Recycled Commodities in Case 1

recycled goods	rate of increase in share parameter	recycled goods	rate of increase in share parameter
recycled construction materials Ⅰ	3	recycled chemical fertilizers	40
recycled construction materials Ⅱ	5	recycled acid and alkali	20
recycled construction materials Ⅲ	10	recycled oils	10
compost	10	recycled plastics	20
recycled organic fertilizers	40	recycled tires	20
recycled organic fertilizers/feeds	10	recycled rubber	10
recycled fiber	20	recycled glass and construction materials Ⅳ	40
recycled wooden products	20	recycled iron	1
recycled pulp and paper	10	recycled non-ferrous metals	1

Table 7 Assumed Rates of Increase in Recycling Rates in Case 2

Waste	rate of increase in recycling rate	Waste	rate of increase in recycling rate	waste	rate of increase in recy-cling rate
Cinder	30	waste plastic	20	waste glass and porcelain	40
organic sludge	40	waste tire	10	slag	3
inorganic sludge	40	shredder dust	0	waste concrete	10
general waste oil	10	waste paper	10	waste asphalt	10
waste solvent	10	waste wood	20	other construction waste	10
solid waste	10	waste fiber	20	soot and dust	10
oil sludge	10	animal and vegeta-ble residue	10	animal waste	10
waste acid	20	waste rubber	(50)	other industrial waste	--
waste alkali	20	waste metal	0		

Note: The recycling rate on waste rubber in case 2 is assumed to be 50% since it is 0% in the base case.

B. Simulation Results

Simulation results of the 6 cases are shown in Figures 2 to 9 where variational ratios of cases 2 to 5 relative to the base case are illustrated. Monetary values are indicated in terms of the relative price system in the base case.

(a) case 1

Although share parameters on recycled materials are increased implying expansion of use of recycled commodities in demand side, impacts of the scenario in this case are estimated to be very small.

Looking at industrial outputs in Figure 4, negative impacts are relatively large on rubber and beverage and feed with impact rate of -0.1%, and plastic with -0.04%. Industries suffered from negative impact can be identified as those suffered from substitution effect where virgin goods are substituted by recycled goods. Positive impacts are found in assembling manufactures and consumption related industries. As use of recycled goods are promoted, price indices of *V*/*R*-composites slightly fall resulting in a moderate expansion in household consumption with a positive equivalent variation of 4.1 billion yen. Moreover, imports of virgin commodities substituted by recycled goods show a decrease as expected.

(b) case 2

In this case, recycling rates are increased endogenously adjusting government subsidies to equilibrate demand and supply of recycled goods. Since small increases in recycling rates are assumed, significant impacts of the scenario of this case are not found as well.

However, government subsidies considerably depreciate prices of recycled goods. There can be observed many recycled commodities with over 10% down in their prices, specifically prices of recycled rubber, recycled organic fertilizer, and recycled pulp and paper show falls of exceeding 30%. This result suggests that a significant decline in recycled commodity prices must be necessary even in a realistic and feasible recycling program.

The additional expense of subsidies is estimated as 9.8 billion yen which straightforwardly reduces government revenues since no additional tax is assumed to compensate the expenditures. On the other hand, since household waste is promoted by 60% up in the recycling rate, government expenditures on *C*-activity are saved by 5.9 billion yen yielding an increase in government savings of 4.7 billion yen.

Substitution effect is observed in imports of several commodities, but the total import increases due to expansion effect in industries and income effect in households.

Households consumption expenditures and savings grow due to income effect of falls in recycled commodity prices leading to a welfare improvement as *EV* shows 14.2 billion yen.

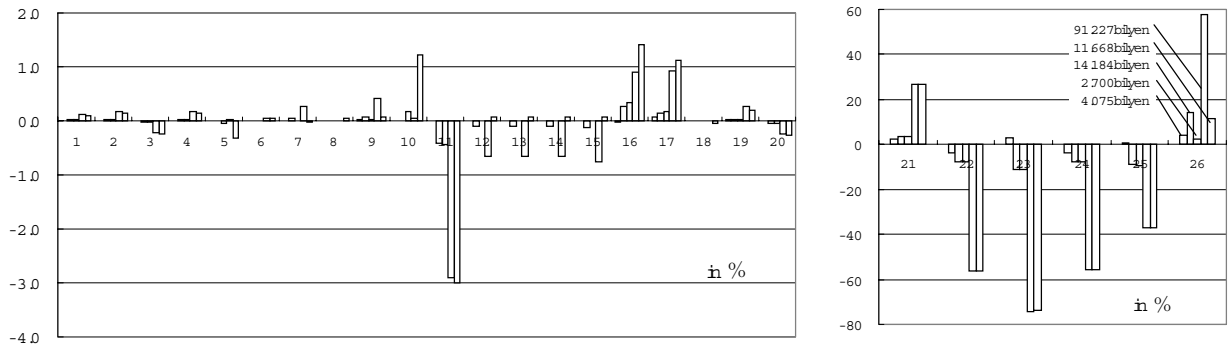

Figure 3 Changes in Key Variables

Note: 1. total output, 2. total industrial output, 3. prefectural gross product, 4. gross product of industries, 5. household full income, 6. household income, 7. household composite consumption, 8. leisure time, 9. household savings, 10. direct taxes, 11. net indirect taxes, 12. government income, 13. government consumption, 14. government current transfers to households, 15. government current transfers to the external sector, 16. government savings, 17. investment, 18. labor demand, 19. capital return rate, 20. price index of composite consumption, 21. total output of *R*-activities, 22. total output of *S*-activities 23. gross product of *R*-activities, 24. gross product of *S*- and *C*-activities, 25. government expenditures on *C*-activity, 26. equivalent variation.

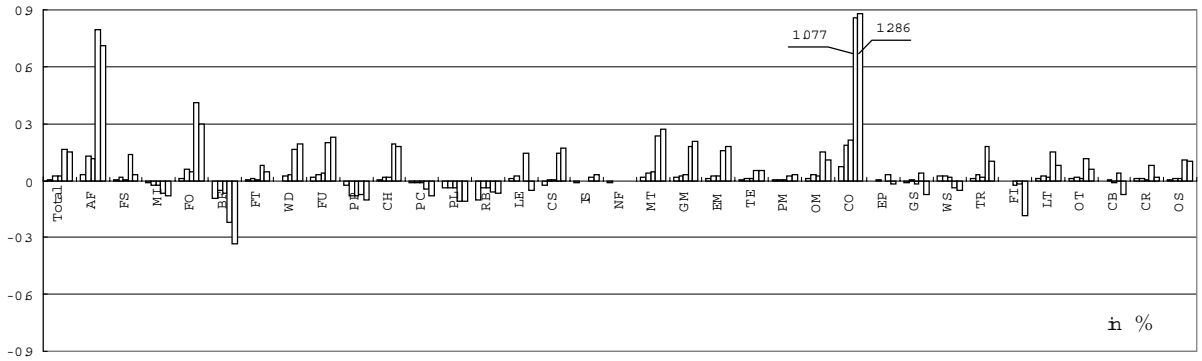

Figure 4 Changes in Outputs of Industries

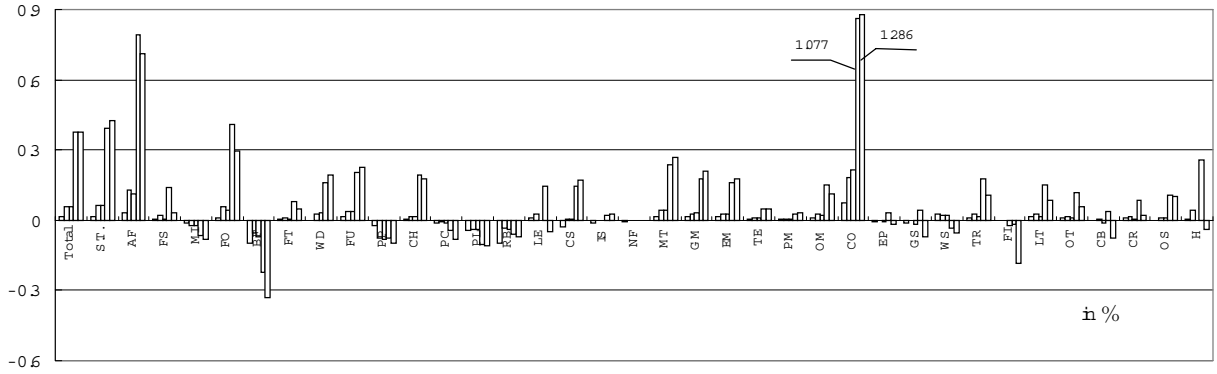

Figure 5 Changes in Waste Generation

Note: S.T.: total volume of industrial waste, H : households

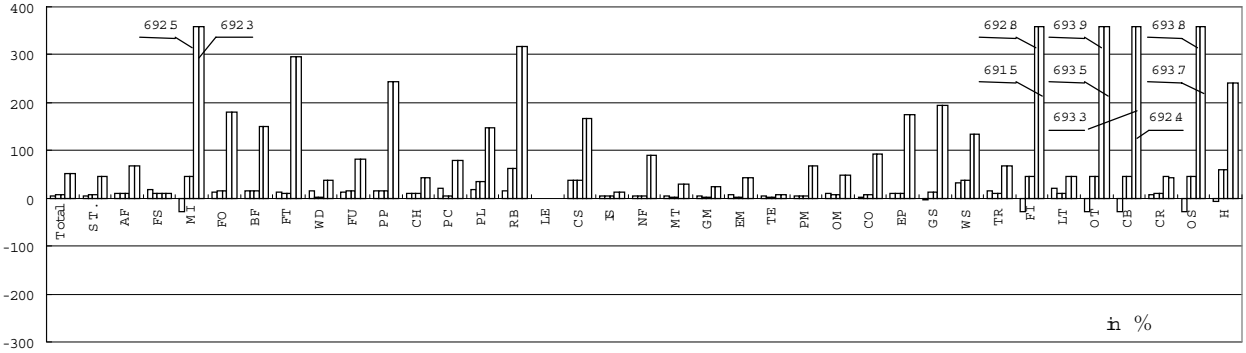

Figure 6 Changes in Recycled Waste

Note: S.T.: total volume of industrial waste, H : households

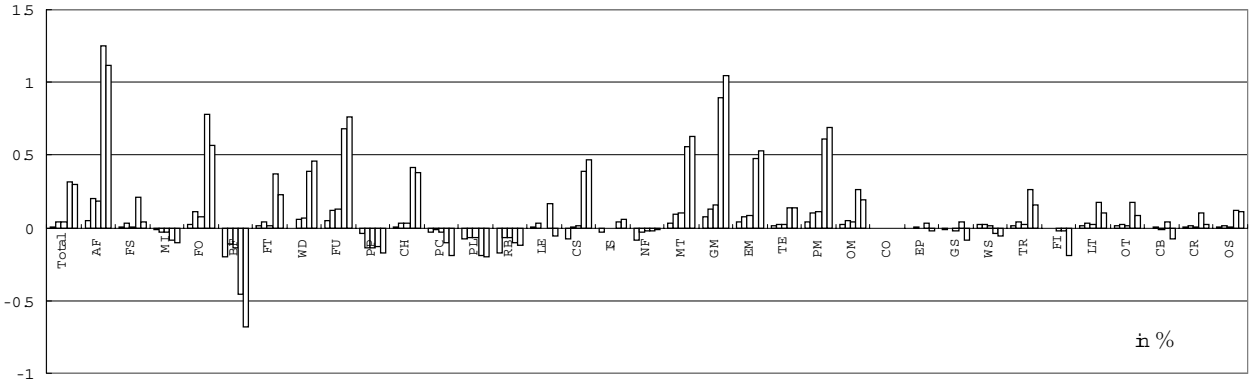

Figure 7 Changes in Imports of Virgin Commodities

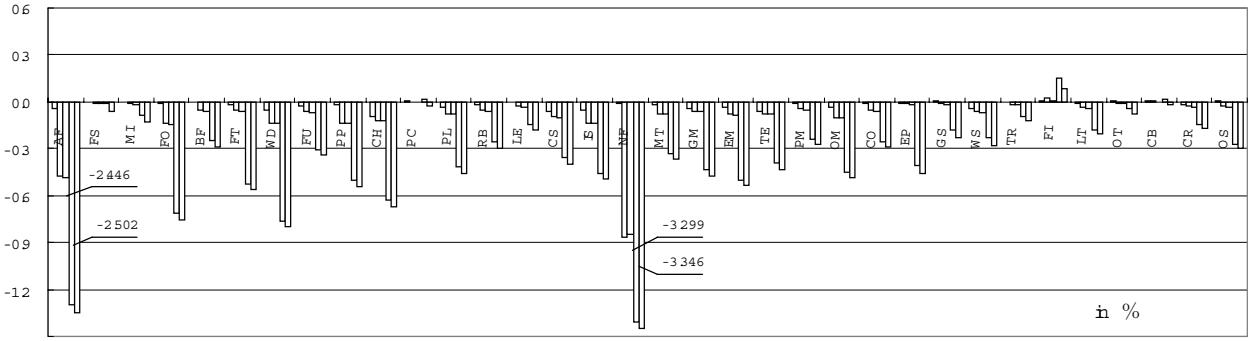

Figure 8 Changes in Prices of Virgin Commodities

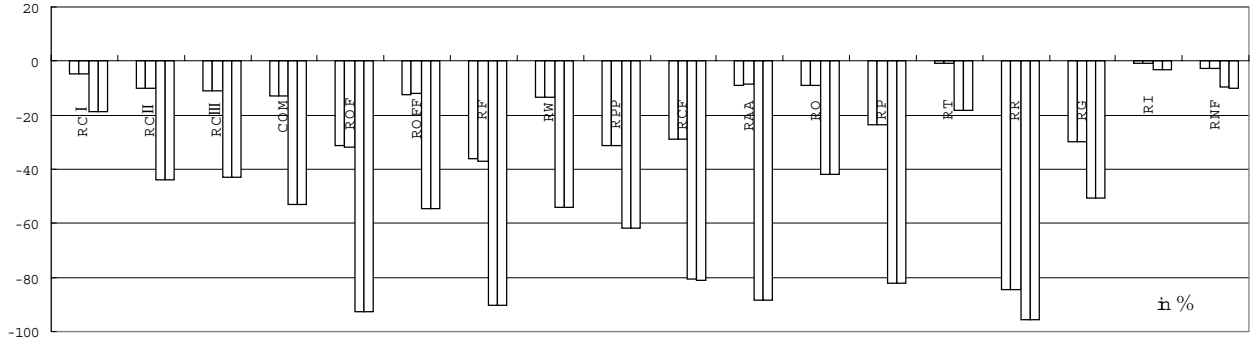

Figure 9 Changes in Prices of Recycled Commodities

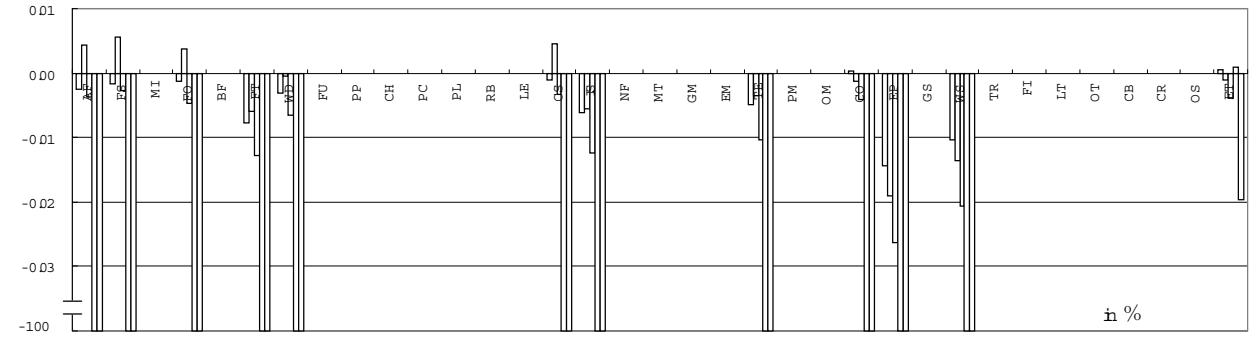

Figure 10 Changes in Prices of Waste Abatement Services

Note: ET: external waste abatement

(c) case 3

In this case, it is assumed that the additional government subsidies on recycling activities are equivalently financed by raising the household direct tax rate. As a result, only direct effects such as a decrease in household disposable income, increases in revenues, consumption expenditures, and savings in the government sector are significant with small indirect repercussive impacts. Although a decrease in household consumption affects a negative impact on household utility, it is compensated by increases in household leisure time and savings leading to a welfare improvement as *EV* depicts 2.7 billion yen.

(d) case 4

This case assumes perfect recycling, i.e. 100% recycling rates on every waste (except household food residue aiming) at realizing a zero-emissions oriented society in Aichi Prefecture. Similar to case 3, additional government subsidies on recycling activities are considered to depreciate prices of recycled commodities.

By assumption, one can see that there are a number of types of waste whose recycled volumes become several times as compared to the base case, yielding significant impacts on the prefectural whole economy. Looking at industrial activities in Figure 4, significant reductions in their outputs can be found due to substitution effect particularly in beverage and feed with impact rate of -0.2%, plastic with -0.1%, pulp and paper with -0.08%, and rubber with -0.06%.

On the other hand, construction, agriculture and forestry, and food industries show increases in output with positive impact rates of 1.1%, 0.8%, and 0.4%, respectively. Assembling industries such as general machinery, electric machinery, and transportation equipment industries expand suggesting an industrial structural change from raw material based industries to assembling industries in the prefectural economy.

Relating to this structural change, imports show a similar manner to industrial outputs, however, their magnitudes are larger than in outputs resulting from impacts on household consumption expenditures and capital investment.

Government subsidies on recycling activities considerably depreciate prices of recycled commodities ranging from 18% to 95% except recycled iron and non-ferrous metals, since they have already been recycled at high recycling rates. Government additional burden on budget resulting from the subsidies is estimated as 66.8 billion yen, yielding a decrease of 13 billion yen in government consumption expenditures. However, public expenditures on *C*-activity are reduced by 23.9 billion yen which in turn increases government savings by 15.6 billion yen.

For households, income effect is significant due to the fall in commodity prices deriving expansions in consumption and savings with welfare improvement of 91.2 billion yen in EV.

(e) case 5

Like case 3, this case also supposes that the additional government subsidies for promotion of recycling in case 4 is equivalently compensated by endogenously raising the household direct tax rate. Similar to

the results in case 3, significant impacts are particularly found in households and in the government. Household disposal income is reduced by an increase in direct taxes, but their consumption expenditures do not show a large decrease with impact rate of only -0.04% being offset by the income effect of commodity price depreciation.

In the government budget balance, government expenditures on *C*-activities are reduced by 24 billion yen in addition to an increase in direct tax revenues leading to an increase of 24.8 billion yen in government savings with an expansion in capital investment. Despite household consumption expenditures decrease, *EV* shows 11.7 billion yen followed by an increase in household leisure time and savings.

Concluding Remarks

This study has significantly extended our previous paper on this topic internalizing waste recycling activities as economic agents, and specifying detailed recycling and waste abatement rates. Even in Japan, data collection is very difficult in waste studies. This article has also attempted to improve the data reliability as far as the authors could. Assuming realization of a zero-emissions society in this study, numerical simulations of the general equilibrium effects of it is highlighted since they have not been examined and reported in the literature.

On the other hand, the actual waste problem has been throwing us various difficulties including recyclability of specific materials, complexity of physical distribution system of waste recycling, and recyclability of materials already accumulated in our society for long time. These are our new targets in the future studies.

Finally, this study is financially supported by the Scientific Grant-in-Aid of Ministry of Education, the Government of Japan (No.0924710 4, No.09680547, and No.09303001).

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Sustainable production - The holistic view

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Sustainability – a holistic concept

There are numerous definitions of sustainable development. We should learn to use adequate interpretations for specific scientific or practical purposes and goals. For my purpose, I prefer to take a holistic view.

In chart 1, I have systemized sustainability within three spheres: object, time and space.[1] In the first line in chart 1, you find the so-called „three column hypothesis", extended with culture and politics. To involve all actors simply means that in pursuing sustainability, all have to take responsibility; there must be no spectators. An important aspect of sustainability is innovation, as innovation paves the path to sustainability. Of course, technical innovations are very important in the technical worlds of modern industrialized societies. But if there is no new behaviour of inventors, producers, users, etc. involved, the new technique can easily get stuck on its way to diffusion.[2] The same argument holds for institutional innovation: a technical innovation most often requires new formal or informal rules (D.C. North) or reforms.

Embedded ness is a very important notion in the context of sustainability (Anthony Giddens). As regards time and space, both intertemptal and interregional responsibility and justice are involved. Furthermore, the short run view must be embedded in the medium run, and these have to be embedded in the long run. As regards space, we are acting locally or in the region while important decisions are made at the national, supra-national and international level.

The specific meaning of sustainability has to be assigned for particular socio-economic actors or groups of actors. For the firm it seems apt to describe sustainability as securing human, natural and technical resources in the long run and organizing them.

[1] To distinguish various elements or spheres of sustainability while talking about a holistic concept seems not very satisfactory. But we never can think a complex entity like sustainability at once as a whole.

[2] Following Ulrich Witt, innovation is defined as utilizing any potential of a new action.

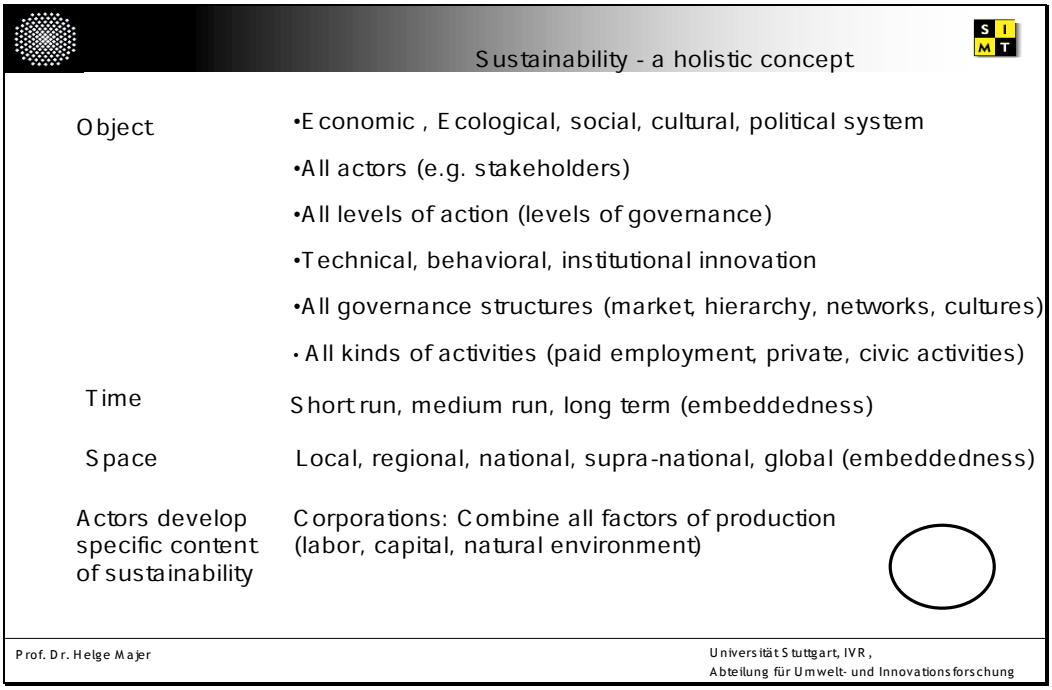


Chart 1

The sustainable firm

For the firm it seems apt to describe sustainability as securing human, natural and technical resources in the long run and organizing them (chart 2). Furthermore, we can break down the holistic elements of sustainability to the level of the firm from chart 1.[3]

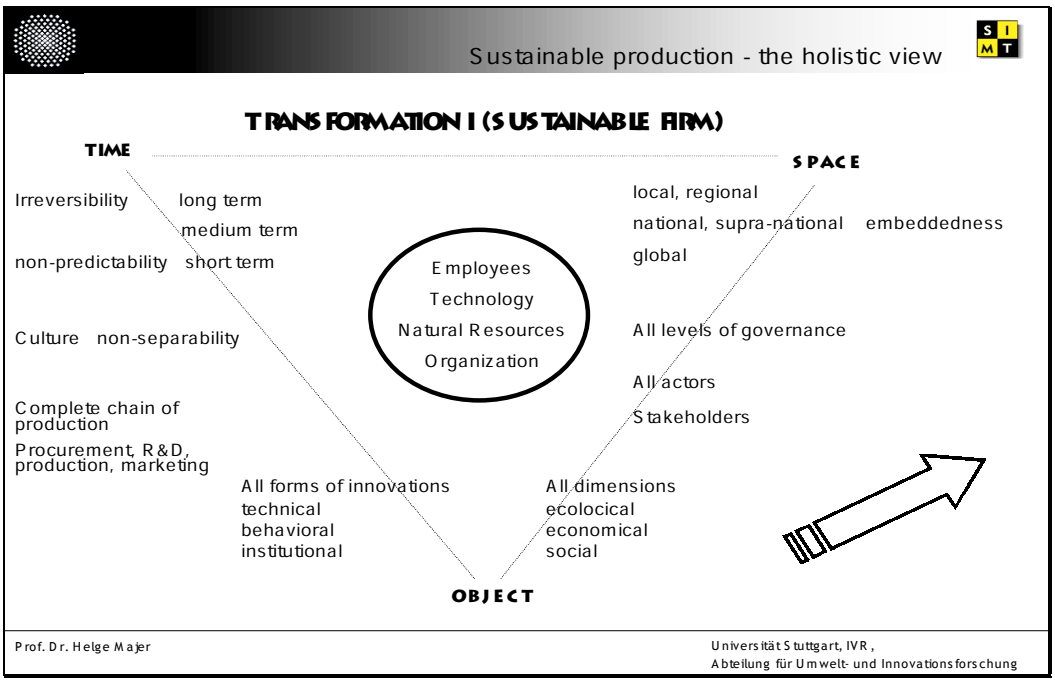


Chart 2

[3] Cf. Helge Majer, Das nachhaltige Unternehmen – Versuch einer Begriffsbestimmung, in: Thomas Beschorner, Reinhard Pfriem (ed.), Evolutorische Ökonomie und Theorie der sozialökologischen Unternehmenspolitik. Handlungstheoretische Grundlagen und Konzeptionen einer Theorie der Firma, Marburg 2000

To arrive at zero-emission solutions in a circular economy, there has to be an adequate organisation at the firm level; if there are and is no visions, ideas, motivations, organisational base at the micro-level, where will the incentive come from to form the circular economy at the meso-level? This bottom-up approach from the individual actors should be supplemented by the top-down approach, which provides the institutional innovations (reforms of regulation, re-regulation in favor of the circular economy)[4]

There are numerous firms in Germany that are either open for sustainable production or who have already implemented it (see below). I will select one (well-known) example: Henkel. As can be seen from chart 3, the time path of the development of a firm from reactive to proactive strategies and measures is quite long and, as Henkel shows, at a certain stage it seems to be irreversable.

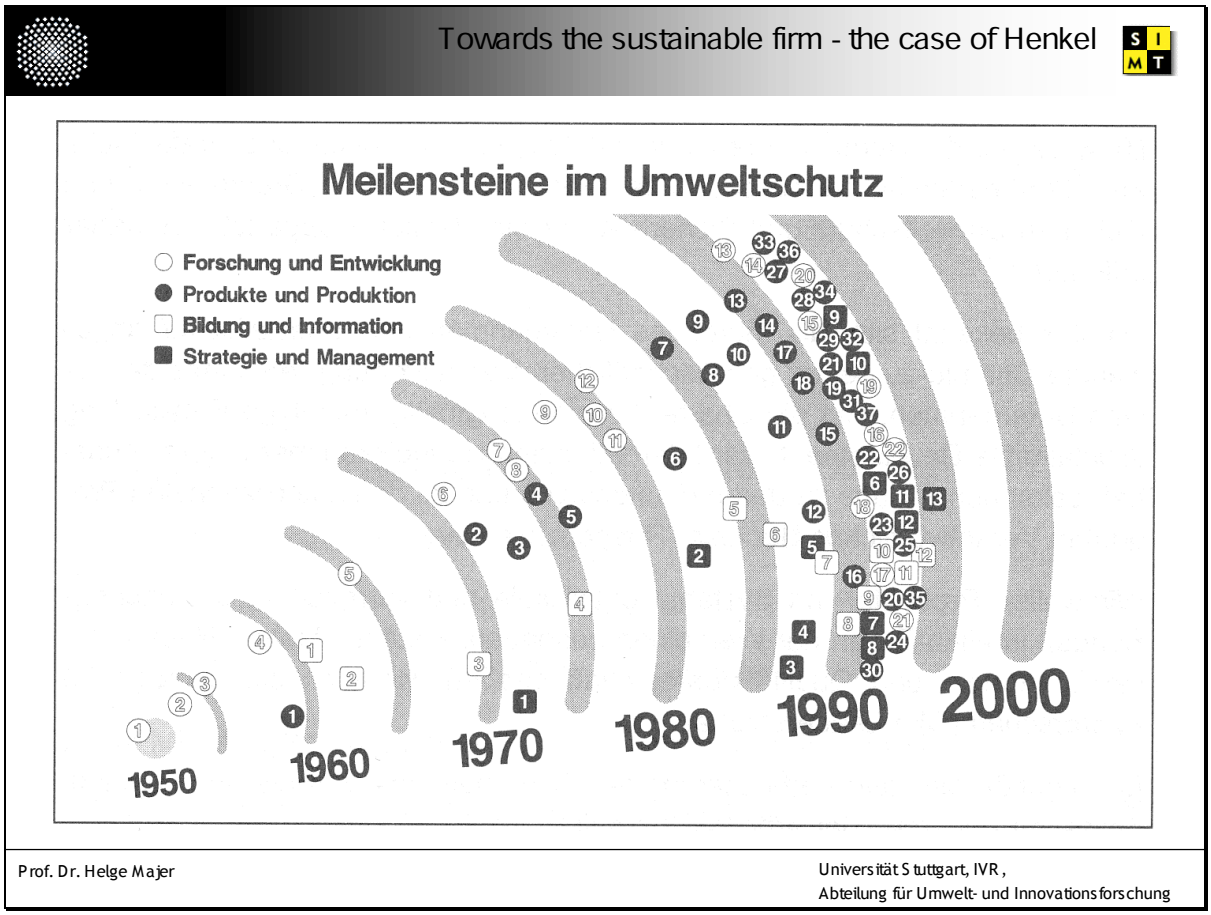


Chart 3

[4] In Germany, this would be e.g. the „Kreislaufwirtschaftsgesetz" of 1996.

In chart 4, I have listed some German firms that have already implemented loops of circular production.

Chart 4

Joint production

Industrial ecology

Environmental Management
Material Balance - Kalundbørg

INDUSTRIAL ECOLOGY

"Industrial ecology is ecological in that it looks to the natural world for models of highly efficient uses of resources, energy and byproducts.[...] Also, it places human activity - industry on the very broadest sense - in that larger context of the biophysical environment."

Dr. Ehrenfeld, Director of the Technology, Business and Environment Program at the Center for Technology, Policy and Industrial Development, MIT.

KALUNDBØRG, DENMARK: AN INDUSTRIAL SYMBIOSIS

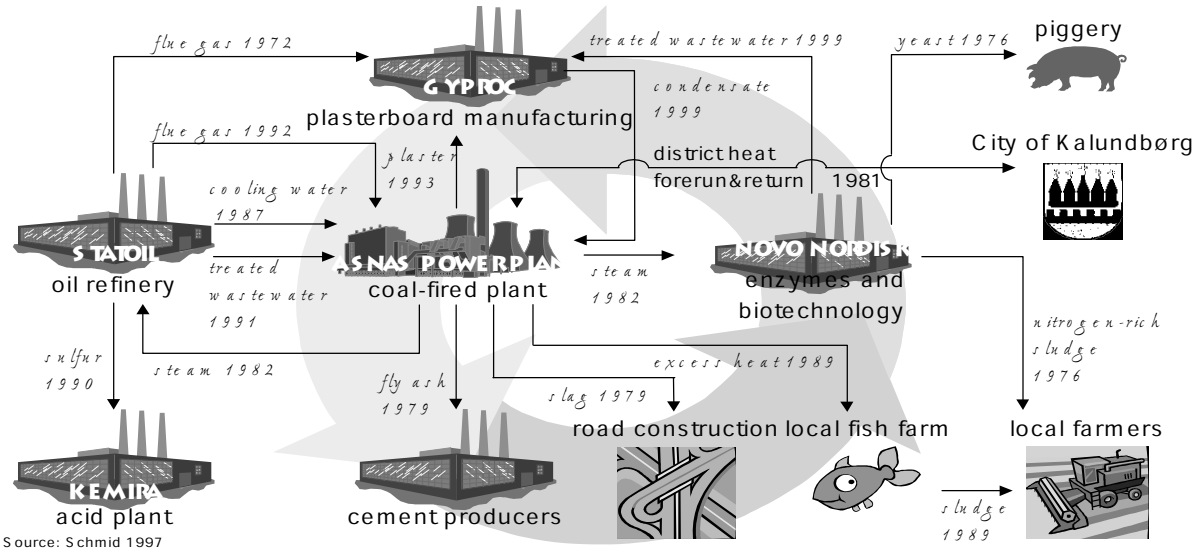
One of the earliest and most successful industrial ecology systems, Kalundbørg, is a town where heavy industry obeys the cyclical laws of a natural ecosystem, with the waste products of one factory used to heat homes or power other factories, forming a web of conservation and dependency. Industries cooperated in money-saving efforts to follow new pollution-control policies, cut back on virgin energy and material inputs and reduce escalating disposal costs.

Kalundbørg has four main industries:
ASNAS POWERSTATION, a coal-fired plant;
NOVO NORDISK, a maker of enzymes and pharmaceuticals;
GYPROC, a plasterboard manufacturer;
and **STATOIL**, a refinery.

Source: Wanjek 1997

Chart 5

Kalundbørg



Source: Schmid 1997

Chart 6

Environmental Management

Material Balance - Kalundbørg

HOW IT WORKS

Asnas produces steam and heat while generating electricity. The company now funnels some of that steam to Statoil and Novo Nordisk. Statoil, which meets 40 percent of its steam requirements this way, uses the steam to heat pipes and tanks. Novo Nordisk gets all its steam from Asnas and uses it as a source of heat and pressure. Asnas also pipes its excess heat to local fish farms and many homes. In fact, the municipality plans to have every home heated this way by 2005. This process of heat and steam recycling has raised the efficiency of coal burning from 40 percent to more than 90 percent. Gyproc benefits from Asnas' waste stream as well, by using the power company's gypsum to make plasterboard. Gypsum, a calcium sulfate, is produced by Asnas's scrubbers, which were set up to reduce sulfur emissions. Cement producers and local contractors also get Asnas's fly ash byproduct. Statoil Refinery also contributes elements of its waste stream. Flue gas, a byproduct of oil refining, goes through a desulfurization process, and the hot, liquid sulfur which is captured is sold to the Kemira Acid Plant across the sea in Jutland. Statoil's sulfur-free flue gas then goes to Gyproc and Asnas instead of being burned off. Asnas saves 30,000 tons of coal a year by using this excess gas, while both companies are able to meet new SOx and CO2 regulations. And for Gyproc, Statoil meets nearly 95 percent of its gas needs. Novo Nordisk gives its nitrogen-rich sludge to local farmers.

Source: Wanjek 1997

A thousand or so farmers, who get this pasty sludge via pipeline or truck, each save about $50,000 a year in fertilizer costs. A 1976 Danish regulation placed serious restrictions on dumping organics into the sea, and landfill space was rapidly dwindling all over Europe, so it became cheaper for Novo Nordisk to install a piping and truck system, treat the sludge and give it to farmers. The company subsequently decided not to charge them, to forestall them from turning elsewhere for fertilizer in the future.

Another efficiently used resource in Kalundbørg is water. Supplies had dwindled through the years, and citizens complained that the big industries were withdrawing too much ground water. Thermal pollution of Kalundbørg Fjord also worried the locals. Consequently, Statoil and Asnas now share water. Statoil dips into nearby Lake Tisso, then sends its cooling water not to the fjord or the lake, but to Asnas's boilers. Statoil also sends treated wastewater to Asnas, which the power company uses to clean and perform other "non-boiler" activities. Asnas does need to use Lake Tisso, but it can get 75 percent of its water from Statoil. Novo Nordisk, having completed its government-mandated wastewater treatment plant in 1992, is now considering sending water to Gyproc if the water is of high enough quality for making plasterboard. Regardless of the environment, these were sound economic decisions in the face of new policies and promises of new technologies. As long as manufactures could keep the price of their "waste" below the market value of virgin materials, they could always find someone to buy it.

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Abteilung für Umwelt- und Innovationsforschung

Chart 7

Kalundborg 1975

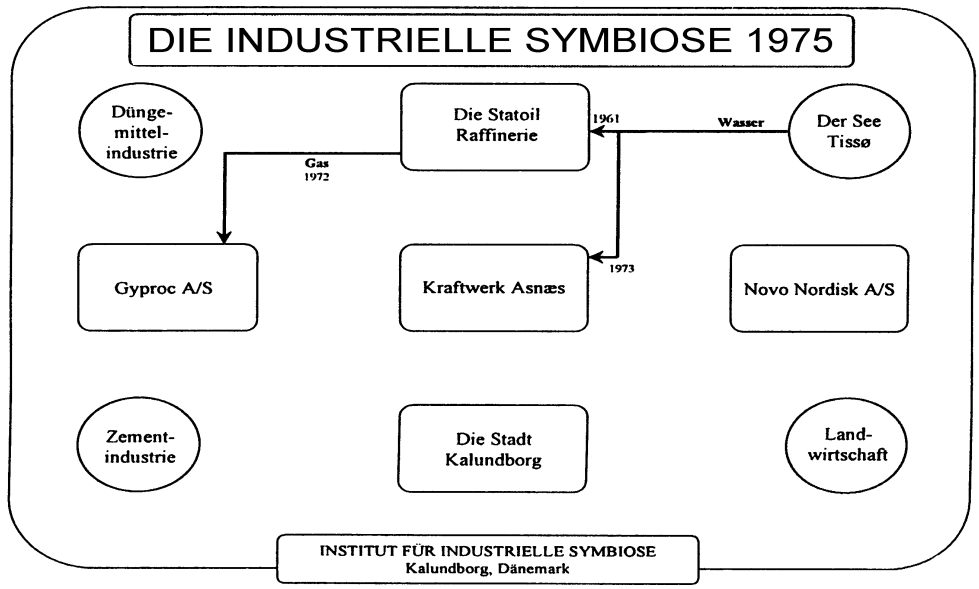

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Chart 8

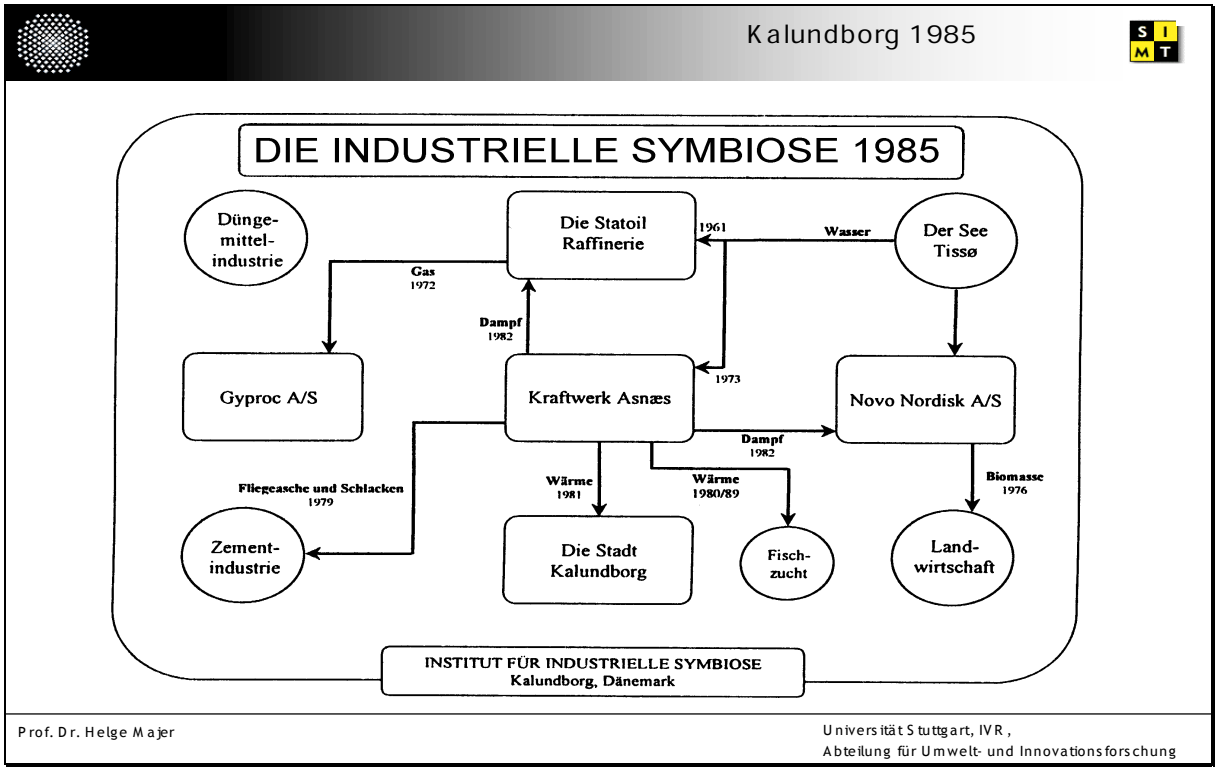

Chart 9

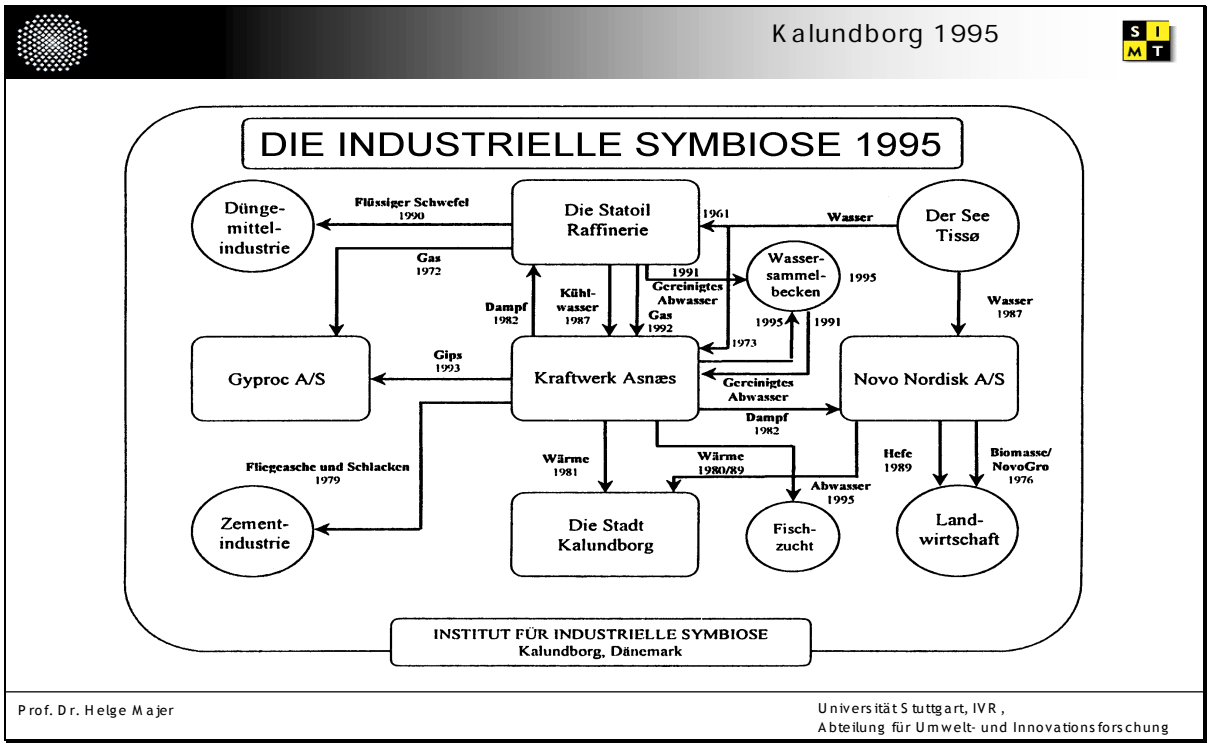

Chart 10

Closing the circle II - industry

- Upper Styria
- Lower Styria
- Pfaffengrund, Heidelberg
- Ruhrgebiet
- Oldenburger Münsterland
- Karlsruhe - Rheinhafen
- Netzwerk Plus
- Rhine-Neckar Triangle

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Chart 11

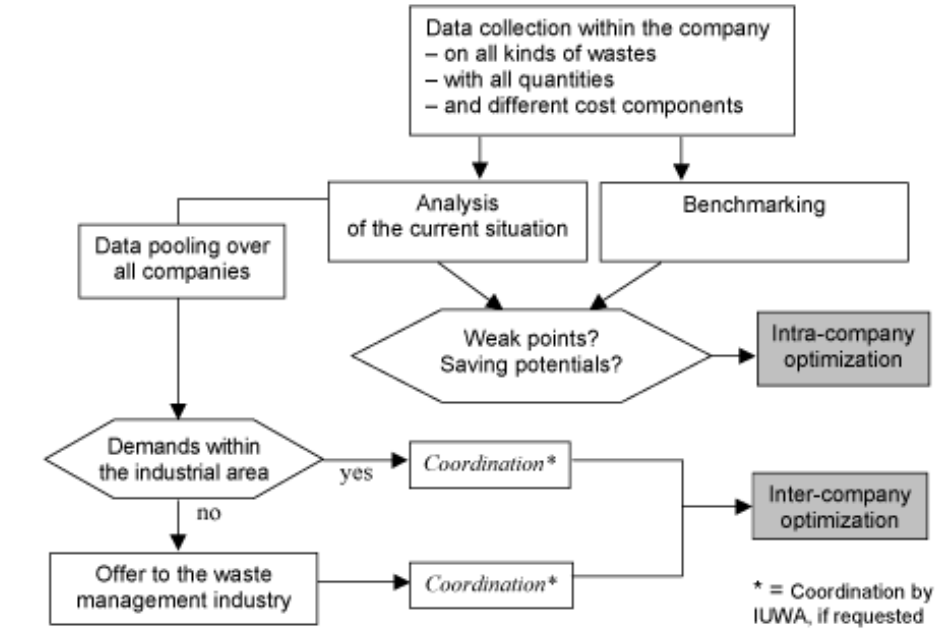


Fig. 1: Implementation steps towards a cross-company management of waste

Chart 12

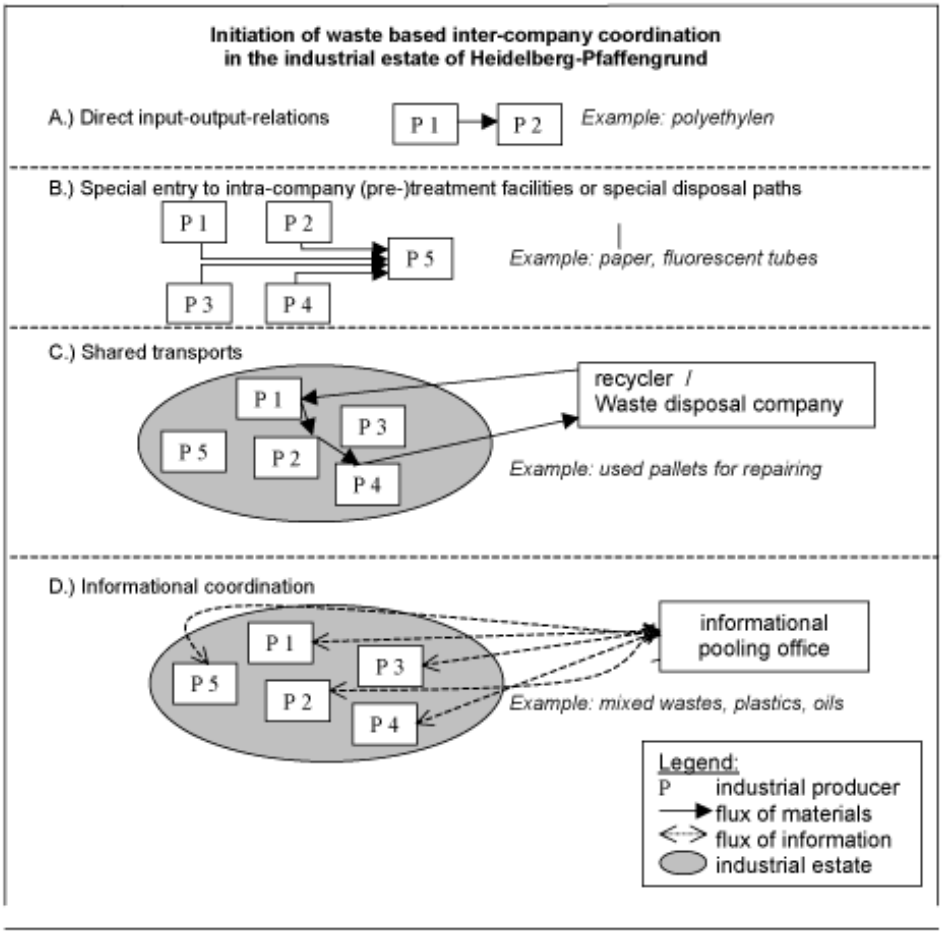
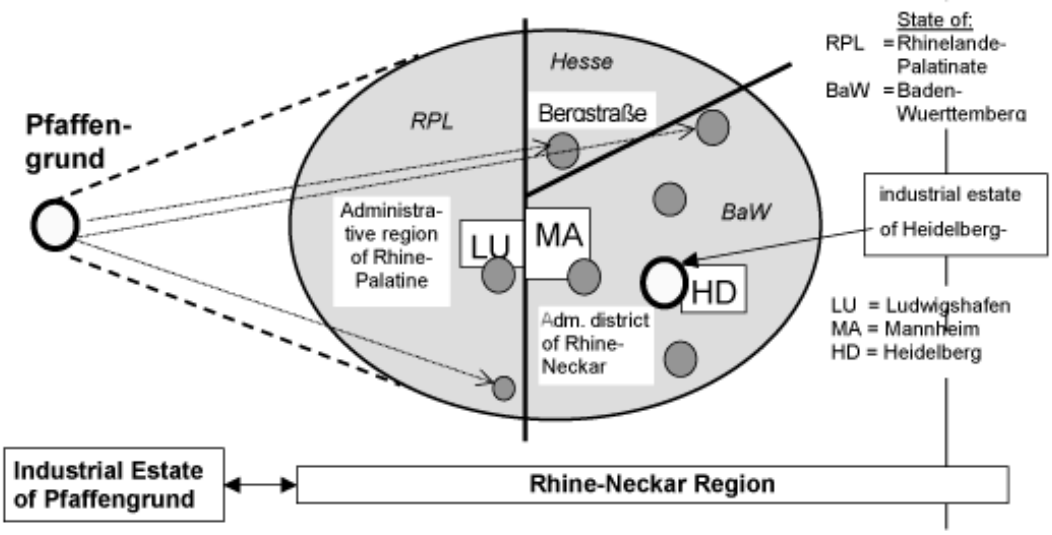


Fig. 2: Waste-based cooperation forms between industrial producers initiated in the industrial estate of Heidelberg-Pfaffengrund

Chart 13

Figure 3:

Economic area of Rhine-Neckar ("Rhein-Neckar-Triangle")



Industrial Estate of Pfaffengrund ↔ **Rhine-Neckar Region**

- Ease of face-to-face contacts
- Sharing of the same territorial unit
- Small spatial distances between potential partners
- Small to medium scale enterprises
- Full transparency about all kinds of wastes

Additional advantages of regional exchange	Disadvantages in relation to the estate approach
• **greater variety of actors** → multiplication of supply and demand → multiplication of potential partners for direct input-output relations between producers • **greater economies of scale** → greater price effects → opening up of new recycling paths • **comprehensive transparency of material flows** → greater use of existing recycling capacities- → increase in knowledge concerning a possible creation or extension of recycling capacities → easier supply with secondary raw materials → rise in the disposal security → visualisation and calculation of niches for new recycling specialists → Opening up of additional potentials which can contribute to a rise in regional sustainability	• **greater distance of the actors** → rise in the costs for the overcoming of spatial and mental distances → rise in the variety of interests → multiplication in the complexity of logistic questions and concepts • **greater significance of indirect communication** → rise in the complexity of communication → rise in the costs of communication → necessity of a central and institutionalized stucturalization and coordination of information • **greater demand for sophisticated electronic data based instruments** → rise in the costs of system maintenance → rise in the know-how that is required

Fig. 3 From the industrial estate of Heidelberg-Pfaffengrund to the regional level of the industrial agglomeration Rhine-Neckar
- towards a regional transparency and exploitation of potentials for waste based material loops

Chart 14

Implementing the circular economy

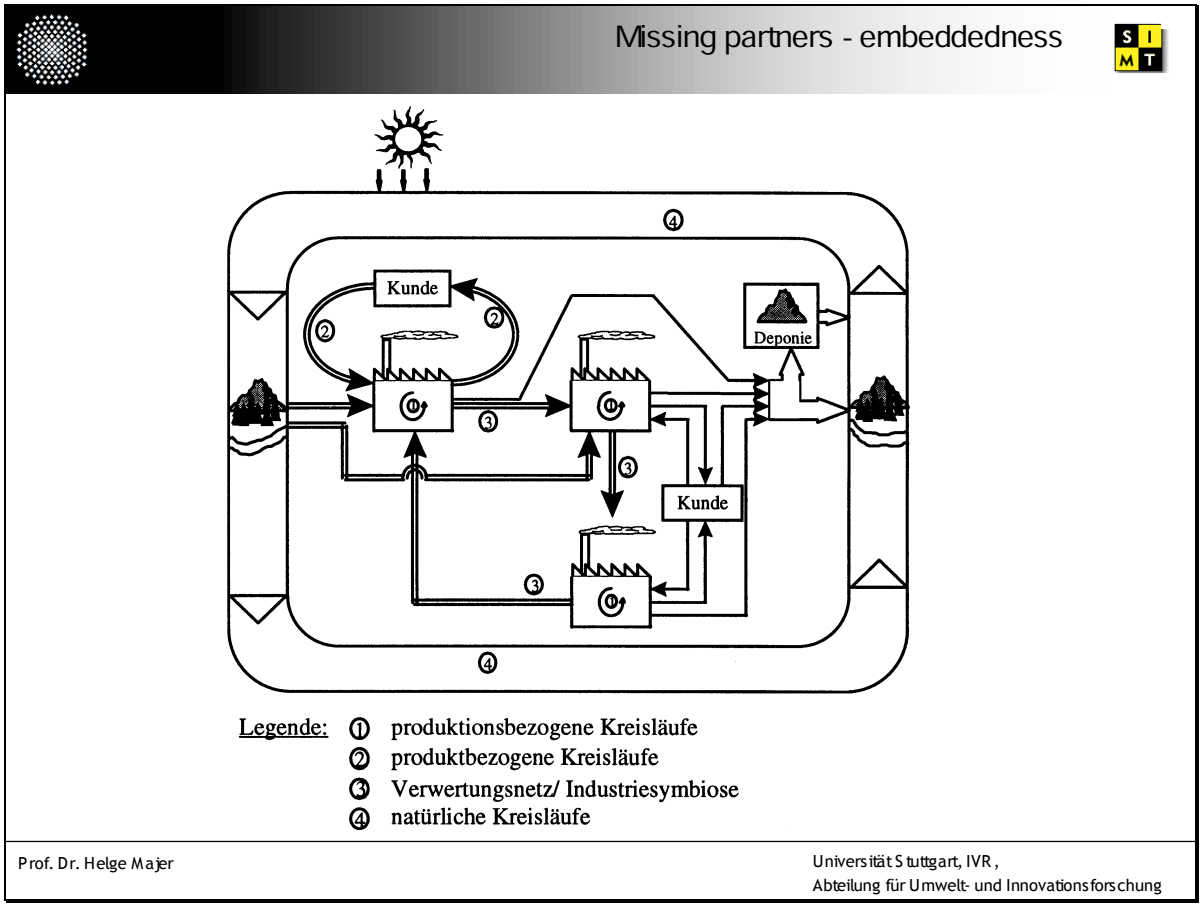


Chart 15

Ulm Initiative for Sustainable Economic Development - Ulmer Initiativkreis nachhaltige Wirtschaftsentwicklung (unw)

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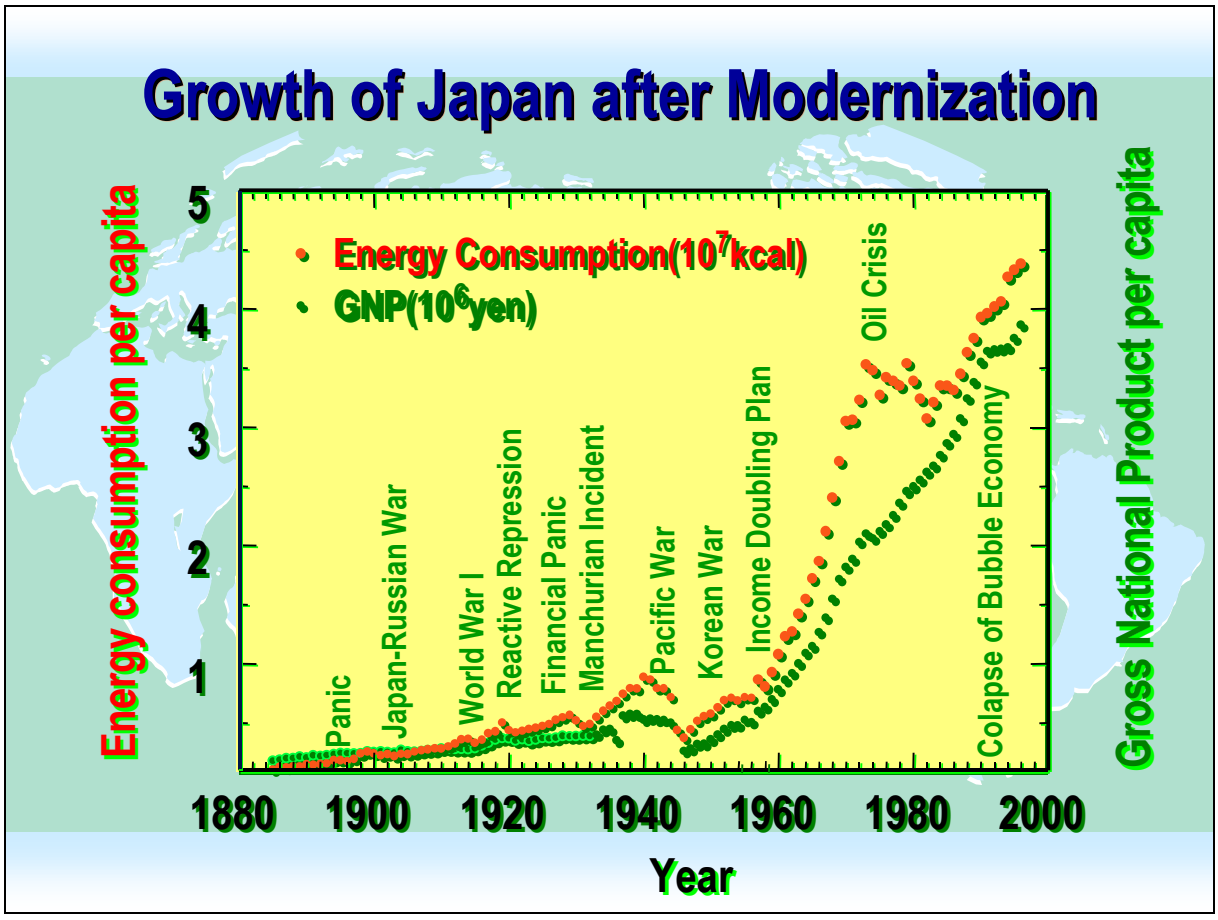
Chart 16

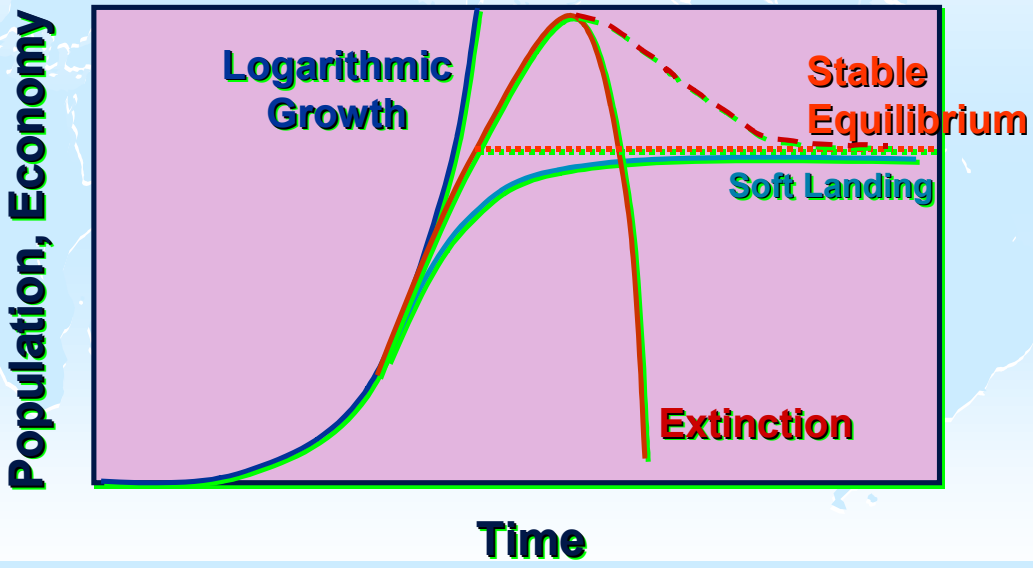
Zero Emissions Activities in Japan

Motoyuki Suzuki

United Nations University, Tokyo



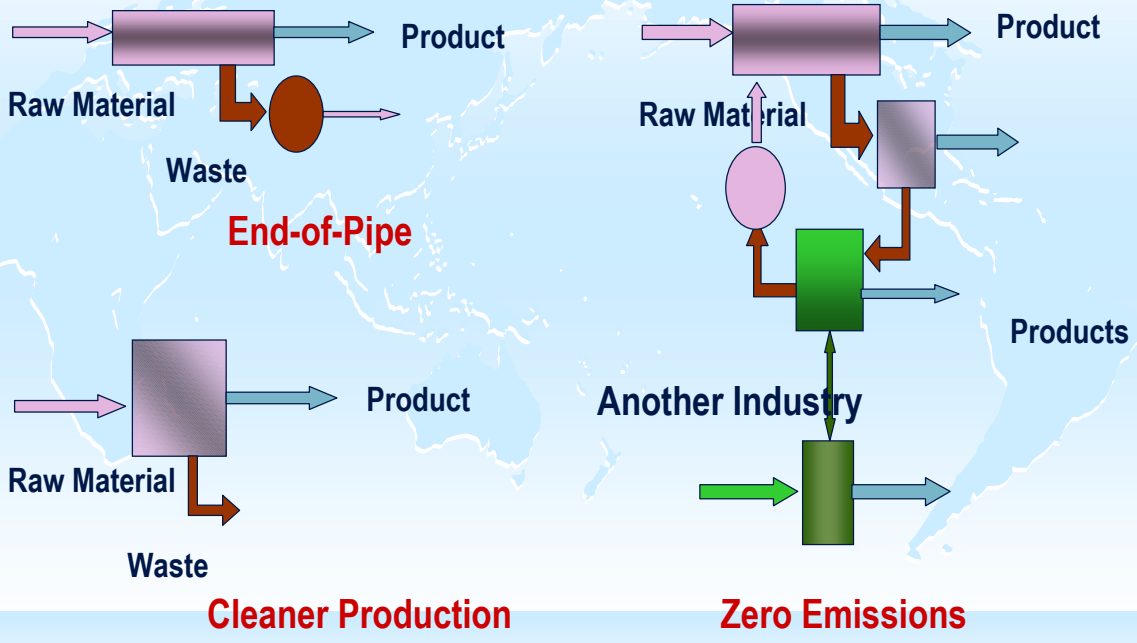
Typical Patterns of Growth Curves



Environmental Policies in Industrial Systems

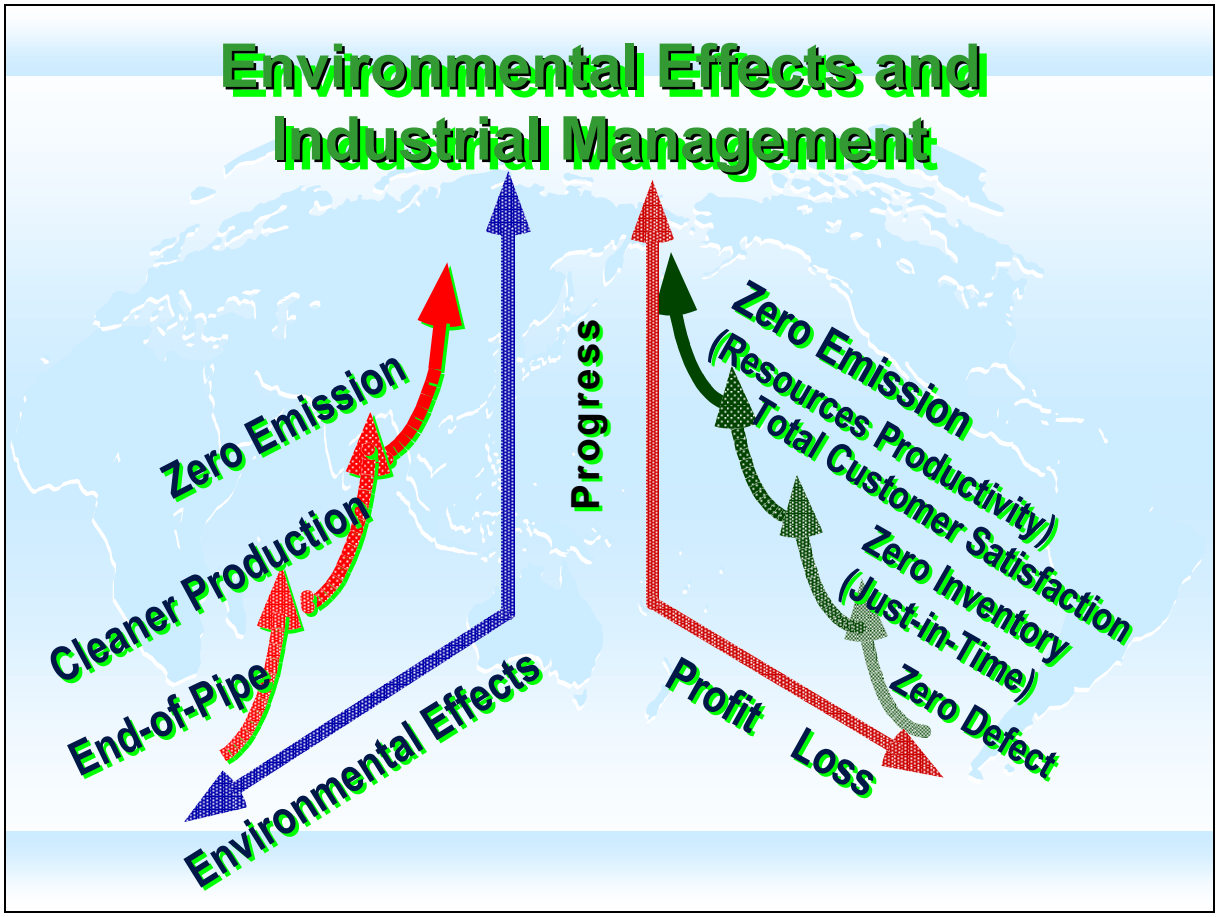
- **High Growth and Pollution Prevention**
  - Development of *End-of-Pipe* Technologies
- **Cleaner Production**
  - Renovation of Production Processes
- **Zero Emissions**
  - Total Reduction of Environmental Load and Maximization of Resources Productivity

End-of-pipe, Cleaner production and Zero Emissions



End-of-pipe, Cleaner production and Zero Emissions

End-of-pipe	Cleaner Production	Zero Emission
Individual processes, Effl. treatment	Process innovation	Industrial clustering
Minimize effects on downstream	(=left)	Create industries and jobs at upstream
Waste treatment, cost minimum	(=left)	Value added
Starting point	Transit	Final goal



Zero Emission Research Projects in Japan

- Grant-in-aid from Ministry of Education, Science, Sport and Culture (Monbusho): Priority Area Research:
  - *Formulation of Material Cycles Oriented to Zero Emission System*
    - Principal Researcher: M. Suzuki, 1997-2000, 80 professors
- United Nations University, Institute of Advanced Studies:
  - *Zero Emission Research Initiative*
    - Founder: Gunter Pauli, 1994-1996, UNU/IAS 1997-
  - *Zero Emission Forum (2000-)*
    - Industry, Government, Academic Networks
- Japan Society for Promotion of Sciences, University-Industry Research Cooperation
  - *Committee on Zero-Emission Systems*
    - Chairman: M. Suzuki, 1997-, Five years, 25 companies + academia

Ministry of Education: Priority Area Research:
Formulation of Material Cycles Oriented to Zero Emission System
Objectives of Three Research Groups

- A-01 : Process Zero Emission: Analysis of material balances and emission minimization in existent production processes
  - 1) Input-output database on various production processes
  - 2) Analysis of material flows including receiving processes
- A-02 : Zero Emission Network: Formulation of industrial networks among different industrial categories
  - 1) Analysis of inter-industrial material flows and formulation of industrial networks
  - 2) Key technology development for process/industry linkage
- A-03 : Local Zero Emission: Formulation of mathematical models for describing material cycles in model regions and assessment of possible zero emission networks
  - 1) Analysis of local material flows including domestic activities
  - 2) Formulation of mathematical model to describe material flows and evaluation of effect of zero emission network formation

Ministry of Education: Priority Area Research:
Formulation of Material Cycles Oriented to Zero Emission
Examples of Research Results

- A01: Process Zero Emission
  - (1-1) Analysis of material flows in production processes
  - (1-2) Development of key technologies for minimization of emission from production processes
- A02: Zero Emission Network
  - (2-1) Analysis of input-output database for prod. Processes
  - (2-2) Development of a network simulator
  - (2-3) Development of conversion technologies for networking of industries
- A03: Local Zero Emission
  - (3-1) Analysis of regional material flows and modeling
  - (3-2) Proposal of methodologies for regional networking to accomplish zero emissions
  - (3-3) Material flows in food production and evaluation of closing material cycles

Zero Emission Material Cycles

- Intake of natural resources:
  - *within the renewable limit*
- Final emission to environment:
  - *within the assimilable limit*
- Total material cycle in the anthropogenic sphere should be clarified as a holistic system
  - *Maximization of residence times of materials/resources in the anthropogenic sphere, consumption patterns, rental systems*
- Optimization not as a single process but as an integrated network system of processes
  - *Industrial Ecology, database for compete material flows, networking simulator, assessment methodology*

In Place of Conclusion

--Realization of Zero Emission Society

- From unit processes to integrated systems
  - *Holistic optimization, role of government*
- Toward a complete recycling
  - *Technology, economy, public systems/legisration, culture*
- Market economy system
  - *Industrial systems, producer's responsibility, economic incentives, etc.*

Materials Flow Analysis and Modeling to Establish a Zero-Emission Network in Regional Areas

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Department of Ecological Engineering, Toyohashi

Abstract

To reduce pollution load into environment, entire human activities in a regional scale, such as industrial production, social systems and our daily life should be evaluated based upon the material and energy flows. Approaches to minimize the emission are categorized into three groups. First is to minimize the materials consumption in industry not been converted into products by refining each unit process of the plant. Alternative process on different principles may be required to eliminate or change the characteristics of emissions. Second is to recycle or reuse the unused materials of a process among factories and industries by cascade-connection of the process and by the industrial clustering. Third is to establish appropriate materials flow systems in a regional scale. First step to actualize the emission minimization is to analyze the material and energy flows in the production process and in the regional area. In this paper we propose a methodology to clarify the materials flow in a regional area by using statistic data such as I/O table and that to construct a material flow networking in the area including industries. Discharge of waste materials from industries in a regional area has been estimated using the methodology.

Concept and Methodology to Minimize Emissions from Industry and in Regional Area

Figure 1 shows the step by step procedures to actualize industrial and regional zero emission. Well, it should be noted that it is impossible to actualize a real zero-emission. The term "zero-emission" reveals the transaction and countermeasures toward emission minimization in a focused production process or in a regional area.

What we have to do first is to analyze the materials and energy flows in industrial process and in a regional area. The information obtained by those investigations should be transferred to whom it may concern in zero-emission by constructing database. Appropriate scenario toward zero emission should be prepared and presented to the concerned people together with the expected effect of the countermeasure proposed in the scenario. This will be followed by a relating legislation or provision of economical incentives, which will promote the actualization of countermeasures in the scenario. Database

on emissions from industries and our daily life based on the materials flow will be of use to understand the present conditions and thus the problems in emissions into environment, and the consumptions of resources and energy. Based upon the information on emissions and the associated problems and that on technologies those will be applied for reduction, treatment and disposal of emissions. Prediction of emission from the industries and the daily life after the countermeasure is taken by introducing new and alternative concept and technologies. New life style, production process, social system and so on should be clearly shown to the people concerned. Additional legislation may be required to establish new social system. Economical incentives may also be required to accelerate the incorporation of new technologies and process into the industries. Energy and material synergetic process, cascade use of materials, process networking and thus industrial clustering are required in industries for complete use of resources and thus for emission minimization.

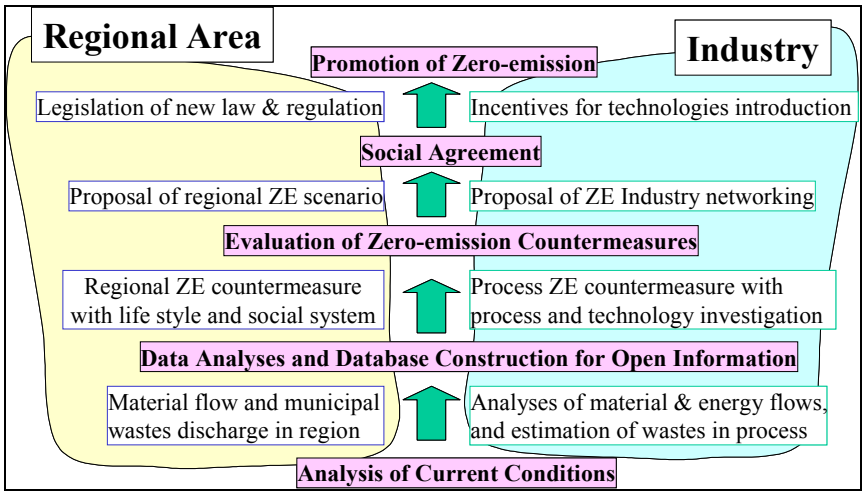


Fig.1 Method to establish zero-emission in industry and regional scale

Analysis of Material Flow in Regional Area toward Zero-Emission

Regional zero-emission requires not only emission reduction in industrial process but also minimization of the emission from the regional area. Material flows, such as products and raw materials, and those in processing, consumption, disposal and recycle are required to investigate to give appropriate information to establish countermeasures for emission minimization. More over materials exchange across the border of the focused regional area are required as well. Materials flow is categorized into three such as valuable (products and raw materials), wasted and renewed. There are no explicit statistics data can be used for the analysis of material flow in a regional area. Therefore the materials flow in regional area must be analyzed using input-output table (I-O table), which shows the cash flow among industries, and the Investigation Report of Industrial Wastes by local government published every five years (Industrial Wastes Report, hereafter). The Industrial Wastes Report includes the discharge, treatment and disposal of wastes from industries in each prefecture.

We proposed a method to analyze regional material flow derived from the statistics as shown in Figure 2. The I-O table shows inter-relation among all industries in cash flow and makes the all industries classify into several sectors (coarse classification is 38 groups, the medium is 93 and that of detailed is 186). Problems in using I-O table is that every five years investigated results in the table may not reflect the on-going industrial activities.

Onset of the conversion of I-O table into materials flow is to pick-up the relating industries to that fo-

cused, and the second is to determine the price of materials and products being traded in the market among those industries. The weighed-average price of the products and materials can be determined from the observation of relating market. Repeating this step clarifies the material flow around the focused sector/industry. It can be supposed that the amount of difference between input and output after subtracting the energy consumption, which is discharged as carbon dioxide into environment, is due to the wasted materials not being converted to products.

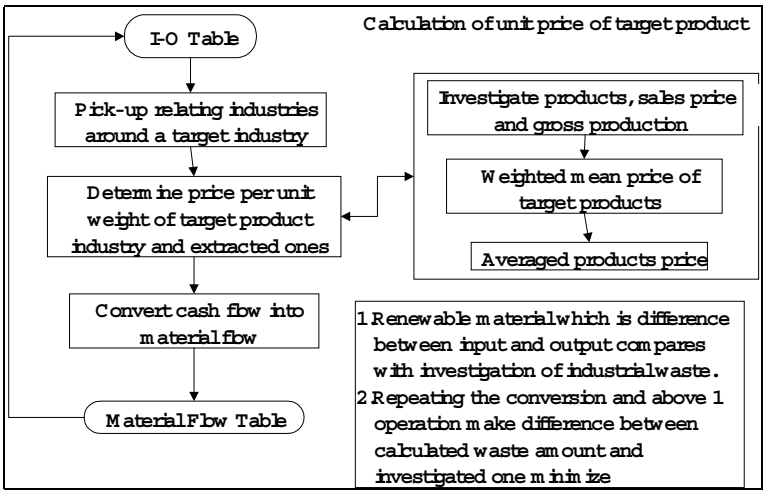


Fig.2 Procedure to convert I-O table to material flow table

Material flow around steel industries in Aichi prefecture was illustratively calculated and shown in Fig.2 using I-O table of Aichi prefecture. Import from other prefectures is 37 % of total input to the steel industries, while the output is about 52% of the total production. Main input is iron ore, scrap iron, limestone and so on.

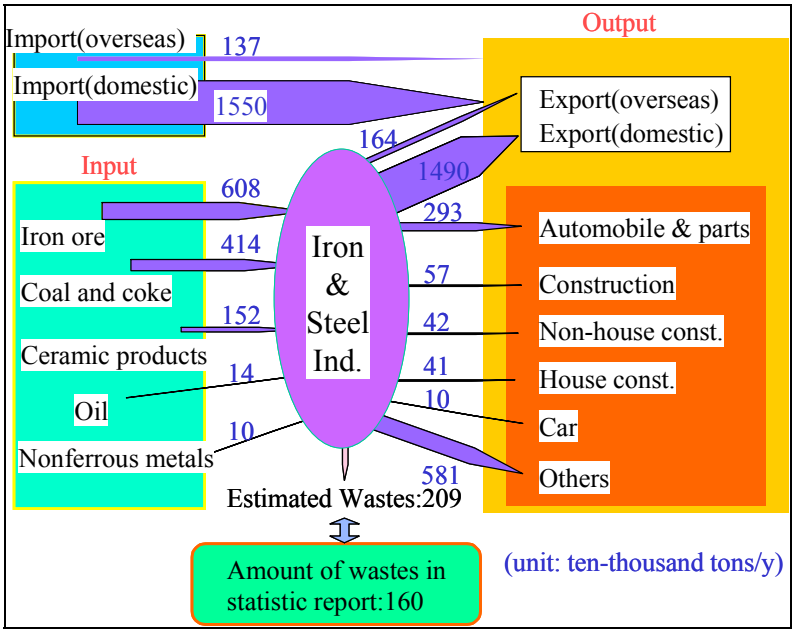


Fig.3 Material balance of steel industries in Aichi prefecture

Profile of Materials Flow in Regional Area

Table 1 shows the discharge of waste materials, their disposal, intermediate treatment for volume reduction and/or reclamation. Five million tons of waste materials is discharged form industries in Aichi prefecture, and as much as 4.5 million tons of discharged materials are recycled with or without intermediate treatment. This high recycle rate in this prefecture is due to the complete reuse of blast furnace slag as aggregate for constructions of road and fabrics. Final disposal is as little as about 0.6 million tons. Note that the amount of industrial wastes discharge reported by the Industrial Wastes Report was 5.1 million tones, while that estimated by the proposed method in the above was 4.25 million tons. The amount of industrial wastes discharge can be estimated by the proposed method.

Table 1 Waste materials flow of steel industry in Aichi prefecture.
□Unit□10,000 t/y□

<table>
<tr><td rowspan="5">Total discharge in industry 510.8</td><td rowspan="4">Wastes 160.3</td><td colspan="2">Final disposal 48.5</td></tr>
<tr><td colspan="2">Volume reduction 11.8</td></tr>
<tr><td colspan="2">Others 0.2</td></tr>
<tr><td>Reclamation 99.8</td><td rowspan="2">Recycle 450.3</td></tr>
<tr><td colspan="2">Valuable materials to be recycled 350.5</td></tr>
</table>

Figure 4 shows profile of material flow in Aichi prefecture estimated from the investigation report on industrial waste. Total amount of industrial wastes discharged in Aichi prefecture is as much as 17million tons per year. Where 57 % of the wastes are discharged from manufacturing and construction industries and livestock farm. Industrial wastes from manufacturing industries and the livestock farm takes large part of the total amount compared to other prefectures. Final disposal of the wastes, which is 3 million tones per year, is 9% of the total wastes discharge. The livestock wastes may be converted to compost for agricultural use. However excess application of N and P into farmyard often brings about the serious pollution of groundwater and river.

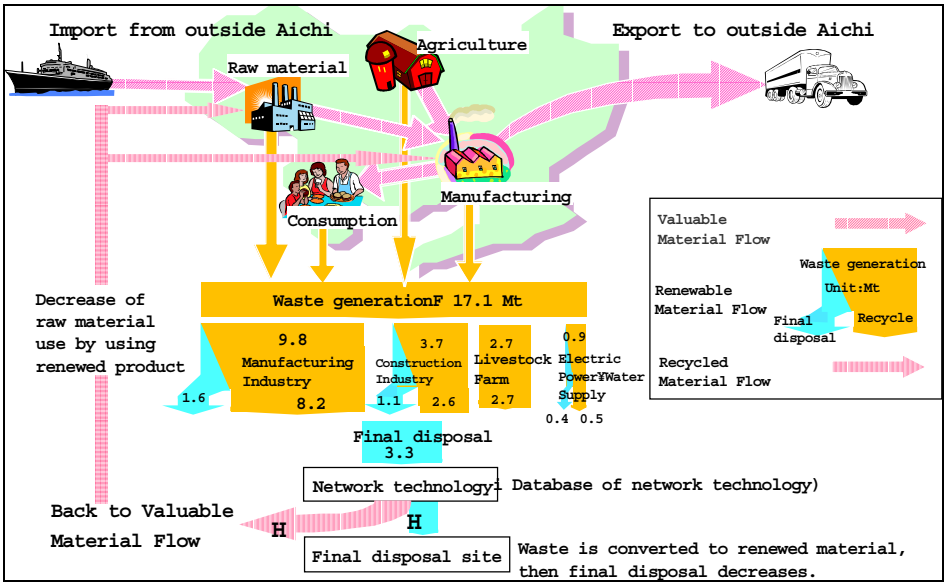


Fig.4 Profile of material flow in Aichi prefecture together with raw and wastes materials and products.

Database of Materials and Technologies for Industrial Clustering in Regional Area

In this paper, as a first step to construct material cycle network among industries for regional zero emission, we proposed a method to estimate the materials flow in the regional area using I/O table and Industrial Wastes Report. Here we also propose a network simulator together with database of wastes materials and reclamation technologies. This method will be applied for the networking of industries and production processes and cascade connect of production process in series for complete utilization of resources and for saving energy by establishing a synergetic process. Figure 5 shows a concept of industrial and process networking together with database of recycling technologies and discharged materials in a regional area. Industrial clustering and networking of processes requires database of discharged materials, which is available for raw material of other process, and that of applicable technologies for reclamation of wastes. Database of raw materials used in each industrial company is required to interlink the industries in the focused regional area. Finally, the effect of materials flow networking proposed for the focused regional area should be quantitatively evaluated to clarify how the networking is effective to minimize the emissions.

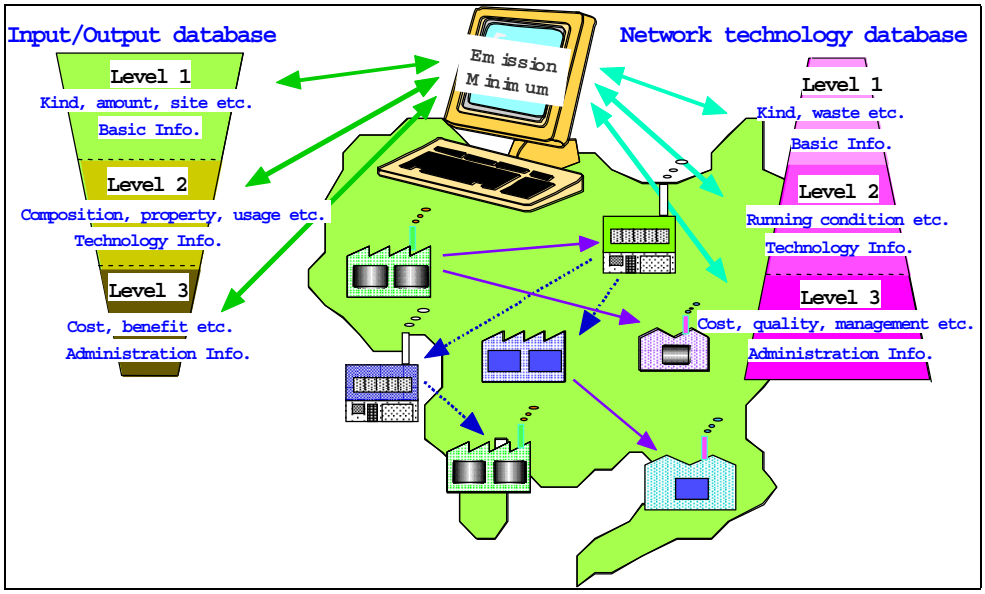


Fig.5 Database for industrial clustering and process networking

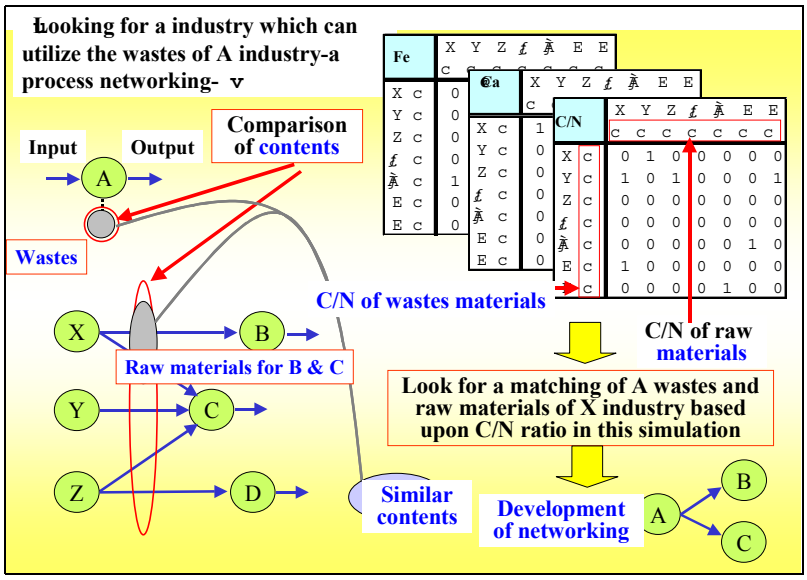


Fig.6 Procedure to Connect Process and Process based on Contents of Materials

To develop a materials flow network by connecting the industrial processes, database as shown in Fig.5 is required to look for candidates, which can accept unused wastes materials as one of the raw materials of the industry. Information on contents in unused wastes materials is essential to investigate the possibility of materials networking. Procedure illustratively shown in Fig.6 represents a example in which information on C/N ratio, other contents such as Ca, Fe, etc. are used to seek an acceptor of the wastes materials. Appropriate database of unused materials is very much helpful to establish process - process or industry - industry networking. It should be noted that the database on available technologies for resources reclamation or wastes regeneration, which is used to convert wastes materials to value added raw materials to be utilized in the other production industry.

Zero-Emission Scenarios and Implementation - as a Conclusive Summary

Observed and collected data can be utilized to establish a process to process networking based upon information of contents of wastes materials, while statistic data of materials flow determined from I/O table can be used to clarify the potential of trans-industry networking. By merging these results, a hypothetical material flow network can be designed. It is needless to say that individual activity for emission minimization in each production industry is essential as shown in the top of Fig.6. Effect of transactions including material flow networking, individual efforts and so on should be quantitatively evaluated to clarify how effectively emissions in the focused area will be reduced. Total quality management, scheduling of materials supply, construction of database, etc. are required to operate such material flow network. Economical incentives and juristic system are necessary after the public consensus for the implementation of zero-emission scenario.

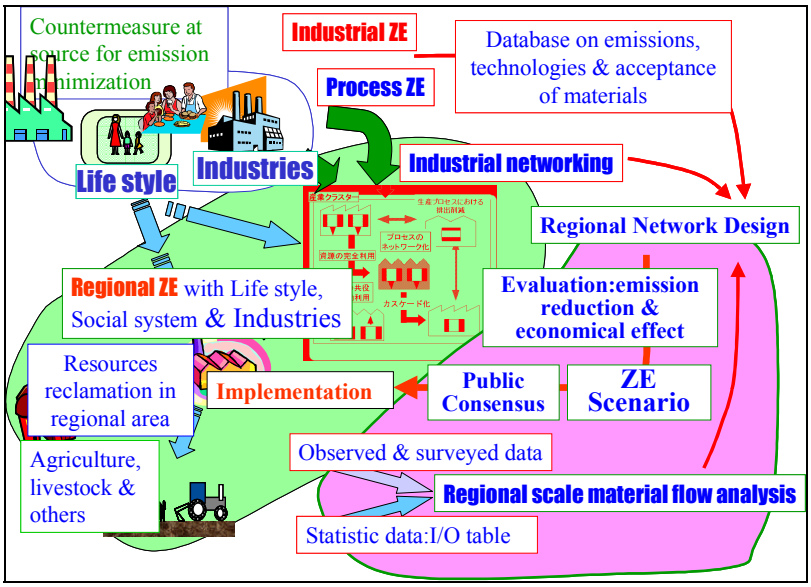
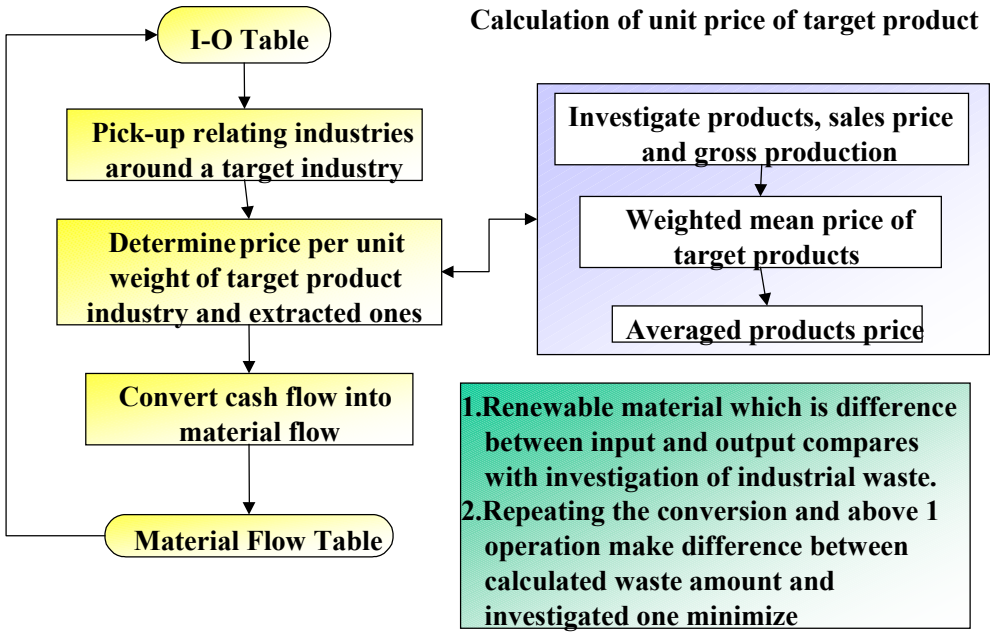


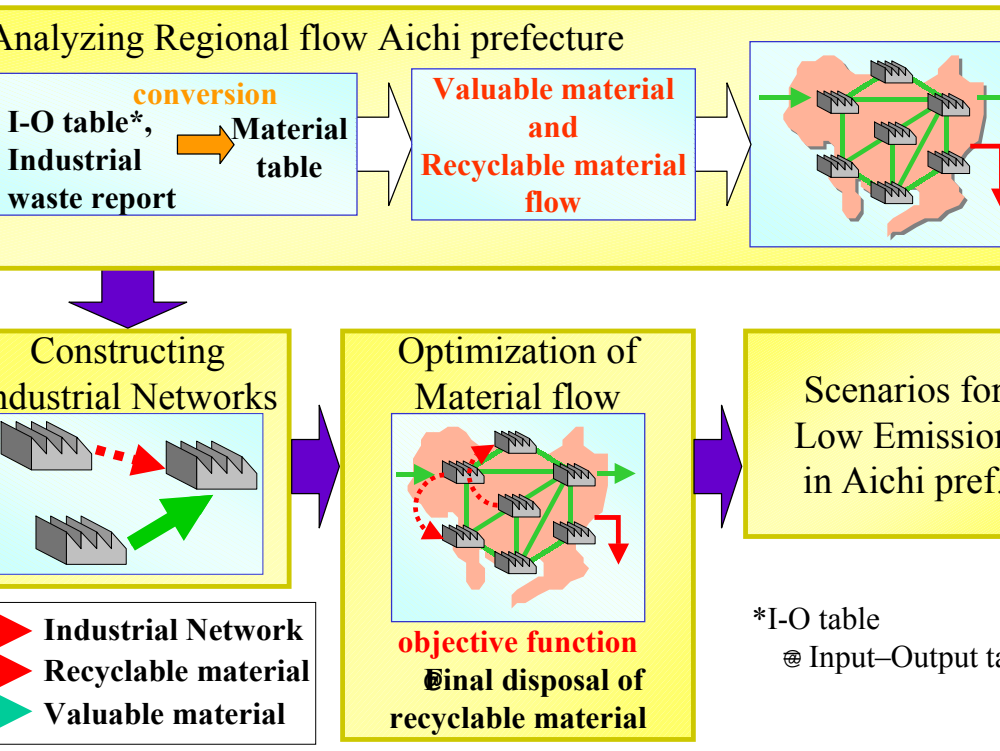
Fig.6 Procedure to develop zero-emission scenario and implementation.

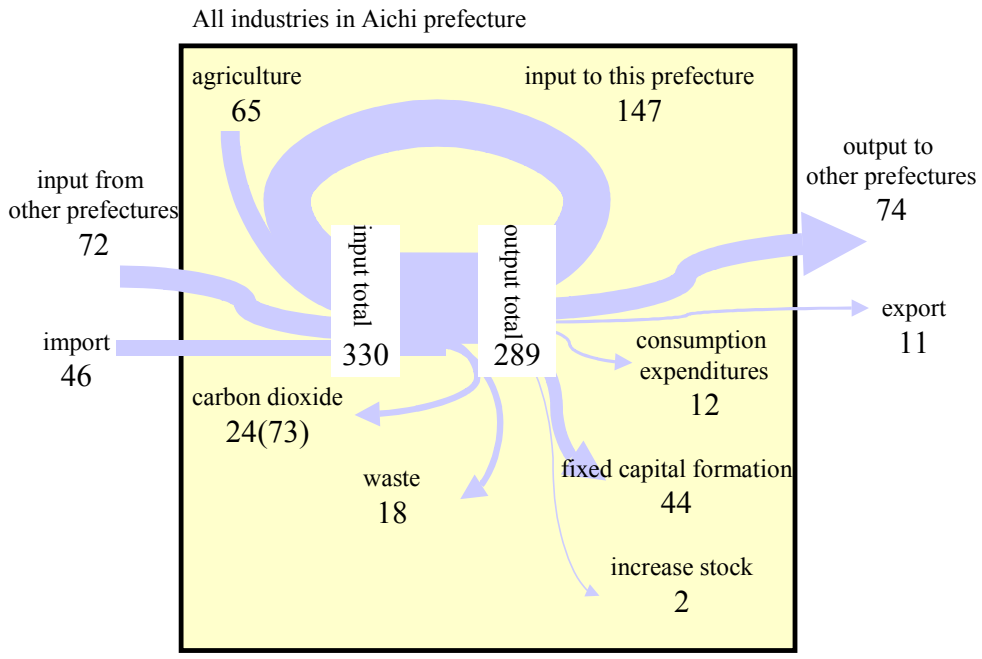
References

- The Ministry of Education, Science, Sports and Culture, Grant-in-Aid for Scientific Research on Priority Areas (A), Zero Emissions Oriented Material Cycle Processes, http://envchem.iis.u-tokyo.ac.jp/ZeroEm/
- Aichi prefecture, Input-Output Table of Aichi Pref., 1995
- Aichi prefecture, Survey report on Industrial Waste of Aichi Pref., 1996

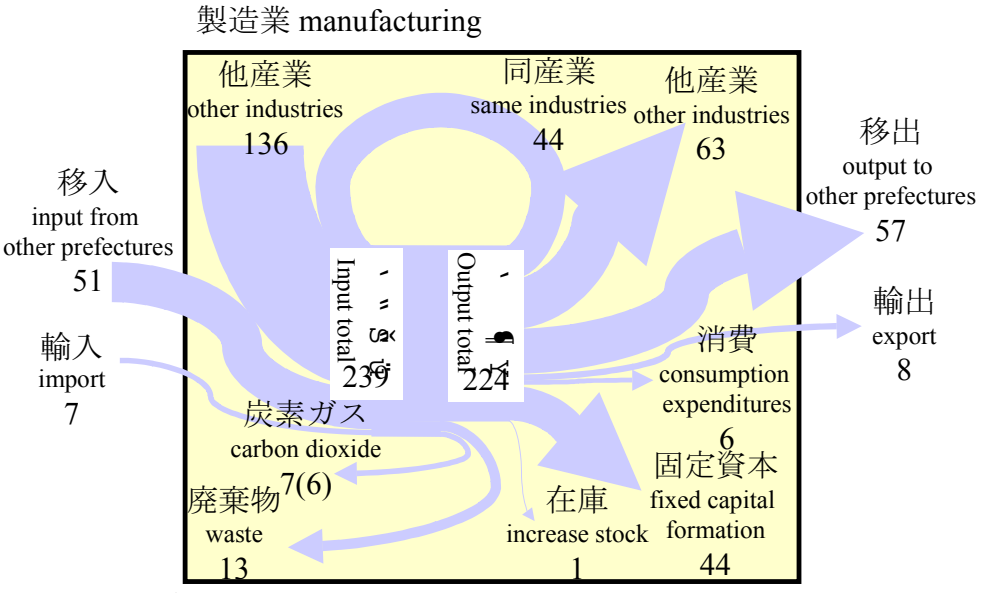


Procedure to convert I-O table to material flow table



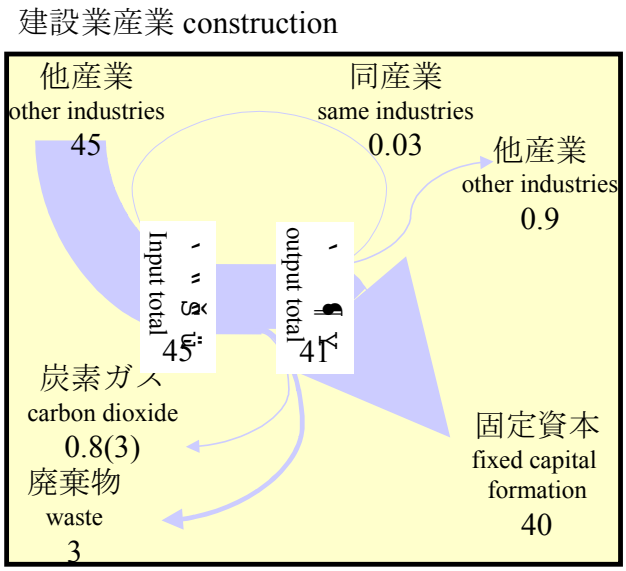


Material flow of all industries
in Aichi Prefecture



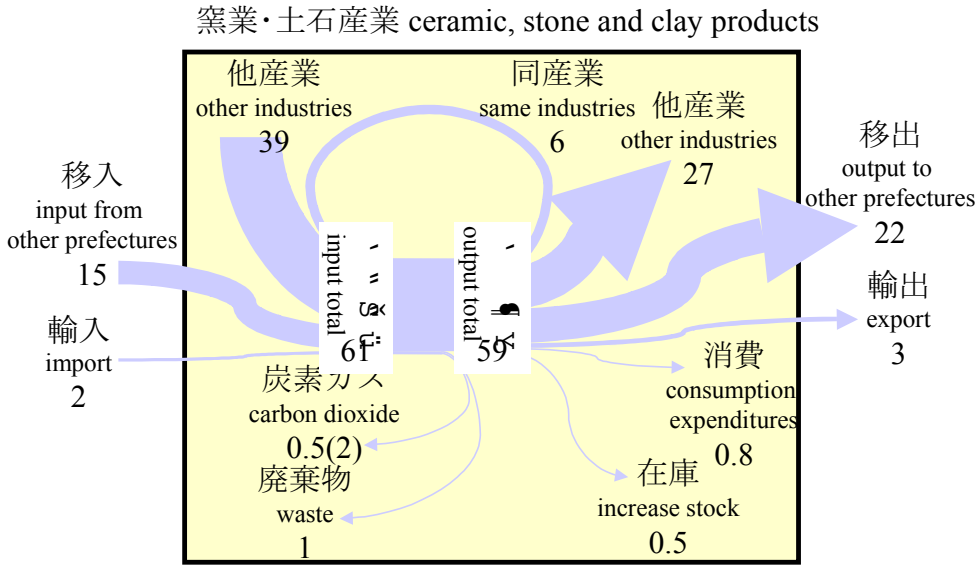
単位：10^6t　※一部の食料品、飲料･飼料･たばこは除く。
＊炭素ガス量は使用された石油･石炭量で、
()内はその炭素含有量より炭酸ガス量に換算したもの

Material flow of all manufacture industries
in Aichi Prefecture



単位：10^6t
＊炭素ガス量は使用された石油･石炭量で、
()内はその炭素含有量より炭酸ガス量に換算したもの

Material flow of construction industries in Aichi Prefecture



単位：10^6t
＊炭素ガス量は使用された石油･石炭量で、
()内はその炭素含有量より炭酸ガス量に換算したもの

Material flow of ceramic, stone and clay products industries in Aichi Prefecture

Zero Emission as an Integrated Approach Towards a Sustainable Society

Marc-Andree Wolf et al.
University of Stuttgart, Institute of Polymer Science and Testing (IKP)

German-Japanese Workshop on
Integrated Approaches Towards Sustainability - Munich, 29 September 2000
Fraunhofer Gesellschaft & United Nations University, Zero Emissions Forum

Zero Emission as an Integrated Approach Towards a Sustainable Society

by

P. Eyerer[1,2], M.-A. Wolf[1,2], T. Kupfer[2], H. Florin[2]

[1] Fraunhofer-Institut Chemische Technologie (ICT), Pfinztal
[2] Institut für Kunststoffprüfung und -kunde (IKP), Stuttgart

Zero Emission as an integrated approach towards a sustainable society

Contents:

- Partnership
- Introduction to ZeroEmission
- Methodology of Life Cycle Engineering (LCE)
- Methodology of Life Cycle Assessment (LCA)
- Extension by social dimension "Life Cycle Manpower" (LCMP)
- Case study on different watch-casings
- Summary

Fraunhofer Institut Chemische Technologie — Universität Stuttgart Institut für Kunststoffprüfung und Kunststoffkunde

Competencies at Fraunhofer-ICT and at University Stuttgart IKP

Technology, R&D (345 Employees, 17 Mio US$ ann. turnover):

Fraunhofer Institut Chemische Technologie

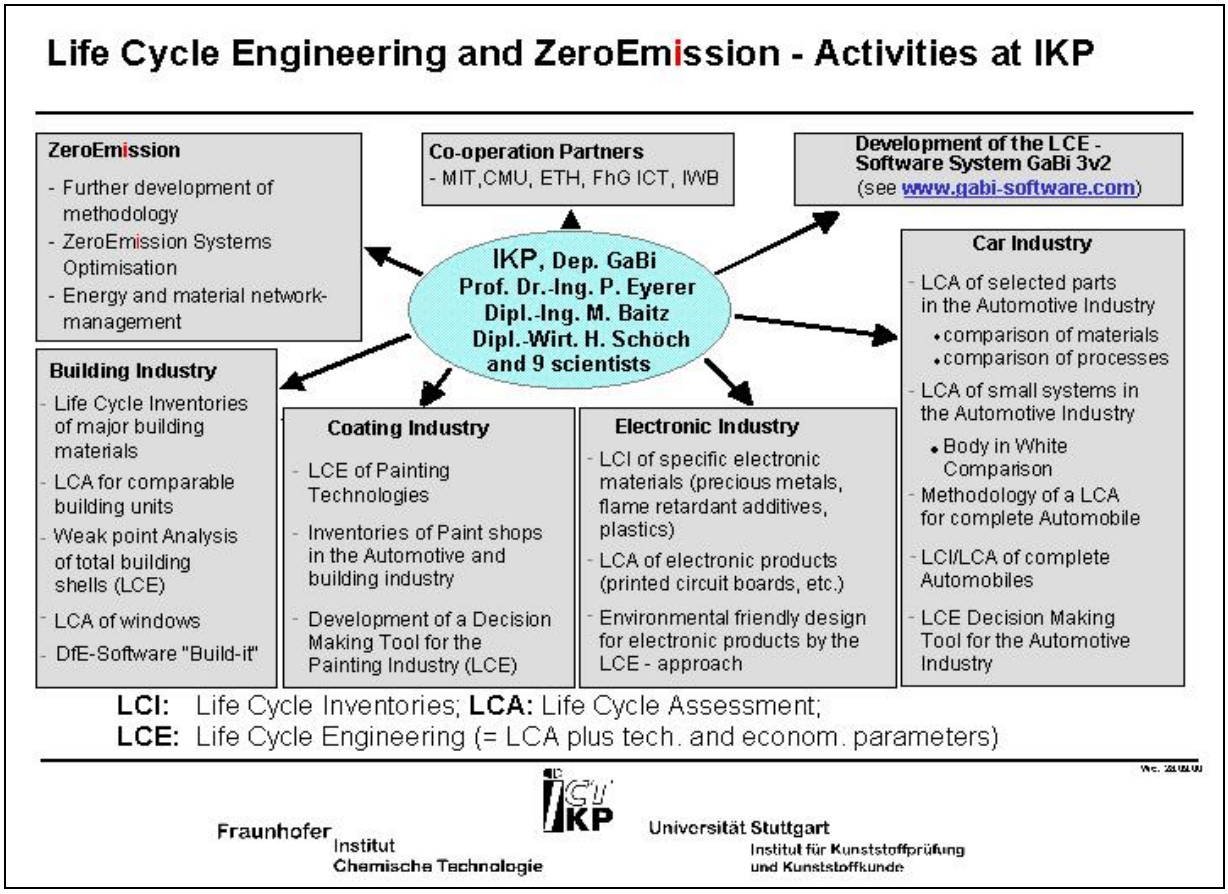
- Material and Part Development
- Recycling Technology
- ZeroEmission Technology
- Rapid Prototyping/Tooling
- Electro Chemistry
- Energetic Products

Research, Systems Analysis (95 Employees, 3 Mio US$):

- Polymer Science and Testing
- Life Cycle Engineering (GaBi Software; Methodology; Projects)
- Environmental Analytics
- ZeroEmission Methodology and Research

UNIVERSITÄT IKP STUTTGART

Fraunhofer Institut Chemische Technologie — Universität Stuttgart Institut für Kunststoffprüfung und Kunststoffkunde


Life Cycle Engineering and ZeroEmission - Activities at IKP
ZeroEmission
- Further development of methodology
- ZeroEmission Systems Optimisation
- Energy and material network-management
Co-operation Partners
- MIT,CMU, ETH, FhG ICT, IWB
Development of the LCE - Software System GaBi 3v2
(see www.gabi-software.com)
IKP, Dep. GaBi
Prof. Dr.-Ing. P. Eyerer
Dipl.-Ing. M. Baitz
Dipl.-Wirt. H. Schöch
and 9 scientists
Car Industry
- LCA of selected parts in the Automotive Industry
• comparison of materials
• comparison of processes
- LCA of small systems in the Automotive Industry
• Body in White Comparison
- Methodology of a LCA for complete Automobile
- LCI/LCA of complete Automobiles
- LCE Decision Making Tool for the Automotive Industry
Building Industry
- Life Cycle Inventories of major building materials
- LCA for comparable building units
- Weak point Analysis of total building shells (LCE)
- LCA of windows
- DfE-Software "Build-it"
Coating Industry
- LCE of Painting Technologies
- Inventories of Paint shops in the Automotive and building industry
- Development of a Decision Making Tool for the Painting Industry (LCE)
Electronic Industry
- LCI of specific electronic materials (precious metals, flame retardant additives, plastics)
- LCA of electronic products (printed circuit boards, etc.)
- Environmental friendly design for electronic products by the LCE - approach
LCI: Life Cycle Inventories; LCA: Life Cycle Assessment;
LCE: Life Cycle Engineering (= LCA plus tech. and econom. parameters)
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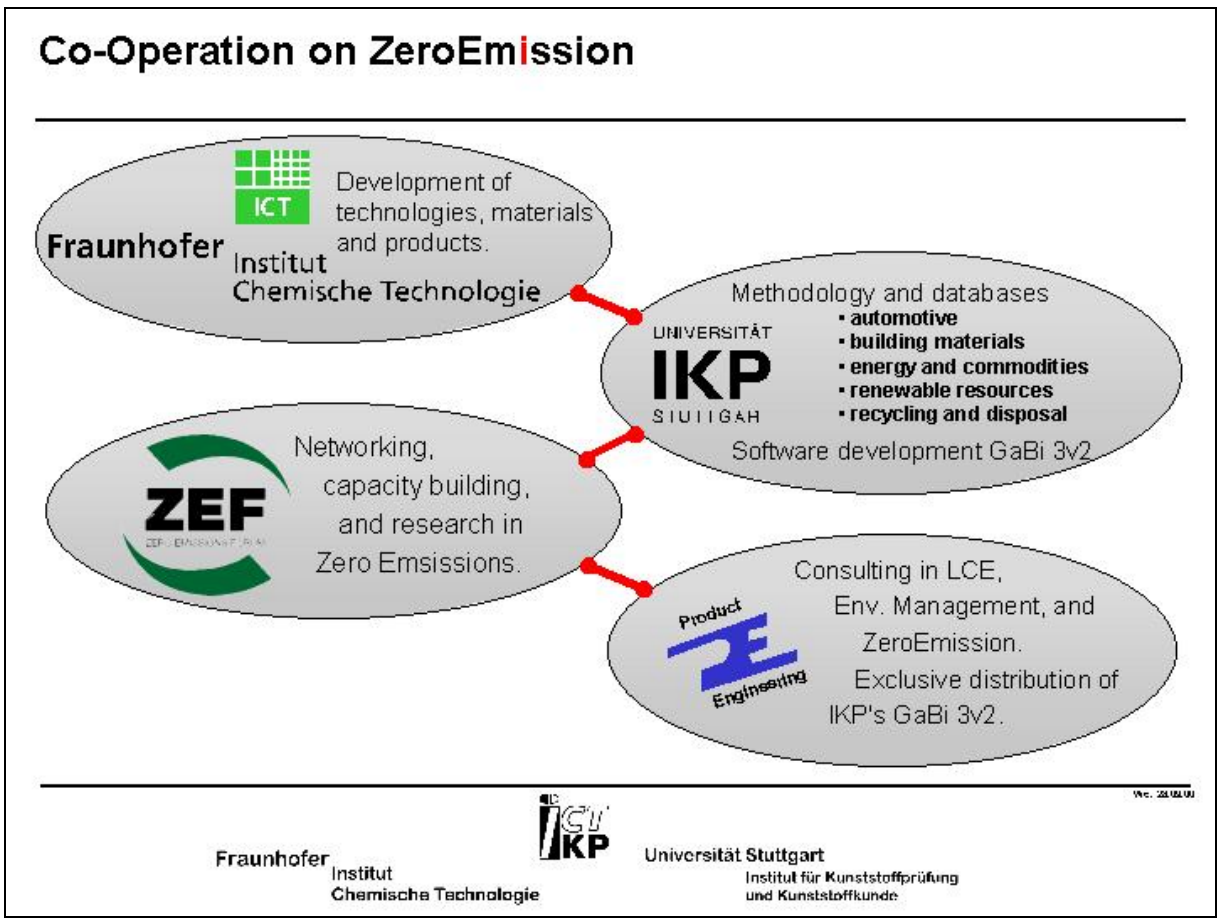
IKP
Universität Stuttgart
Institut für Kunststoffprüfung und Kunststoffkunde


Co-Operation on ZeroEmission
Fraunhofer ICT Institut Chemische Technologie
Development of technologies, materials and products.
Methodology and databases
UNIVERSITÄT IKP STUTTGART
• automotive
• building materials
• energy and commodities
• renewable resources
• recycling and disposal
Software development GaBi 3v2
ZEF
Networking, capacity building, and research in Zero Emsissions.
Consulting in LCE, Env. Management, and ZeroEmission.
Product Engineering
Exclusive distribution of IKP's GaBi 3v2.
Fraunhofer Institut Chemische Technologie
IKP
Universität Stuttgart
Institut für Kunststoffprüfung und Kunststoffkunde

Introduction to ZeroEmission -I-

What is ZeroEmission?

Does ZeroEmission just mean:

"no emissions, no waste"?

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Introduction to ZeroEmission -II-

No, ZeroEmission is much more !

Our aims for ZeroEmission are:

- ✓ Protect the environment
- ✓ Save natural resources
- ✓ Secure economic interests
- ✓ Provide employment
- ✓ Educate the youth

By creating this situation - where everybody wins -
we strengthen the present and the next generation.

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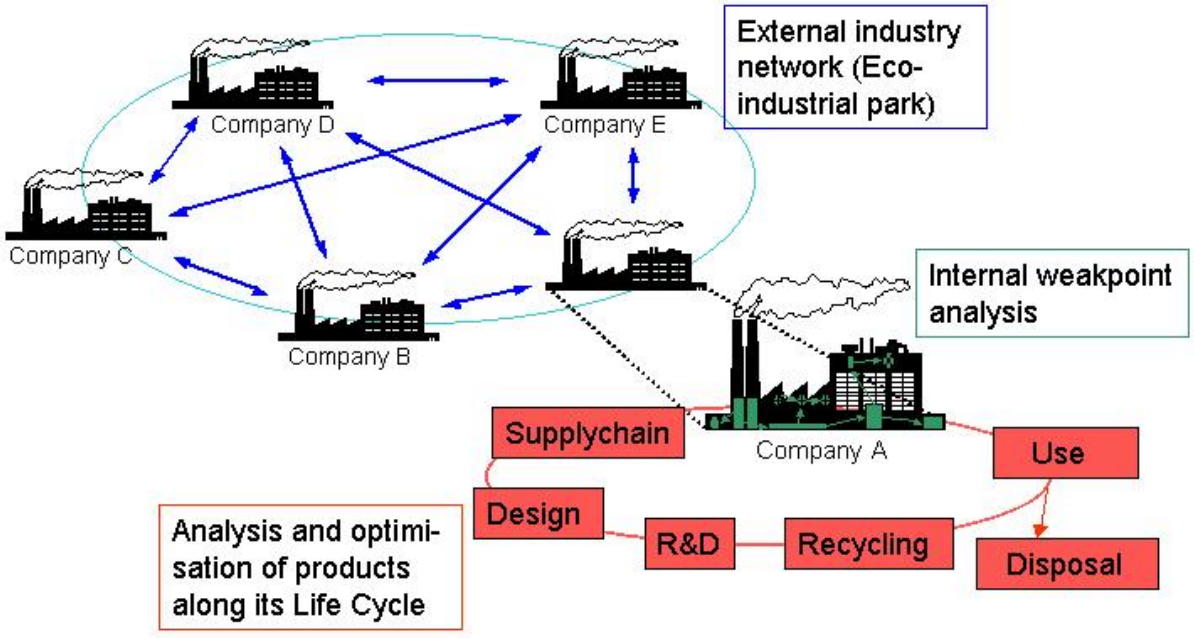
Product-Optimisation, Site-Analysis, and Eco-Industrial Parks

The Product, Site, and Spatial Approaches of ZeroEmission



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Areas for ZeroEmission projects

- **Process/Technology** (e.g. minimum lubrication system "LUBRILEAN")
- **Material** (e.g. ***development of high-quality biopolymers for foam applications***; lignin vs. Synthetic additives for concrete)
- **Product and service** (***e.g. watch-case made from "liquid wood"***)
- **Process network** (e.g. integrated energy production and nutrient management for a liquid manure benefication plant)
- **Production site** (e.g. cellulose plant)
- **Eco-Industrial Network** (intelligent linking of material and energy flows within a industrial area, ***e.g. Energy-Net in the TechnologyRegion Karlsruhe***)
- **Eco-Industrial Park** (newly designed industrial parks for optimum performance)
- **Eco-City and Eco-Region** (intelligent linking of of material and energy flows in a whole city or region)

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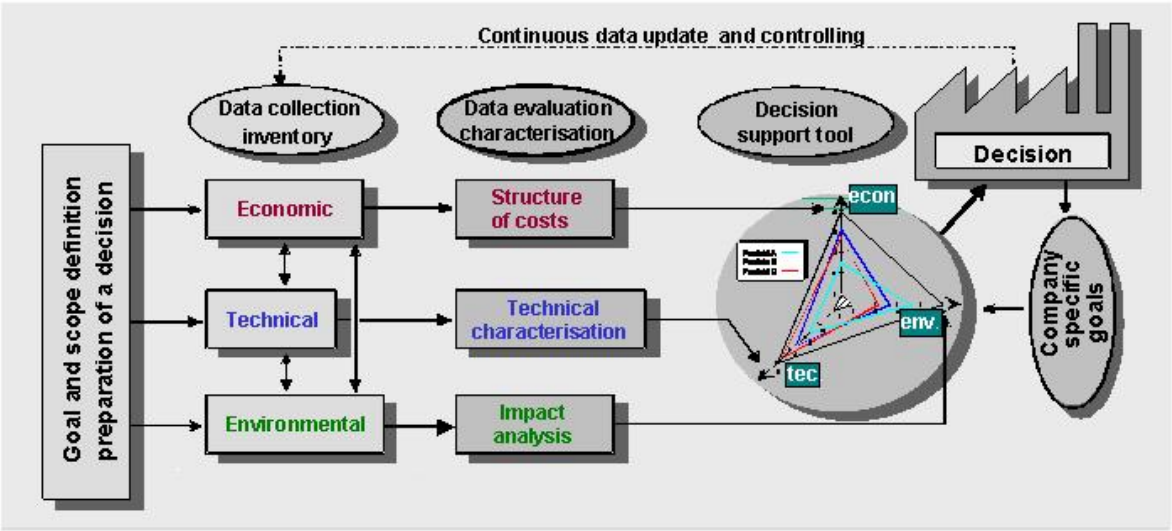
Life Cycle Engineering (LCE) - the base for ZeroEmission

Analysis of environmental, economic, and technical parameters along the life cycle



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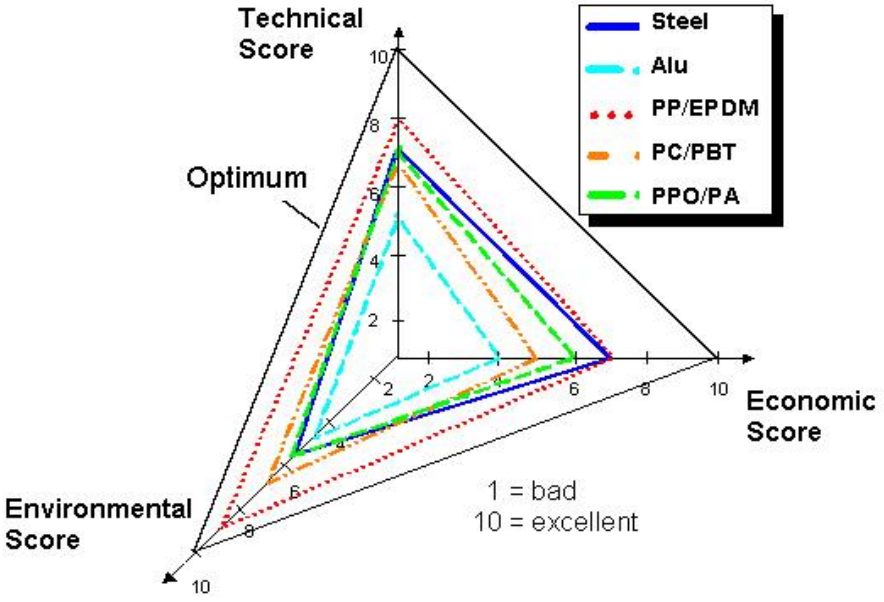
Presentation of the Overall Results of an LCE Case Study

3-D Port-Folio-Technique (Example: comparison of different alternatives of fenders)



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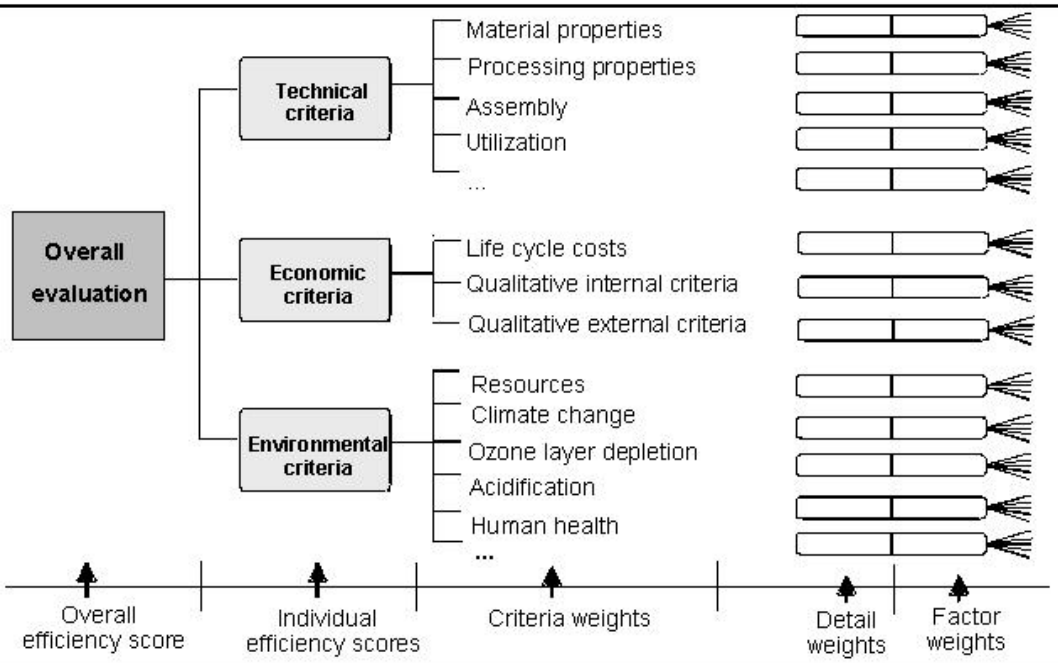
Life Cycle Engineering - Structure

Steps towards the overall evaluation



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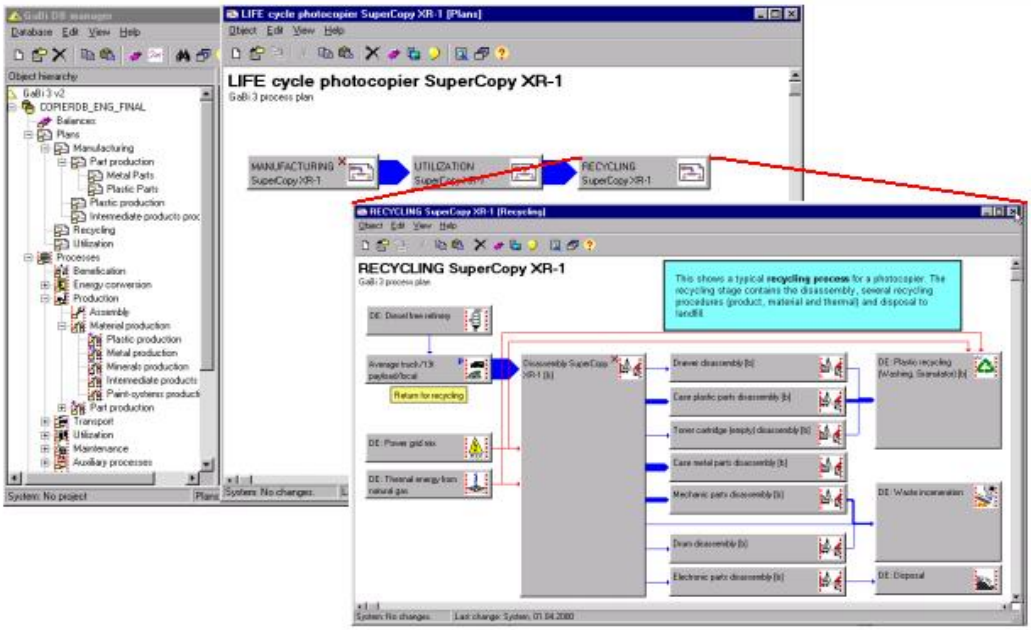
Screenshots of Hierarchical Work Plan inside GaBi 3v2

Extract from the Life Cycle of a Photocopier



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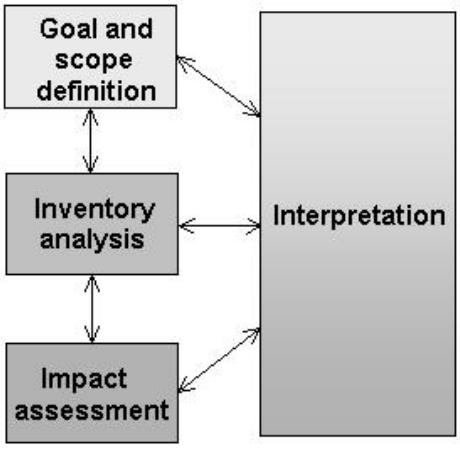
Methodology for Life Cycle Assessment (LCA)

ISO 14040 principals and frame work

LCA - Life Cycle Assessment

(ISO/DIS 14040 ff.)



Def.: LCA studies analyse the environmental aspects and potential impacts throughout a product's life cycle (e.g., cradle-to-grave) from raw material acquisition through production, use and disposal (**ISO**).

Use:

- Product development
- Product improvement
- Strategic planning
- Public policy making
- Marketing

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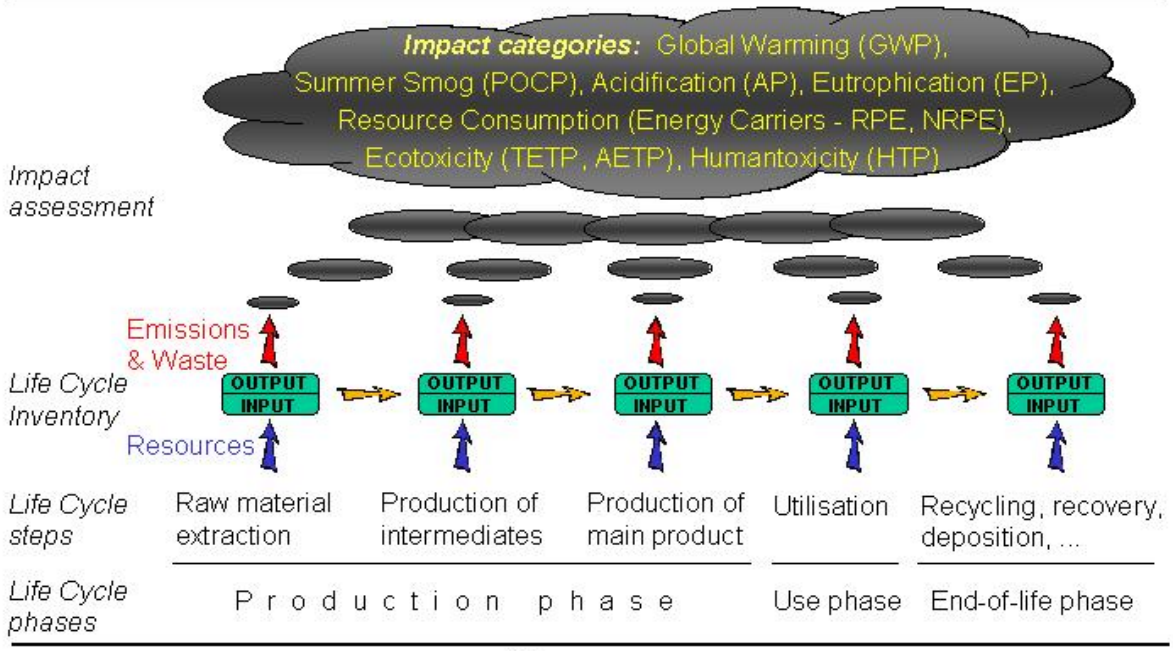
What is done in a Life Cycle Assessment ?

Scheme



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Steps within a Life Cycle Assessment - I -

Goal & Scope definition (ISO 14040)

1) Goal of the Life Cycle Assessment study

- intended applications
- reasons for carrying out the study
- intended audience

2) Scope of the study

- function of the system
- functional unit
- description of the system
- system boundaries
- allocation procedures
- impact categories and the impact model
- requirements for data
- data assumptions
- limitations
- data quality requirements
- peer view
- the kind of reporting

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Steps within a Life Cycle Assessment - II -

Life Cycle Inventory (ISO 14041); Life Cycle Impact Assessment (ISO 14042)

3) Life Cycle Inventory (LCI)

- data collection
- description of the inventory

4) Life Cycle Impact Assessment (LCIA)

- classification
- characterisation
- normalisation

5) Interpretation

- evaluation and discussion

6) Report

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Extension by Social Dimension "Life Cycle Manpower"

First approach for an integrated sustainability evaluation

- **Modelling** of process-related workforce for each single production step along the products complete life cycle
- **Aggregation** of workforce as <Person-seconds workforce per unit product>
- **Integration** into the decision support as a new - social - dimension

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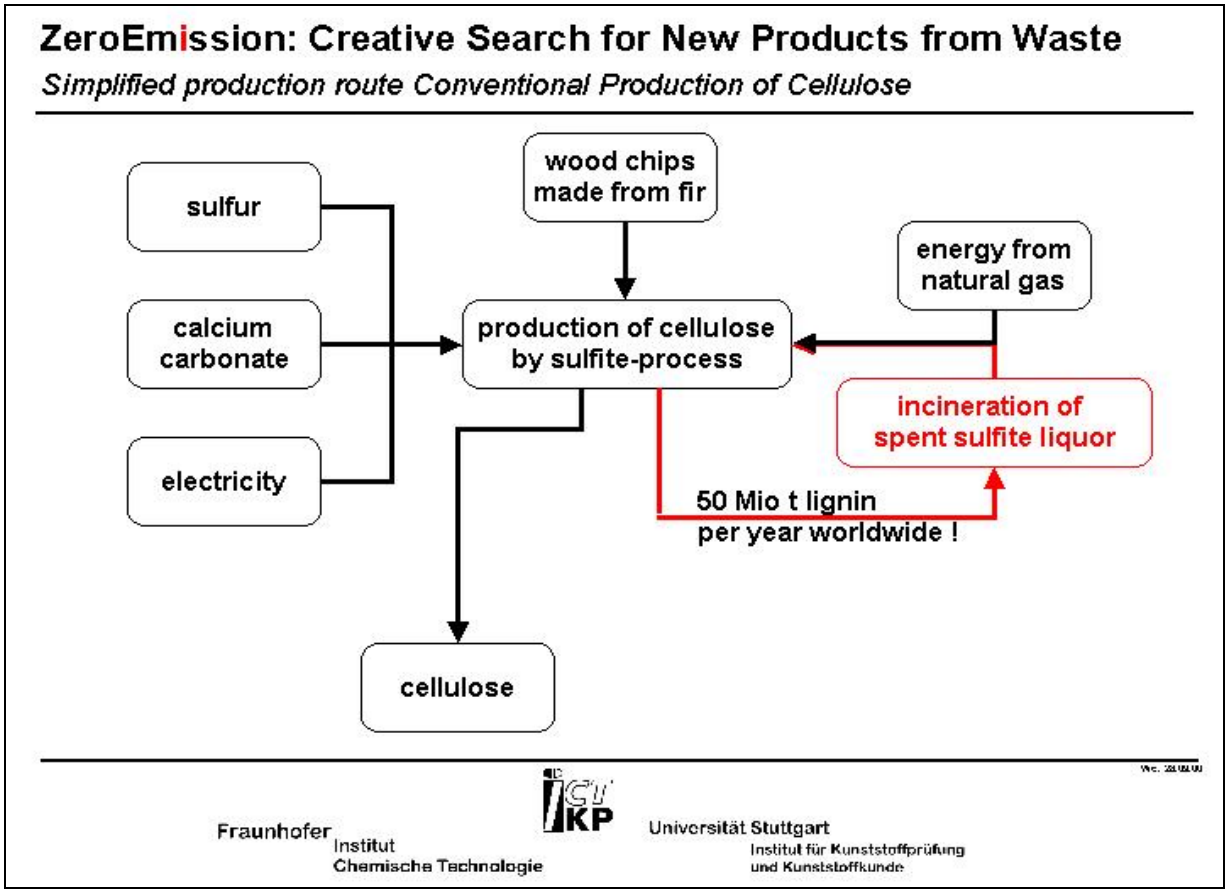
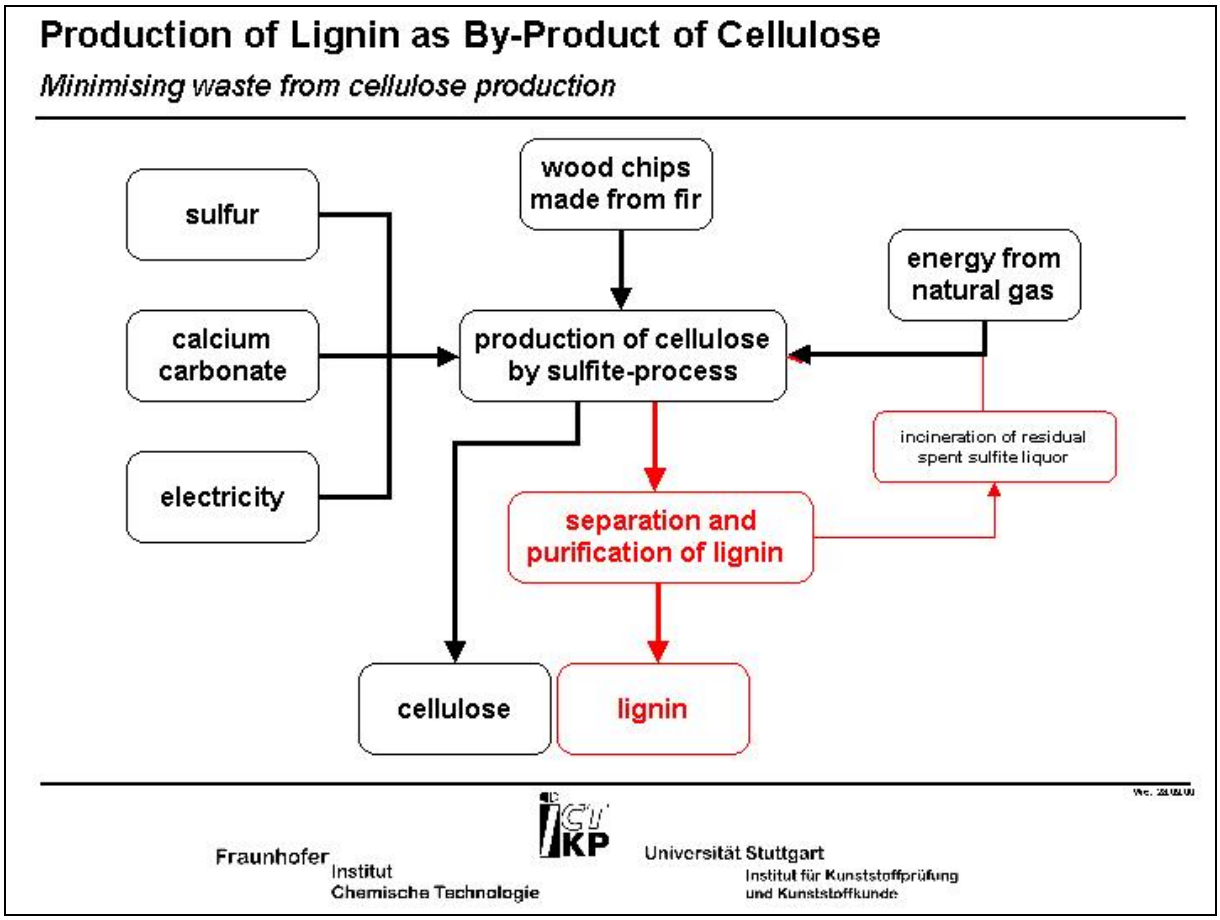

ZeroEmission: Creative Search for New Products from Waste
Simplified production route Conventional Production of Cellulose
wood chips made from fir
sulfur
energy from natural gas
calcium carbonate
production of cellulose by sulfite-process
incineration of spent sulfite liquor
electricity
50 Mio t lignin per year worldwide !
cellulose
Fraunhofer Institut Chemische Technologie
ICT IKP
Universität Stuttgart
Institut für Kunststoffprüfung und Kunststoffkunde


Production of Lignin as By-Product of Cellulose
Minimising waste from cellulose production
wood chips made from fir
sulfur
energy from natural gas
calcium carbonate
production of cellulose by sulfite-process
incineration of residual spent sulfite liquor
electricity
separation and purification of lignin
cellulose
lignin
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Universität Stuttgart
Institut für Kunststoffprüfung und Kunststoffkunde

Lignin - Material Made from Waste for Use as a Polymer

Ligno-sulfonate
(50 Mio t per annum world-wide)

+

Natural fibres
Flax, hemp, sisal, bamboo, etc.

→ **polymer pellets** → **processable with injection molding**

Results:

- Properties: composite, comparable to glass fibre-reinforced polyamides or to ABS. (Data: tensile strength10-22 N/m², elastic modulus 1000-5000 N/m², density 1,3 g/cm³, thrinkage after extrusion 0,1-0,3%. Disadvantages: brittleness, odour)

Products (on the market / currently under development):

- Core of steering wheels for high quality cars
- Internal parts for automobiles
- Core of window frames
- Core of veneered furniture and of parquet floor
- ***Body for watch and for pen***
- etc.

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ZeroEmission Case Study: Comparison of Watch-Cases

Technical settings of watch-cases

	Lignin-Polymer	ABS
Weight [g]	6	5
Reinforcement	30% flax fibers	no
Production Process	Injection molding	Injection molding
Recycling of Production-Waste	yes	yes
Coated	yes	no
End-of-Life Scenario	Incineration with energy recovery	Incineration with energy recovery

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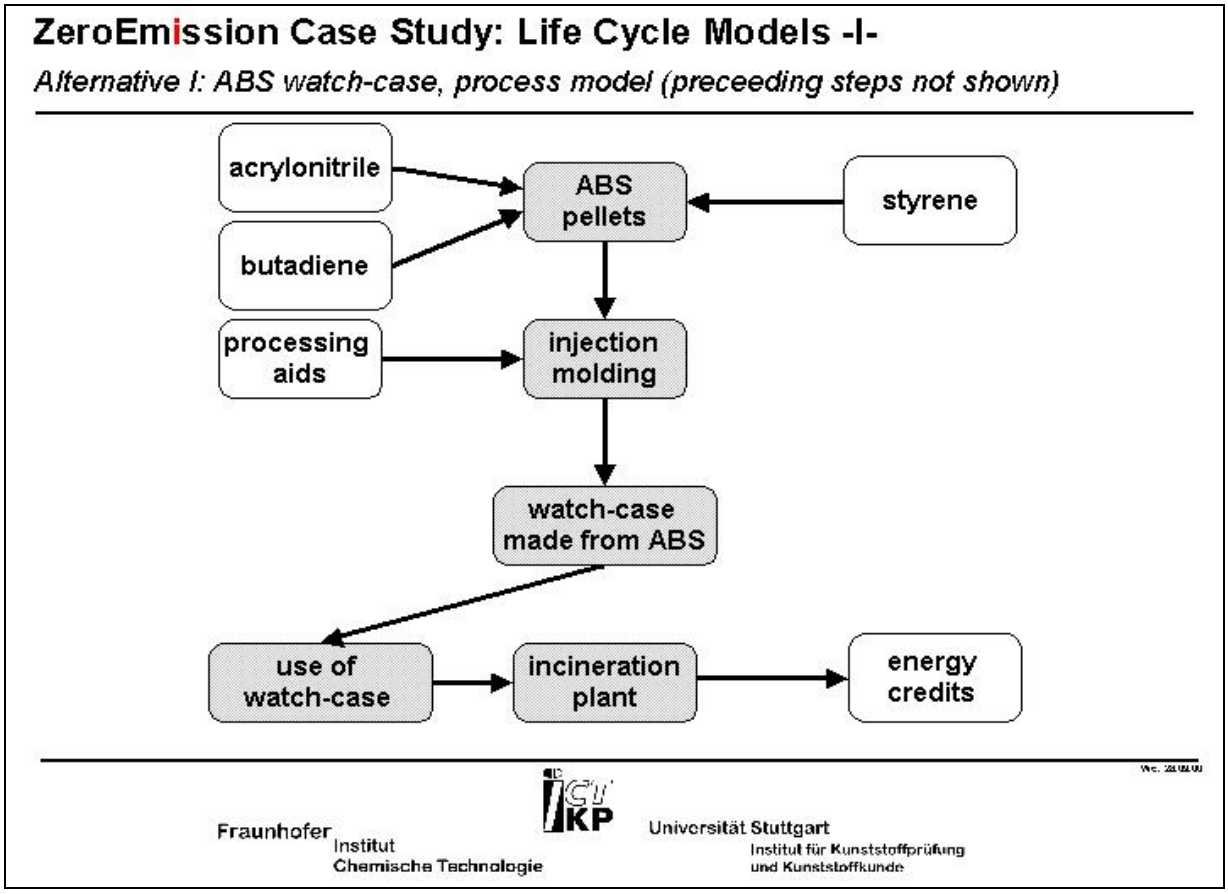
ZeroEmission Case Study: Life Cycle Models -I-
Alternative I: ABS watch-case, process model (preceeding steps not shown)
acrylonitrile
butadiene
ABS pellets
styrene
processing aids
injection molding
watch-case made from ABS
use of watch-case
incineration plant
energy credits
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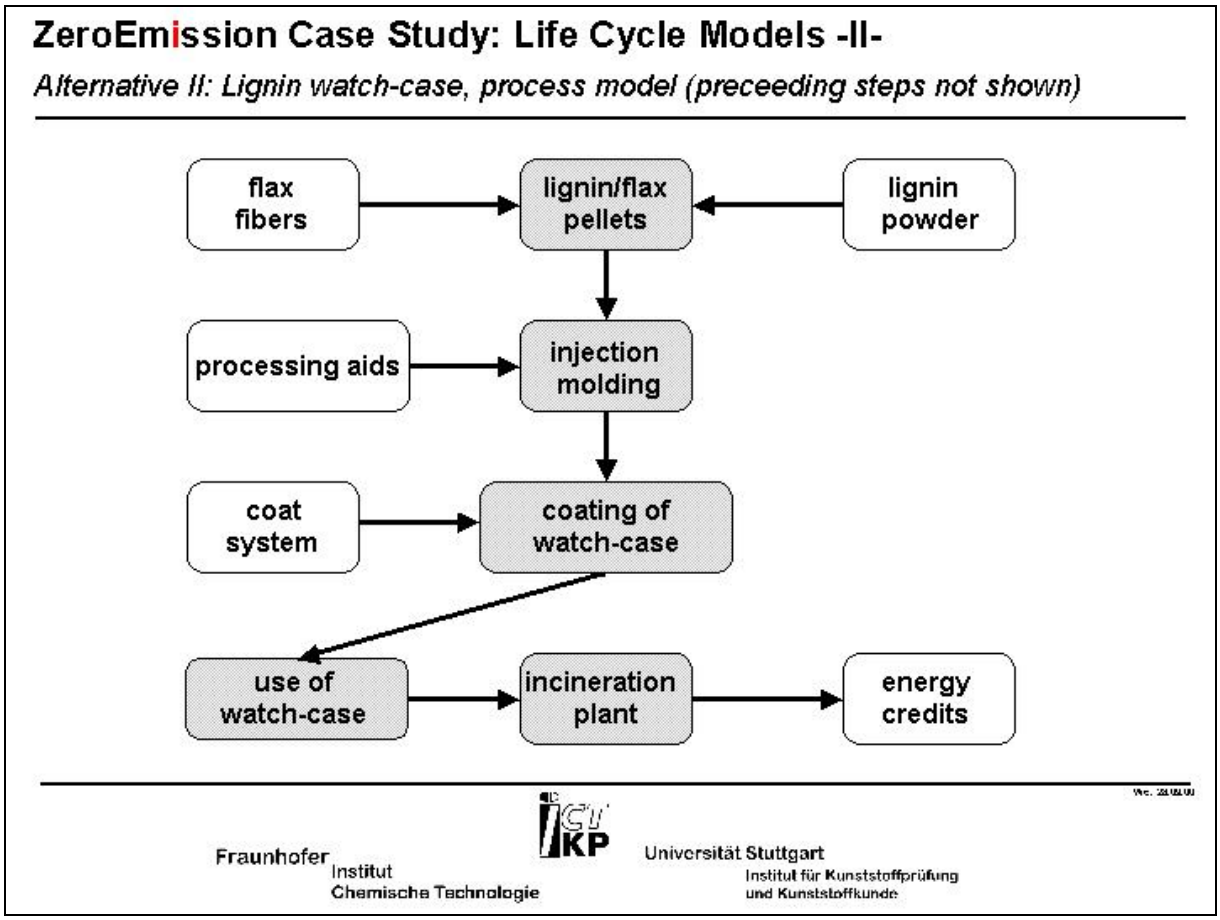
ZeroEmission Case Study: Life Cycle Models -II-
Alternative II: Lignin watch-case, process model (preceeding steps not shown)
flax fibers
lignin/flax pellets
lignin powder
processing aids
injection molding
coat system
coating of watch-case
use of watch-case
incineration plant
energy credits
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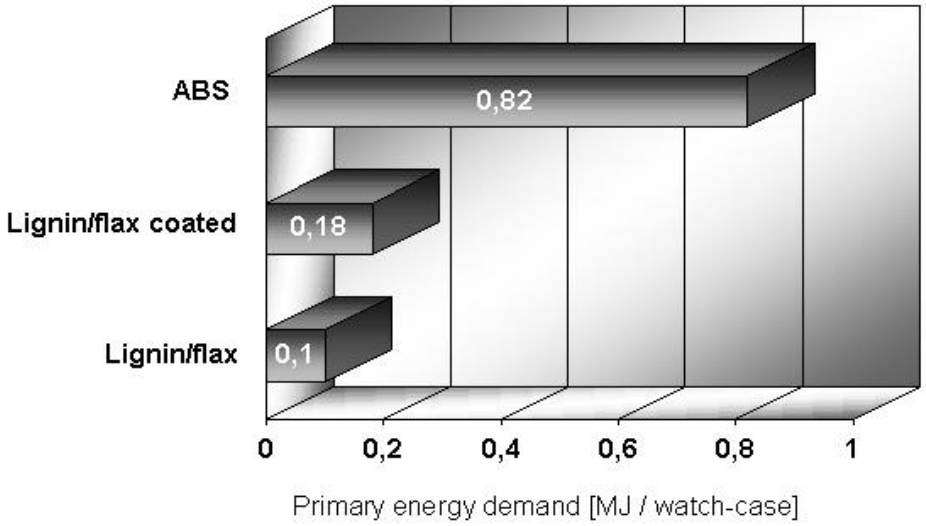
ZeroEmission Case Study: Results -I-

Demand on primary energy for the total life cycle of different watch-cases



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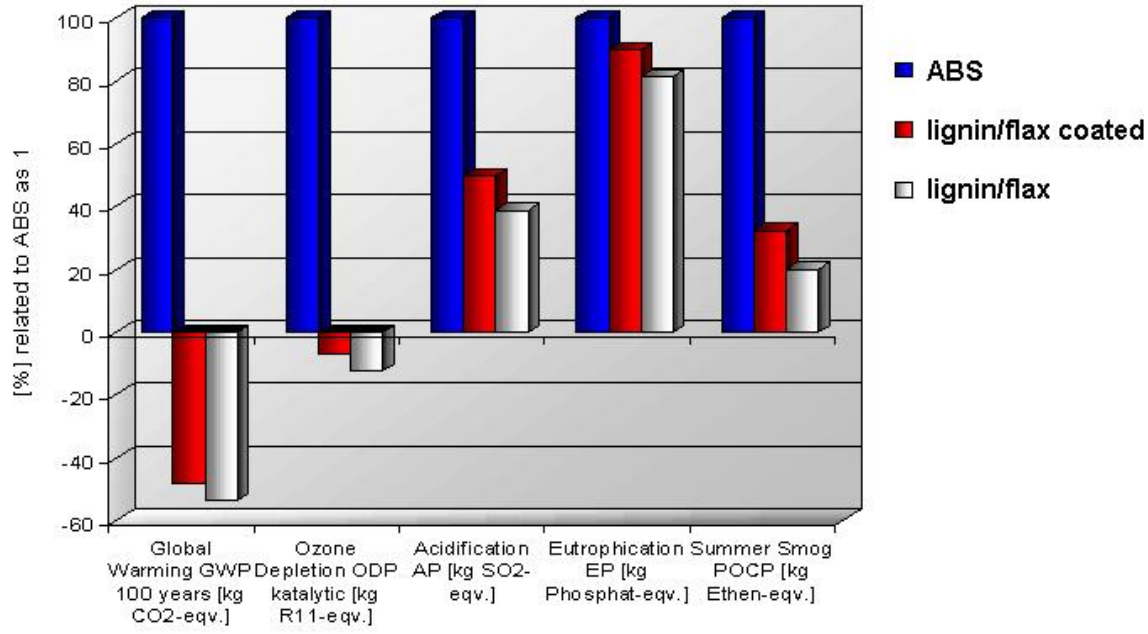
ZeroEmission Case Study: Results -II-

Environmental Life Cycle Impact Assessment



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ZeroEmission Case Study: Results -III-

Economic Evaluation (Life Cycle Costing)

Material costs for ...

- flax-fibre reinforced lignin: US$ 2.5 to 3.0 per kg
- glass-fibre reinforced polyamide: US$ 3.5 to 4.0 per kg
- ABS US$ 1.0 to 2.0 per kg

Costs of watch-case made from ...

- flax-fibre reinforced lignin: ca. US$ 2,50 per unit
- ABS: ca. US$ 1,10 per unit

Weak points of lignin-based product are...

- longer cycle-times for injection molding
- additional costs for coating
- smell, color, relative brittleness of material
- higher material costs

Through technological innovation the weak points are presently improved

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ZeroEmission Case Study: Results -IV-

Socio-Economic Evaluation (LCMP)

Quantitative results:

- 33,5 s manpower per watch-case made from fibre-reinforced lignin compared to 15,1 s for standard product made from ABS
- 96,3 s manpower per kg fibre-reinforced lignin granulate compared to 14,7 s per kg ABS granulate

Assuming a market of 100.000 t per year this means many jobs created on a net base.

Further quantitative and qualitative aspects:

- Saving of natural resources (through reduced consumption of fossile energy resources)
- Improvement of the quality of life (through reduced emissions of substances contributing to acid rain and photosmog; reduced emission of other toxic substances to air and reduced discharge of spent liquor to rivers)
- Cellulose is produced worldwide; the required technologies (extraction, injection-molding) are also available in developing countries. Lignin can hence improve the income-situation worldwide
- New source of income for poorly developed regions through increased demand for agrarian products (fibres from flax, sisal, or hemp etc.)

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Socio-Economic Evaluation (LCMP) - further development

Focus of further development of the LCMP methodology:

- include also jobs not directly linked to production process (overhead)
- differentatiate between different qualification levels of workforce
- include quality of working place (accidents, noise, daily working hours, etc.)
- evaluate possibilities to quantitatively include qualitative product-related aspects

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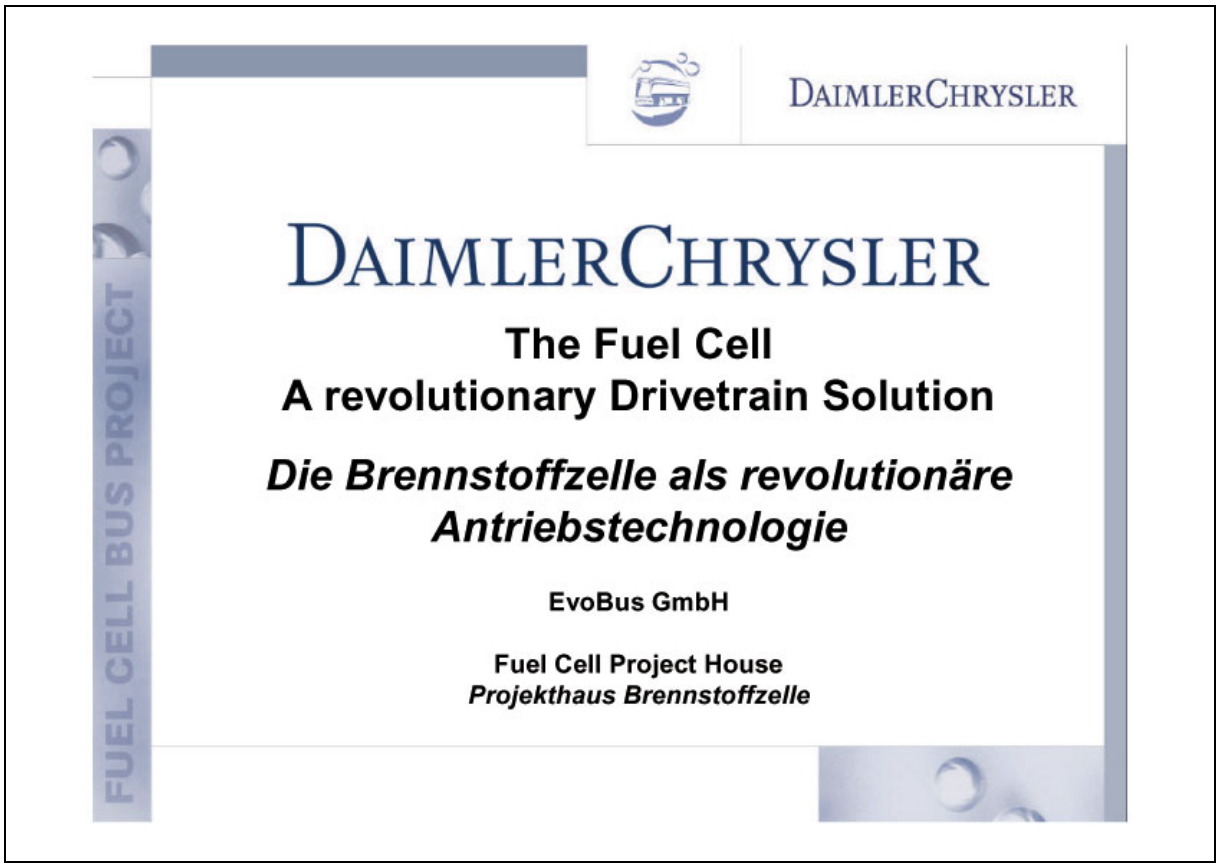
ICT IKP

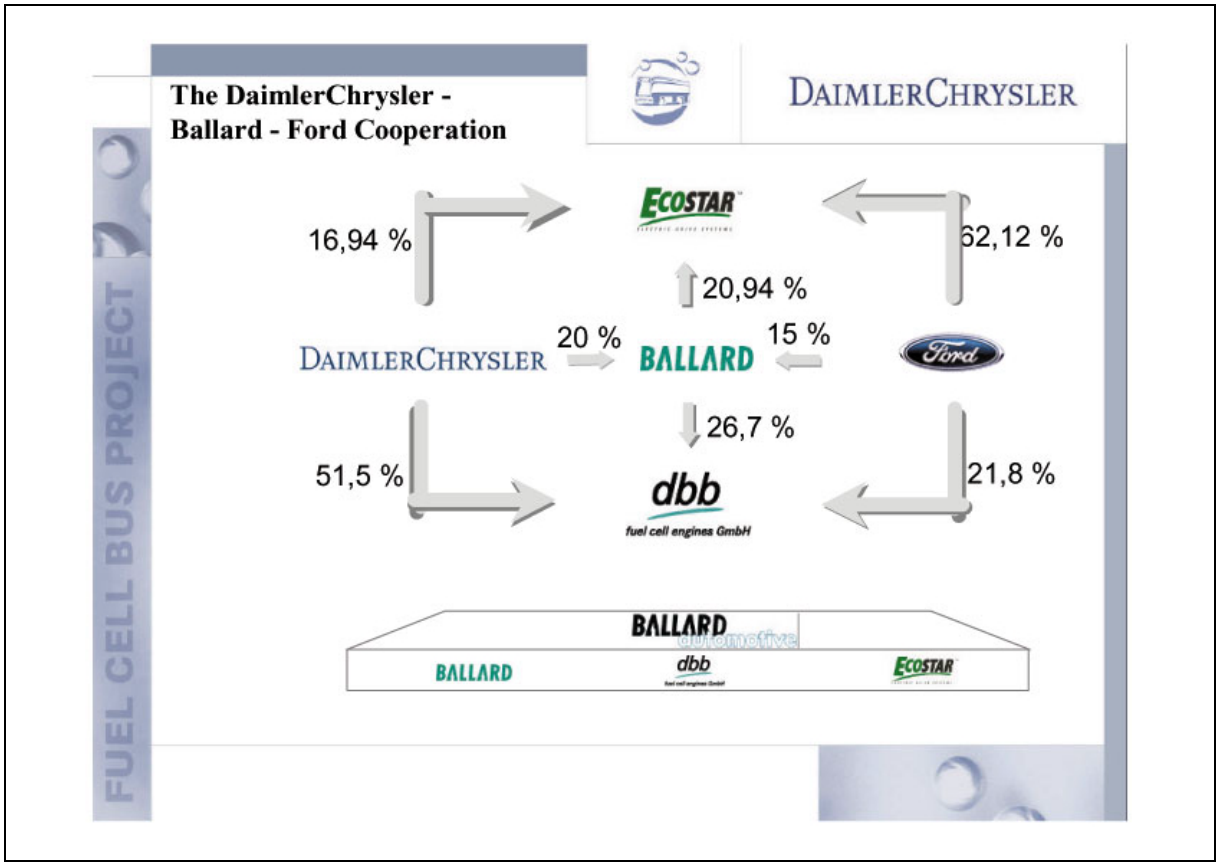
Universität Stuttgart Institut für Kunststoffprüfung und Kunststoffkunde

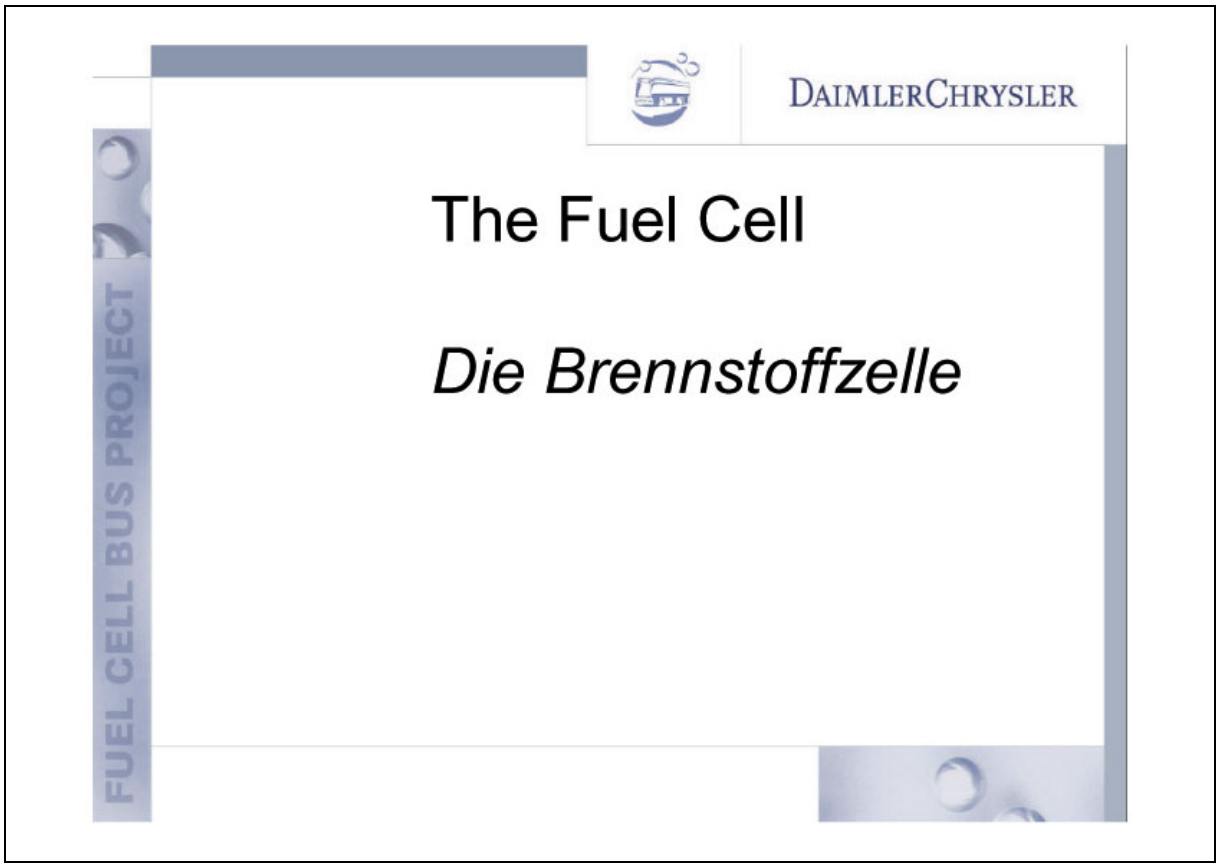
Fuel cells as efficient and marketable energy conversion system in transport systems

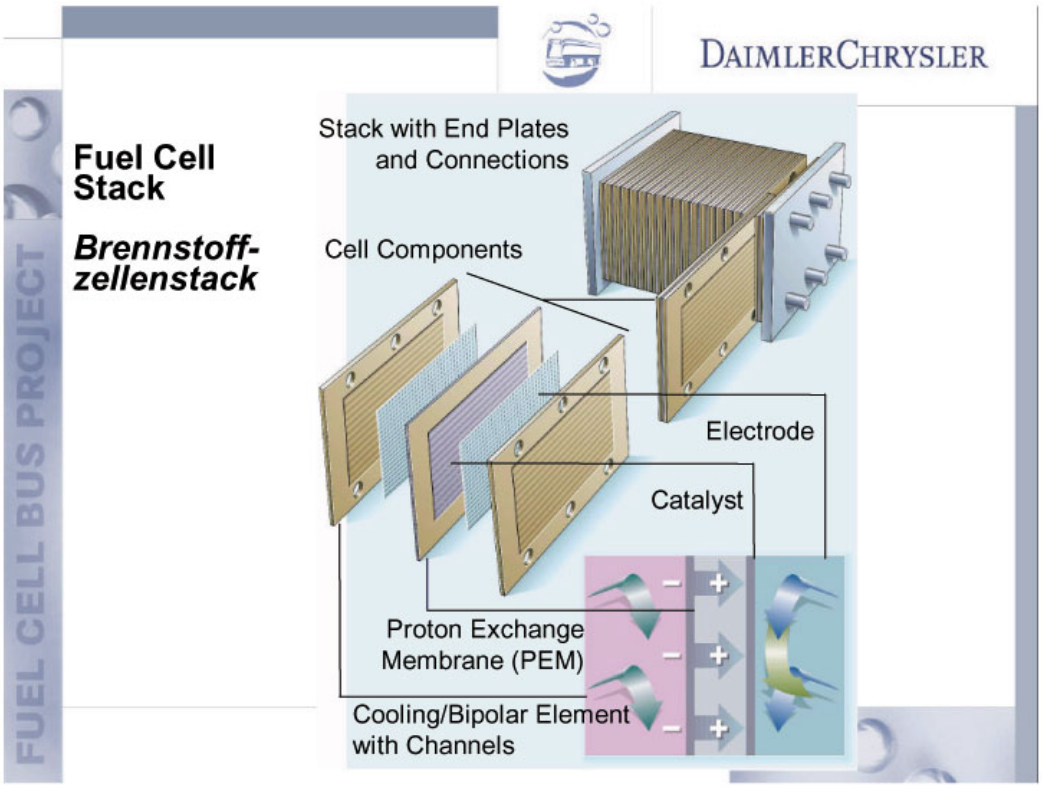
Manfred Schuckert

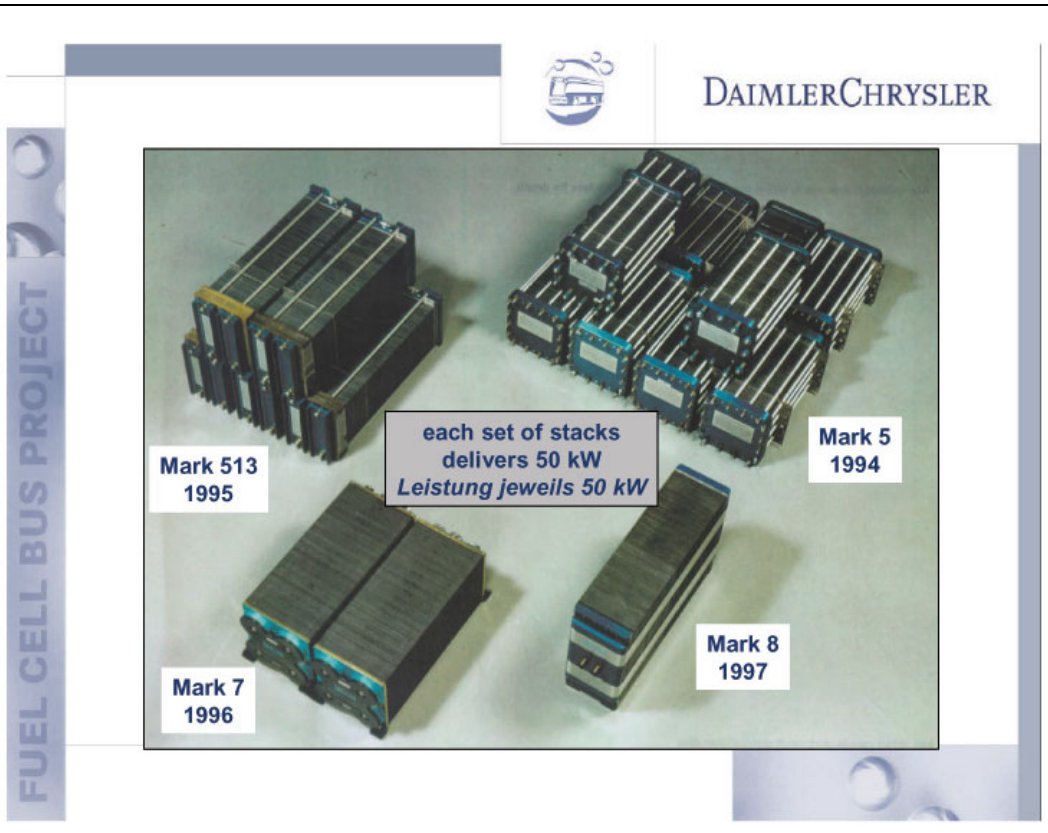
Daimler-Chrysler Evobus




The DaimlerChrysler -
Ballard - Ford Cooperation
DAIMLERCHRYSLER
FUEL CELL BUS PROJECT
ECOSTAR
16,94 %
62,12 %
20,94 %
DAIMLERCHRYSLER
20 %
BALLARD
15 %
Ford
26,7 %
51,5 %
21,8 %
dbb
fuel cell engines GmbH
BALLARD
automotive
BALLARD
dbb
ECOSTAR


DAIMLERCHRYSLER
FUEL CELL BUS PROJECT
The Fuel Cell
Die Brennstoffzelle


DAIMLERCHRYSLER
FUEL CELL BUS PROJECT
Fuel Cell Stack
Brennstoff-zellenstack
Stack with End Plates and Connections
Cell Components
Electrode
Catalyst
Proton Exchange Membrane (PEM)
Cooling/Bipolar Element with Channels


DAIMLERCHRYSLER
FUEL CELL BUS PROJECT
each set of stacks delivers 50 kW
Leistung jeweils 50 kW
Mark 513 1995
Mark 5 1994
Mark 7 1996
Mark 8 1997

DAIMLERCHRYSLER

FUEL CELL BUS PROJECT

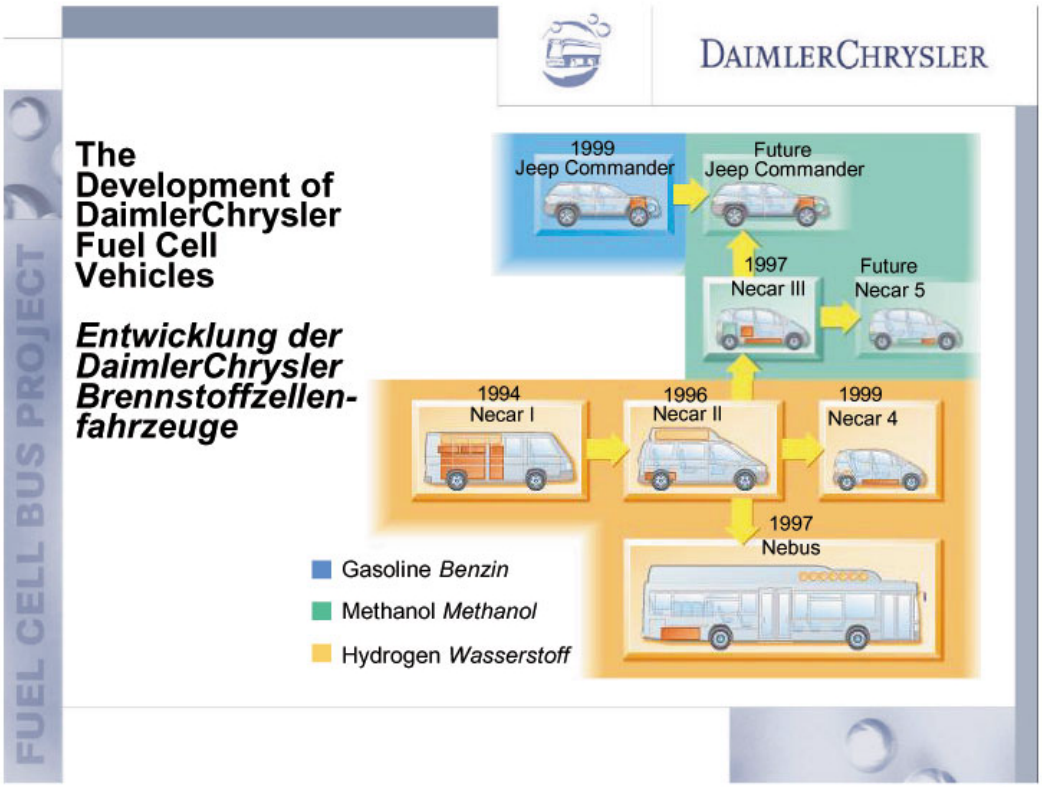
Mark 9 - 2000
maximum power *Maximalleistung*: 80 kW on hydrogen *Wasserstoff*/
75 kW on methanol reformate *Methanolreformat*
weight *Gewicht:* 90 kg / volume *Volumen:* 77 ltrs.

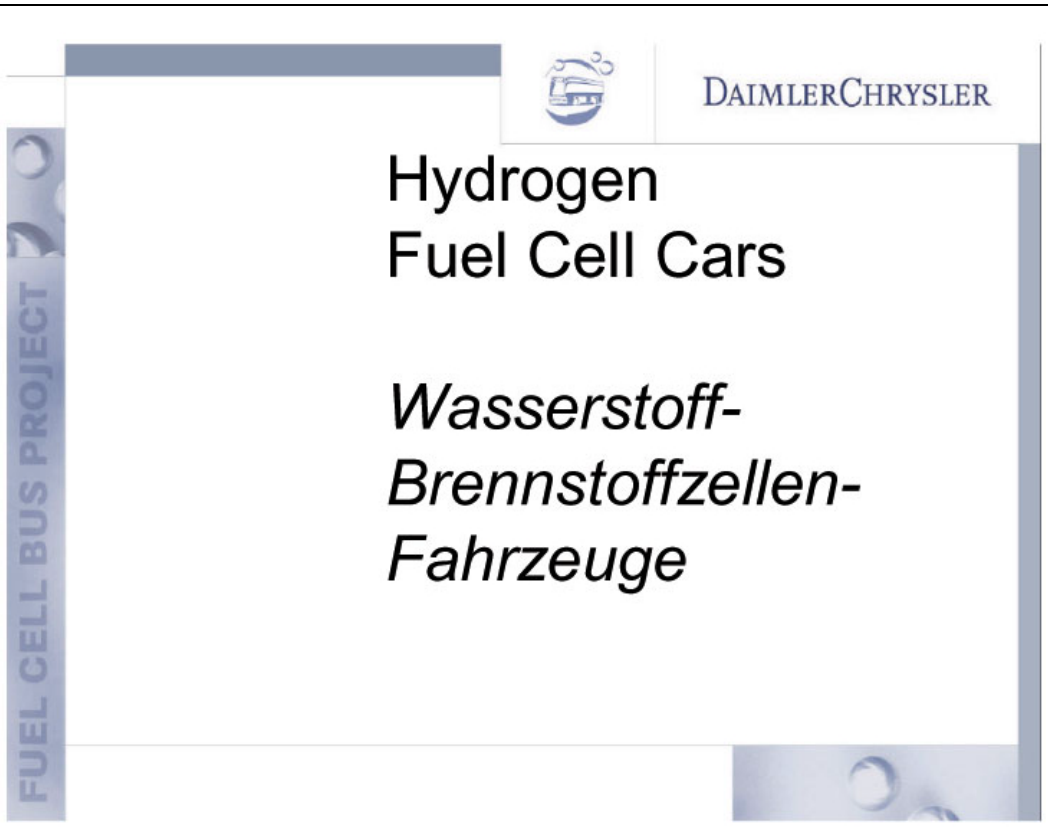
DAIMLERCHRYSLER

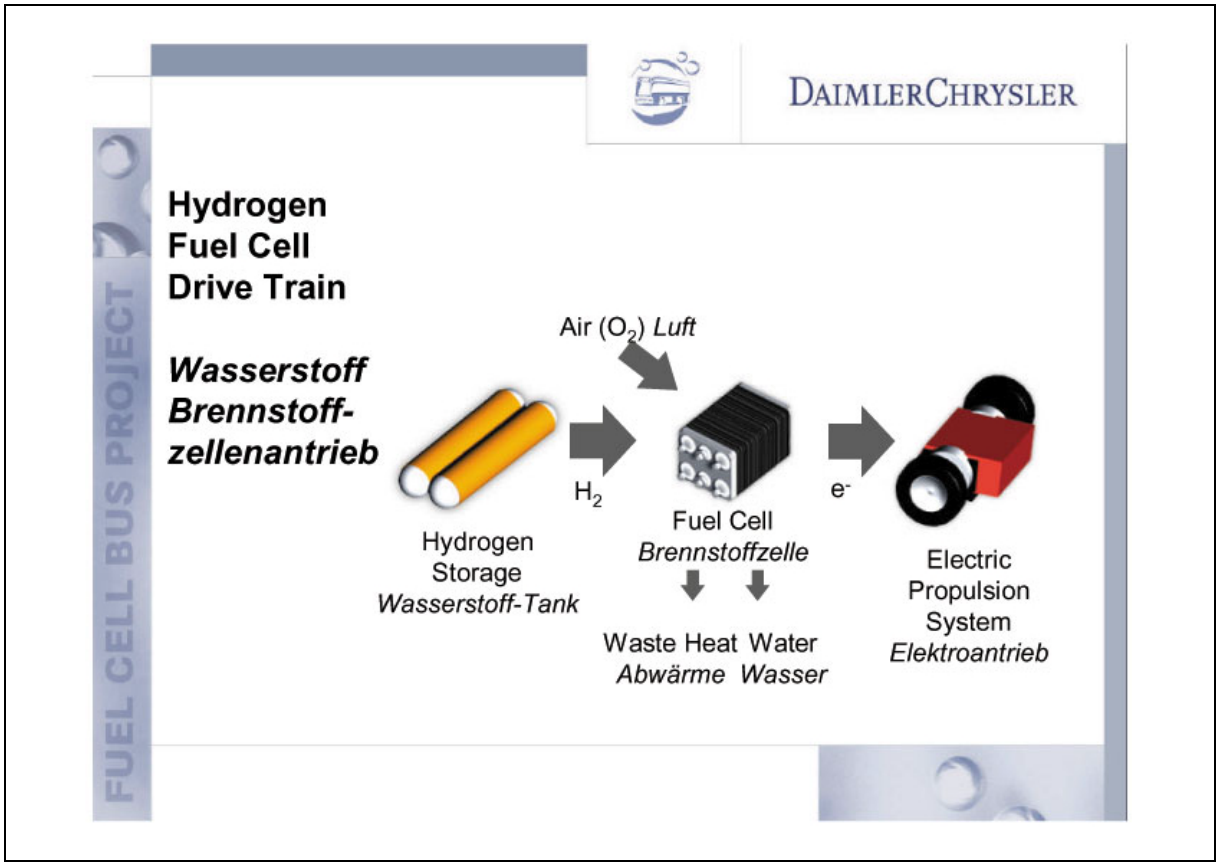
FUEL CELL BUS PROJECT

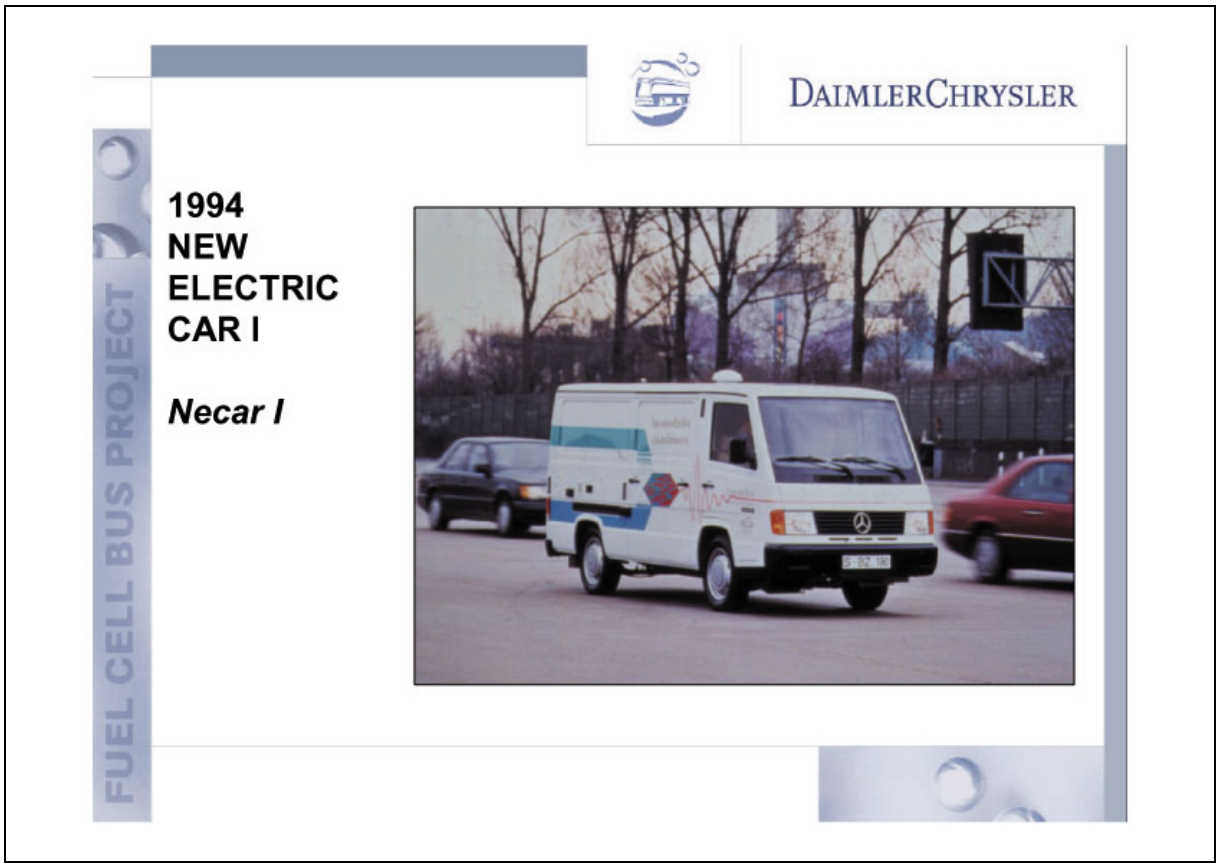
The Fuel Cell Vehicles

Die Brennstoffzellen-Fahrzeuge


DAIMLERCHRYSLER
FUEL CELL BUS PROJECT
The Development of DaimlerChrysler Fuel Cell Vehicles
Entwicklung der DaimlerChrysler Brennstoffzellen-fahrzeuge
1999 Jeep Commander
Future Jeep Commander
1997 Necar III
Future Necar 5
1994 Necar I
1996 Necar II
1999 Necar 4
1997 Nebus
Gasoline Benzin
Methanol Methanol
Hydrogen Wasserstoff


DAIMLERCHRYSLER
FUEL CELL BUS PROJECT
Hydrogen Fuel Cell Cars
Wasserstoff-Brennstoffzellen-Fahrzeuge


DAIMLERCHRYSLER
FUEL CELL BUS PROJECT
Hydrogen
Fuel Cell
Drive Train
Wasserstoff
Brennstoff-
zellenantrieb
Air (O_2) Luft
H_2
e-
Hydrogen
Storage
Wasserstoff-Tank
Fuel Cell
Brennstoffzelle
Waste Heat Water
Abwärme Wasser
Electric
Propulsion
System
Elektroantrieb


DAIMLERCHRYSLER
FUEL CELL BUS PROJECT
1994
NEW
ELECTRIC
CAR I
Necar I

FUEL CELL BUS PROJECT

DAIMLERCHRYSLER

1996
NEW
ELECTRIC
CAR II

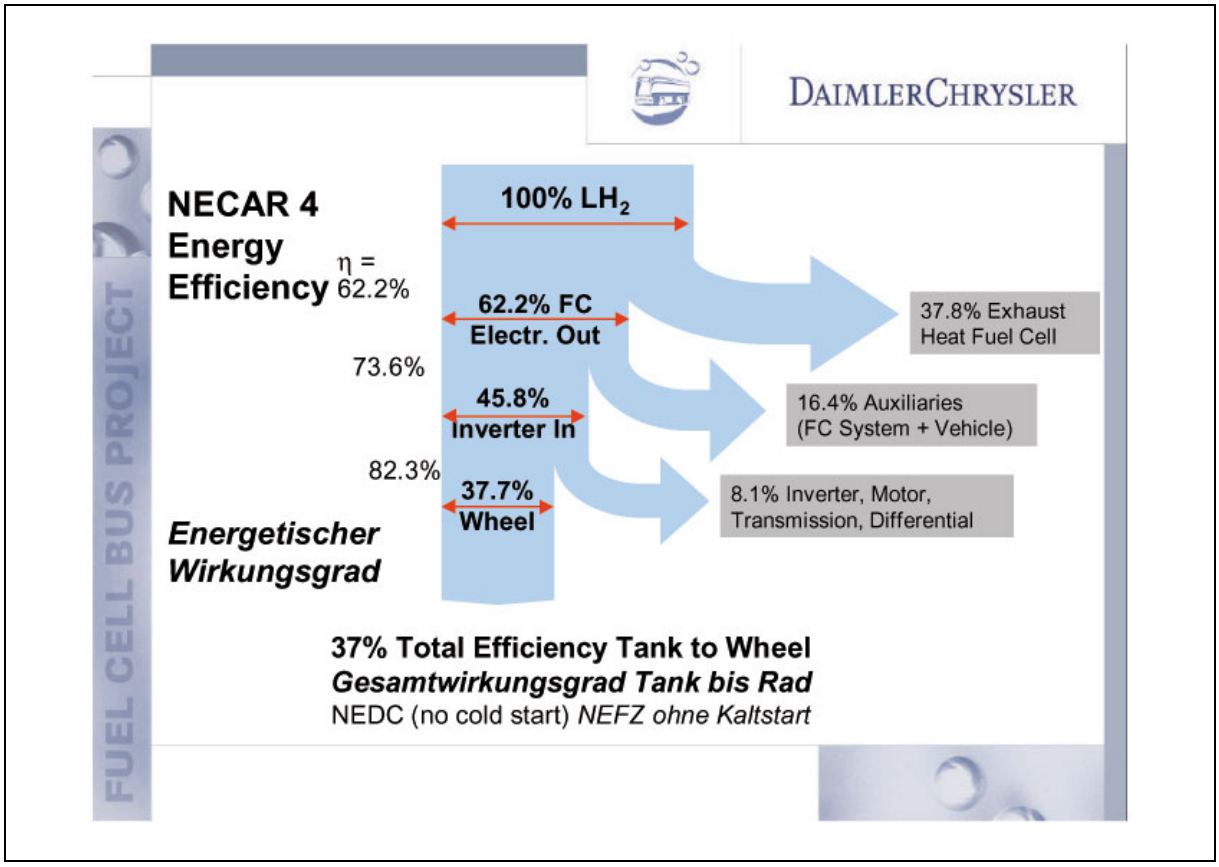
Necar II

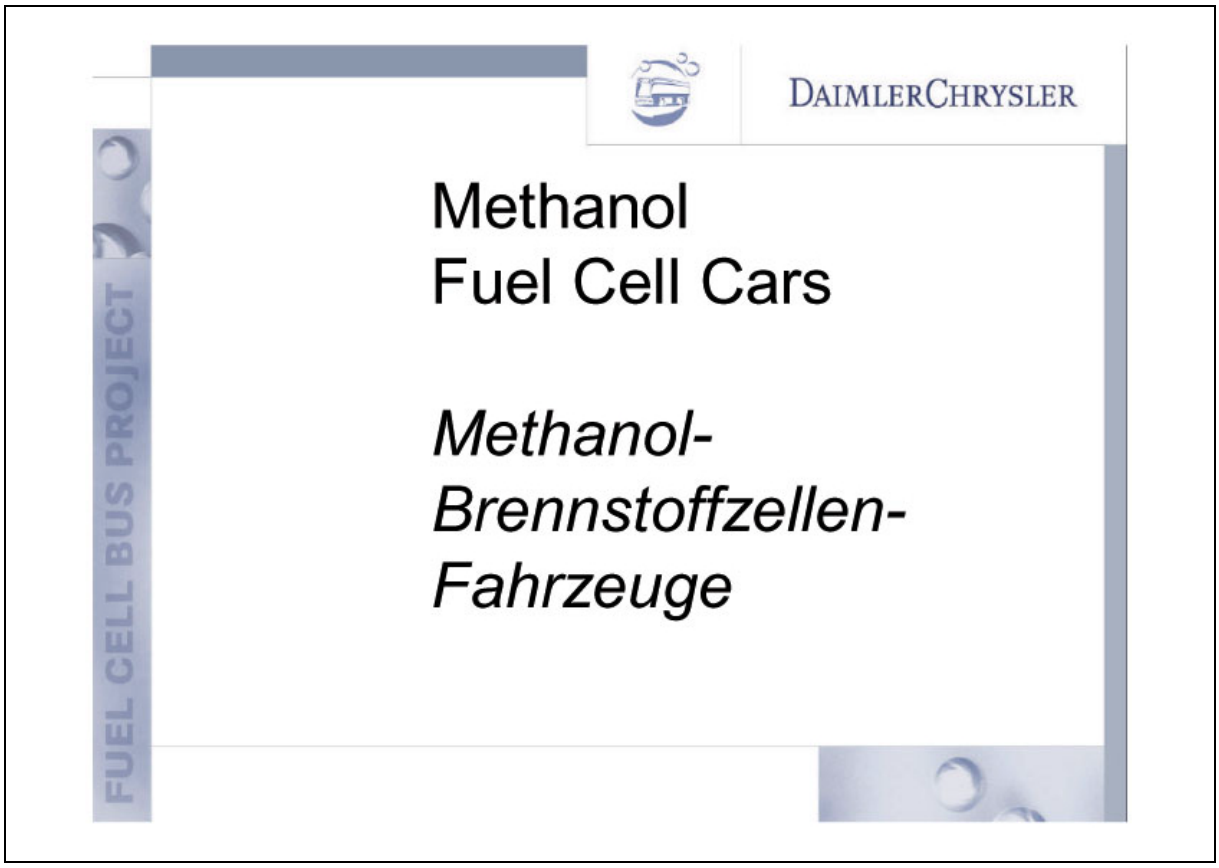
FUEL CELL BUS PROJECT

DAIMLERCHRYSLER

1999
NEW
ELECTRIC
CAR 4

Necar 4


DAIMLERCHRYSLER
FUEL CELL BUS PROJECT
NECAR 4
Energy
Efficiency
η = 62.2%
100% LH2
62.2% FC
Electr. Out
37.8% Exhaust
Heat Fuel Cell
73.6%
45.8%
Inverter In
16.4% Auxiliaries
(FC System + Vehicle)
82.3%
37.7%
Wheel
8.1% Inverter, Motor,
Transmission, Differential
Energetischer
Wirkungsgrad
37% Total Efficiency Tank to Wheel
Gesamtwirkungsgrad Tank bis Rad
NEDC (no cold start) NEFZ ohne Kaltstart

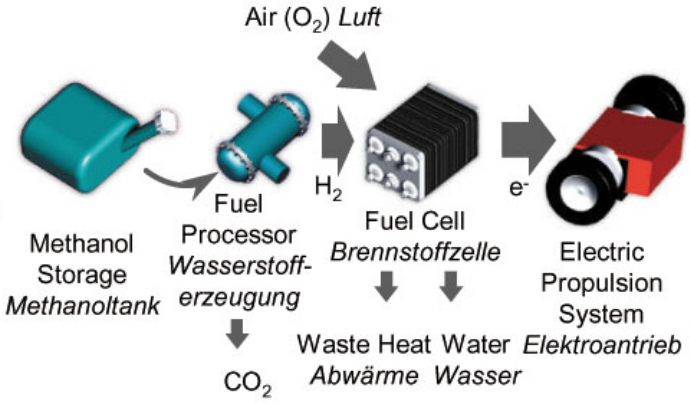

DAIMLERCHRYSLER
FUEL CELL BUS PROJECT
Methanol
Fuel Cell Cars
Methanol-
Brennstoffzellen-
Fahrzeuge

DAIMLERCHRYSLER

FUEL CELL BUS PROJECT

Methanol Fuel Cell Drive Train

Methanol Brennstoff-zellenantrieb



DAIMLERCHRYSLER

FUEL CELL BUS PROJECT

1997 NEW ELECTRIC CAR III

Necar 3

DAIMLERCHRYSLER

FUEL CELL BUS PROJECT

Hydrogen Fuel Cell Busses

Wasserstoff-Brennstoffzellenbusse

DAIMLERCHRYSLER

FUEL CELL BUS PROJECT

NEBUS Engine

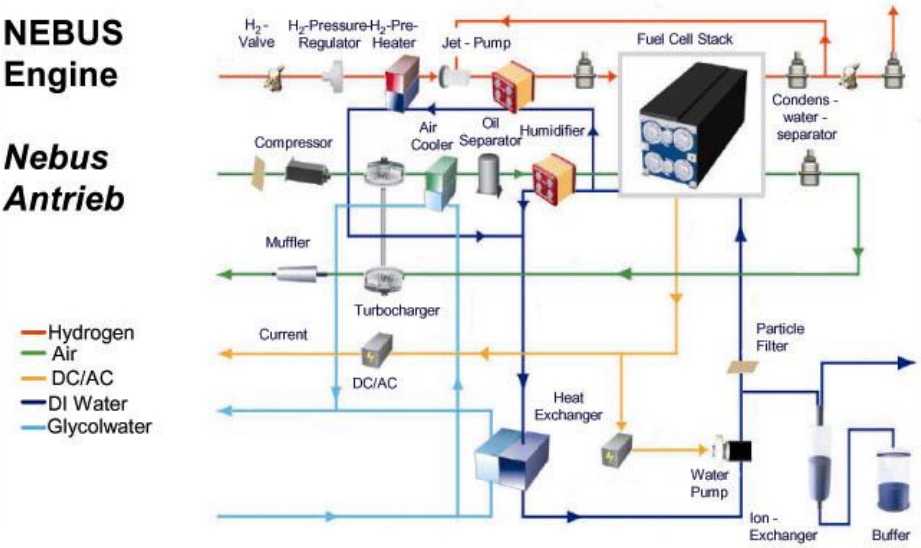
Nebus Antrieb

DAIMLERCHRYSLER

FUEL CELL BUS PROJECT

NEBUS Engine

Nebus Antrieb

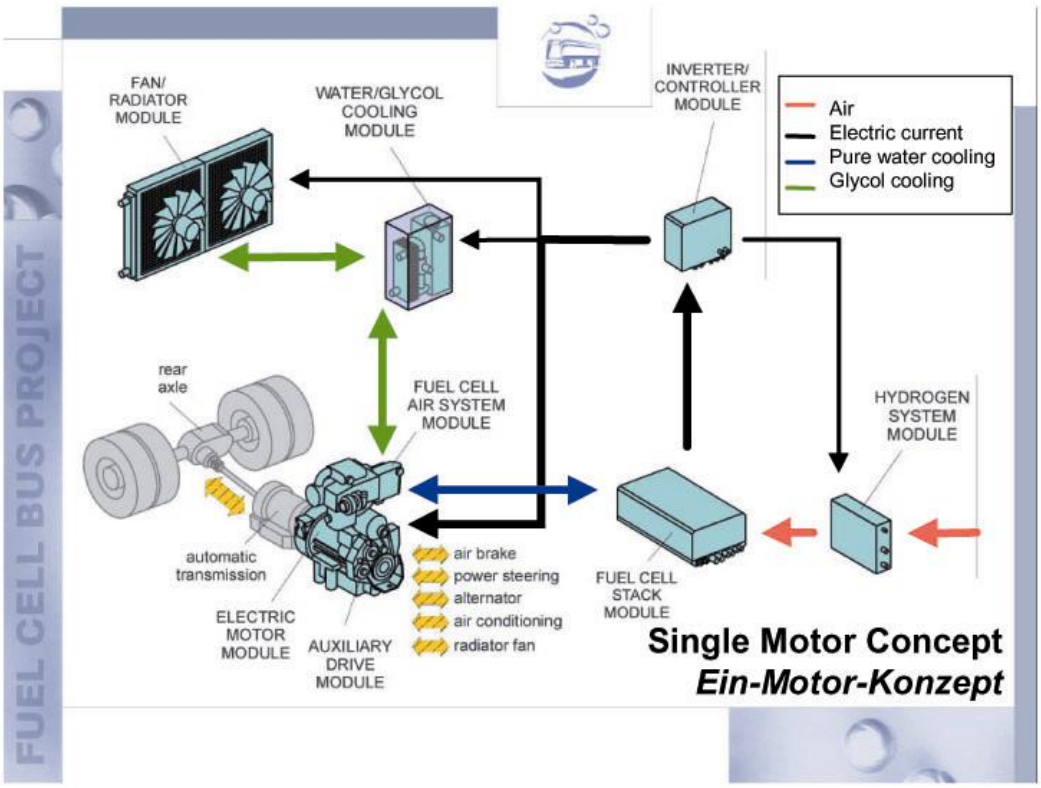


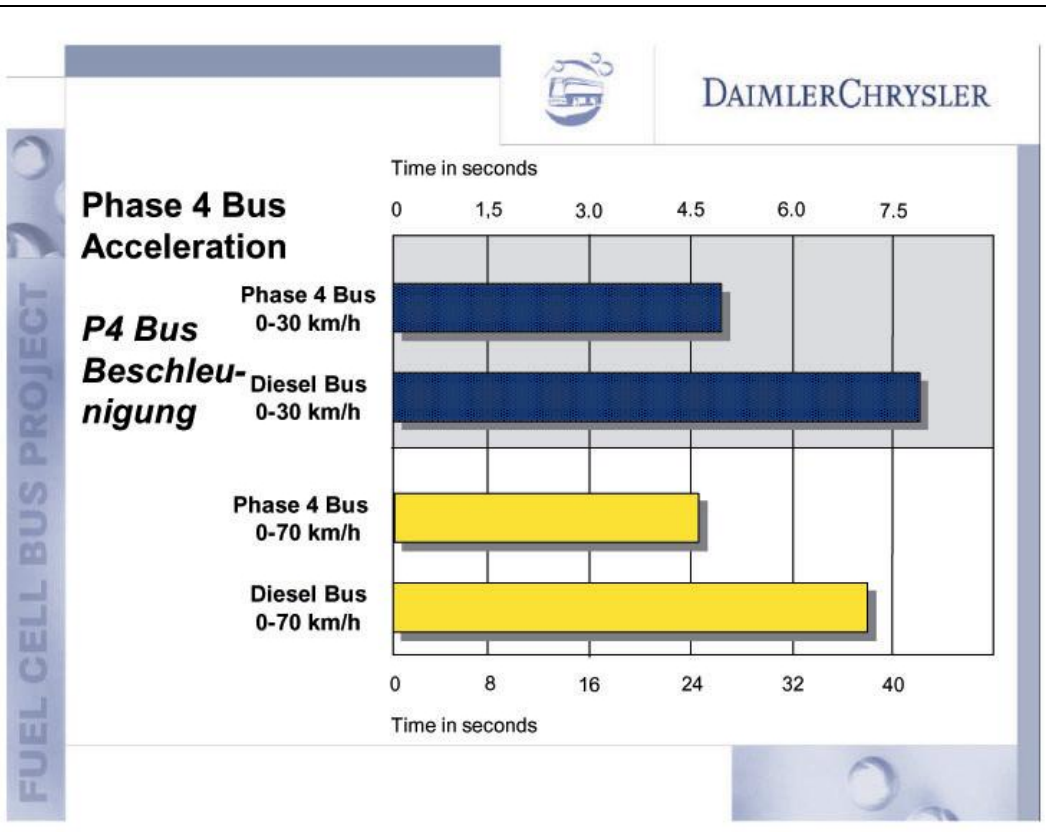
DAIMLERCHRYSLER

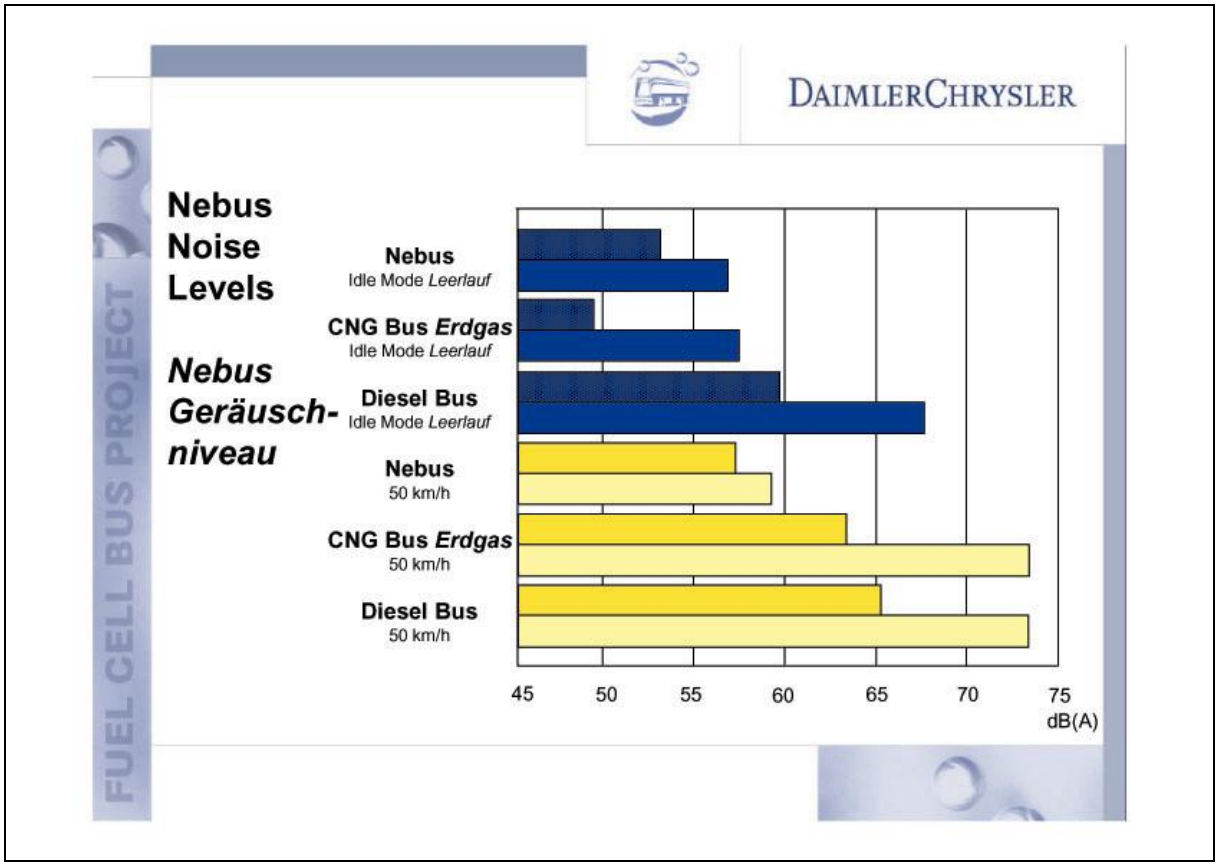
FUEL CELL BUS PROJECT

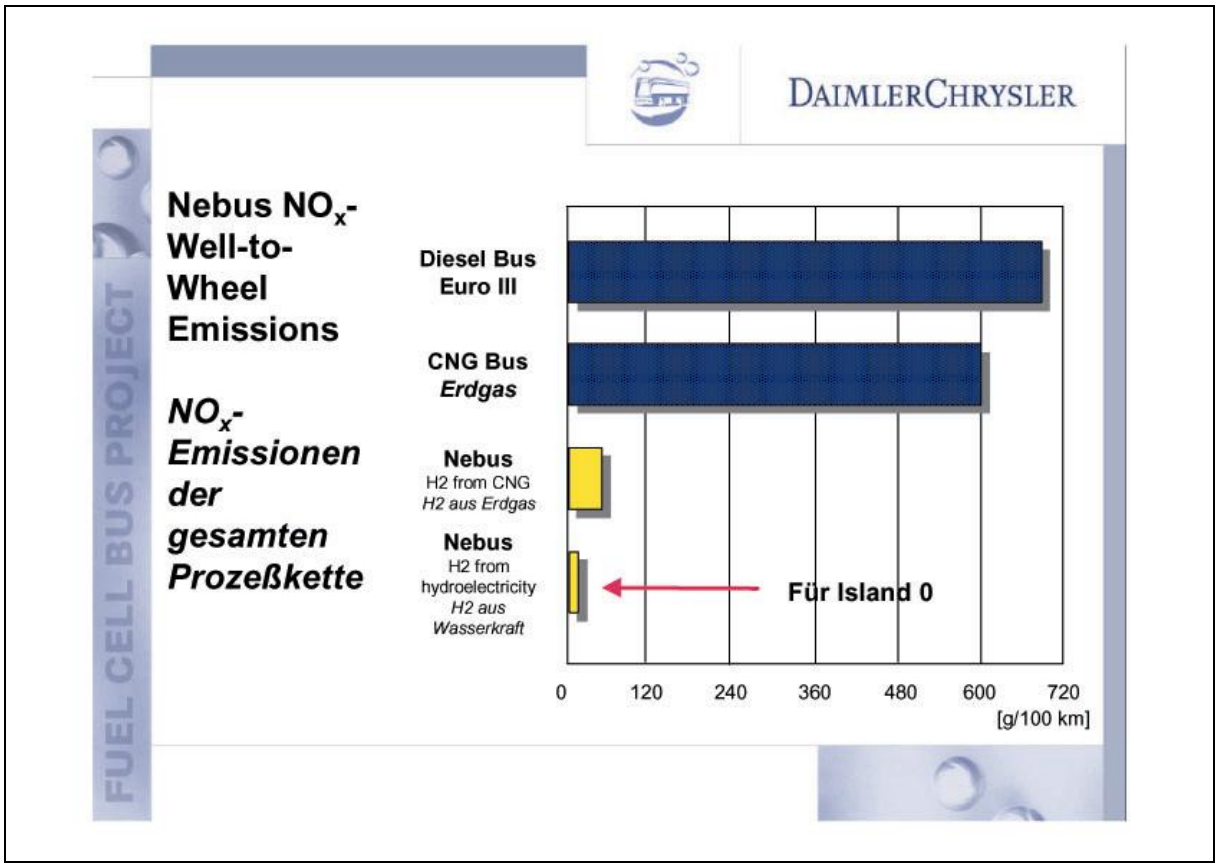
Phase 4 Bus

Bus der 4. Generation


FUEL CELL BUS PROJECT
FAN/
RADIATOR
MODULE
WATER/GLYCOL
COOLING
MODULE
INVERTER/
CONTROLLER
MODULE
Air
Electric current
Pure water cooling
Glycol cooling
rear
axle
FUEL CELL
AIR SYSTEM
MODULE
HYDROGEN
SYSTEM
MODULE
automatic
transmission
air brake
power steering
alternator
air conditioning
radiator fan
FUEL CELL
STACK
MODULE
ELECTRIC
MOTOR
MODULE
AUXILIARY
DRIVE
MODULE
Single Motor Concept
Ein-Motor-Konzept


FUEL CELL BUS PROJECT
DAIMLERCHRYSLER
Phase 4 Bus
Acceleration
P4 Bus
Beschleu-
nigung
Time in seconds
0
1,5
3.0
4.5
6.0
7.5
Phase 4 Bus
0-30 km/h
Diesel Bus
0-30 km/h
Phase 4 Bus
0-70 km/h
Diesel Bus
0-70 km/h
0
8
16
24
32
40
Time in seconds


DAIMLERCHRYSLER
FUEL CELL BUS PROJECT
Nebus Noise Levels
Nebus Geräusch-niveau
Nebus
Idle Mode Leerlauf
CNG Bus Erdgas
Idle Mode Leerlauf
Diesel Bus
Idle Mode Leerlauf
Nebus
50 km/h
CNG Bus Erdgas
50 km/h
Diesel Bus
50 km/h
45
50
55
60
65
70
75
dB(A)


DAIMLERCHRYSLER
FUEL CELL BUS PROJECT
Nebus NOx-Well-to-Wheel Emissions
NOx-Emissionen der gesamten Prozeßkette
Diesel Bus
Euro III
CNG Bus
Erdgas
Nebus
H2 from CNG
H2 aus Erdgas
Nebus
H2 from hydroelectricity
H2 aus Wasserkraft
Für Island 0
0
120
240
360
480
600
720
[g/100 km]


FUEL CELL BUS PROJECT
Fuel Cell Busses
Brennstoff-zellenbusse
NEBUS
no emission
Vancouver
Chicago
Stuttgart/Nabern

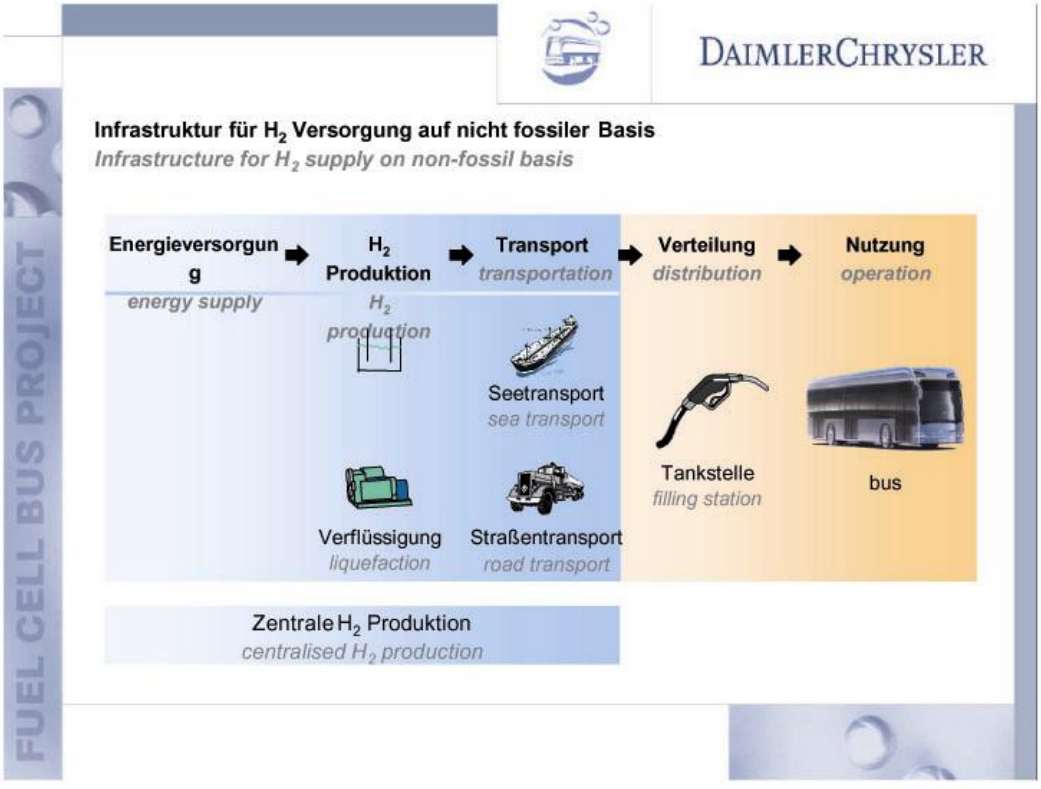

FUEL CELL BUS PROJECT
DAIMLERCHRYSLER
DAIMLERCHRYSLER
NEFLEET - Der erste Flottenversuch mit Mercedes-Benz Brennstoffzellen-Omnibussen
NEFLEET - The first fleet experiment ever with Mercedes-Benz Fuel Cell Buses

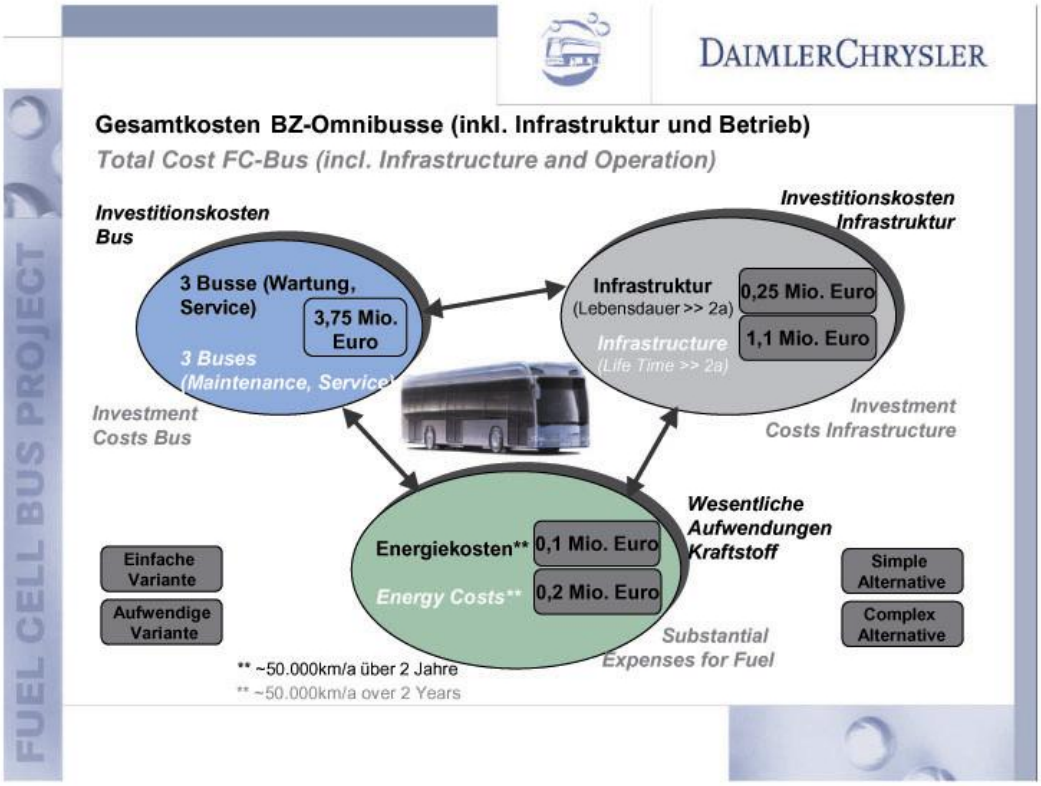
DAIMLERCHRYSLER

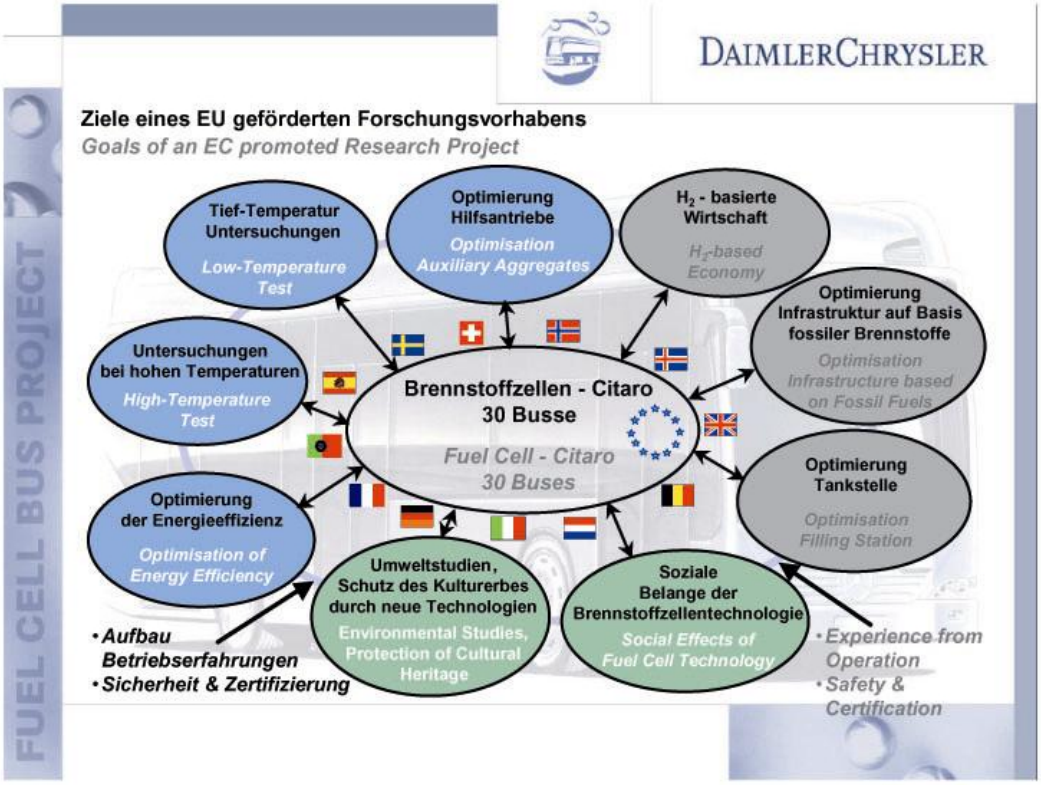
NEFLEET - Aufbau des Brennstoffzellen-Omnibusses

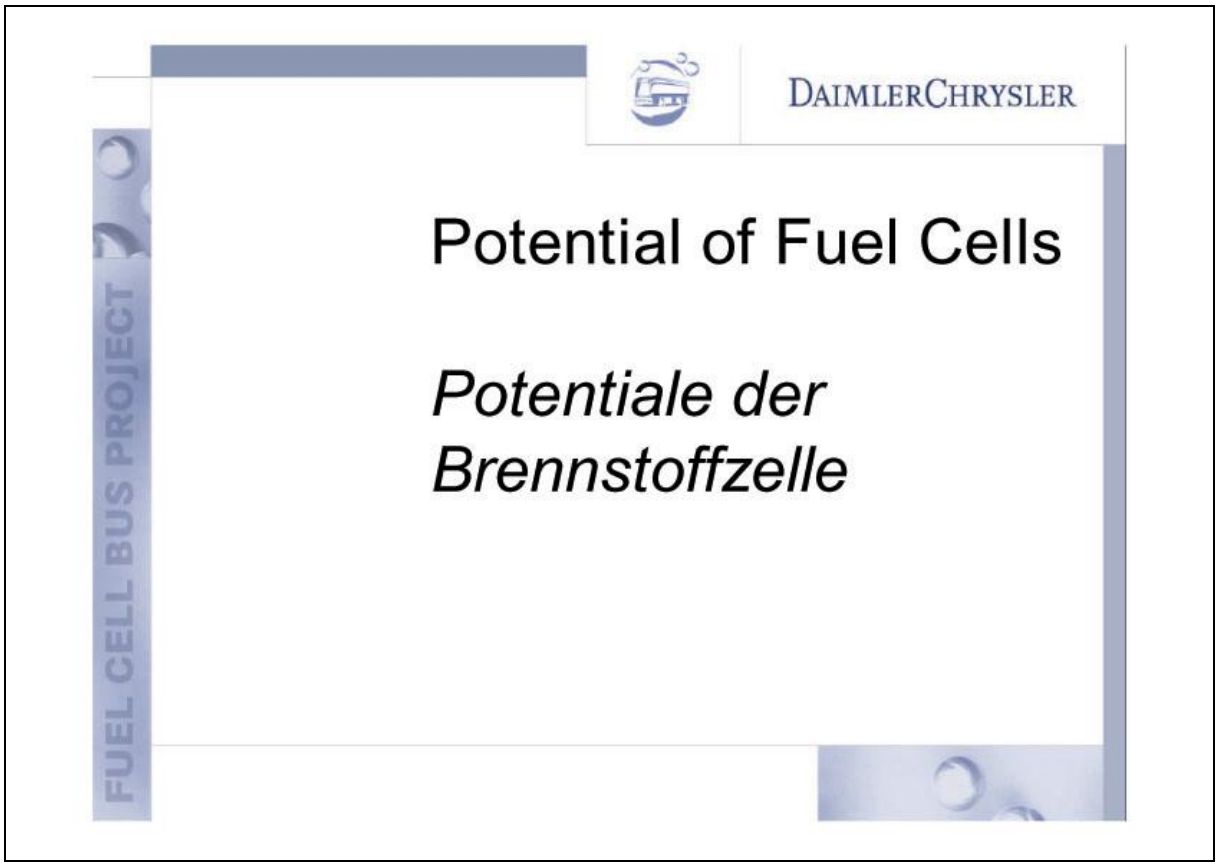
NEFLEET - Design of the Fuel Cell Bus

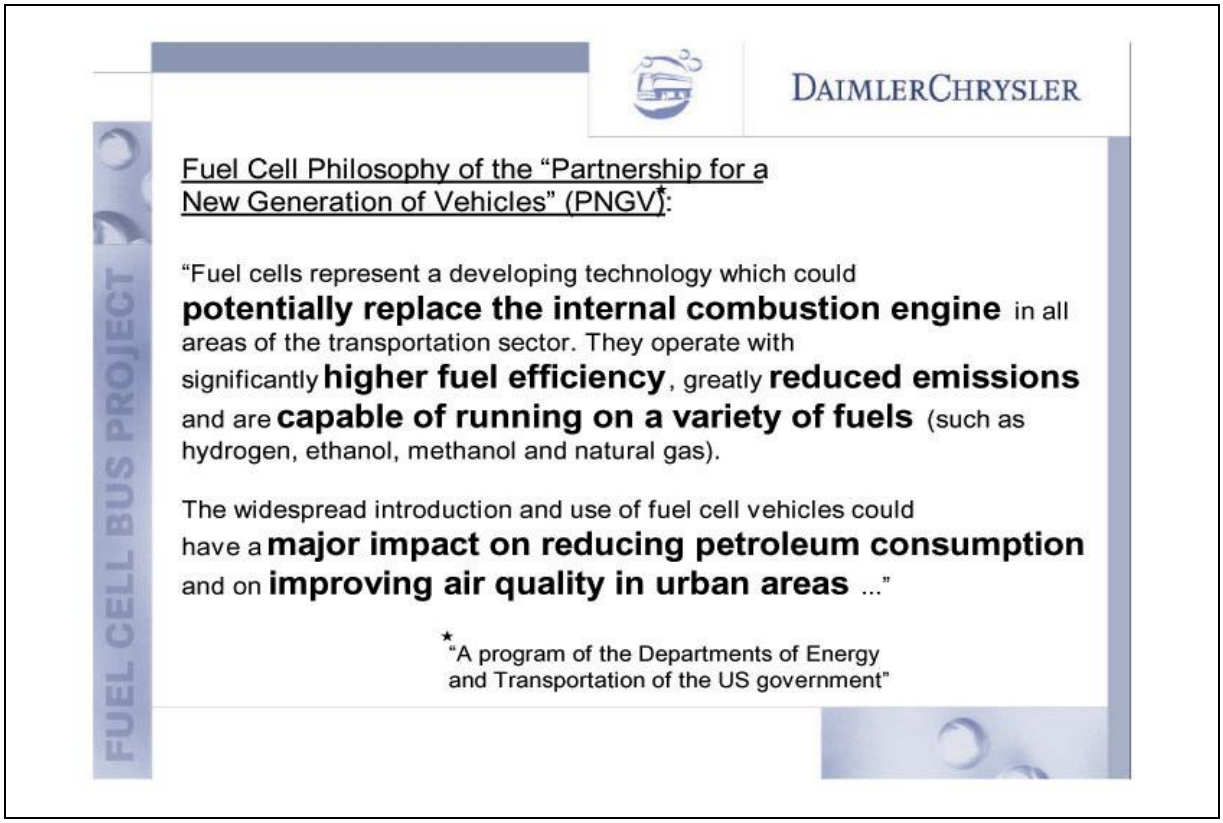
compartment

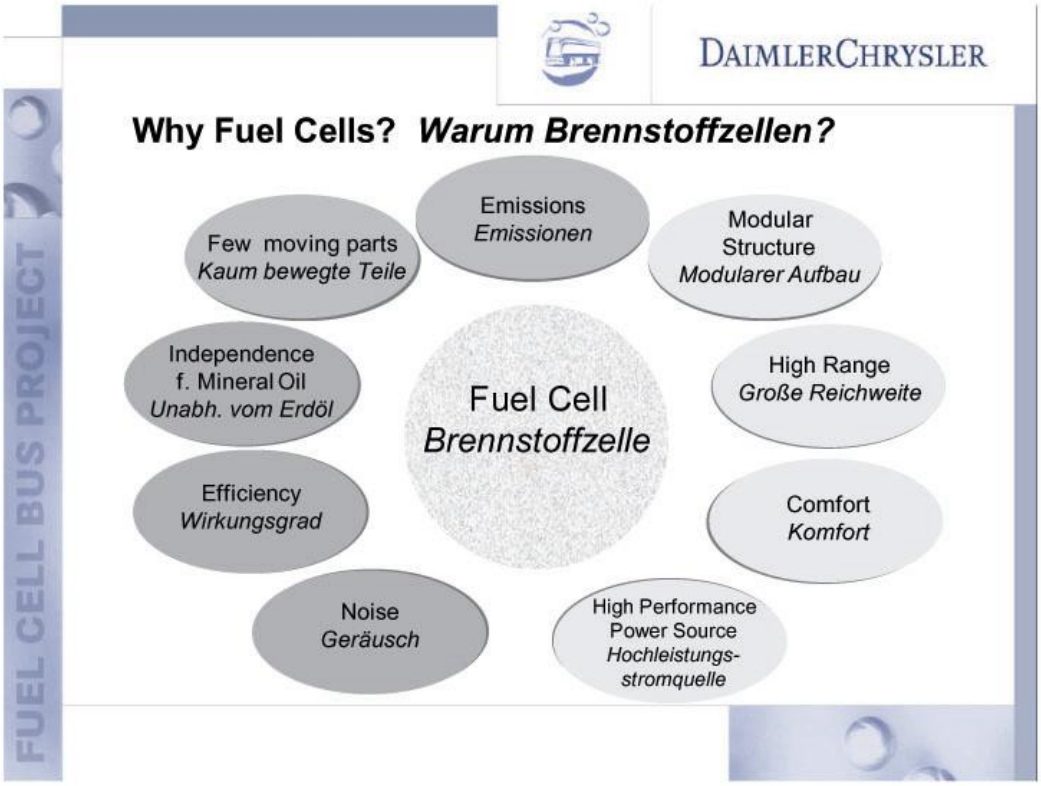


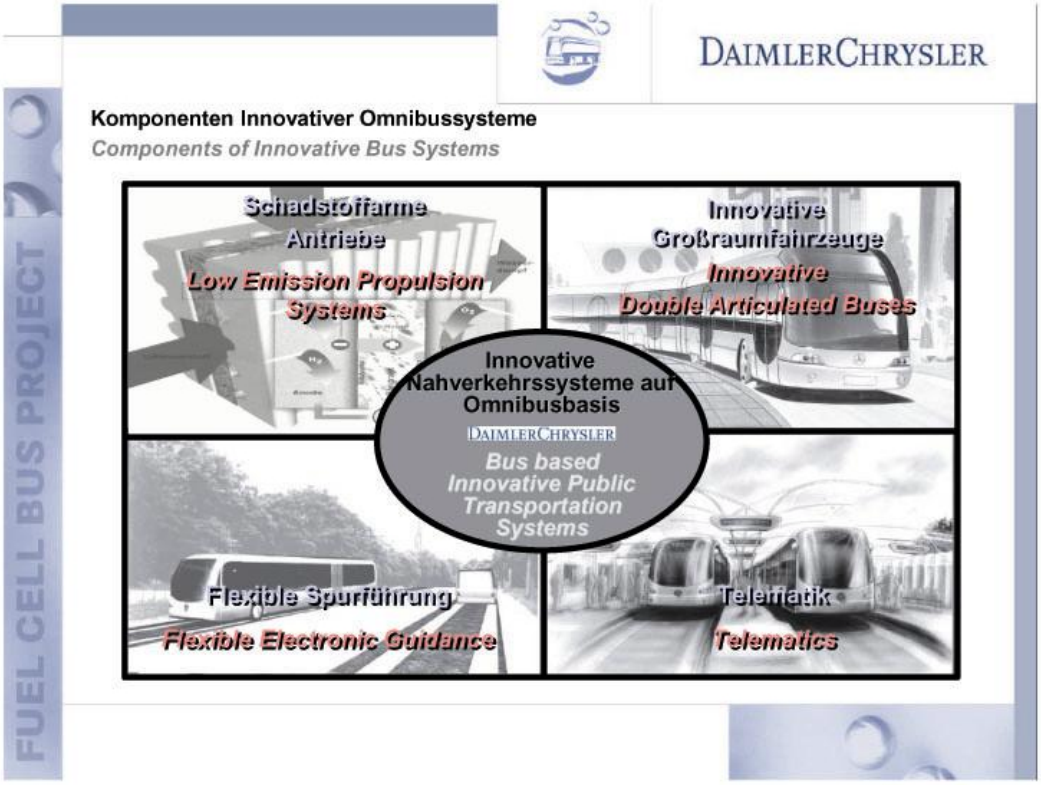

DAIMLERCHRYSLER
FUEL CELL BUS PROJECT
Gesamtkosten BZ-Omnibusse (inkl. Infrastruktur und Betrieb)
Total Cost FC-Bus (incl. Infrastructure and Operation)
Investitionskosten Bus
3 Busse (Wartung, Service)
3,75 Mio. Euro
3 Buses (Maintenance, Service)
Investment Costs Bus
Investitionskosten Infrastruktur
Infrastruktur (Lebensdauer >> 2a)
0,25 Mio. Euro
Infrastructure (Life Time >> 2a)
1,1 Mio. Euro
Investment Costs Infrastructure
Wesentliche Aufwendungen Kraftstoff
Energiekosten**
0,1 Mio. Euro
Energy Costs**
0,2 Mio. Euro
Substantial Expenses for Fuel
Einfache Variante
Aufwendige Variante
Simple Alternative
Complex Alternative
** ~50.000km/a über 2 Jahre
** ~50.000km/a over 2 Years


DAIMLERCHRYSLER
FUEL CELL BUS PROJECT
Ziele eines EU geförderten Forschungsvorhabens
Goals of an EC promoted Research Project
Tief-Temperatur Untersuchungen
Low-Temperature Test
Optimierung Hilfsantriebe
Optimisation Auxiliary Aggregates
H2 - basierte Wirtschaft
H2-based Economy
Optimierung Infrastruktur auf Basis fossiler Brennstoffe
Optimisation Infrastructure based on Fossil Fuels
Untersuchungen bei hohen Temperaturen
High-Temperature Test
Brennstoffzellen - Citaro 30 Busse
Fuel Cell - Citaro 30 Buses
Optimierung Tankstelle
Optimisation Filling Station
Optimierung der Energieeffizienz
Optimisation of Energy Efficiency
Umweltstudien, Schutz des Kulturerbes durch neue Technologien
Environmental Studies, Protection of Cultural Heritage
Soziale Belange der Brennstoffzellentechnologie
Social Effects of Fuel Cell Technology
• Aufbau Betriebserfahrungen
• Sicherheit & Zertifizierung
• Experience from Operation
• Safety & Certification


DAIMLERCHRYSLER
FUEL CELL BUS PROJECT
Potential of Fuel Cells
Potentiale der Brennstoffzelle


DAIMLERCHRYSLER
FUEL CELL BUS PROJECT
Fuel Cell Philosophy of the "Partnership for a New Generation of Vehicles" (PNGV)*:
"Fuel cells represent a developing technology which could potentially replace the internal combustion engine in all areas of the transportation sector. They operate with significantly higher fuel efficiency, greatly reduced emissions and are capable of running on a variety of fuels (such as hydrogen, ethanol, methanol and natural gas).
The widespread introduction and use of fuel cell vehicles could have a major impact on reducing petroleum consumption and on improving air quality in urban areas ..."
* "A program of the Departments of Energy and Transportation of the US government"


DAIMLERCHRYSLER
FUEL CELL BUS PROJECT
Why Fuel Cells? Warum Brennstoffzellen?
Few moving parts
Kaum bewegte Teile
Emissions
Emissionen
Modular
Structure
Modularer Aufbau
Independence
f. Mineral Oil
Unabh. vom Erdöl
Fuel Cell
Brennstoffzelle
High Range
Große Reichweite
Efficiency
Wirkungsgrad
Comfort
Komfort
Noise
Geräusch
High Performance
Power Source
Hochleistungs-
stromquelle


DAIMLERCHRYSLER
FUEL CELL BUS PROJECT
Komponenten Innovativer Omnibussysteme
Components of Innovative Bus Systems
Schadstoffarme
Antriebe
Low Emission Propulsion
Systems
Innovative
Großraumfahrzeuge
Innovative
Double Articulated Buses
Innovative
Nahverkehrssysteme auf
Omnibusbasis
DAIMLERCHRYSLER
Bus based
Innovative Public
Transportation
Systems
Flexible Spurführung
Flexible Electronic Guidance
Telematik
Telematics

Zero Emission Initiative in Japan towards Sustainable Growth

Toyoharu MORITA

Ebara Research Co., Ltd., Fujisawa

Introduction

Zero-Emission, a concept which aims to approach the ideal of zero environmental stress by suppressing resource consumption and minimizing waste of the whole society with circulation chains between industries, as well as utmost effort in each industry, provides us a suggestive viewpoint for such discussion. It is now progressing into realization stage in actual industries and societies, beyond a mere symbolic concept.[5]

Legal Aspects of Environmental Issues

At present, great expectation is held regarding waste related issue, and these expectations are changing the social structure.

The Target now is to create a society that gives priority to less waste generation, less resource consumption, and less adverse environmental impact. To cope with the change, the law for the promotion of a closed loop society and several laws to promote recycling have been recently established. With the concerted efforts of relevant people, the enactment of these law have produced favorable result, such as ceased growth of the waste generation, amount, better recycling rates and reduced final disposal amount. The packaging waste recycling law stipulates the producers' responsibility, which is further extended by the home appliances recycling law along with the recycling route. Things are definitely improving.

[5] Appendix 1 was presented at Zero Emission Conference at Rome, Italy, September 1999. Now Current situation is almost same with this paper, so please refer to attached paper.

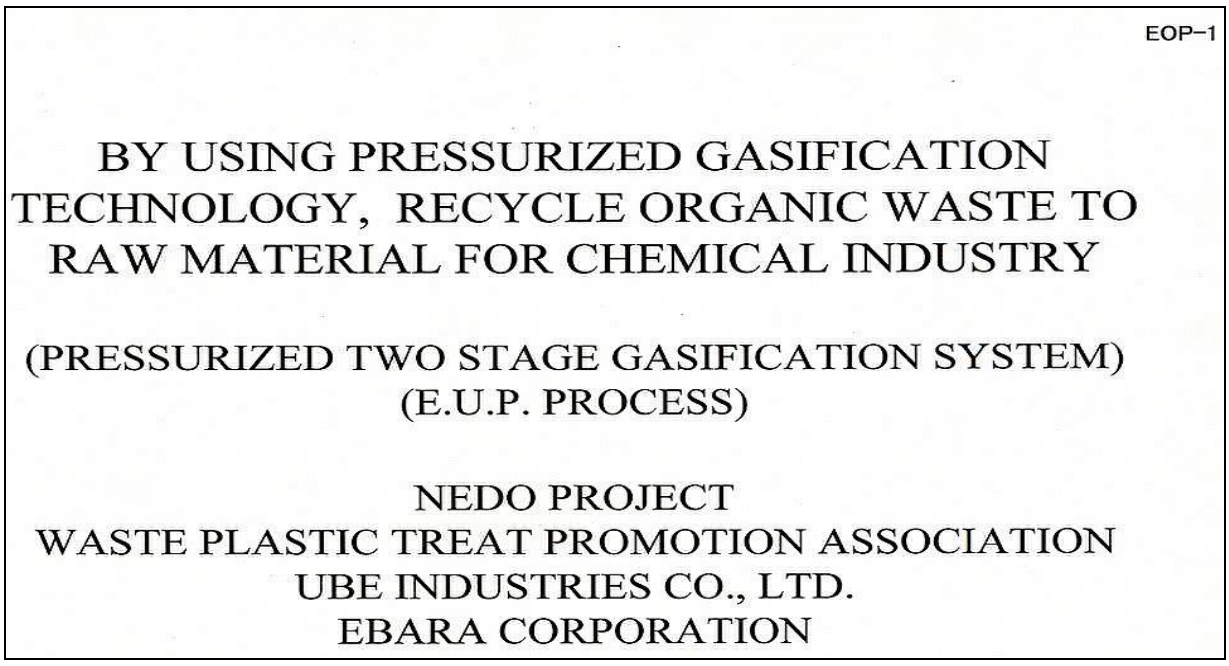
Environmental Business

In Japan, the environmental business is expected to grow further in the 21st century. An official estimation by the Japanese government (MITI) shows that the domestic market size will be 35 trillion-yen in 2010, more than double of 1994. A considerable portion of the market expansion is thought to be achieved with development of Zero Emission technologies. To solve environmental problems, growth of environmental industries is vitally needed. To achieve growth of environmental industries, legislation of law, to strengthen of regulation figures, enforcement to follow the regulation, government investment, various incentive including tax system are necessary items. Based on Packaging Waste Recycling Law and Household Appliance Recycling Law, the market for recycling these items is emerging. But these businesses are just started, now we could not evaluate these businesses successful or not. It will take a time move, so hopefully be successful and profitable.

Example of Zero-Emission System

E.U.P PROCESS

One typical system is chemical recycling system which synthesize chemical compound from waste. E.U.P Process makes circulation use of resources by conversion of waste from municipality to resources for another industry. It is to be based on formation of industrial clusters by optimum combination of industrial sectors, minimizing resources, as well as enjoying economic advantage. They utilize unused waste as resources. The system converts waste to raw gas for chemical industry through a gasification process performed under reductive condition in a primary low-temperature gasification furnace, followed by a secondary high-Temperature furnace. The raw gas can be easily processed to useful chemical composed such as hydrogen and carbon oxide.

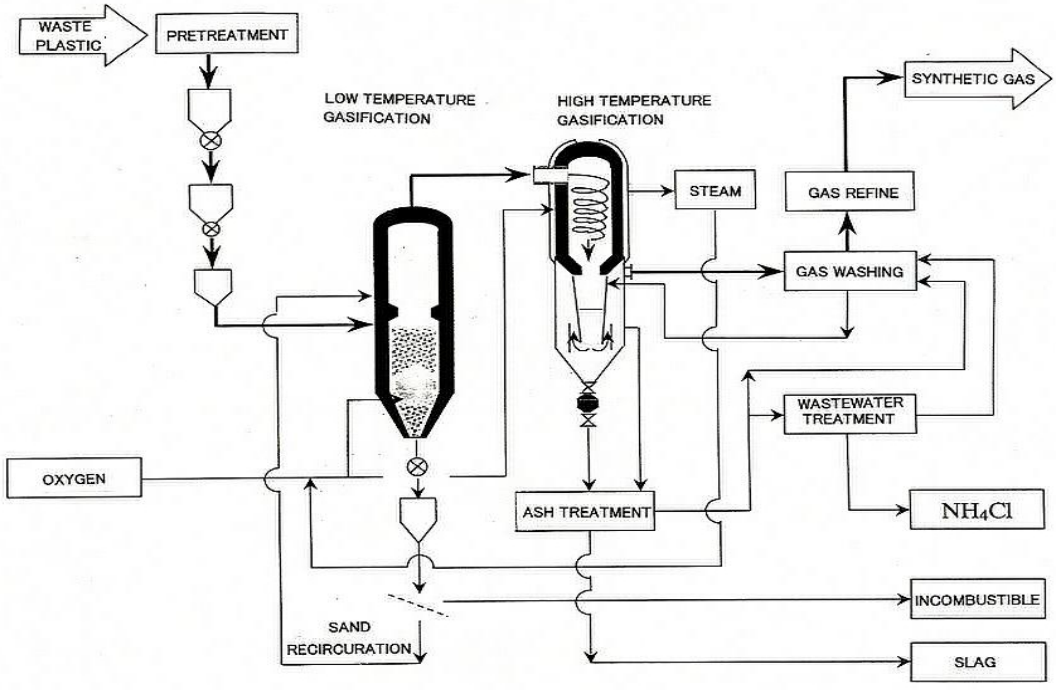


EOP–2

CHARACTARISTIC OF GASIFICATION

- POSSIBLE TO RECEIVE VARIOUS WASTE.
- SEPARARION IS NOT NEEDED FOR VARIOUS PLASTIC MATERIAL
  EASY TO COLLECT PLASTIC WASTE.
- POSSIBLE TO TREAT WASTE PLASTIC WITH OTHER FOSSIL FEUL.
- POSSIBLE TO RECOVER REFINED GAS POSSIBLE TO DIRECT CONNECTION TO NEXT PROCESS.

EOP–3



PRESSURIZED TWO STAGE GASIFICATION PROCESS
(CAPACITY 30^T/D)

EOP-4

COMPOSITION OF RAW MATERIAL AND RECOVERED GAS (CALCULATED FIGURE)

- COMPOSITION OF WASTE PLASTIC(Dry Base)

C	67.48 wt%
H	9.45
O	9.36
N	0.31
S	0.01
Cl	3.39
Ash	10.00

- CAROLIFIC VALUE (HHV)・・Dry Base
  : 8,340 kcal/kg

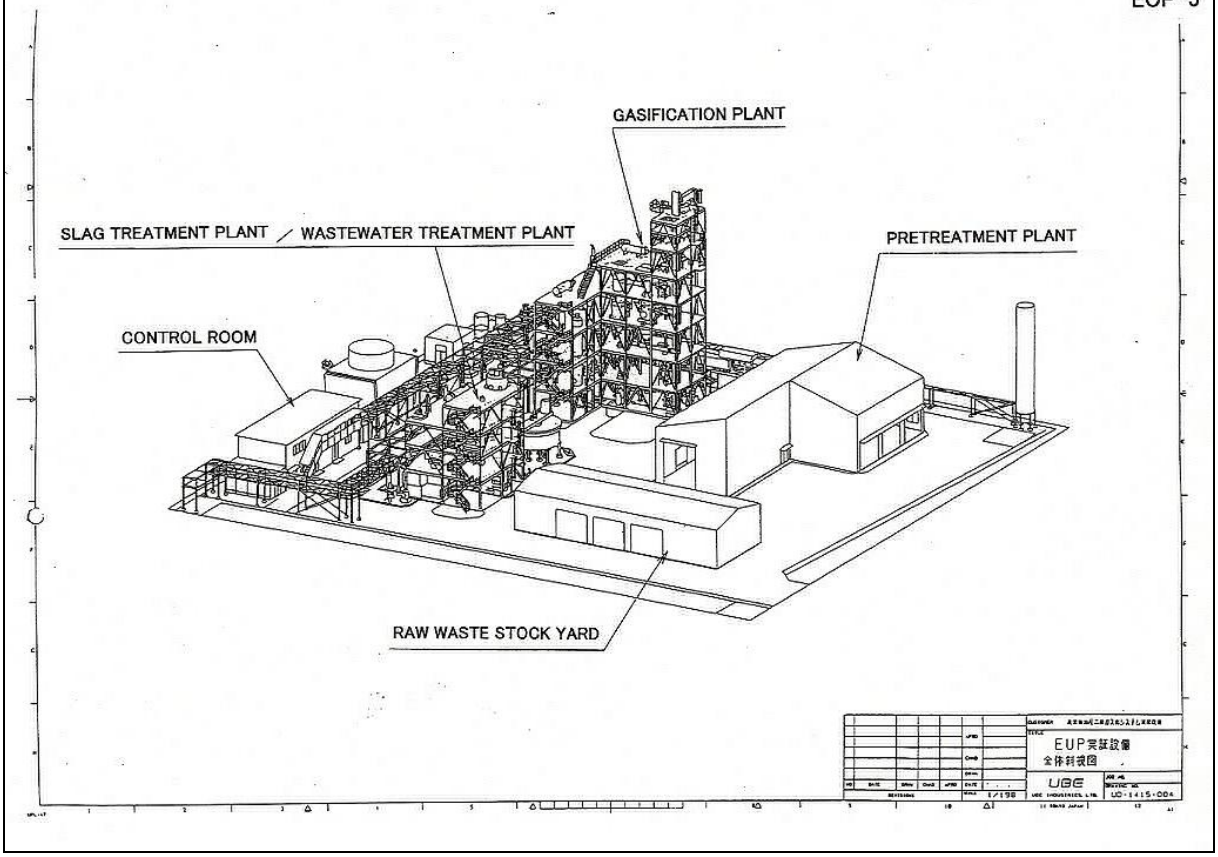
- COMPOSITION OF RECOVERED GAS (CALCULATED FIGURE)

H_2	49.9 vol%
CO	33.6
CO_2	15.2
N_2+Ar	2.3

- PER TONNAGE OF WASTE PLASTIC

$CO+H_2$: 2,062Nm^3

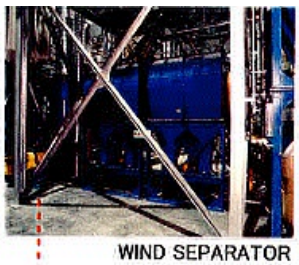
EOP-5



T.P.R Plant

Based on Package Recycling Raw, Ebara established Tokyo Pet Bottle Recycling Company. This company is collecting waste pet bottle, and convent waste pet bottle to flake. The flake is sold to chemical company and Textile Company.

FLAKE WASHER



WIND SEPARATOR

PVC COLORED BOTTLE SEPARATOR

CRASHER

LABEL SEPARATOR

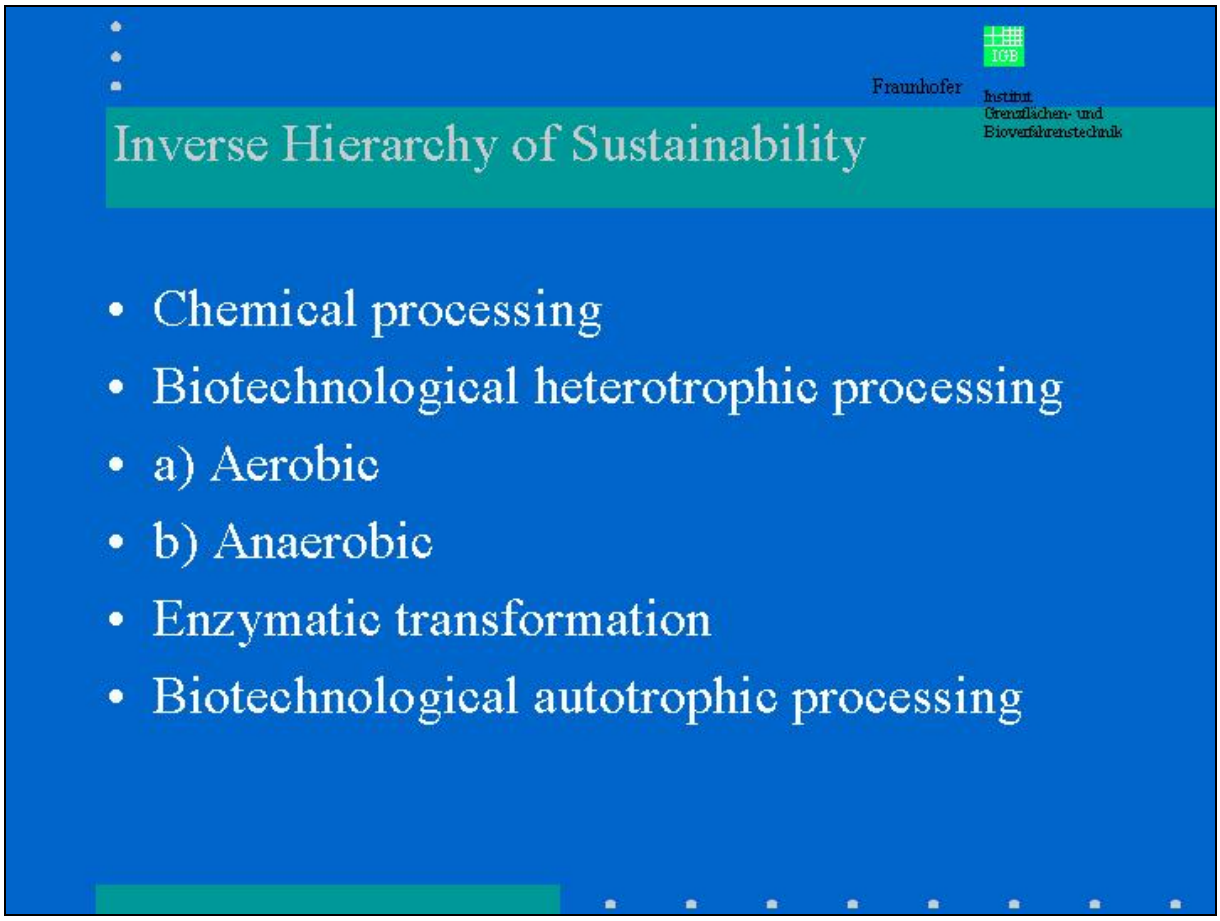
ALUMINUM SEPARATOR

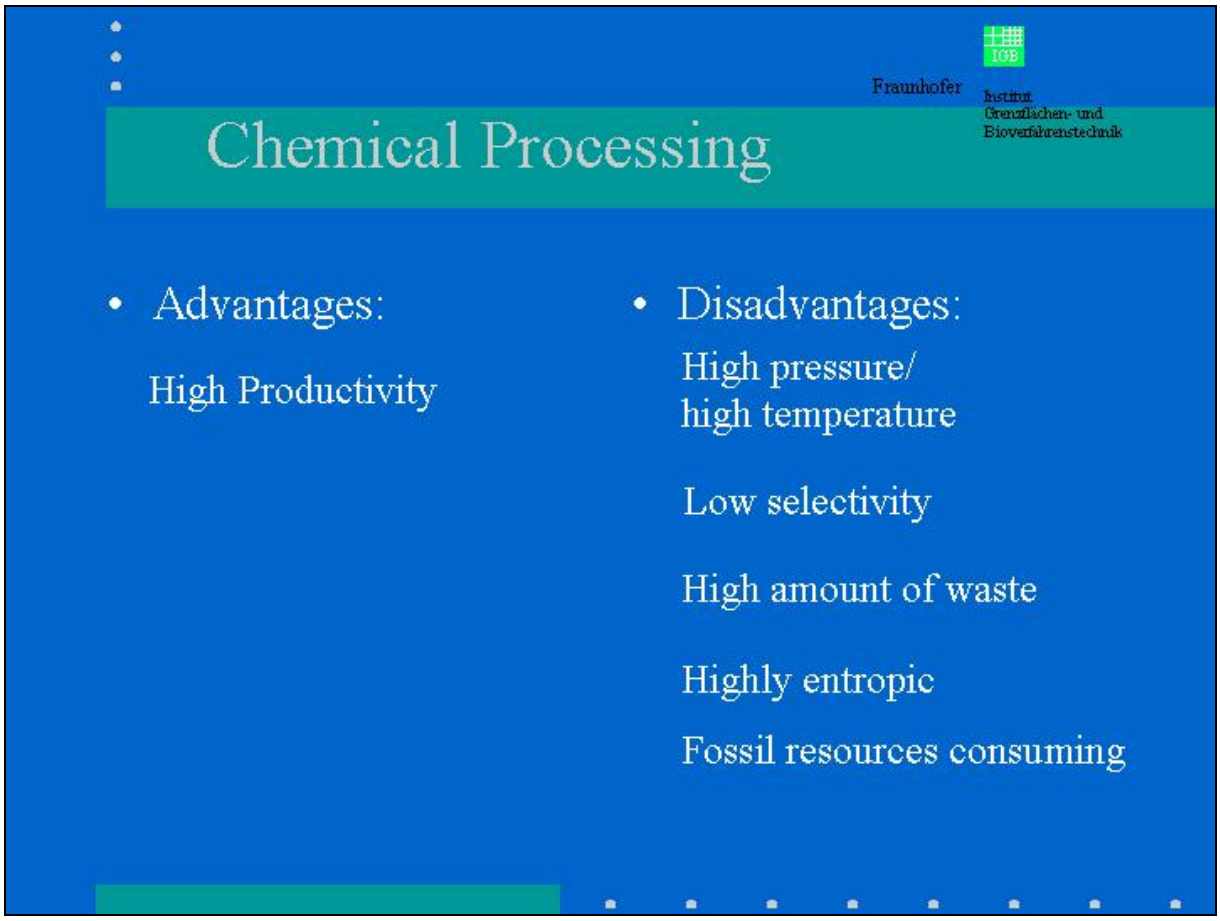

フレーク
RECOVERED FLAKE
再生品
PET
PRODUCT FROM RECOVERED FLAKE

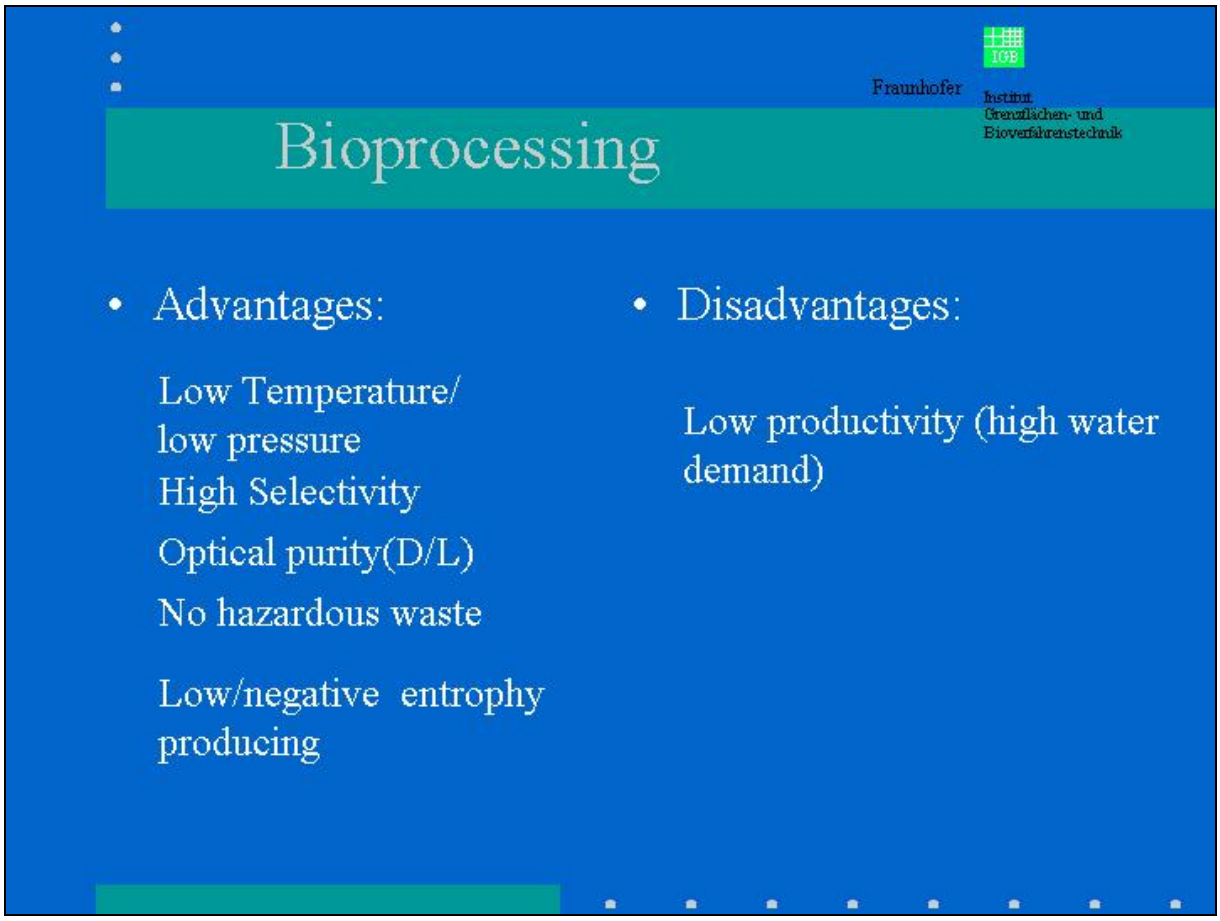
Environmental Biotechnology – the Challenge of Biomimetics – A Vision –

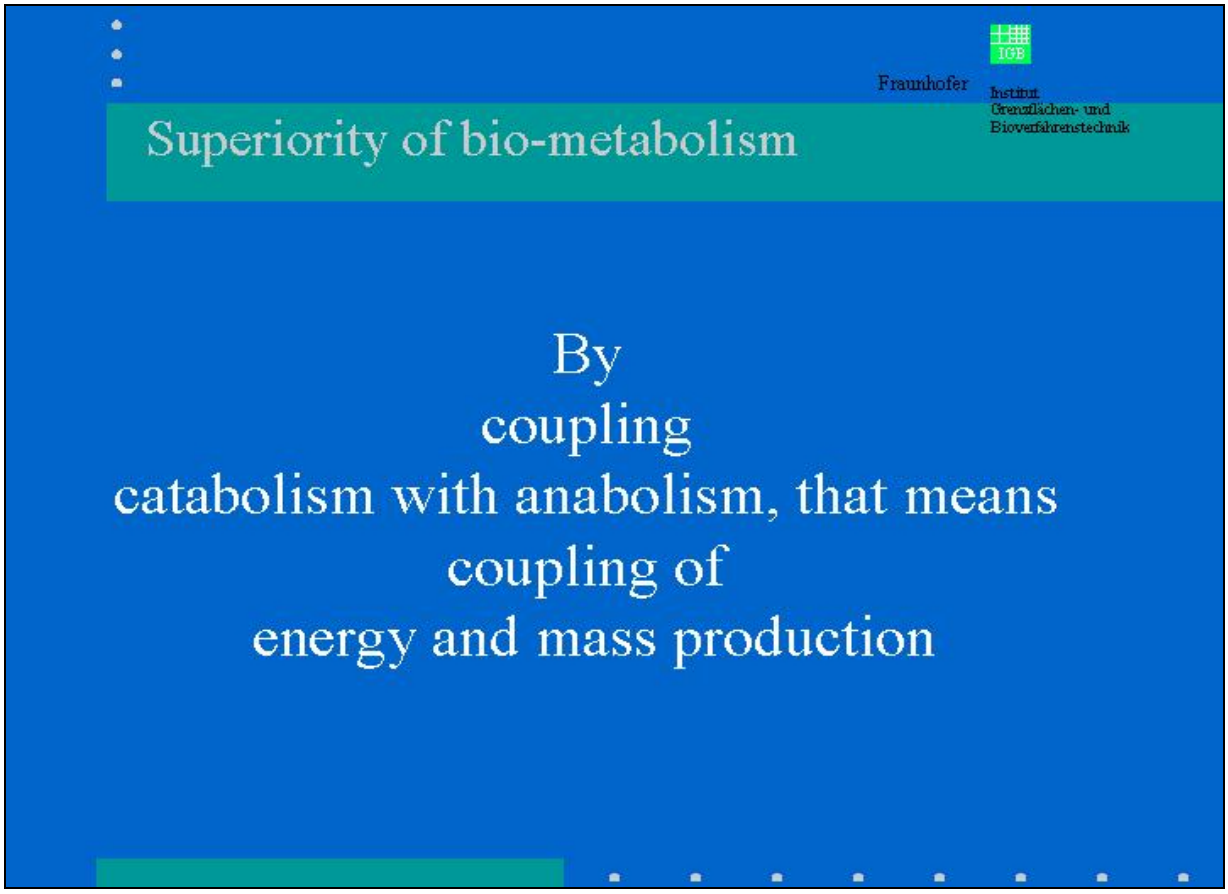
Walter Trösch

Fraunhofer Institute for Interfacial Engineering and Biotechnology, Stuttgart




Fraunhofer
IGB
Institut
Grenzflächen- und
Bioverfahrenstechnik
Chemical Processing
• Advantages:
High Productivity
• Disadvantages:
High pressure/
high temperature
Low selectivity
High amount of waste
Highly entropic
Fossil resources consuming


Fraunhofer
IGB
Institut
Grenzflächen- und
Bioverfahrenstechnik
Bioprocessing
• Advantages:
Low Temperature/
low pressure
High Selectivity
Optical purity(D/L)
No hazardous waste
Low/negative entrophy
producing
• Disadvantages:
Low productivity (high water
demand)


Fraunhofer
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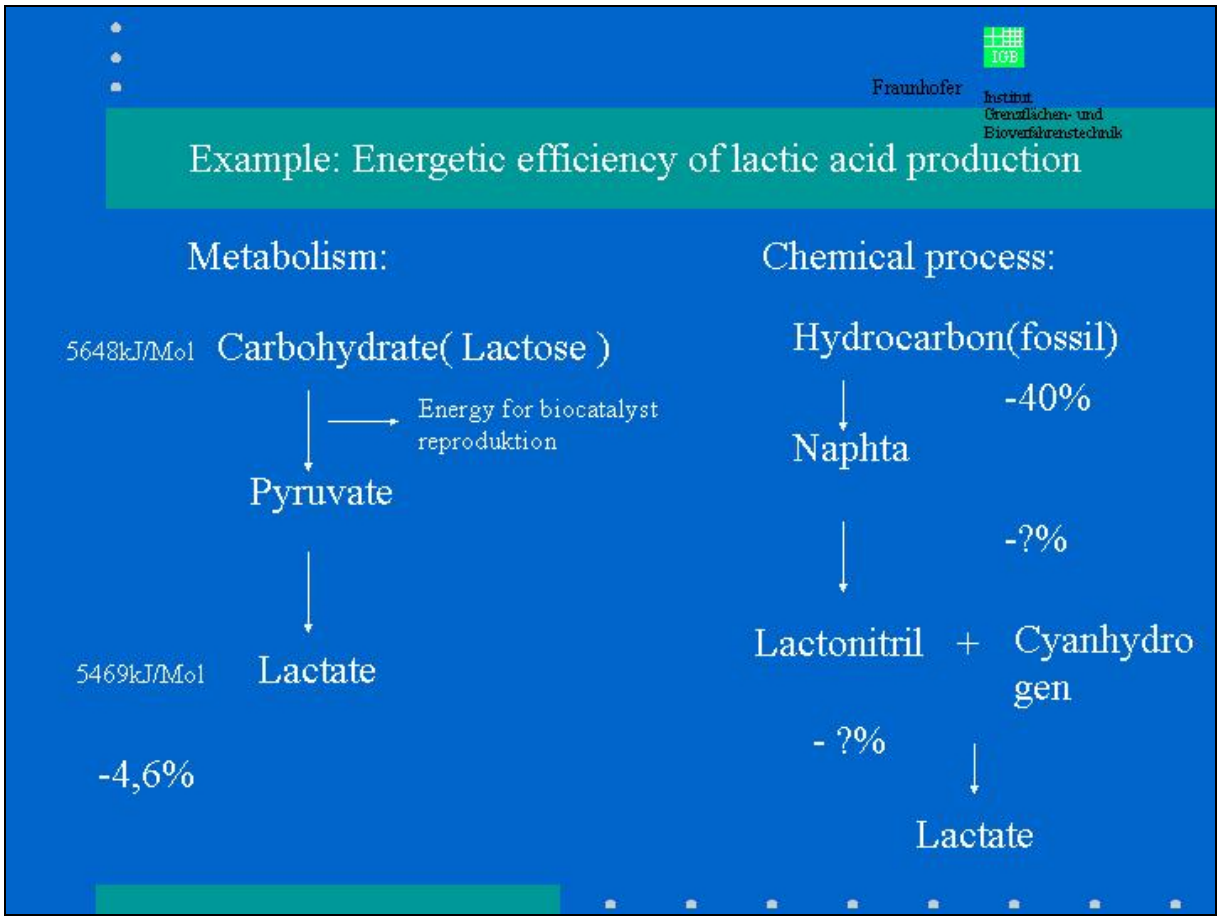
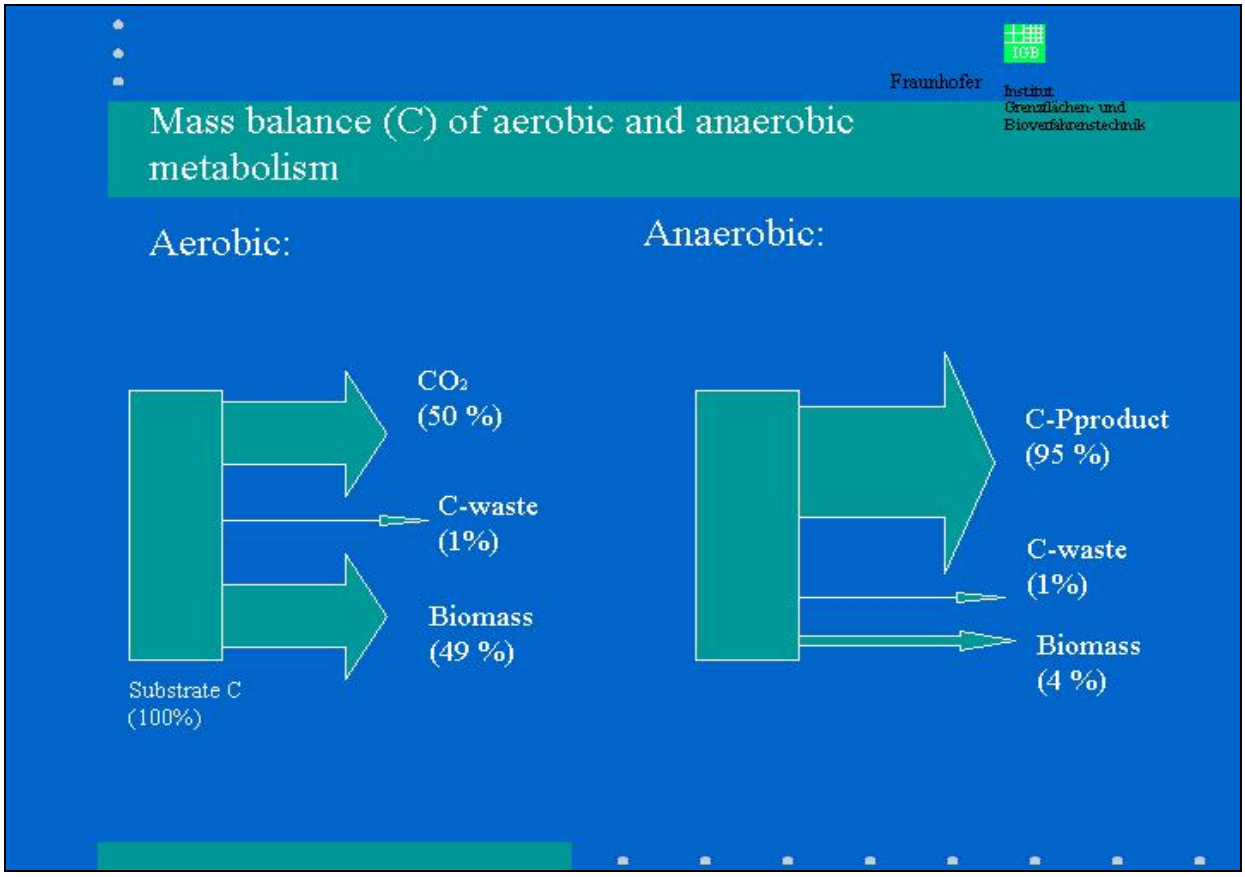
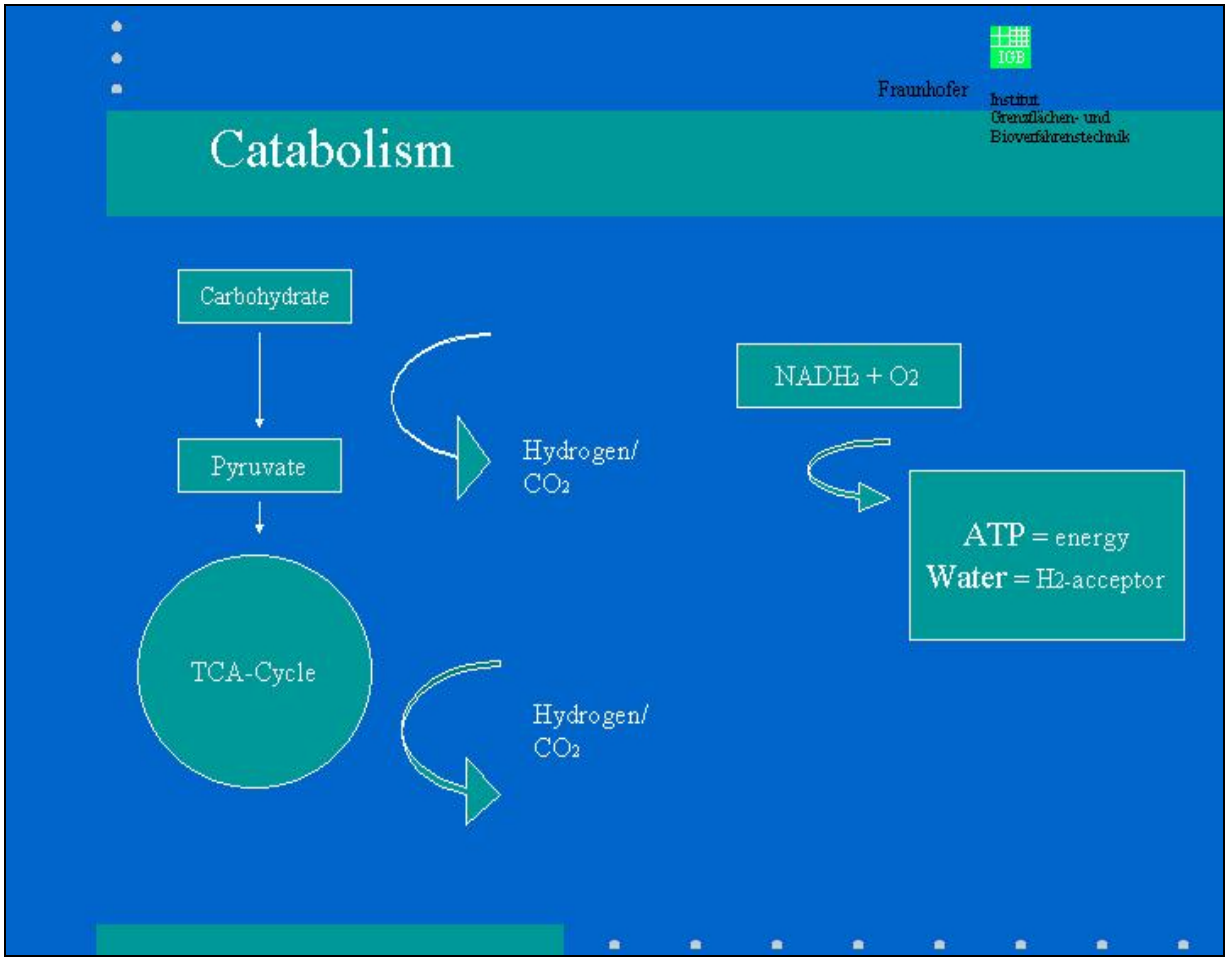
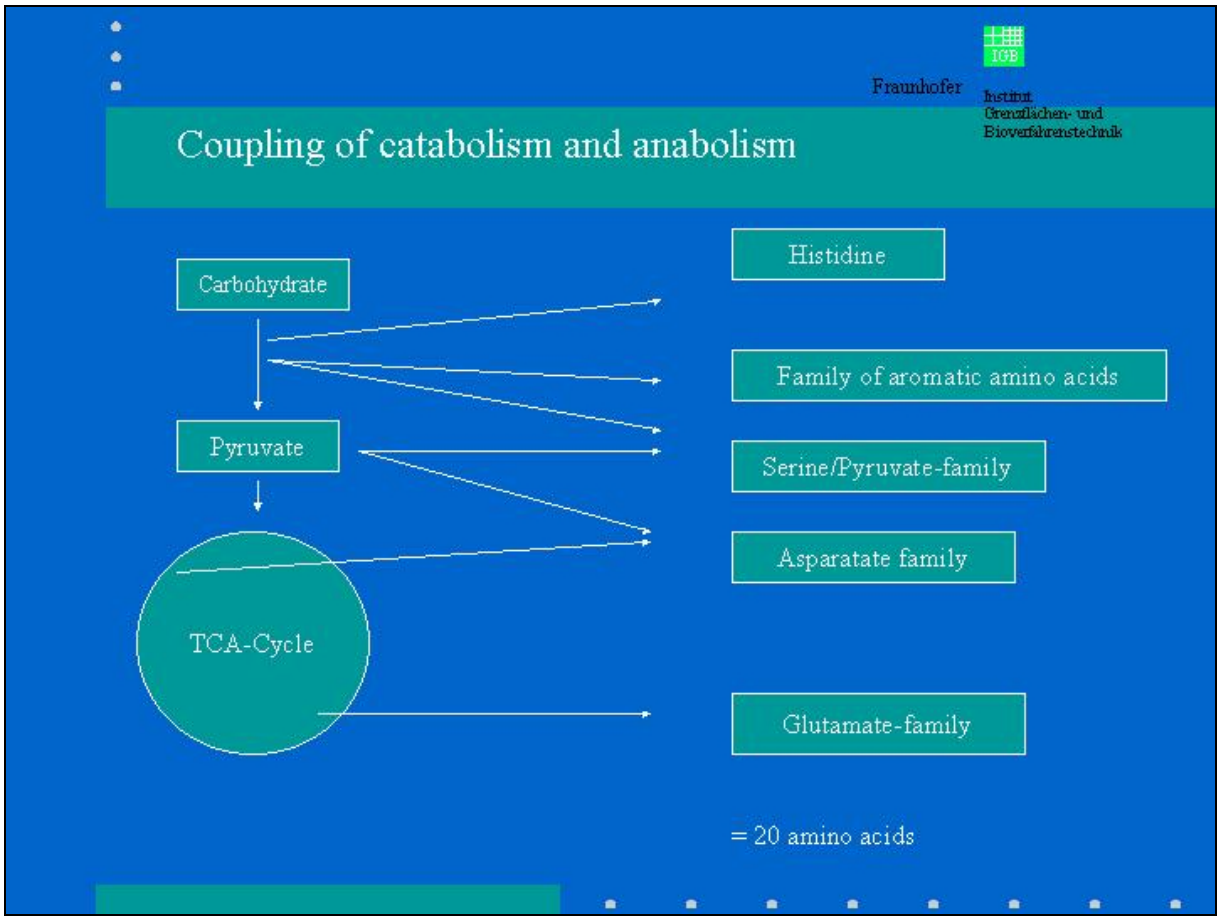
Institut
Grenzflächen- und
Bioverfahrenstechnik
Superiority of bio-metabolism
By
coupling
catabolism with anabolism, that means
coupling of
energy and mass production


Fraunhofer
IGB
Institut
Grenzflächen- und
Bioverfahrenstechnik
Example: Energetic efficiency of lactic acid production
Metabolism:
5648kJ/Mol
Carbohydrate(Lactose)
Energy for biocatalyst reproduktion
Pyruvate
5469kJ/Mol
Lactate
-4,6%
Chemical process:
Hydrocarbon(fossil)
-40%
Naphta
-?%
Lactonitril
+
Cyanhydrogen
- ?%
Lactate


Fraunhofer
Institut
Grenzflächen- und
Bioverfahrenstechnik
Mass balance (C) of aerobic and anaerobic metabolism
Aerobic:
Anaerobic:
CO2
(50 %)
C-waste
(1%)
Biomass
(49 %)
Substrate C
(100%)
C-Pproduct
(95 %)
C-waste
(1%)
Biomass
(4 %)


Fraunhofer
Institut
Grenzflächen- und
Bioverfahrenstechnik
Catabolism
Carbohydrate
Pyruvate
TCA-Cycle
Hydrogen/
CO2
Hydrogen/
CO2
NADH2 + O2
ATP = energy
Water = H2-acceptor


Fraunhofer
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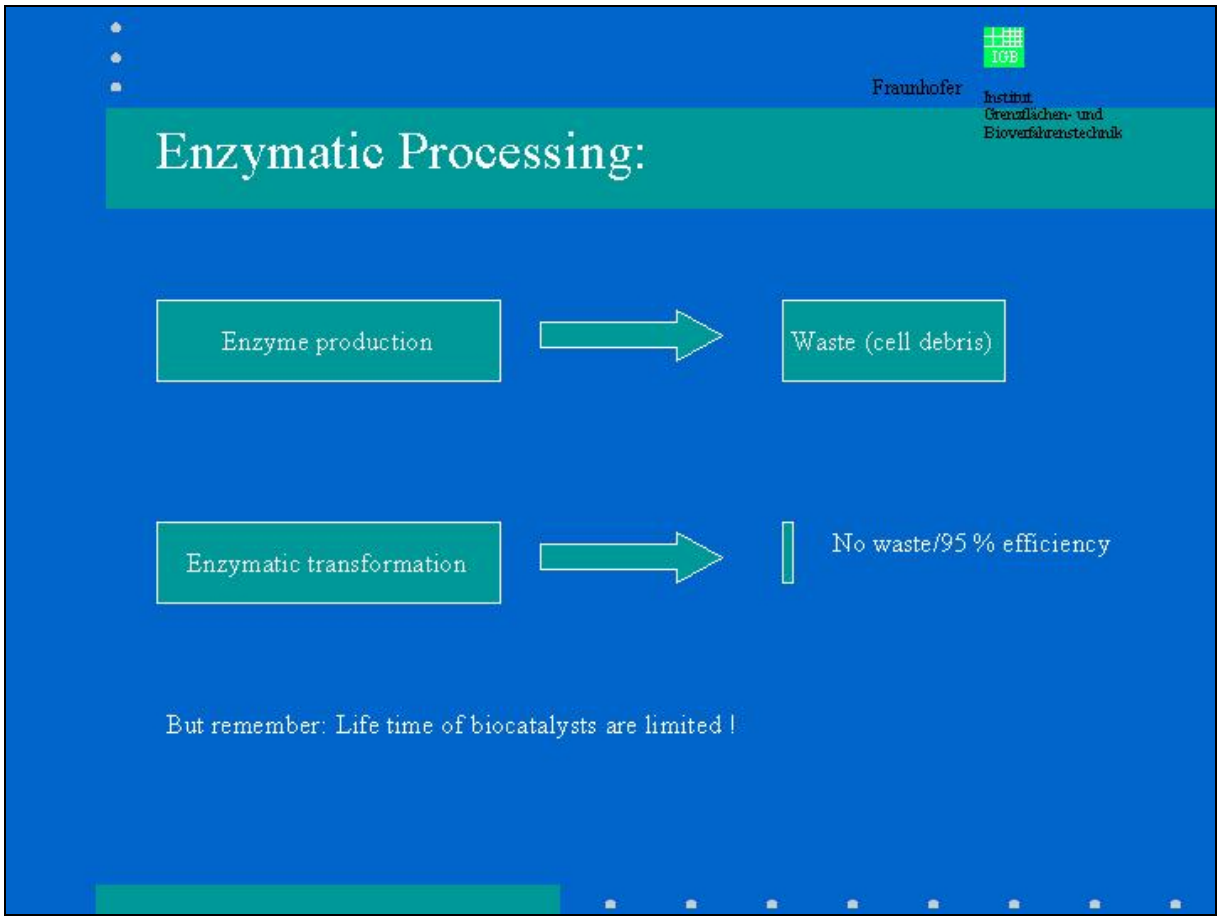
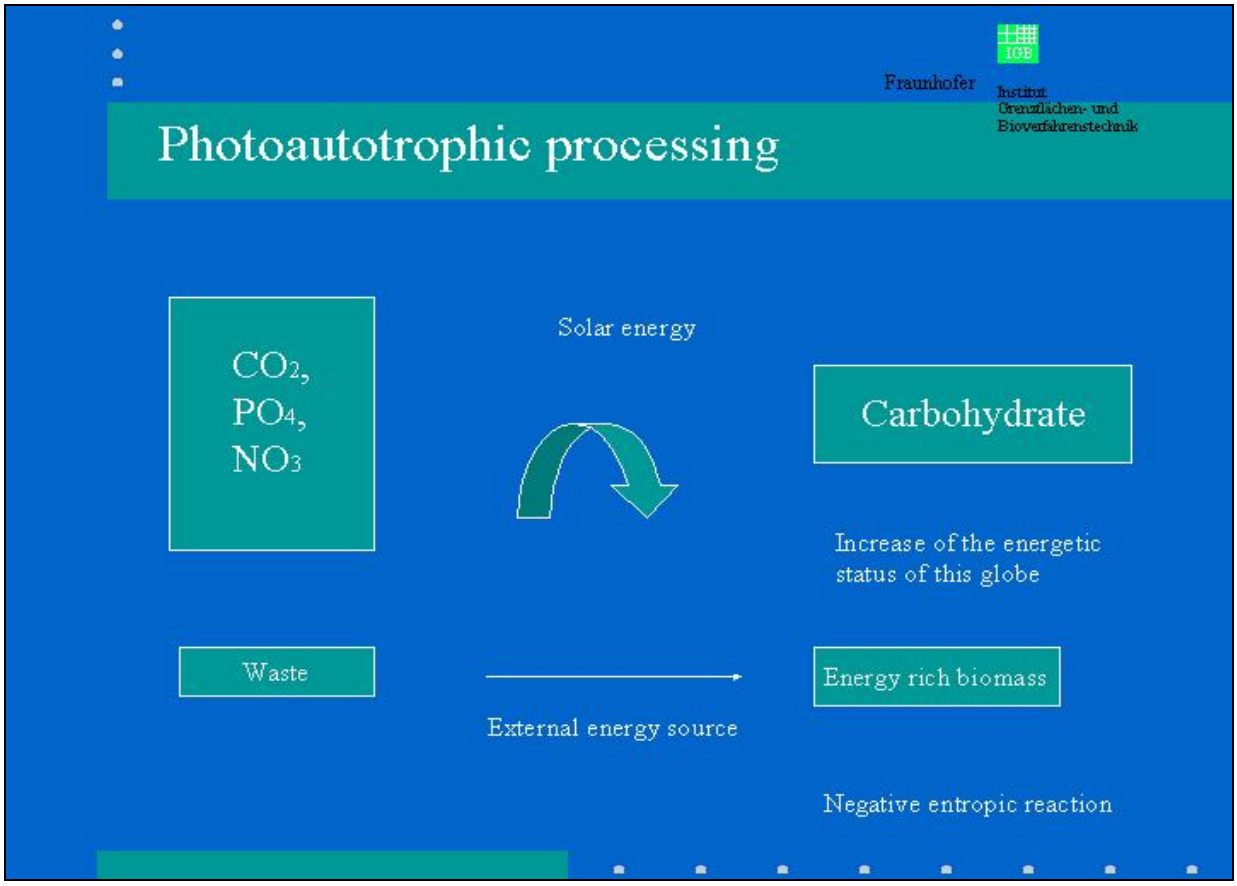
Bioverfahrenstechnik
Coupling of catabolism and anabolism
Carbohydrate
Pyruvate
TCA-Cycle
Histidine
Family of aromatic amino acids
Serine/Pyruvate-family
Asparatate family
Glutamate-family
= 20 amino acids


Fraunhofer
IGB
Institut
Grenzflächen- und
Bioverfahrenstechnik
Enzymatic Processing:
Enzyme production
Waste (cell debris)
Enzymatic transformation
No waste/95 % efficiency
But remember: Life time of biocatalysts are limited !


Fraunhofer
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Institut
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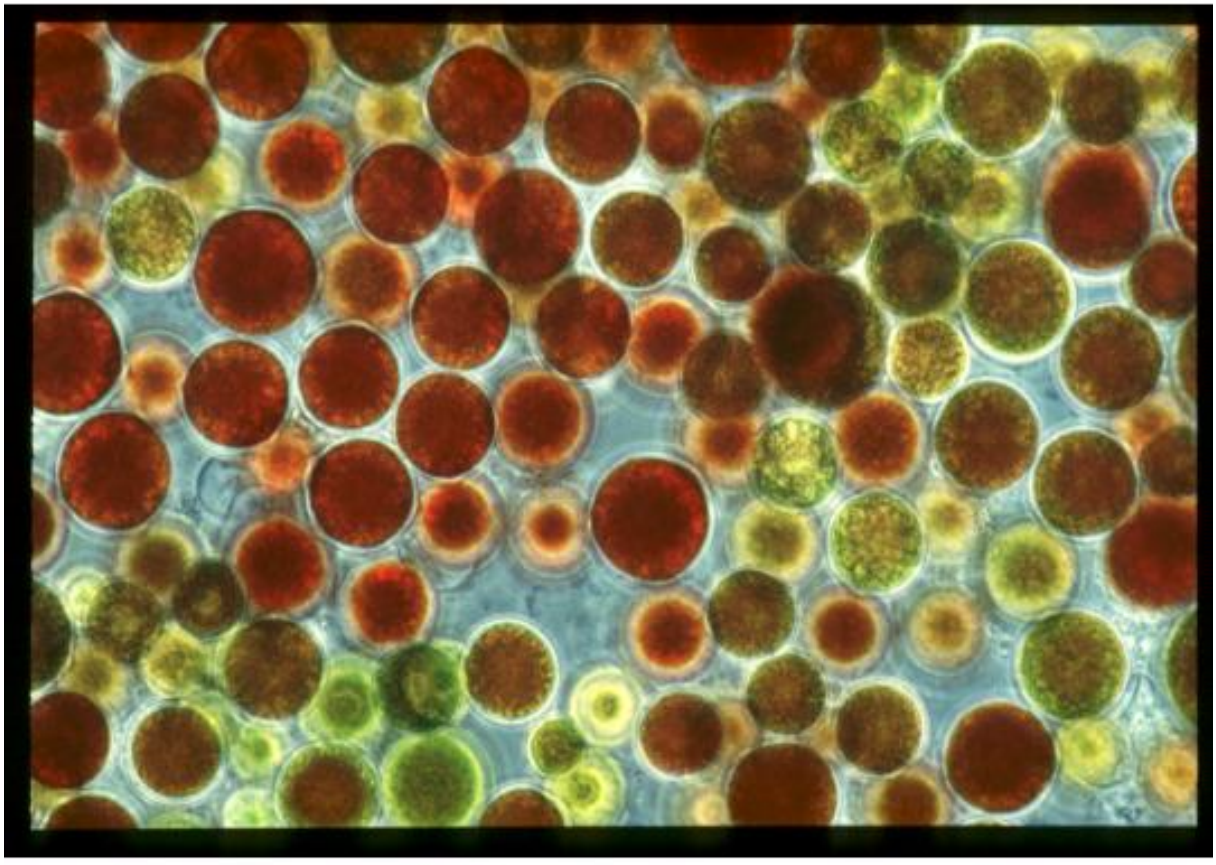
Bioverfahrenstechnik
Photoautotrophic processing
CO_2,
PO_4,
NO_3
Solar energy
Carbohydrate
Increase of the energetic
status of this globe
Waste
Energy rich biomass
External energy source
Negative entropic reaction

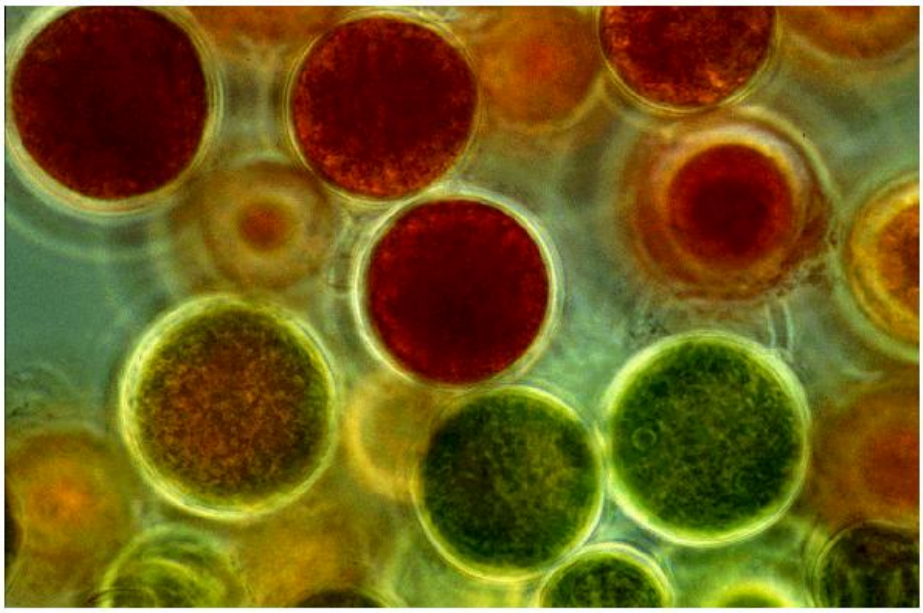
Titel der Folienserie

Astaxanthin in Mikroalgen

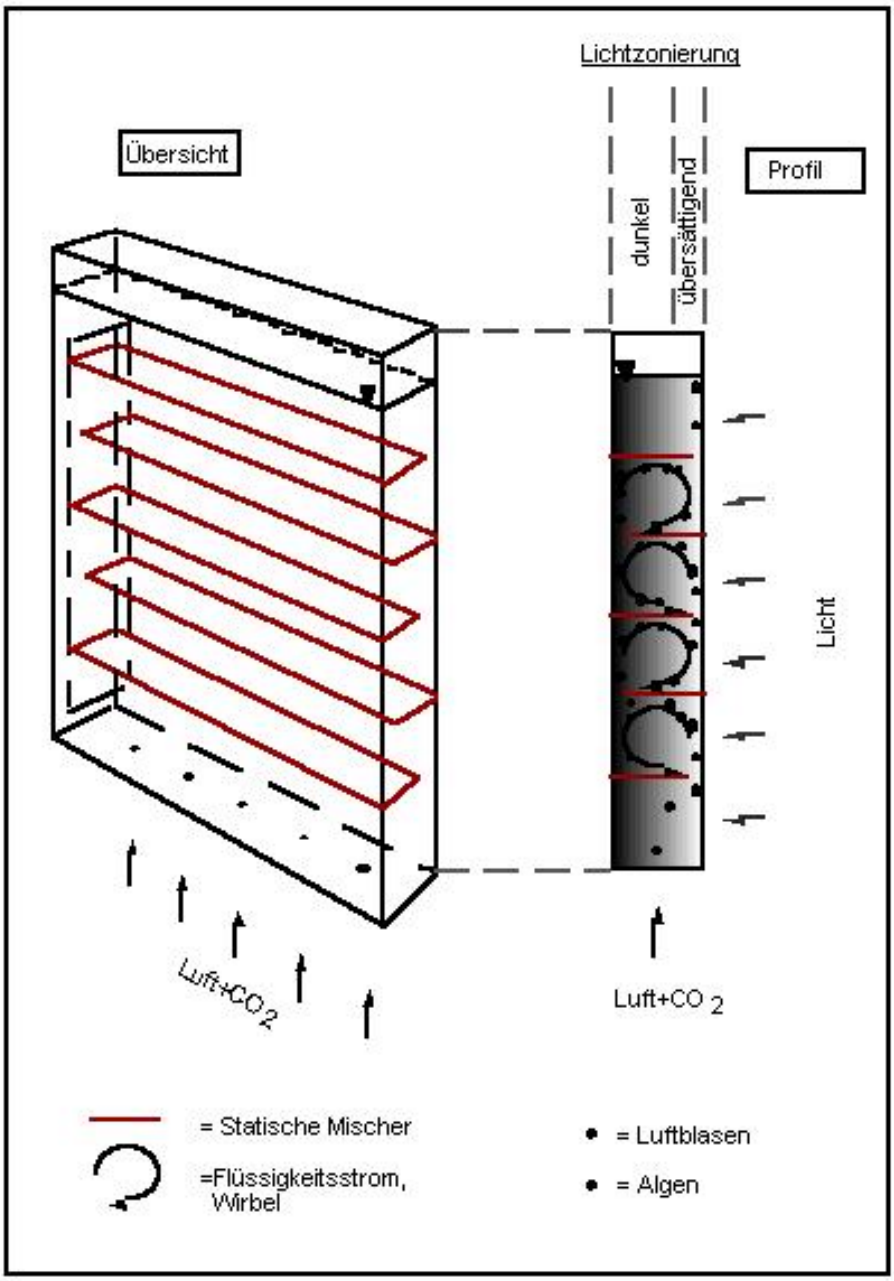
Haematococcus pluvialis



Fraunhofer Institut Grenzflächen- und Bioverfahrenstechnik



Fraunhofer Institut Grenzflächen- und Bioverfahrenstechnik

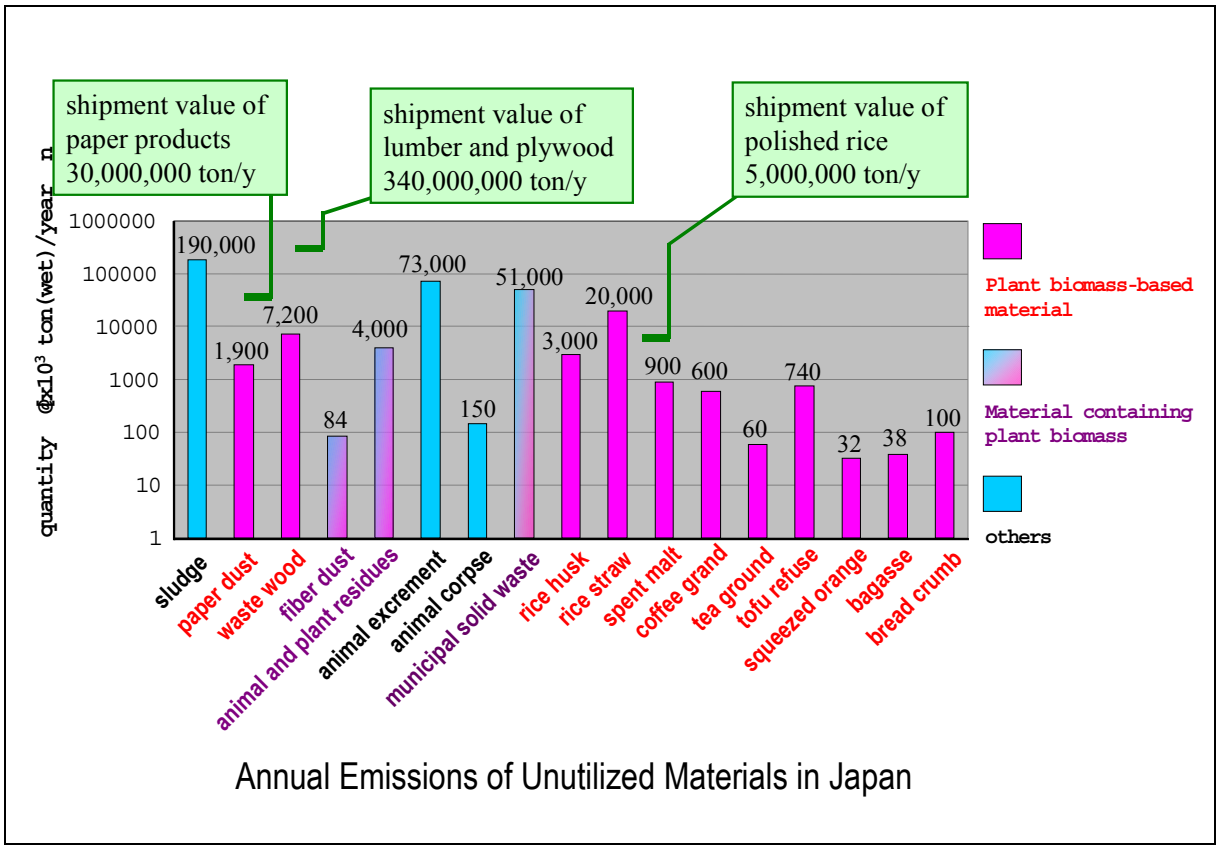


Fraunhofer Institut Grenzflächen- und Bioverfahrenstechnik

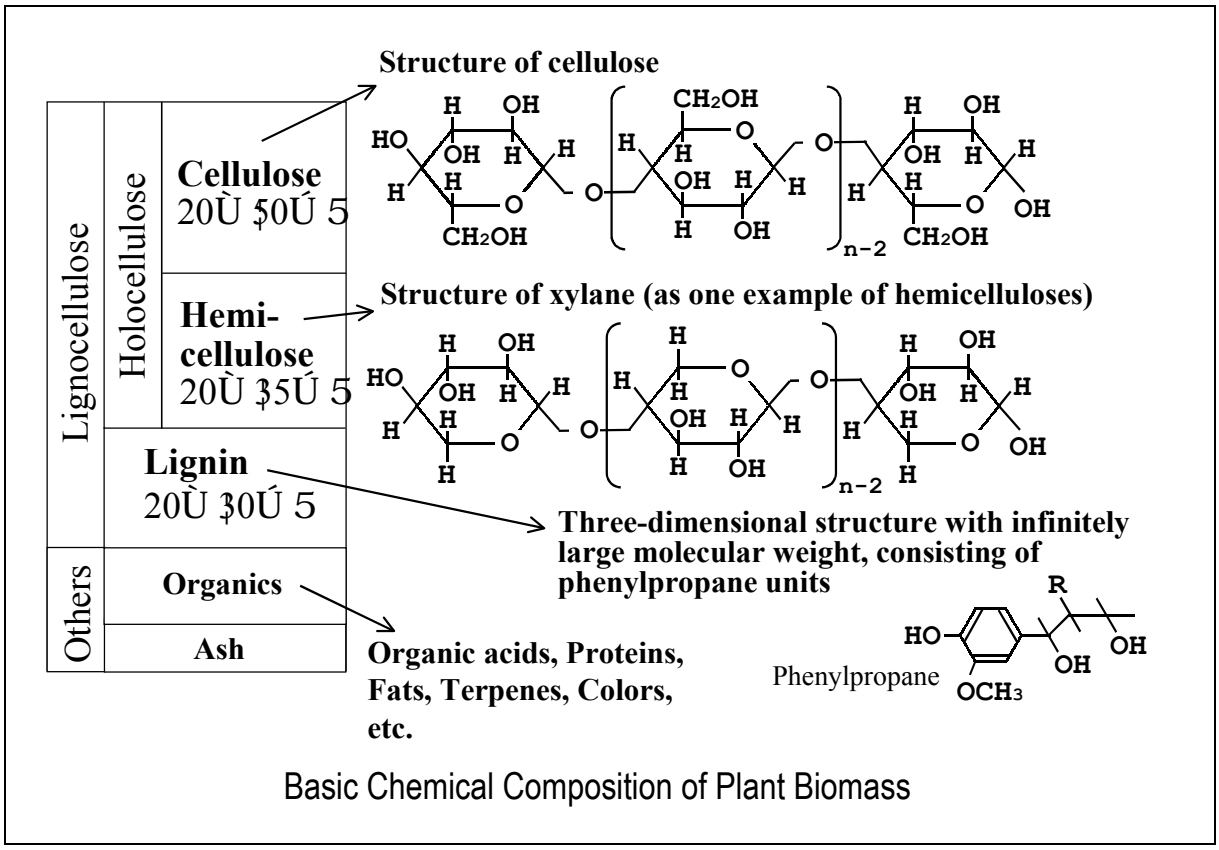
Physicochemical Conversions of Biomass

Akiyoshi Sakoda

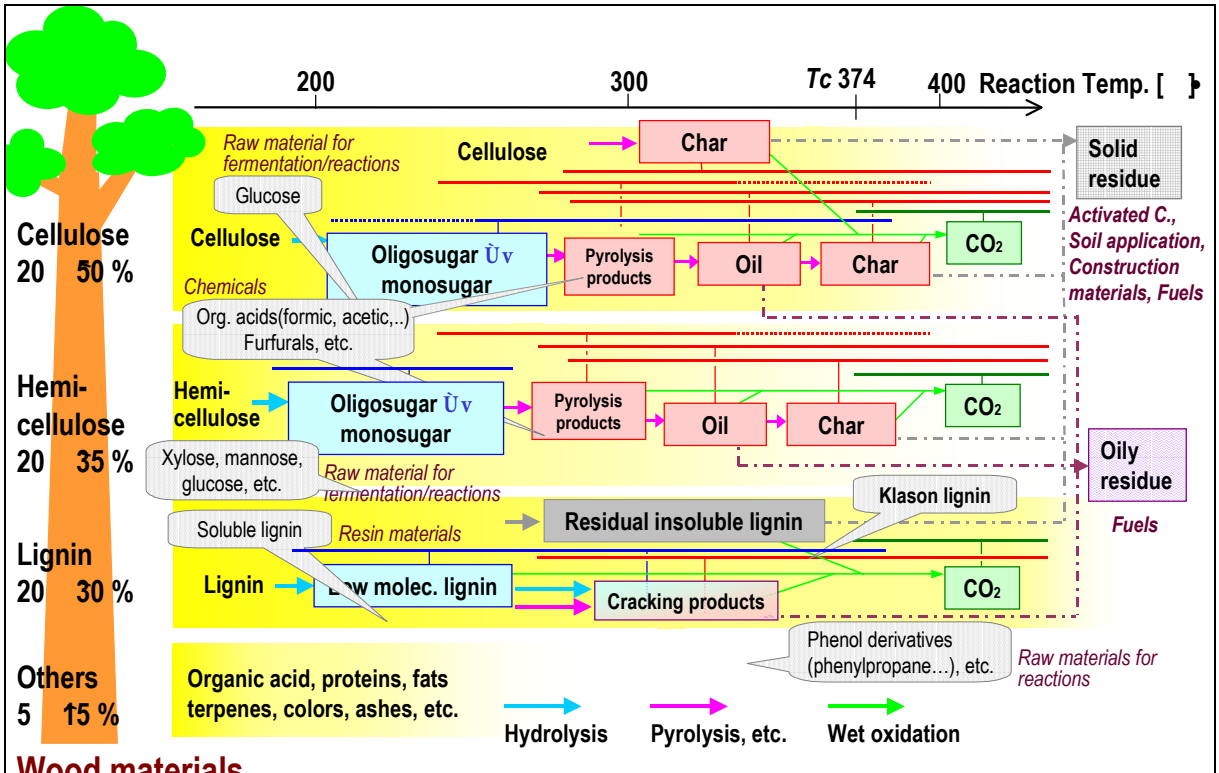
University of Tokyo, Institute of Industrial Science, Tokyo



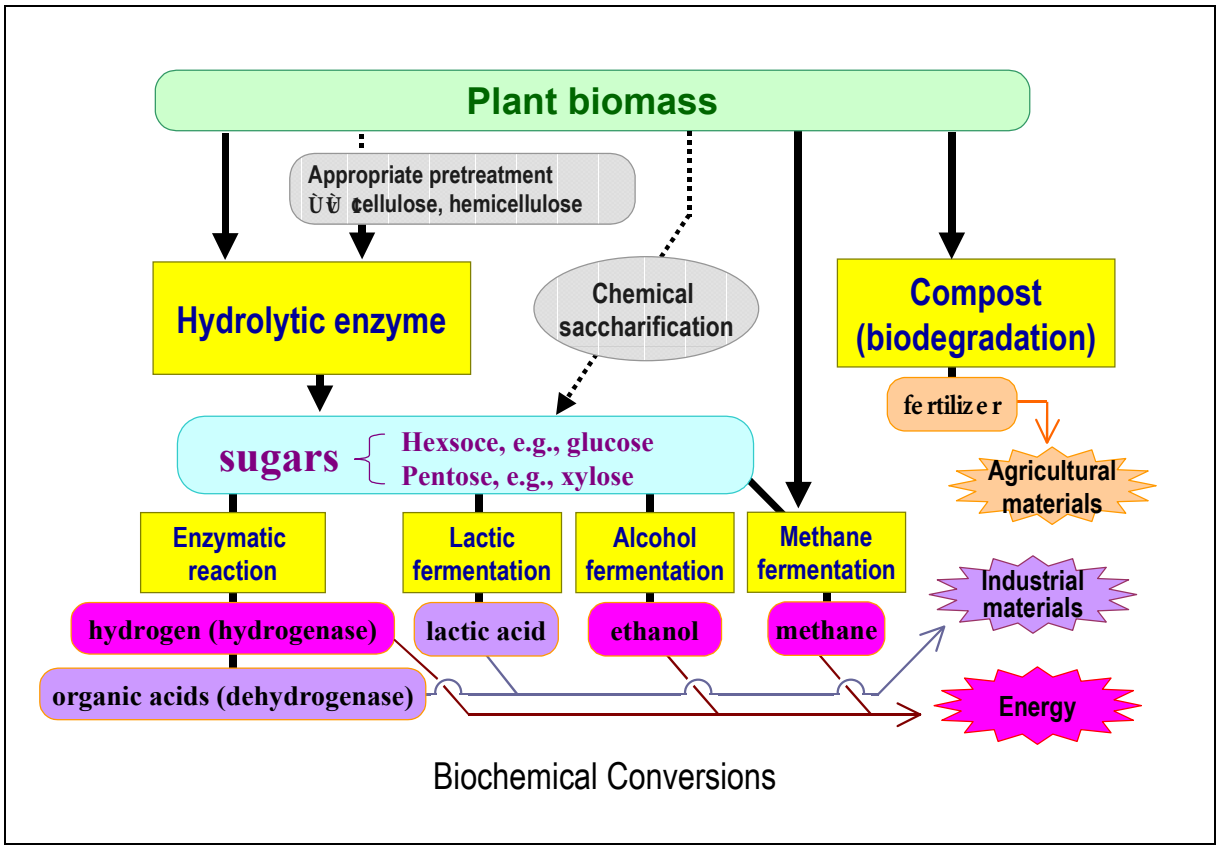
Annual Emissions of Unutilized Materials in Japan

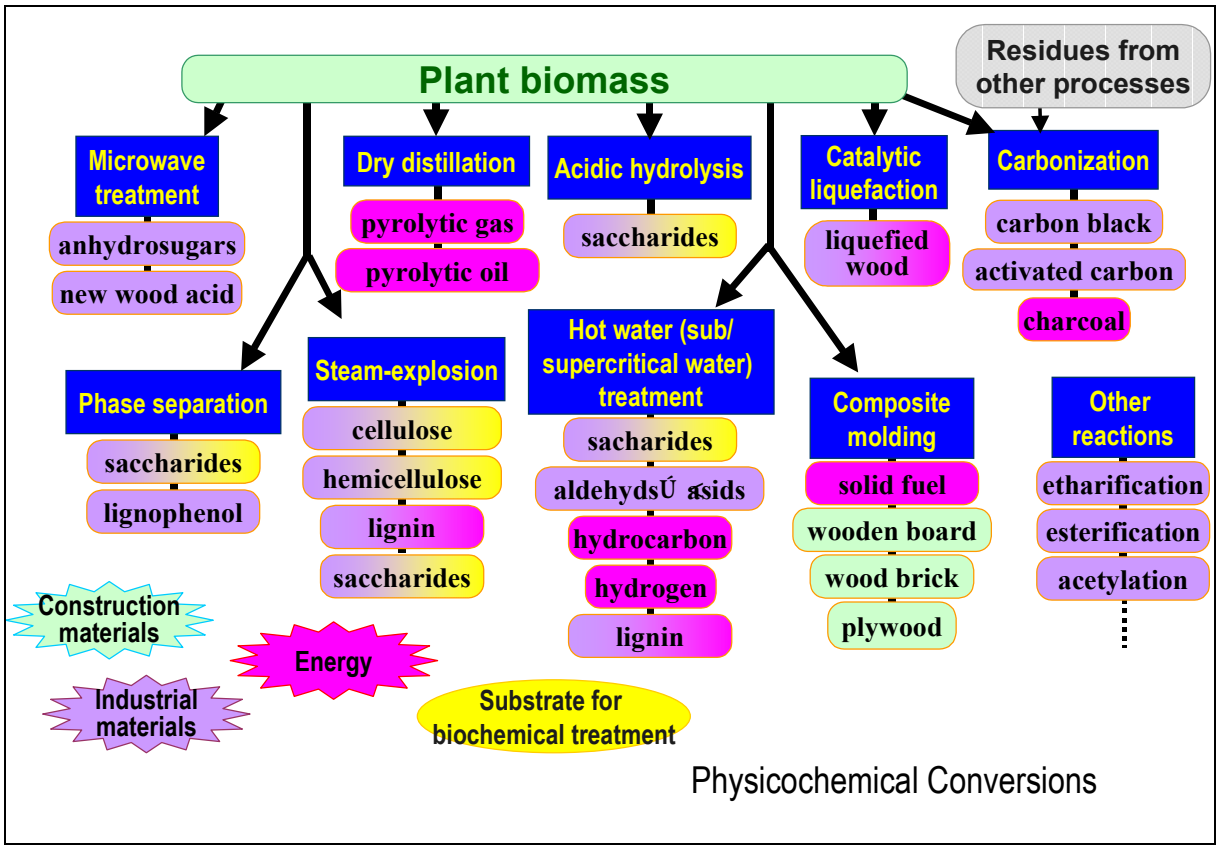


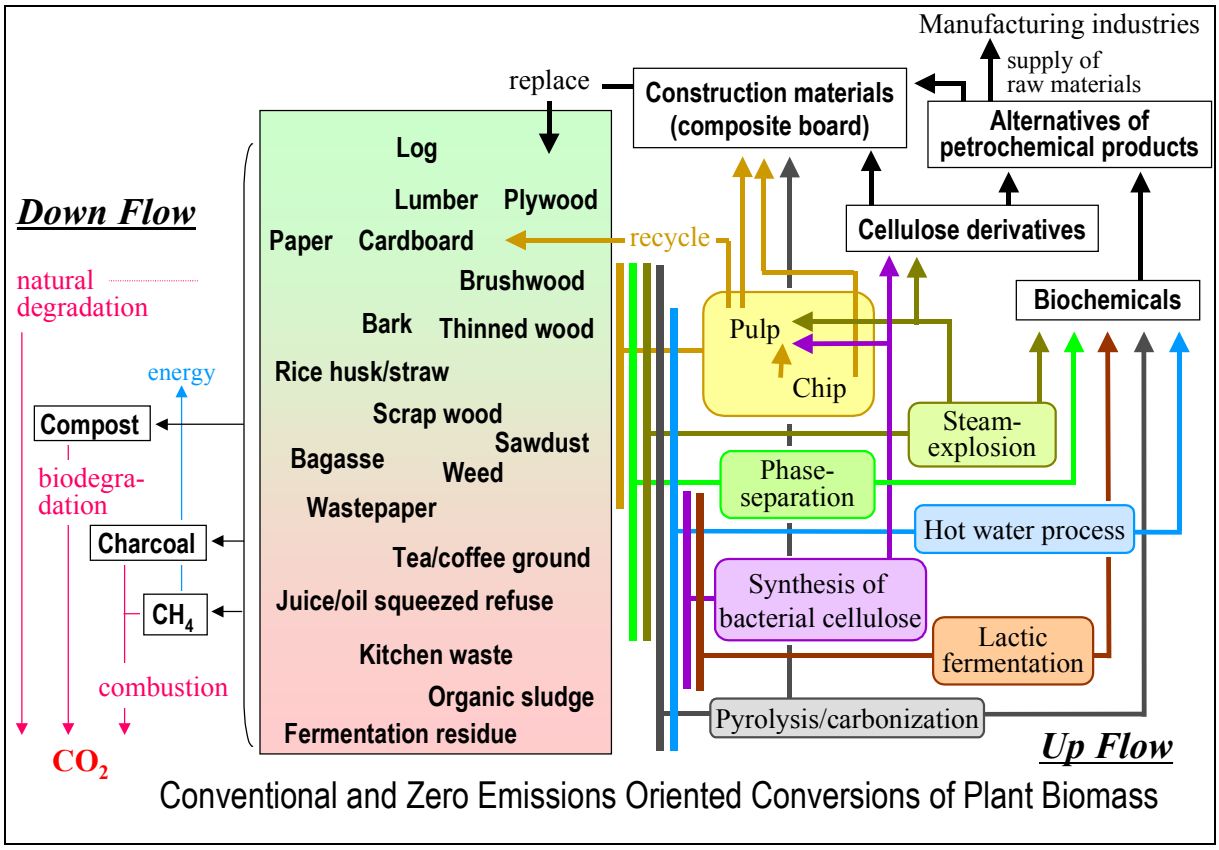
Basic Chemical Composition of Plant Biomass



Reactions and Products of Plant Biomass by Hot Water Process


Plant biomass
Appropriate pretreatment
ÙÙ cellulose, hemicellulose
Hydrolytic enzyme
Chemical saccharification
Compost (biodegradation)
fertilizer
Agricultural materials
sugars
Hexsoce, e.g., glucose
Pentose, e.g., xylose
Enzymatic reaction
Lactic fermentation
Alcohol fermentation
Methane fermentation
Industrial materials
hydrogen (hydrogenase)
lactic acid
ethanol
methane
organic acids (dehydrogenase)
Energy
Biochemical Conversions


Residues from other processes
Plant biomass
Microwave treatment
anhydrosugars
new wood acid
Dry distillation
pyrolytic gas
pyrolytic oil
Acidic hydrolysis
saccharides
Catalytic liquefaction
liquefied wood
Carbonization
carbon black
activated carbon
charcoal
Phase separation
saccharides
lignophenol
Steam-explosion
cellulose
hemicellulose
lignin
saccharides
Hot water (sub/ supercritical water) treatment
sacharides
aldehydsÚ asids
hydrocarbon
hydrogen
lignin
Composite molding
solid fuel
wooden board
wood brick
plywood
Other reactions
etharification
esterification
acetylation
Construction materials
Energy
Industrial materials
Substrate for biochemical treatment
Physicochemical Conversions



Conventional and Zero Emissions Oriented Conversions of Plant Biomass

Sustainability in teacher training courses at universities - an investigation of higher education in North Rhine-Westphalia

Christa Henze

University of Essen, Centre for Environmental Education, Essen

Framework of the investigation - goals and methods

In February 2000 a research project has been completed at the Centre for Environmental Education at the University of Essen that was orientated to the idea of sustainability in teacher training courses at universities. The area of teacher training is significant as, having the future activities in school in mind, students should be encouraged to investigate the field of sustainable development already during their studies. It is only by training activities that incorporate the contents and methods of Agenda 21 that key qualifications necessary for future changes can be conveyed. The enquiry was financially supported by the North Rhine-Westphalia Ministry of Schools, Education, Science and Research.[6]

The empirical investigation had a structural stock-taking character. The collection of data was confined to lectures, both research areas and the efforts of individual universities to implement an environmental management system (for example, initiating and actualising an 'eco-audit') had been excluded from investigation. Particular emphasis was given to teacher training courses which more or less could be subsumed under the theme of Agenda 21. The aim was to find out if there are some university courses which are already comparatively concerned with themes related to sustainability, and if so, whether they have already been able to create a distinctive profile. The survey should also indicate the factors that either promote or impede the implementation and dissemination of an education for a sustainable development in teacher training courses.

The research region was the state of Northrhine-Westphalia (Figure 1). This state, with almost 18 million inhabitants, is the most densely populated in Germany. In Northrhine-Westphalia, there are 13 universities providing teacher training in various subjects.

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[6] The results of the research project including positive examples of „good practice" implemented by individual lecturers on their way to achieve a training for a sustainable development will be published in Germ an language at the beginning of the year 2001.

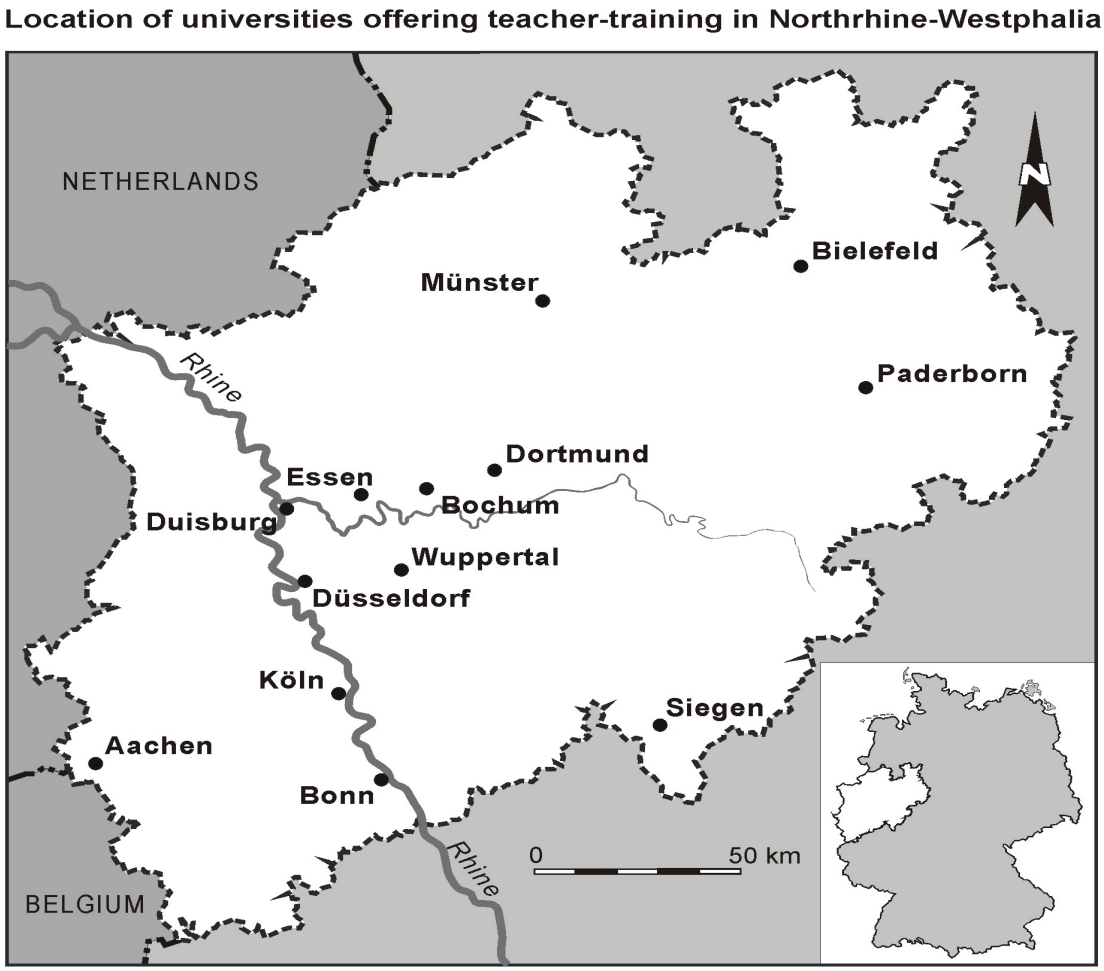

Figure 1: Location of universities providing teacher training in North-Rhine-Westphalia/Germany

The study was based on two data collections: In a first step, based on the winter semester 1998/99 lectures timetables both lectures that stated 'sustainability' in the title and where the relevance to Agenda 21 was apparent were included. In cases of doubt the commentaries on these lectures issued to students were used. Furthermore, lectures that taught key qualifications relevant to sustainability were included as well. This group includes topics as orientation towards systems and problem solving, communication and values and participation as well as innovative forms of teaching and learning (see Bund-Länder-Kommission für Bildungsplanung und Forschungsförderung, 1998, p 27).

In a second step, a group of selected university teachers were interviewed on the themes of special courses, the form of learning, the organisational/institutional framework, and on the factors that promote or hinder the implementation of an education for sustainability in teacher training courses at universities. The university teachers were also requested to comment on the degree of support they got by their departments and/or university and political organisations.

Investigation Results

Some of the main results of the reserach project can be summarized as follows:

1. In all the universities considered lectures relevant to the survey could be detected. However, at the same time, the contributions of individual subjects or subject areas differ widely: There is marked activity in some social and scientific subject areas. Geography is of special significance here, but also social and political sciences deal comparatively intensively with Agenda 21. In some faculties of geography, the value placed on sustainability was graded as „*enormously high*"; as a result of this grading, several teachers participate in the debate of Agenda 21 and offer theme-orientated lectures. Without any doubt, geography is one of the subjects where one can detect an initial implementation on sustainability themes.

   In several other subjects also, tendencies towards Agenda related activities are discernible. Among others, biology, educational sciences, economics, and psychology. However, in comparison with the subjects previous mentioned, these have less outstanding internal cooperation and the number of university teachers engaged in each institute with agenda-relevant aspects, is fewer.

   Considerable deficits are revealed in the following subjects or subject areas: languages, the fine arts, music, mathematics, information technology, sports, philosophy, history and chemistry, as well as some professional groupings, for example printing and design technology or production technology.

2. The expert interviews as well as the commentaries on many lectures reveal that some teacher-training courses only pick out one special aspect of sustainability as a central theme. As far as the educational sciences it is often the social dimension as for example questions of an intercultural education; in biology, ecology themes are dealt with. With regard to technologically orientated subjects, the subject contents can often be identified as a reaction to ecological problems and attitudes. An example are environmental technologies designed to minimise certain harmful elements in the atmosphere. In total, a remarkable amount of the courses offered do not come up to the demands of an integrative thinking of ecological, economic and social aspects of Agenda 21. The contributions considered, rather map out approximately the range of the links - seen from the aspect of content - for a training for sustainable development and, simultaneously, sketch the field or the patchwork that future efforts could work into.

3. The interviews with selected university lecturers indicate clearly that, in many cases, the discussion and integration of Agenda 21 related themes depend on individual convictions. Thereby, the individual interest and engagement of the responsible teacher is shown to be a dominant factor in the organisation of the corresponding courses offered. Such personalities were described by the university lecturers questioned as „*pioneers*" or „*loners*".

   The interest and the efforts of individuals often develop into a considerable burden for those concerned. This is revealed, for example, in inadequate, or completely absent support from the institution concerned (e. g. university administration) as also from specialist colleagues, in the realisation of events. Thus, many of the university lecturers interviewed expressed a wish for more recognition within their own departments and within the university in general.

4. In the discourse on the development of sustainability, intersubject relationships were revealed as a decisive and essential key requirement. An example is the German environmental report of 1994 by the Council of Environmental Experts (Der Rat von Sachverständigen für Umweltfragen, 1994), where the network principle was emphasised as the central principle of innovative educational processes.

   In the present data, there is only a small number of interdisciplinary oriented lectures. During the research period only two lectures with contributions by seven (!) subjects, two lectures with contributions by three subjects, and seven lectures with two subjects contributing could be detected. When, at the same time, one of the persons taking part in the conversation remarks that „*interdisciplinary cooperation is the most interesting thing* (offered) *at university level*", the result undoubtedly demonstrates that interdisciplinary techniques are not taught in an sufficient way. Thus, it is clear that the concept of interdisciplinary cooperation and participation, not only in the context of sustainable development, but also from the perspective of general trends and expectations (see, among other sources, the Wissenschafts- and Technikdelphi des Fraunhofer Instituts für Systemtechnik und Innovationsforschung, 1998) will not work out.

   The university lecturers interviewed gave various explanations in cases that interdisciplinary cooperation was either insufficiently developed or missing completely. As far as formalistic terms are concerned there is difficulty with the evaluation of seminar assignments. Moreover, political tendencies to shorten the total time of university studies may cause a reduction of the volume of matter to be studied. Finally, interdisciplinary courses can make it more difficult to calculate the appropriate teaching times of the lecturers as they have to be proved against the university administrations.

   Further hindrances to inter-subject and interdisciplinary cooperation are to be found on the subject level. One example is the statement of one university lecturer that a pre-requirement for interdisciplinary cooperation is „*the readiness to accept certain things in a somewhat more superficial way*". Another person describes this with these words: „*The price of interdisciplinary cooperation is scientific precision*". Such statements imply that in interdisciplinary cooperation, what is of importance is not scholarly thoroughness, but the knowledge of connecting areas. This, however, is, as always, in massive conflict with the interest of every department to „*give (students) a solid basis of knowledge*".

   Further hindrances to inter-subject and inter-disciplinary cooperation are to be found on the level of attitudes. Here, many of those interviewed plainly said that there is little general readiness to accept other worlds of thought and the ideas of other subject areas. This is true of both lecturers and students alike. Scepticism and fear of contact were also given as reasons for the lack of interdisciplinary exchange. The necessity for the development of a new understanding of language was repeatedly mentioned. One university lecturer said that colleagues of different subjects/disciplines „*speak completely different languages*" and that they „*are normally not aware of this*". Thus it is necessary first of all to find a new common language in order then to work out a theme in an interdisciplinary way. For another person questioned, the problem of the lack of cooperation lies with the fact that *„... we have absolutely no tradition of university cooperation. We are strongly differentiated, even within our own subjects*".

   And what is more is that university teachers are not adequately qualified. On the one hand, a number of interviews made it obvious that particularly long-used teaching habits can only be changed and modified slowly, step by step. The readiness to experiment with new methods and

thus to risk losing one's footing is not a matter of course for scholars. In general, it may be stated that the retention of traditional teaching methods corresponds to a lack of readiness to accept interdisciplinary cooperation and participation. On the other hand, the regular modes of a successful career are to impede participatory and interdisciplinary methods of working; for example, dissertations are written individually.

Conclusions

The facts presented clearly show that at some Northrhine-Westphalian universities there are interesting courses and engaged lecturers that remarkably contribute to the implementation and dissemination of sustainable development perspectives in teacher training courses. At the same time, there is a clear need to expand and complete syllabuses, methods and teaching staff. But the interviews with experts at many institutes indicated that relevant efforts and processes are, at least partly, being impeded.

As an indispensable starting point for training processes in the context of sustainable development, on the one hand, there are efforts to simplify and unify the acknowledgement of relevant courses. This is the only way to ensure that interdisciplinary cooperation and an inter-subject and inter-departmental form of studies is rated more positively. On the other hand, it seems to be necessary to make sustainability themes compulsory in examinations. However, this ensues the reduction of other compulsory topics in order to use the time at disposal for interdisciplinary forms of work. In general, the aim should be to include the environment and its development as an interdisciplinary area in the syllabus of those subjects which are closely related to the debate on sustainability. These are not exclusively subjects with an affinity to nature or technology, but also subjects with a cultural, social, polical and economics direction.

Many of the interviewed considered that „*a gentle nudge ... would do no damage*". The phrase „*exercise of authority*" was also used in a metaphorical sense. Corresponding remarks indicate unmistakably that the Agenda theme should be declared as compulsory to teacher training by the Ministry and University Administrations. Innovative processes and changes can not be expected only to be grassrooted.

Among other factors, this calls for a purposeful encouragement of the new generation of scholars. The problem of the actual, often intense, but nevertheless isolated engagement of many individuals was aptly described by one of the university lecturers interviewed: „*When these people retire, the whole matter dies. There is nobody to take their places*". So measures must be taken to provide professional horizons for young people - horizons which to date have been lacking. One area where this can profitably be done is new appointments: here the job description must clearly consider sustainable development.

The efforts of single working groups and /or subject groups must, in addition, receive financial support. This can be used as motivation if it is used in the form of purposeful development programmes. Compulsory participation and interdisciplinary cooperation should here always be a central criterion for evaluation and grants, but it also demands a new, radically changed concept of university organisation to include terms like „network", „cooperation" and „independent and self-directing groups". The present study strongly indicates that a lack of interdisciplinary cooperation is a hindrance to a speedy and optimal treatment of the theme of sustainability in university studies. To this degree it is indispensable that measures be taken to loosen up inflexible structures and well-worn teaching methods and to demand that efforts be made towards training in modern, innovative forms of teaching and learning. This is all the more important in that current specialist-orientated - and not problem-orientated - forms of today's

university education widely, if not systematically, impede the acquisition of competent professionals to research and work out questions related to sustainability.

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Citizen Participation System towards Sustainability - Strategic Environmental Assessment and Scoping -

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EIA for Sustainability

The Japanese EIA Act of 1997, which provides new EIA system, was enacted from June 1999. We can observe improvements of the EIA system by the Act, e.g. introducing screening and scoping processes. The comments are invited from everybody who has concerns to the environment. But citizen participation system provided by the law is still not enough.

As EIA process starts at the stage of the project plan is not too solid, we could take a strategic approach. It is required to write the results of comparison of alternatives in Draft Environmental Impact Statement to show the efforts of the proponent to mitigate the impacts. This is the major part of the accountability of environmental awareness. It means that the scope of possible alternatives to the proposed project should be examined in the scoping process.

Planning Process and SEA

Human activities should be controlled for sustainable development. But even if we were successful in dealing with each project to make it environmentally sound, there is a limitation. It is impossible to mitigate the cumulative impacts by various projects done in a certain area. This is a shortcoming of Project EIA.

Japanese planning system has an essential problem for sustainable development. Environmental impact assessment (EIA) process starts after the planning process. We should change our planning process by involving the EIA process inside. We must change the EIA system to start it at earlier stages of planning process. This is Strategic Environmental Assessment (SEA).

SEA is applied to the earlier decision making of strategic levels to get rid of shortcomings of Project EIA. It can be applied to a wide range of decision making from legislative process to city and regional

planning. But the aim is clear. The proponents of a big project, both public and/or private, have to explain the rational for sustainable development. SEA is a way to reach this goal. It requires information disclosure and public involvement.

Though the Japanese society is not familiar with an open planning system, the EIA Act provides an opportunity of making our planning system more open. Introducing the scoping process has a very important meaning. EIA process should start in a planning process which is different from the old EIA system in Japan. The old system started at the point when the planning process was almost finished. It, therefore, was impossible to compare alternatives.

Towards SEA

It is common that most cases of EIA are those on Projects not only in Japan but also in American and European countries. But recently, some examples of SEA are emerging in those countries. For instances, some of EU countries started their EA systems on policies, plans and programs. The most important topic is the proposal of EC Directive of SEA in December 1996. It was modified in February 1999. The proposal was sent to the EU Parliament in 2000.

The decision-making process towards a project has a three layers system of policy, plan or program, and project in general. SEA is a common word utilized the environmental assessment applied to the up-stream decision making stages of the project. The Japanese system has almost same structure as this. But decision making process of the previous stage has been very opaque in Japan. Same kind of things happens in other countries. Though, NEPA system had SEA system from the start, the experience of NEPA shows the most of EIAs were project EIA.

The evaluation perspective of SEA should be wide enough to include not only natural environmental aspects but also social and economic aspects. It is essential for conducting SEA.

Scoping Process as the First Step

I show a recent example. This is a case of the 2005 World Exposition Project in Aichi Prefecture, which is called “Aichi Banpaku”. As the main theme of the exposition is “Beyond Development: Wisdom of the Nature”, EIA was required by the Cabinet agreement in 1995 though the project was not necessary to apply EIA. The framework of the EIA Act was applied prior to its implementation.

The scoping process was started from April 1998 and it was finished in February 1999 when the D-EIS was published. The proponent did not show a wide scope of the alternatives. It compared only two alternatives whose difference was very trivial. The alternatives should include those with different views or different degrees of environmental protection. This reluctant attitude shown in the scoping process caused a big delay of the implementation of the project. Scoping process should be considered the essential part of citizen participation in project decision making for sustainable development.

Reference:

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Research Activities in Germany

Helmut Schulz
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Sustainable Management
Orientation towards sustainability
Objectives are:
• to increase energy and resource efficiency;
• to ease the burden on the environment;
• to find economic solutions;
• to improve competitiveness of industry;
• to create new markets, jobs and welfare
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Federal Ministry of Education and Research
Munich, 27.09.2000


Sustainable Development (SD)
• Starting point for SD in German politics was the protection of the environment
• Today priority is given to integrated approaches in all policy areas
• Green Cabinet supported by a Council for Sustainable Development
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Federal Ministry of Education and Research
Munich, 27.09.2000

Sustainable Development (SD)

- Environmental policy
- R&D policy

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Munich, 27.09.2000

Environmental Policy in Germany

- Progress by strict environmental legislation
- Command and control policy is reaching its limits in Germany (cost - benefit)
- **Challenge:** increasing wealth while at the same time reducing environmental damage
- New policy approaches are needed to implement sustainable development

bmb+f Federal Ministry of Education and Research

Munich, 27.09.2000


Environmental Policy in Germany
How to meet the challenges?
• Re-regulation
• More economic instruments and cooperation
• Stipulation of environmental objectives
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Munich, 27.09.2000


R&E Policy for Sustainable Development
• Integration of sustainability into national R&D programmes
• Education is an important prerequisite for the development of a sustainable corporate culture
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Federal Ministry of Education and Research
Munich, 27.09.2000

R&D Policy for Sustainable Development

- Integration in R&D programmes such as energy, construction and housing, transportation/mobility, „Green chemisty", ICT
- „Research for the Environment"
  (Key programme for sustainable development)

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Federal Ministry of Education and Research

Munich, 27.09.2000

Federal Programme „Research for the Environment"

- **Regional approaches towards sustainability** 119,9
- **Global Change Research** 108,0
- **R&D for Sustainable Management** 131,3

(Integrated environmental protection for a sustainable economy)

359,2 Mio. DM
in 2000

bmb+f
Federal Ministry of Education and Research

Munich, 27.09.2000

R&D Policy for Sustainable Development

One of five key concepts of research policy in Germany is **„Sustainable global growth“**

- A perceptible rise in ecological efficiency is required worldwide
- In addition basic innovations are required opening up fundamental new, more enviromentally acceptable paths for technology and product development

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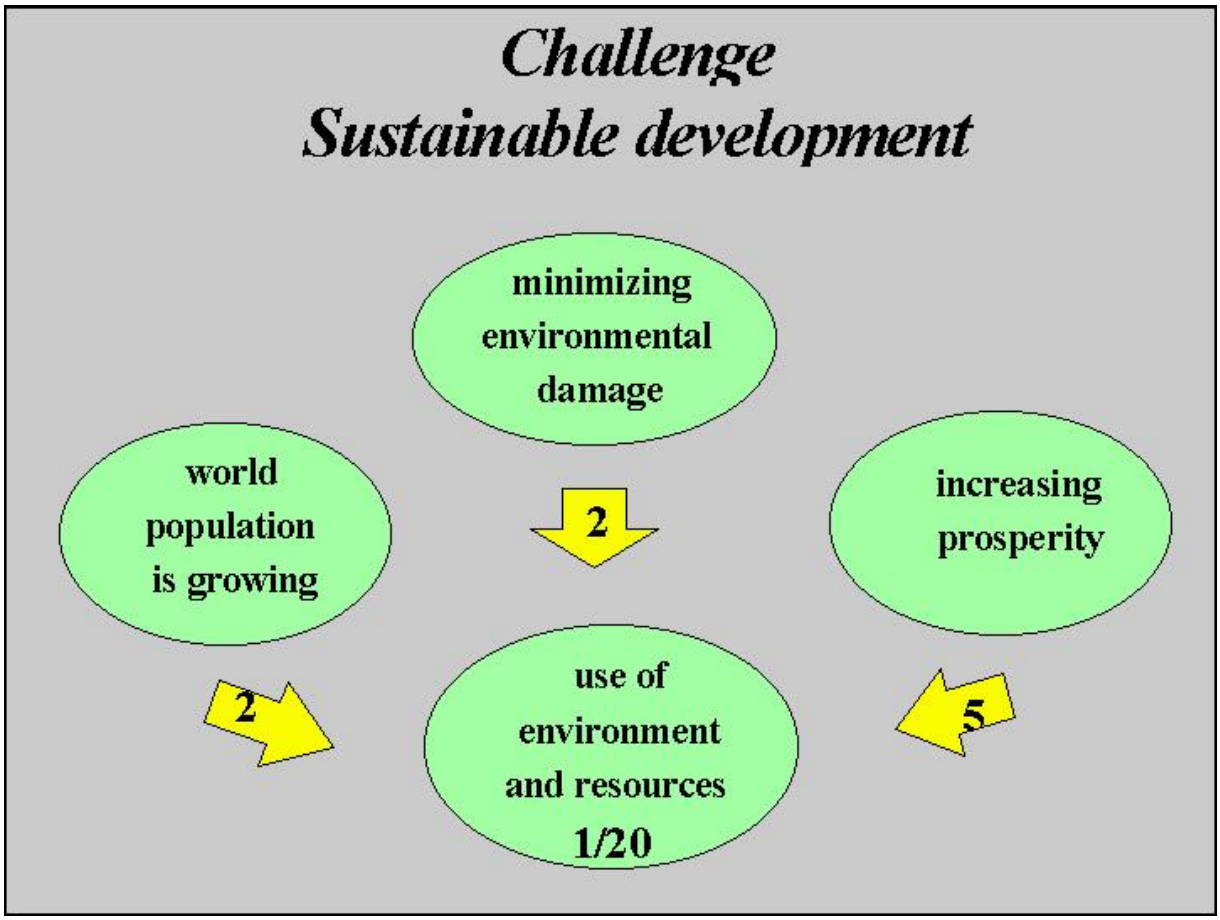

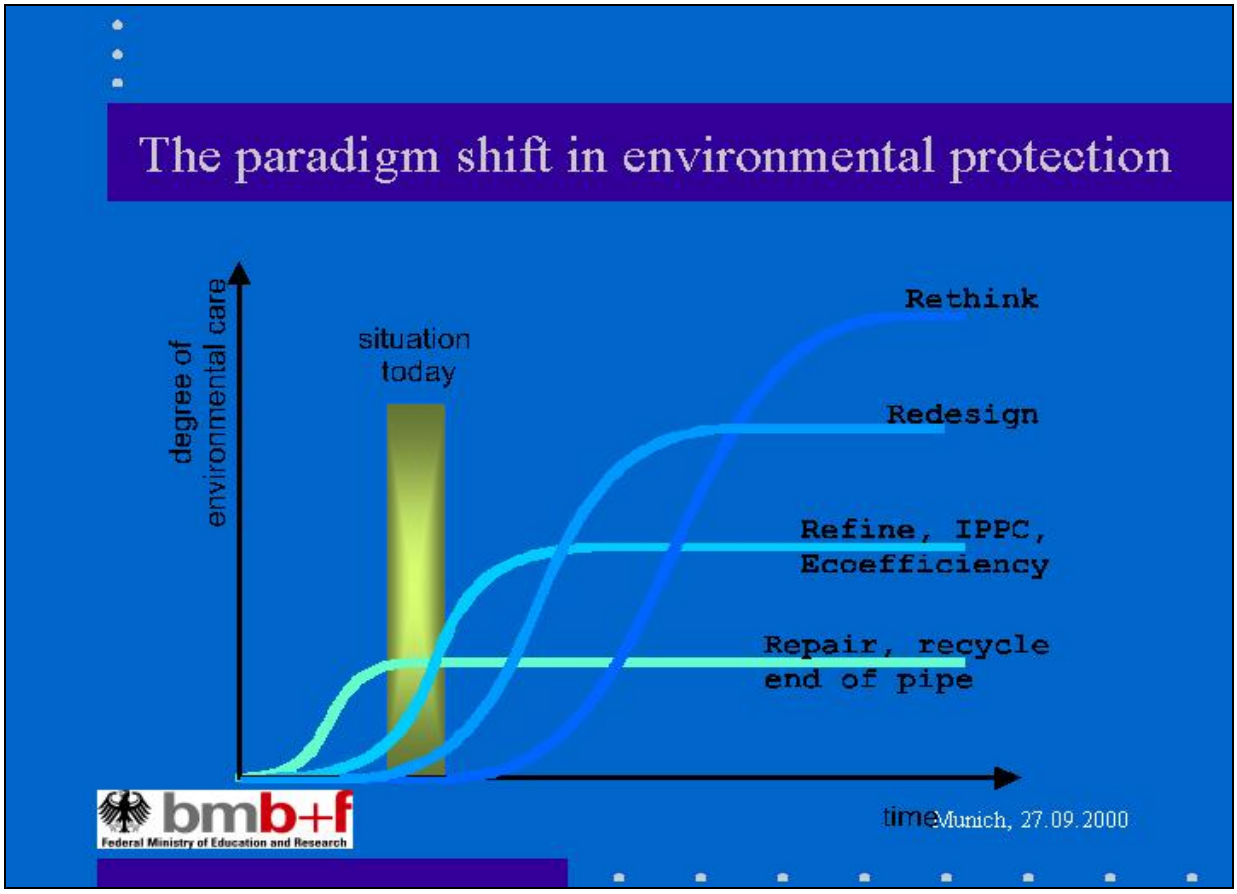
The paradigm shift in environmental protection
degree of environmental care
situation today
Rethink
Redesign
Refine, IPPC, Ecoefficiency
Repair, recycle end of pipe
time
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Air pollution
Raw material
Energy
Water
Manpower, capital
Products, services
Waste
Waste water, sludge
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Sustainable Management
One ton of waste are
• 700 kg wrong conditions
• 200 kg mental laziness
• 100 kg real waste
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Sustainable Management
• Wrong conditions
• Mental laziness
• Real waste
institutional innovations
social innovations
technological innovations
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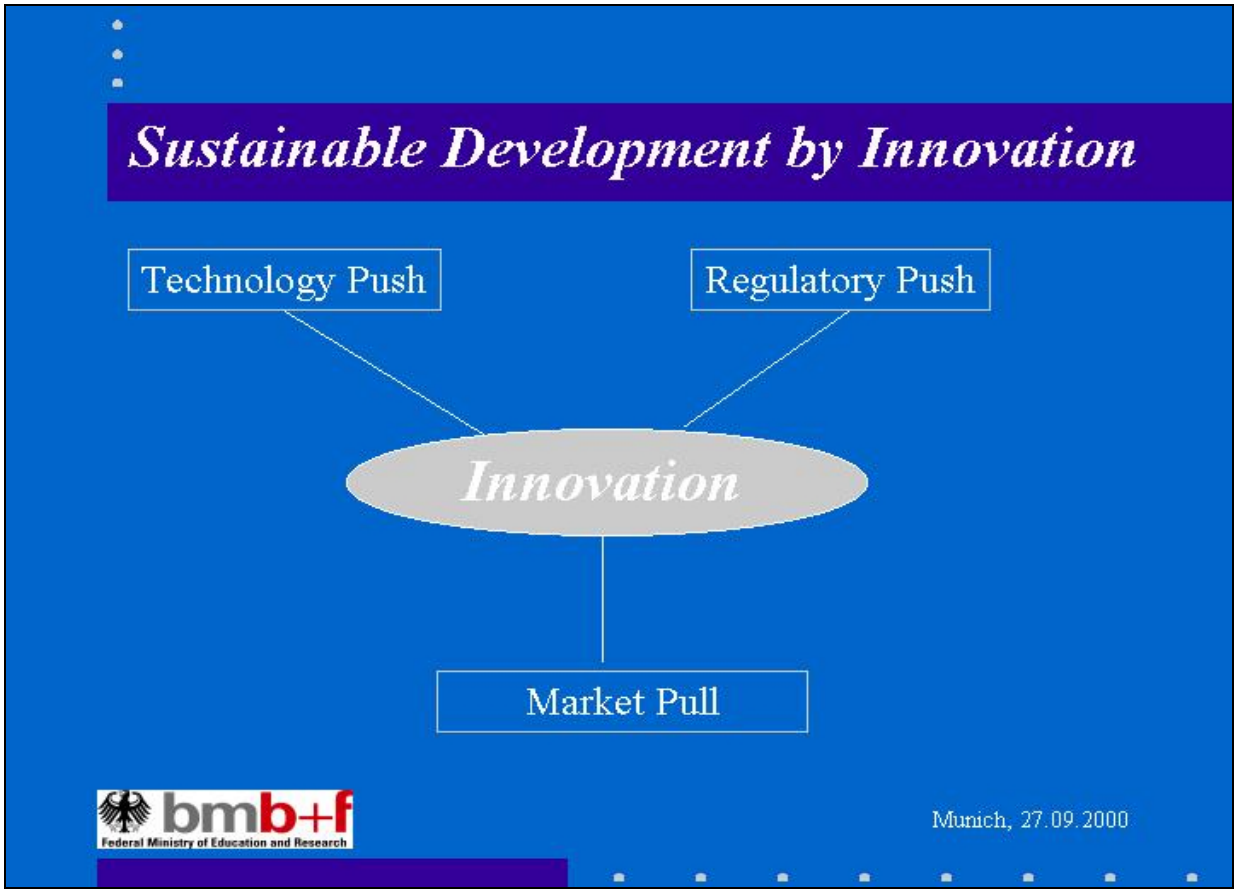

Research for clean production, sustainable products and consumption

Sectors	Production	Product	Instruments	Demand
Agriculture and food processing industry				
Chemicals and plastics				
Textiles and leather				
Forestry and wood processing	*R&D to promote innovations*			
Metal producing industry				
Electronics industry				
Construction industry, glass and ceramics				

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Sustainable leather production
• by reducing consumption of fresh water
• by reducing waste-water contamination
• by minimizing the use of chromium
• by new formulae for tanning systems
• by improved purification plants for process water
• by low-temperature conversion for processing and re-using sludge
Result: economic and environmentally compatible solutions
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Eco-efficient fertilizer
Objective: minimizing nitrogen emissions, improvement of production, higher yields with the same quantity of fertilizers
• fertilizer with nitrification inhibitors
• coated fertilizers
• slow-acting fertilizers
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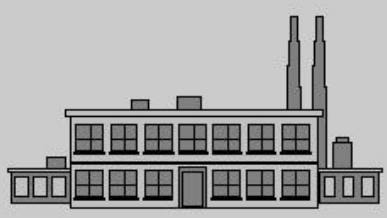
Munich, 27.09.2000

Higher resource efficiency, sustainable products and systems

Zero emission

High efficiency in using raw materials, energy and water, qualified manpower, capital



Sustainable products

Almost no waste, waste water, sludge

Closing loops in the production process, material flow management

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Sustainable Development by Innovation

- New strategies for the use of products (e.g. car sharing, repairing)
- Framework conditions
- Sustainable consumption

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Can a company, a consumer be „Sustainable“ in an environment that is not?
“Sustainability” is not a clear defined final state, but a set of rules.
The appearance of “Sustainability” will be different in different cultures and thus a “Sustainable Company” can exist in any socio-economic environment.
Any company can start to respect the rules of Sustainability right now, even under existing social, technical and economical conditions.
R&D, education and information will offer new options.
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Federal Ministry of Education and Research
Munich, 27.09.2000

"FEASIBLE INDUSTRIAL ZERO EMISSIONS SYSTEMS FOR RESOURCE RECOVERY AND ENERGY PRODUCTION"[7]

Hiroyuki FUJIMURA

EBARA Corporation, Japan

Current Situation of Zero Emission Activities in Japan

The Earth Summit, held in 1992 at Rio, prompted many countries to incorporate environmental aspects into their industrial strategy as basic national policy, seeking viable industrial and social systems for sustainable development.

Also in Japan, not only the Environment Agency, but also ministries directly related to the industrial sector are emphasizing their commitment to environment--oriented policies. For example, a report on the perspective of environment- friendly industry, issued by the Ministry of International Trade and Industry in 1994, recognizes the environmental aspects as a vital issue for the whole industry. It describes the current situation of environmental protection, future trends and new environmental technologies in 15 fields ranging from the steel industry to the distribution sector, clearly showing that recycling- oriented industry is essential for Japan's future.

Along with this commitment by the government, the private sector has been promoting Zero Emission activities, typically seen in the recent increase of a 'zero waste declaration' at factories. Here 1 would like to introduce to you a closed system of photocopy machine recycle by Fuji Xerox Co., Ltd. as one example. They collect, not only toner cartridges, but also the machines themselves through sales agents and dismantle them at their factories. Some parts and assemblies are directly put into manufacturing processes for re-use, while others are utilized for material recycling.

Another example is the "Zero Emission Brewery" by Asahi Breweries, Ltd. They have achieved a 100% recycling rate in their breweries, including waste malt from brewery processes, packaging materials and general waste from offices, and have reduced discharge of industrial waste to zero level. Asahi has also developed new recycling systems for waste malt, which is the largest waste from breweries in volume, other than conventional recycling into livestock feed or compost for farmland. It can be utilized

[7] Presented at International Symposium "Towards Zero Emissions, The Challenge for Hydrocarbons", Rome (Italy) 11-13 March 1999

as a culturing medium for mushroom, or can be converted to granular charcoal that is effective as a soil conditioner for farmland.
These examples have proved that Zero Emission manufacturing systems can contribute to cost reduction by reducing material consumption or waste management fee, showing the way to harmonize environment with economy. That stimulated many private companies to become conscious of environment, so that the number of Japanese companies qualified with ISO 14000 certification has reached 1632 as of January 1999, which is the largest in the world.
On the other hand, local governments, which are responsible for core environmental services such as sewage treatment or waste treatment, are tackling with a new type of local development that integrates local industry and environmental administration by Zero Emission viewpoints. For example, more than 60 local governments have started feasibility studies in cooperation with private firms, universities, research institutes and NG0s on the 'Eco-Town Projects' sponsored by the Ministry of International Trade and Industry Ministry. Some of the projects are now coming to an actual stage, and attracting national attention. Joetsu city, located in northern japan, has started the Joetsu Eco-City Plan, which aims to establish a comprehensive recycling system. It is going to collect waste from the agricultural sector and industrial complexes in the city and to utilize it through combination of various processes such as metal recovery, composting, conversion to cement material, oil production from plastics and thermal recycling. A comprehensive waste and night soil treatment plant, the core facility of the project, is now under construction.

Kita-Kyushu city, one of Japan's major industrial cities, also announced its “Kita-Kyushu Eco Town Plan”, which consists of three major policies; promotion of 'inverse manufacturing' industry; development of advanced environmental technologies; and information and education services on environmental issues. Recycling of automobiles and electric appliances is now under consideration.

Regarding ISO 14000, local governments show positive attention and some of them, including before -mentioned Joetsu city, have already obtained certification, while Tokyo Metropolitan government is also seeking certification.

Furthermore, the academic sector is aggressively promoting research on Zero Emission technologies. Dr. Motoyuki Suzuki, a professor of institute of Industrial Science, University of Tokyo, developed a research project titled “Zero Emissions Oriented Material Cycle Processes” sponsored by the Grant-in-aid for Scientific Research from Ministry of Education in 1997. The project, performed under three themes of Process Zero Emissions, Zero Emissions Network and Regional Zero Emissions, bore such fruit as a conversion technology of fish waste to amino acids or proteins through sub-critical water reactions. This project has been approved by the 168th Committee of Japan Society for the Promotion of Science for further research.

Technology Development Towards Zero Emission

As shown in these examples, commitment to realization of recycling- oriented Zero Emission society is steadily progressing in Japan, by introduction of advanced environmental- friendly technologies.
It should be noted that Zero Emission technologies are different from conventional environmental

technologies in such point that they should be evaluated from LCA (Life Cycle Assessment) standpoints. Namely, qualitative and quantitative analysis of total environmental stress on a society brought by the introduction of a technology is indispensable for evaluation of the technology.

Here is an example of LCA analysis applied to solid waste treatment systems. This analysis is a system comparison between a gasification combustion & ash melting system, an advanced waste treatment technology, and a conventional incineration system equipped with a power generator. The gasification system converts waste to raw gas for chemical industry through a gasification process performed under reductive condition in a primary low-temperature gasification furnace, followed by a combustion process in a secondary high-temperature melting furnace. The raw gas can be easily processed to useful chemical compounds such as hydrogen or ammonia. Although our intuition cannot give us any suggestion in such a complicated comparison on which system is better, LCA analysis that employs industry-matrix analysis methods can make quantitative comparisons of various environmental parameters. The result shows that the gasification and chemical recycling system has lower environmental impacts compared with the waste incineration system with a generator, in all terms of emission of greenhouse gases, consumption of non-renewable resources and emission of acid rain pollutants. That is to say, the gasification system is a highly effective technology for realization of Zero Emission society. Further analysis is currently under way in a case that a fuel cell system is applied for power generation, instead of ordinary boiler-turbine systems. It is expected that fuel cell systems can reduce environmental impacts because they produce electric power through chemical reaction by hydrogen and oxygen, without high temperature combustion accompanied with NOx pollutants. Application of biomass resources as hydrogen donors to fuel cells is also an interesting theme for researchers.

As shown in these examples, it is an outstanding advantage of LCA analysis that it can compare and evaluate different kinds of technology in quantitative and objective way. It is important to apply LCA viewpoints not only to technological fields but also to analysis on social or economic systems.

Tasks to Be Tackled for Zero Emission Promotion

As 1 introduced to you here, the public and private sectors in Japan are increasingly devoted to Zero Emission initiative. However, we still have many tasks and issues to be tackled for realization of actual Zero Emission society.

First of all, further technology development is necessary. In the energy field, technologies for utilization of renewable and alternative energy such as natural energy or biomass energy should be developed, while energy and resource-saving technology, especially cascading use of energy or recycling use of materials by inverse manufacturing systems, is also important.

The second issue is formation of industrial clusters by optimum combination of industrial sectors. As typically shown in the before -mentioned case of the gasification system, it is essential to create industrial clusters which make circulation use of resources by conversion of waste from an industry to resources for another industry, because it is impossible to achieve Zero Emission within one industry completely. In the case of the gasification system, actual industrial cooperation for chemical recycling

from waste is already progressing in Japan between Ebara corporation, an environmental engineering firm, and Ube Industries, Ltd., a chemical giant.
Also in China, an actual cluster is being organized between electric power industry, fertilizer distributors and the agricultural sector, by introduction of a conversion technology that produces chemical fertilizer from exhaust gas from coal-fired thermal power stations.

Third, it is impossible to realize sustainable recycling- oriented society by development of technologies alone, and it is essential to create and organize various social frameworks, which support the Zero Emission systems. Environmental laws or regulations, including accompanying penalties, should be set stricter as a general framework of society, while incentive systems including taxation or subsidies are to be arranged to promote competition or technology development within the framework. Changes of life-style and paradigm among people, and environmental education for such paradigm shifts, are also necessary. These are issues to be solved through comprehensive commitment by all of the public sector, private firms and citizens.

Next, it is important that the LCA methods 1 mentioned before should be applied to whole social systems. It would help us to make effective design, review and evaluation of social systems, which can harmonize economy with environment, through full cost accounting of environmental factors. At this standpoint, we are currently promoting a research program on an LCA-based evaluation system for social systems, called Zero Emission System Analysis (ZESA).

Finally, I have to refer to international co-operation. It is clear that it would result in rapid depletion of resources and catastrophic destruction of global environment, if developing countries take the same courses as developed countries have in the past. Therefore, it is responsibility of developed countries to co-operate with developing countries to promote their environmental -friendly economic development by transferring technologies or systems for sustainable society, including ones 1 mentioned here. And it will accelerate realization of Zero Emission society on the global basis if the developing countries in return provide the developed countries with their own technologies and know-how obtained from actual experiences. That will achieve international cooperation in a true sense, in which both of developing and developed countries provide their wisdom with each other for future of human being.

Conclusions

Now it is time to conclude my presentation, which introduced to you actual commitment towards Zero Emission in Japan. The commitment in Japan, as well as in other countries, has just started and it is important to promote further exchange of information and technologies. I sincerely hope that this symposium provides you chances for such exchange towards realization of Zero Emission.

Thank you very much for your kind attention.

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