Effect of Different Weighting Methods on the Identification of Key Issues in LCA

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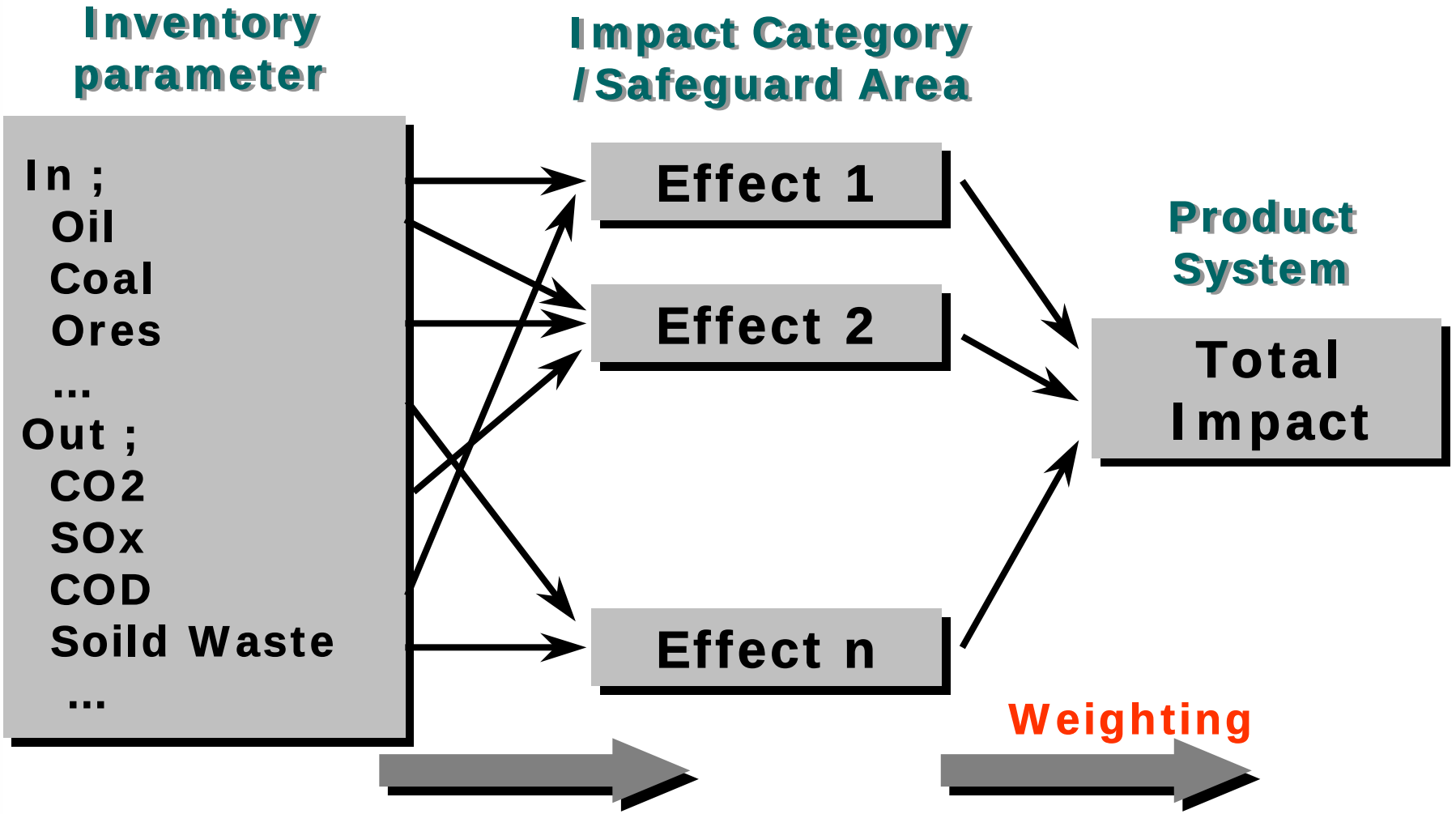
Background

- DfE ;
  Pollution Prevention Alternative
- LCA ;
  Tool for Ecodesign
  Evaluation of environmental aspects
- Identification of key issues ;
  Characterized or Weighted impact
- Impact of a product system
  needs a weighting step

Objective

Assessment of the effect of different weighting methods on the identification of key issues of a product system

Weighting Approach



Weighting

What is it ?

- Relative importance of the different impact categories is weighted against each other
- Step to aggregating the results in very specific cases and only when meaningful (ISO 14042)

Weighting

Why do we need it ?

- To express the total environmental burden of a product system in a single score
- Internal use in companies for product development application

Weighting Approaches

- Either quantitative or qualitative
- Quantitative step
  - Expert panel method
  - Monetization method
  - Distance-to-Target method

Expert Panel Method

- **Method ;**
  questionnaires, interviews or group discussion
- **Group of panelist ;**
  experts, stakeholders or lay-people
- **Procedure ;**
  one-round or multi-rounds procedure

Monetization Method

- Similar to the panel method
- Similarity ;

  People are asked to distribute points on the different impact categories
- Difference ;

  People are asked to put monetary value on the impact category

Distance to Target Method

- Relating the weighting factors(w_i) to some sort of target
- Targets ;

  standards, environmentally quality, political reduction targets, ...
- General form of the weighting factor ;

  T_i / N_i

Several Existing Weighting Methods

- Index of Environmental Friendliness(IEF)
- Environmental Priority Strategies(EPS)
- EDIP
- Ecoindicator 99 ...

Korean Weighting Method

$$Eco\text{-}indicator = WI = \sum \frac{CI_i}{N_i} \frac{N_i}{T_i} f_i$$

WI ; weighted impact of a product system

CI_i ; characterized impact of the i^{th} impact category(IC)

N_i ; normalization reference of the i^{th} IC

N_i / T_i ; reduction factor of the i^{th} IC

f_i ; relative significance factor of the i^{th} IC

Weighting Factor, W_i

$$W_i = \frac{N_i}{T_i} f_i$$

Product of
the reduction factor($RF = N_i / T_i$)
and
the relative significance factor(f_i)

RF and f_i

RF(N_i / T_i) ;

- Internal aspects of an impact category
- Degree of seriousness of the impact in a given impact category

f_i ;

- External aspects of an impact category
- Degree of relative significance of the impact among different impact categories

Reduction Factor

Normalization reference (N_i)

- 1995 year
- Impact based on actual data

Target reference (T_i)

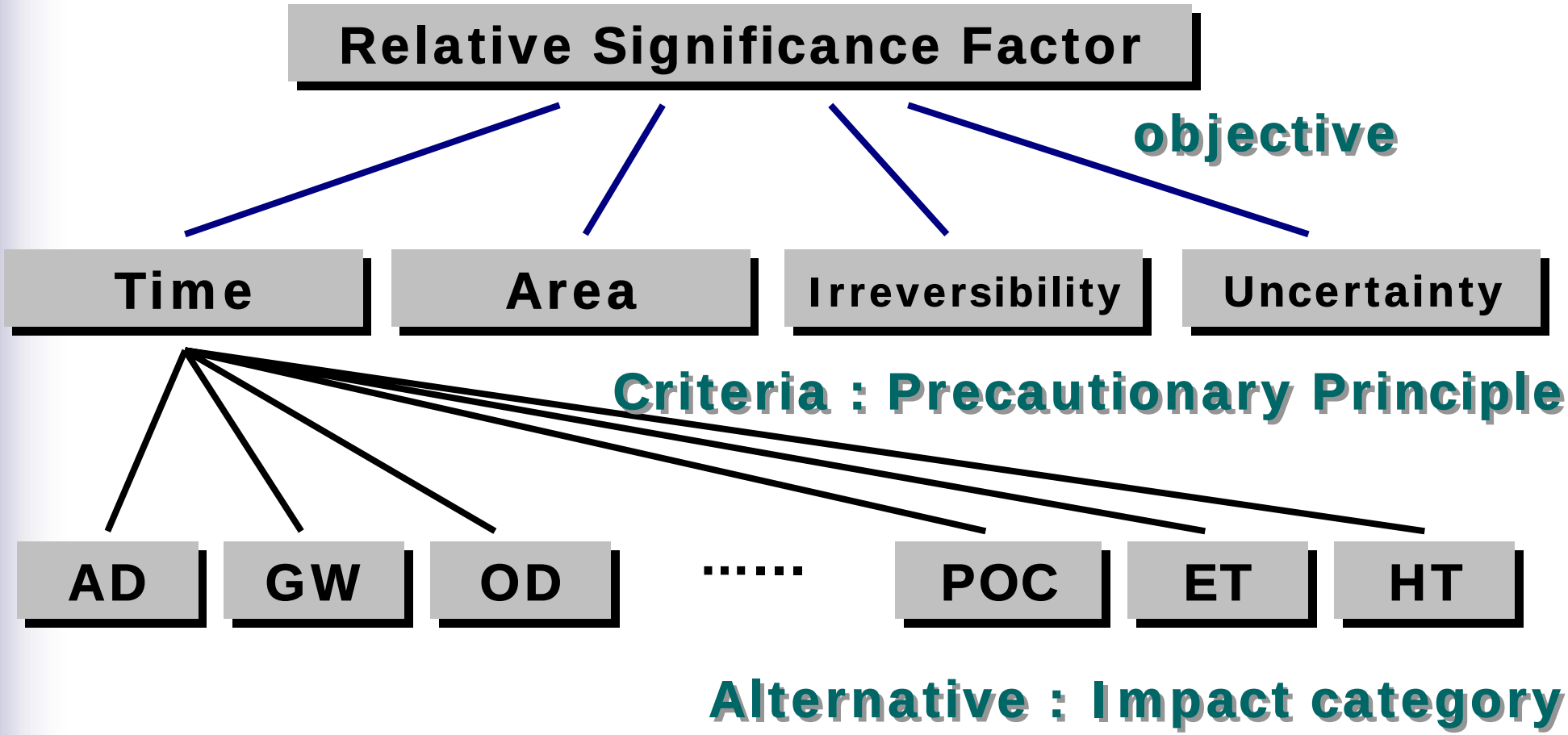
- 2000 year
- Political target
- Data collection ;

  Global impact : International target
  Regional Impact : Korean target

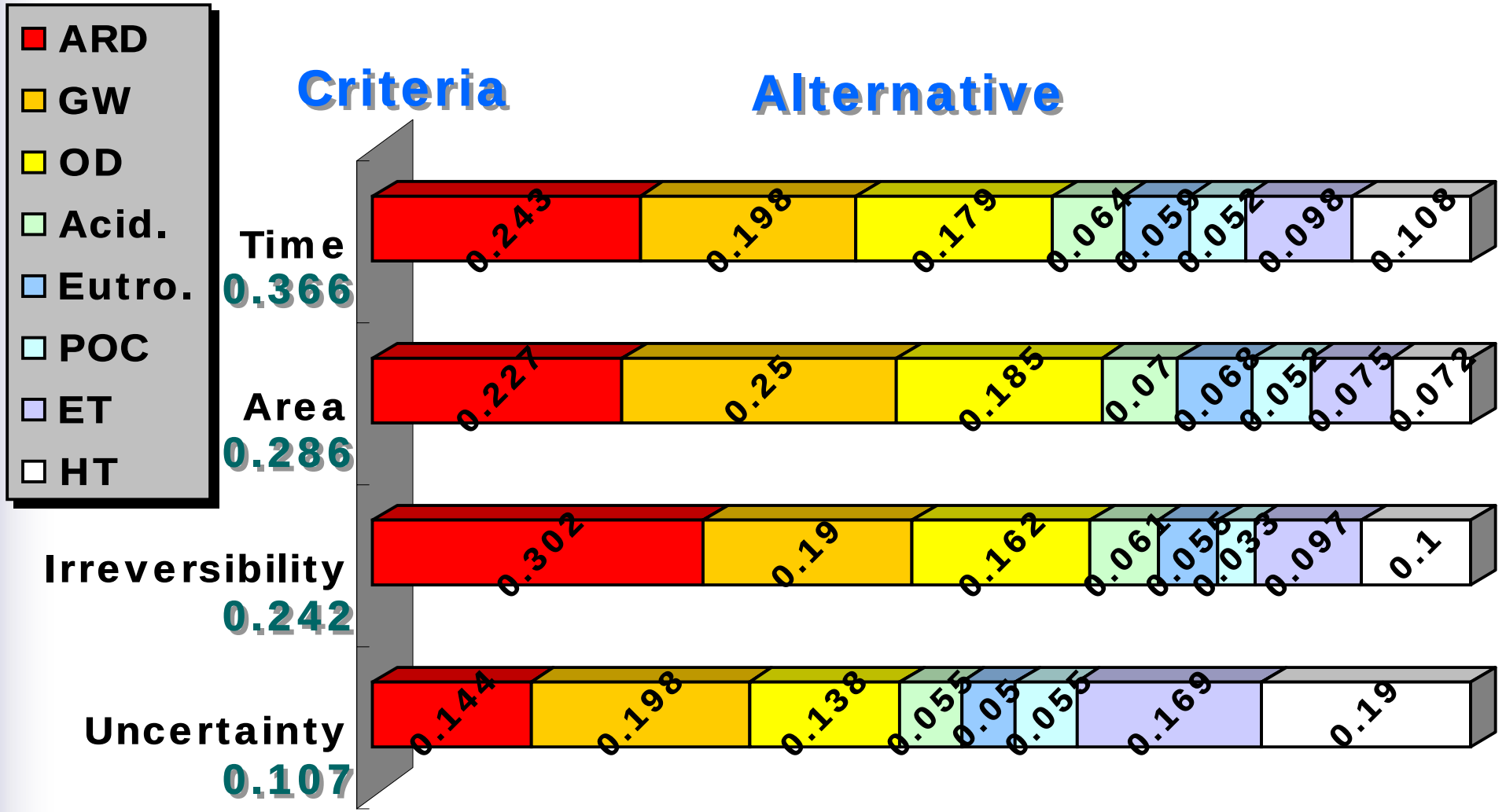
Relative Significance Factor

- Analytic Hierarchy Process (AHP)
- Hierarchy structure
  - Objective, Criteria and Alternative
- Pair-wise comparison
  - Questionnaire
  - Criteria and Alternative
- Questionnaire
  - Korean LCA experts

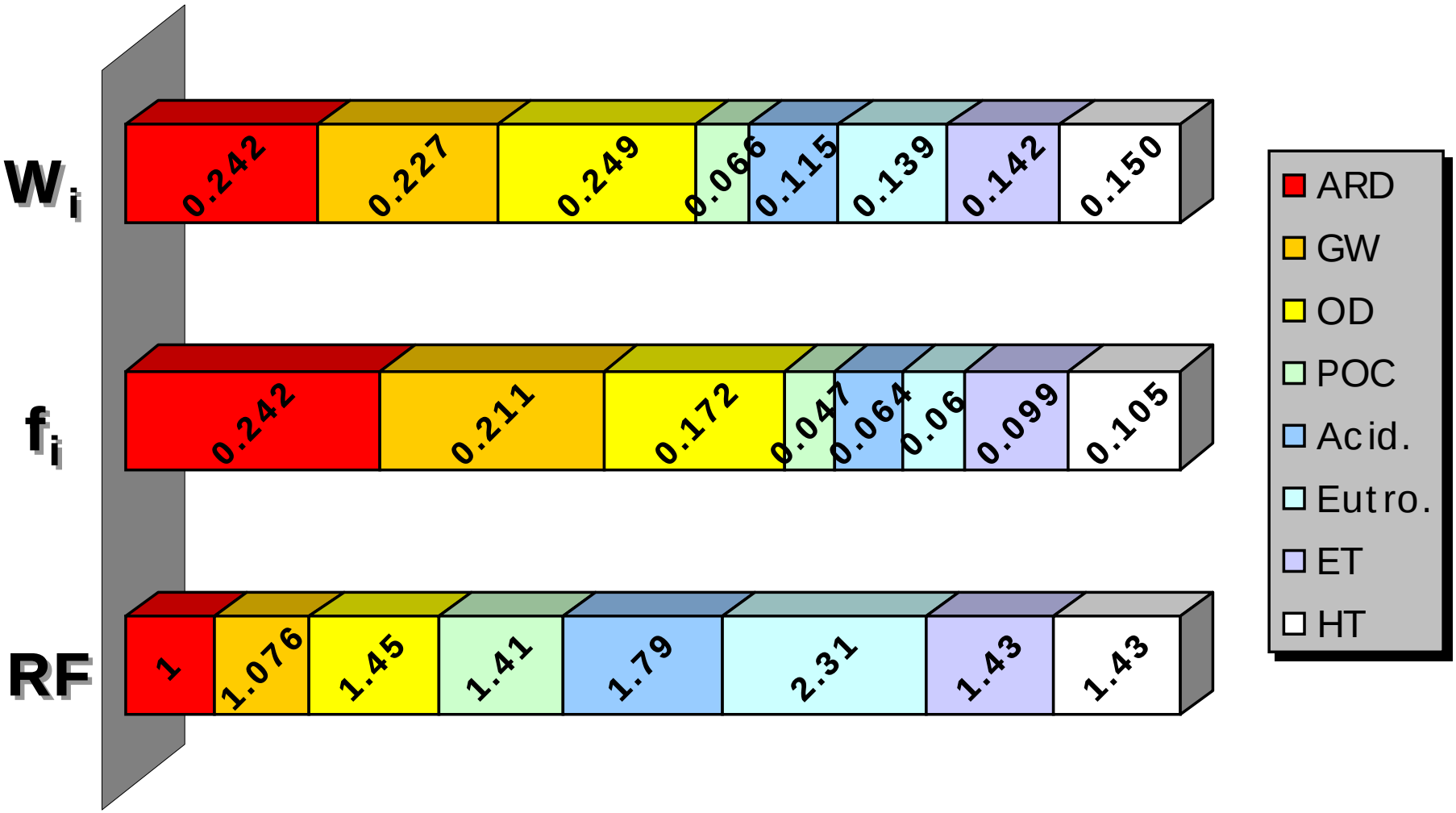
Relative Significance Factor



Relative Significance Factor



RF, f_i and W_i


W_i
0.242
0.227
0.249
0.066
0.115
0.139
0.142
0.150
f_i
0.242
0.211
0.172
0.047
0.064
0.06
0.099
0.105
RF
1
1.076
1.45
1.41
1.79
2.31
1.43
1.43
ARD
GW
OD
POC
Acid.
Eutro.
ET
HT

Analysis – General Information

Method	Developer / Organization
IEF	Puolamma M. / Statistics Finland
EPS	Steen B. / CPM
EDIP	Wenzel H. / Technical Univ. of Denmark
Ecoindicator99	Goedkoop M. / PRE Consultants B.V.
Korean	Kun M. Lee / Ajou University

Analysis – Goal

Method	Goal
IEF	Decision Making Tool, Provide information of *environmental aspects* to designer in product development
EPS	
EDIP	
Ecoindicator99	
Korean	

Analysis – Spatial Boundary

Method	Spatial Extension
IEF	Nation(Finland)
EPS	Global
EDIP	Global/Nation(Denmark)
Ecoindicator99	Europe
Korean	Global/Nation(Korea)

Analysis – Safeguard Subjects

Method	Safeguard Subjects
IEF	Not Considered
EPS	Human Health, Ecosystem, Abiotic Resources, Biodiversity, Cultural & Recreational Value
EDIP	Environmental Impact,Resources Consumption, Working Environment
Ecoindicator99	Human Health, Ecosystem Quality, Resources
Korean	Human Health, Ecosystem, Resources

Analysis – Impact Category

Method	Considered Impact Category
IEF	GW, OD, Acid., Eutro., POC, ET, RD, Biodiversity, Radioactivity and Noise
EPS	Life Expectancy, Morbidity, Nuisance, Crop, Wood, Fish / Meat, Acid., water, Fossil, Species
EDIP	GW, OD, POC, Acid., Eutro., ET, HT, RD and Working Environment
Ecoindicator99	Carcinogenic, Respiratory, Climate Change, Ionizing Radiation, ET, Acid., Eutro., and RD
Korean	ARD, GW, OD, Acid., Eutro., POC, ET and HT

Analysis – Weighting Principle

Method	Weighting Principle
IEF	Expert Panel (AHP)
EPS	Monetization (WTP to avoid changes)
EDIP	Distance-To-Target
Ecoindicator99	Expert Panel (Questionnaire)
Korean	Combination DtT & Expert Panel(AHP)

Analysis – Impact Category Indicator

Method	Impact Category Indicator
IEF	Impact Potentials
EPS	End Point Effects
EDIP	Impact Potentials
Ecoindicator99	Damage
Korean	Impact Potentials

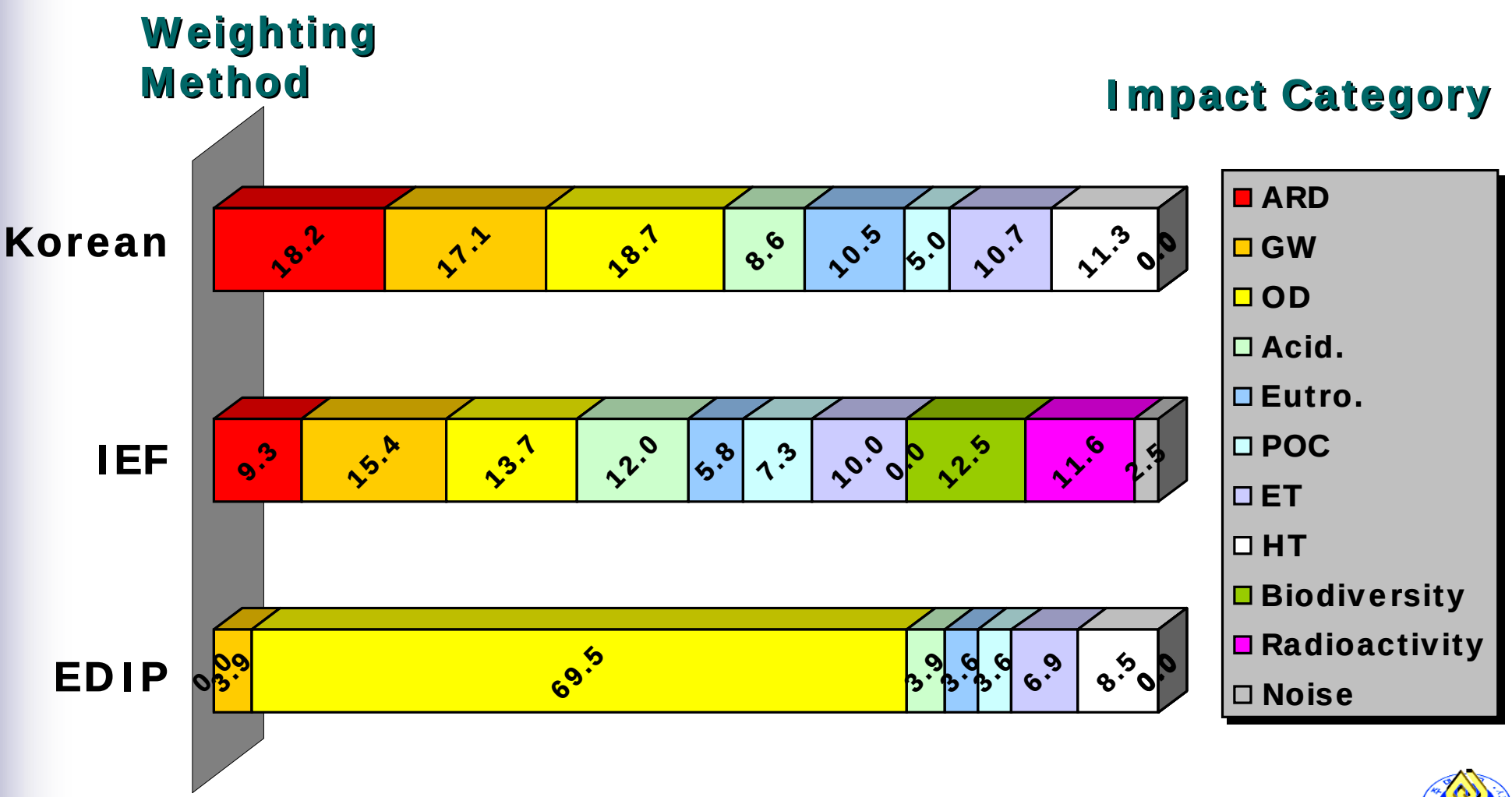
Analysis – W_i

IC	Korean	IEF [1)]	EDIP [2)]
ARD	0.242	9.3	-
GW	0.227	15.4	1.3
OD	0.249	13.7	23.0
Acid.	0.115	12.0	1.3
Eutro.	0.139	5.8	1.2
POC	0.066	7.3	1.2
ET	0.142	10	2.3
HT	0.150	-	2.8
Biodiversity	-	12.5	-
Radioactivity	-	11.6	-
Noise	-	2.5	-

1) $W_i = f_i$

2) $W_i = N_i / T_i$

Analysis – W_i


Weighting Method
Impact Category
Korean
IEF
EDIP
18.2
17.1
18.7
8.6
10.5
5.0
10.7
11.3
0.0
9.3
15.4
13.7
12.0
5.8
7.3
10.0
0.0
12.5
11.6
2.5
0.0
3.9
69.5
3.9
3.6
3.6
6.9
8.5
0.0
ARD
GW
OD
Acid.
Eutro.
POC
ET
HT
Biodiversity
Radioactivity
Noise

Analysis – Impact Indices

Example)

[unit : millipoints/kg]

Substance	Index	Substance	Index
Al®	5.66E-02	As	3.07E+02
Bauxite	1.19E-02	Benzene	2.67E-02
Copper ore®	9.87E-03	Cd	2.18E+03
Iron ore®	6.90E-04	CO2	2.97E-02
Lead ore®	8.75E-03	CH4	4.68E-02
Nickel ore®	5.83E-03	NOX	2.12E+00
Zinc ore®	1.78E-03	SOX	6.60E-01
Coal®	5.99E-03	NMVOC	1.36E-02
Crude oil®	1.40E-01	As(aq)	6.98E+02
Natural gas®	1.80E-01	Cd(aq)	7.92E+02
Oil®	1.44E-01	Cr(aq)	3.65E+03

Analysis – Impact Indices

Example)

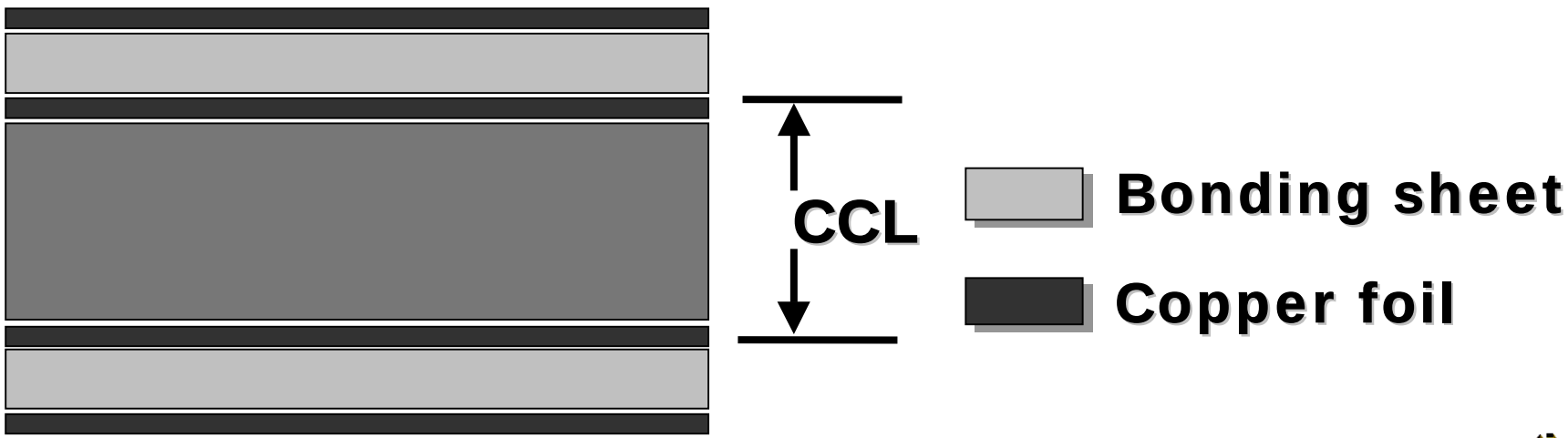
[unit : ELU/kg]

Substance/ Activity	Index	Substance/ Activity	Index
Ag®	54000	CFC11	541
Al®	0.439	H1303	2200
Cu®	208	NMVOC	2.14
Fe®	0.961	PAH	64300
U®	1190	BOD	0.00201
As	95.3	COD	0.00101
Benzene	3.65	Tot-P	0.055
CH_4	2.72	Aldrin	119
CO_2	0.108	Captan	0.0274
CO	0.331	Land Use	0.001562
NO_X	2.13	Forestry	6.25[1)]
SO_X	3.27	Littering	13.9[2)]

1) ELU/m^3, 2) ELU/m^2

Case Study - Product System

- Product : Printed Circuit Board(PCB)
- Functional unit : 1m² PCB
- Reference flow : 2.638kg
- Cross sectional view of PCB

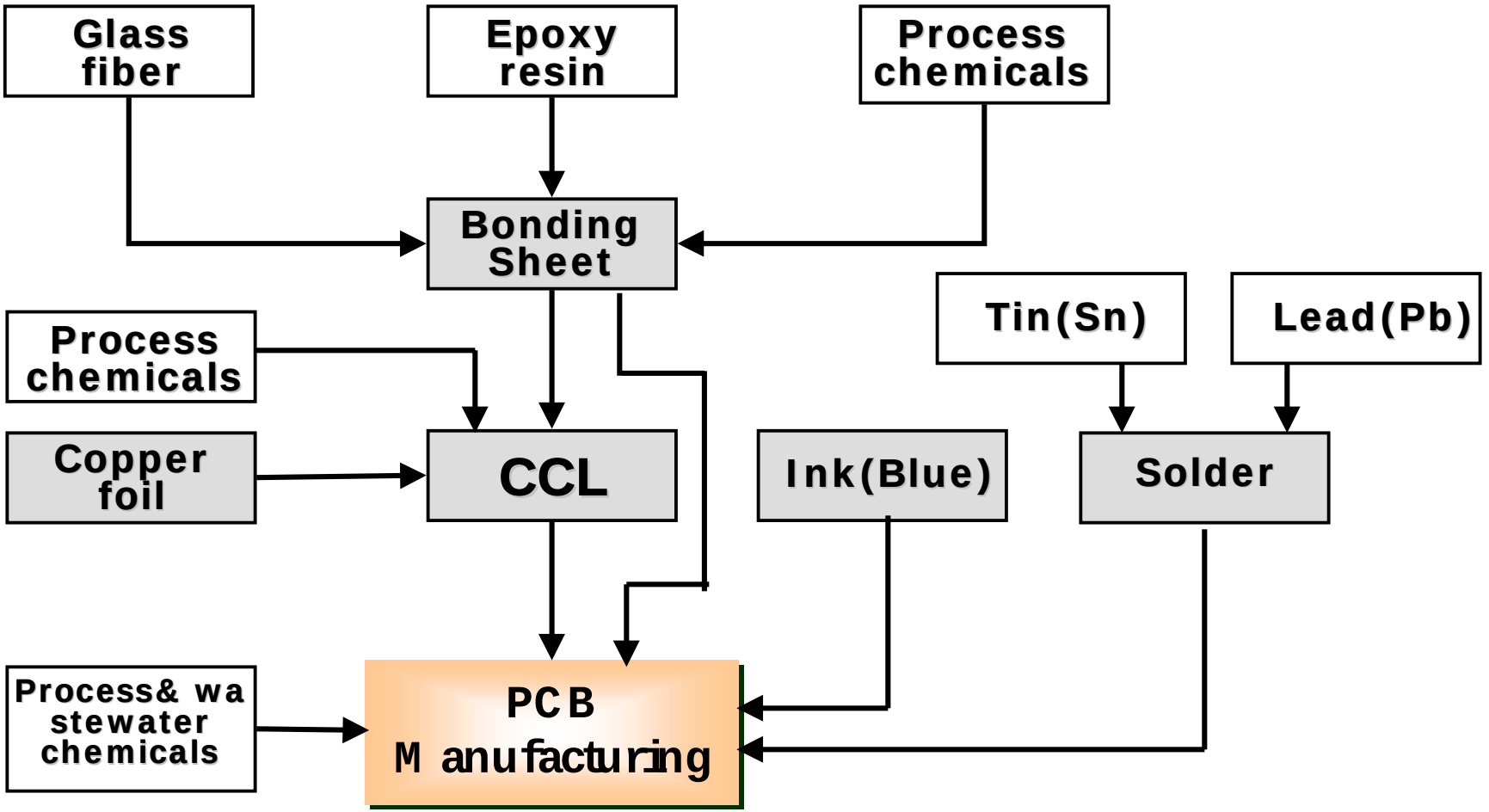


Case Study – G and S Definition

- Cradle-to-gate
- 99% cumulative weight cut-off
- Data : 1 year on site (1998 year)

  : Database, literature, similar processes
- LCA software : LCAiT 3.0

Case Study - Process Tree



Results - Identified key Issues on CI

Category	Key Materials/Emissions	Key Processes
ARD	Crude oil® [47.6%] Natural gas® [19.9%] Coal® [17.3%] Uranium® [7.2%] Copper ore® [4.25%] Pb® [2.4%]	Manufacturing [51.6%] Bonding sheet [21.0%] CCL [15.0%] Chemicals [4.7%] Solder [4.5%] Copper foil [2.7%]
GW	CO_2 [97.2%] CH_4 [2.0%]	Manufacturing [79.0%] Solder [6.0%] Chemicals [5.2%] CCL [4.0%] Bonding sheet [3.5%] Copper foil [2.5%]

[Continued]

Results – Summary:Key Issues (CI)

Key Materials/Emission			Key Process
Crude oil® Natural gas® Coal® Uranium® Copper® Pb®	CO_2 CH_4 Halon1301 HC VOC NO_x SO_x	Tot-N NH_3 BOD COD Cu As Oil n-Hexane Cr	Manufacturing Bonding sheet CCL Solder Chemicals Copper foil

Results - Korean Weighting

Identified Key Issues based on WI

Key Materials/ Emissions	[%]	Key Processes	[%]
Crude oil®	30.8		
Natural gas®	12.9		
SO_X	12.1		
Coal®	17.3	Manufacturing	57.6
CO_2	6.2	Bonding sheet	13.4
NO_X	4.9	CCL	10.2
Uranium®	4.7	Solder	10.1
Cu(aq)	4.1	Chemicals	5.3
Copper ore®	2.8	Copper foil	2.6
As(aq)	1.9		
Pb®	1.5		
Tot-N(aq)	1.5		

Results - Expert Panel, IEF

Identified Key Issues based on WI

Key Materials/ Emissions	[%]	Key Processes	[%]
Crude oil®	27.0		
SO_X	12.4		
Natural gas®	11.3		
Coal®	9.8	Manufacturing	60.6
CO_2	9.6	Bonding sheet	12.0
Cu(aq)	6.7	CCL	9.6
NO_X	5.0	Solder	8.7
Uranium®	4.1	Chemicals	6.1
As(aq)	3.0	Copper foil	2.9
Copper ore®	2.4		
HC	2.2		
Oil(aq)	2.0		

Results – Monetization, EPS

Identified Key Issues based on WI

Key Materials/ Emissions	[%]	Key Processes	[%]
Copper ore®	94.7	Manufacturing	92.8
Uranium®	5.2	Bonding sheet	3.2
		CCL	1.8

Results - Distance to Target, EDIP

Identified Key Issues based on WI

Key Materials / Emissions	[%]	Key Processes	[%]
NO_X	43.7	Manufacturing	87.6
Tot-N	31.3	Solder	5.8
SO_X	10.8	Chemicals	2.8
CO_2	8.6	Bonding sheet	1.7
HC	2.3	CCL	1.5
NH3	1.2		

Results – Ecoindicator99

Identified Key Issues based on WI

Key Materials / Emissions	[%]	Key Processes	[%]
CO_2	30.9		
Copper ore®	22.8	Manufacturing	51.0
Crude oil®	14.1	Chemicals	12.6
NO_X	13.4	CCL	11.3
SO_X	11.3	Copper	9.0
Coal®	2.1	Solder	9.0
Pb	1.6	Bonding sheet	7.0
Cr(aq)	1.1		

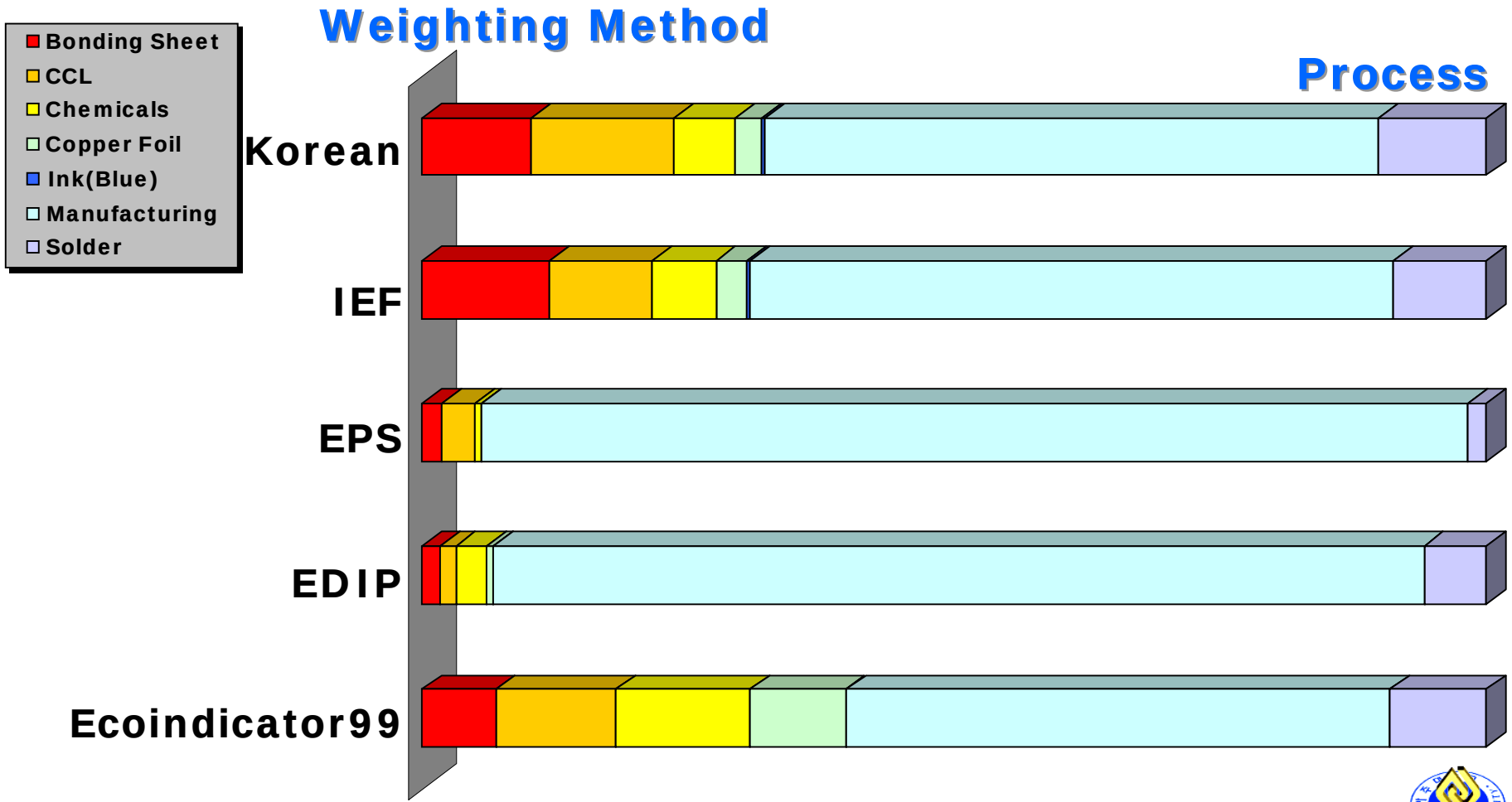
Discussion

Comparison of key processes among different methods

Key Processes	Contribution to total WI [%]				
	Korean	IEF	EPS	EDIP	Eco99
Manufacturing	57.6	60.6	92.8	87.6	51.0
Bonding Sheet	13.4	12.0	3.2	1.7	7.0
CCL	10.2	9.6	1.8	1.5	11.3
Solder	10.1	8.7	-	5.8	9.0
Chemicals	5.3	6.1	-	2.8	12.6
Copper Foil	2.6	2.9	-	-	9.0

Discussion

Contribution of each process based on WI



Discussion

- Key processes from the Korean and IEF methods based on the WI results are identical to those based on the CI results

- Key materials/emissions from the Korean and IEF methods based on the WI results are quite similar to those based on the CI results

Discussion

- Key processes and materials/emissions from the Ecoindicator99 method based on the WI results are similar to those based on the CI results
- Key processes and materials/emissions from the EDIP and EPS methods based on the WI results are different from those based on the CI results

Conclusions

- Key issues based on the WI results should be compared with those based on the CI results
- If two results agree with each other, then the identified key issues are judged correct. This is based on the assumption that key issues based on the CI results are the true key issues

Conclusions

Key processes and its contribution to the total WI

- The Korean and IEF results are almost identical
- The Ecoindicator99 results are similar to the Korean and IEF results
- The EDIP and EPS results are similar with each other, but differ completely from the Korean and IEF results

Conclusions

- The Korean, IEF and Ecoindicator 99 methods would be the weighting methods of choice that can identify true key issues of a product system