

# **Use of LCA & TCA for the Evaluation of Pollution Prevention Alternatives**

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**S. Ha, S. Suh, Kun Lee**

**Environmental Engineering**

**Ajou University**

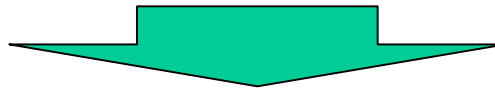


## **Background(1)**

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### *-Sustainable Development: Earth Summit in Rio (1992)*

- **Prevention is better than cure**
- **Polluter pays principle**
- **Green purchasing network**
- **Design for Environment**
- **Extended Producer Responsibility**
- **Ecolabeling, Type I, II, III**



**Need for  
Environmentally friendly products & processes**



## **Background(2)**

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### **- Existing Studies**

**focus on environmental aspects of the  
manufacturing stage only**

### **- Overlook**

- product system**
- entire life cycle stages**
- Capital and O & M costs**



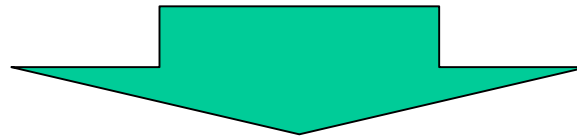
## Background(3)

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**Development of environmentally friendly products & processes requires**

- evaluation of environmental aspects : LCA
- evaluation of economical aspects:

**Total Cost Analysis  
(TCA)**



**Selection of an alternative that minimizes both cost and environmental impact**



## Background(4)

### *- Characteristics of selected evaluation criteria*

	<b>Pass-fail</b>	<b>Less (or more) is better</b>
<b>Environmental aspects</b>		<input type="radio"/>
<b>Economical aspects</b>		<input type="radio"/>
<b>Product performance</b>		<input type="radio"/>
<b>Regulatory compliance</b>	<input type="radio"/>	
<b>Technical feasibility</b>	<input type="radio"/>	
<b>Financial feasibility</b>	<input type="radio"/>	



## • Background(5)

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### - *Feasibility test for “pass-fail” criteria*

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**Regulatory  
compliance**

**Referring to the related clauses of  
applicable laws**

**Technical  
feasibility**

**Communicating between technical experts**

**Financial  
feasibility**

**Cash flow analysis**

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## Background(6)

- *Quantitative assessment*

*for “less (or more) is better” criteria*

**Environmental  
aspects**

**LCA**

**Economical  
aspects**

**TCA**

**Product  
performance**

**beyond the scope  
of this study**



## Background(7)

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- *Need for decision-making tool (Ecoscore) for “less (or more) is better” criteria*
- **Normalization by the reference product**
- **Weighting between environmental and economical aspects**



## Objectives

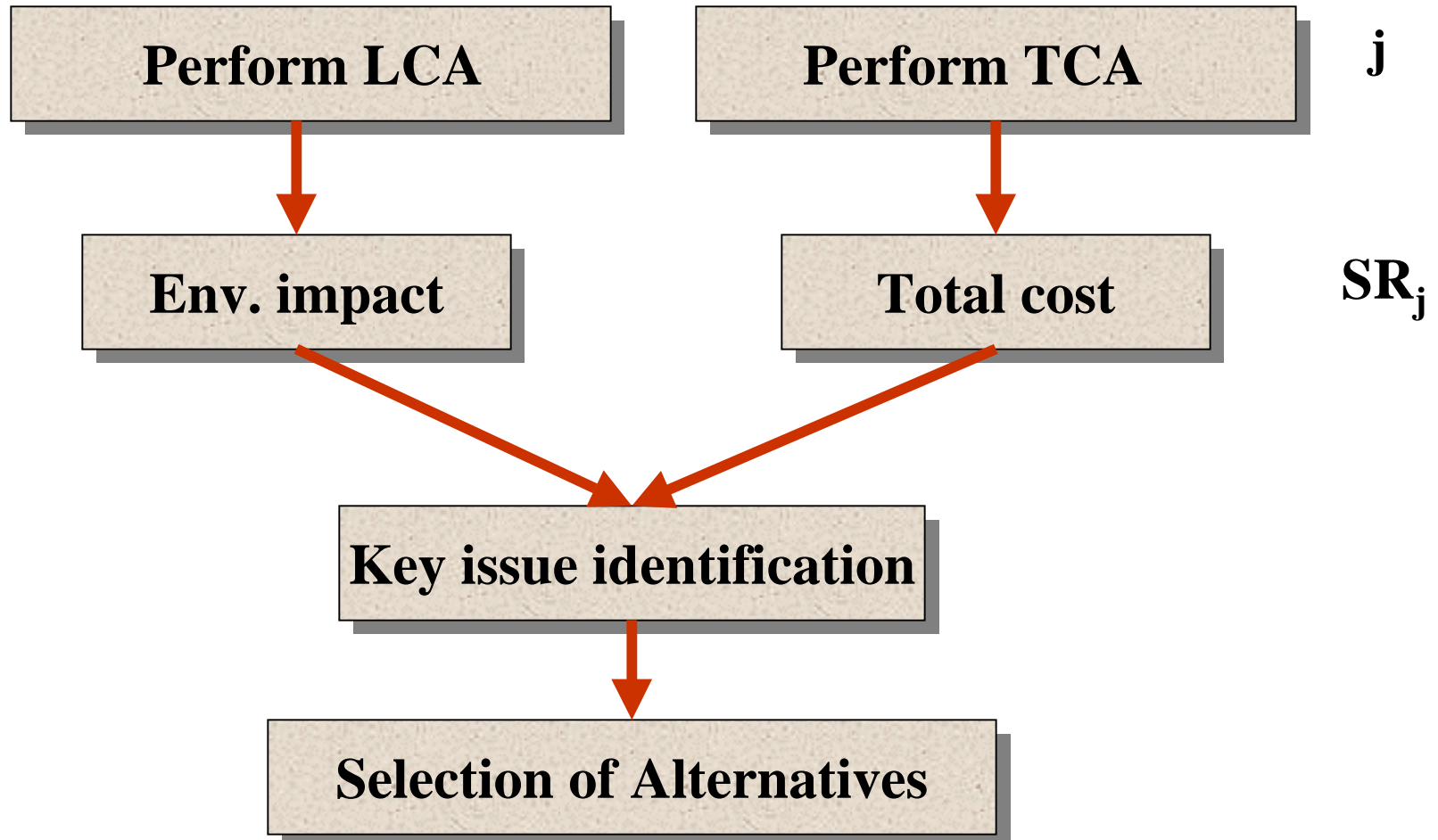
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- **Identification of PP alternatives of a product system(product) based on LCA and TCA**
- **Evaluation of PP alternatives based on Ecoscore**



# Methodology(1)

## Reference product



## Methodology(2)

### Alternative Product $i$

Perform LCA



Env. impact

Perform TCA



Total cost

$j$

$S_{ij}$



## Methodology(3)

$$\mathbf{Ecoscore}_i = \sum_j \frac{S_{ij}}{SR_j} \cdot w_j$$

Where,

$S_{ij}$  :  $j^{\text{th}}$  aspect value of the  $i^{\text{th}}$  alternative product

( $j$  = env. impact, total cost, ...)

$SR_j$  :  $j^{\text{th}}$  aspect value of the reference product

$w_j$  : weighting factor of the  $j^{\text{th}}$  aspect



## Methodology(4)

- *Annualized Cash Flow (ACF)*

Considering both interest rate and inflation rate

$$i_c = (1 + i)(1 + f) - 1$$

$$= i + f + i \cdot f$$

$$\approx i + f$$

$i$  : interest rate

$f$  : inflation rate

$i_c$  : real interest rate

**Differentiation between  
one time cash flow and recurring cash flow**



## • Methodology(5)

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- *Evaluation of economical aspects (Perform TCA)*

### Reference product

- **Operating costs(including labor costs)**
- **Raw and ancillary materials costs**
- **Pollution abatement costs**
- **Fines**



## • Methodology(6)

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- *Evaluation of economical aspects (Perform TCA)*

### **Alternative product**

- **Additional capital investment cost**
- **Operating costs (including labor costs)**
- **Raw and ancillary materials costs**
- **Pollution abatement costs**
- **Fines**



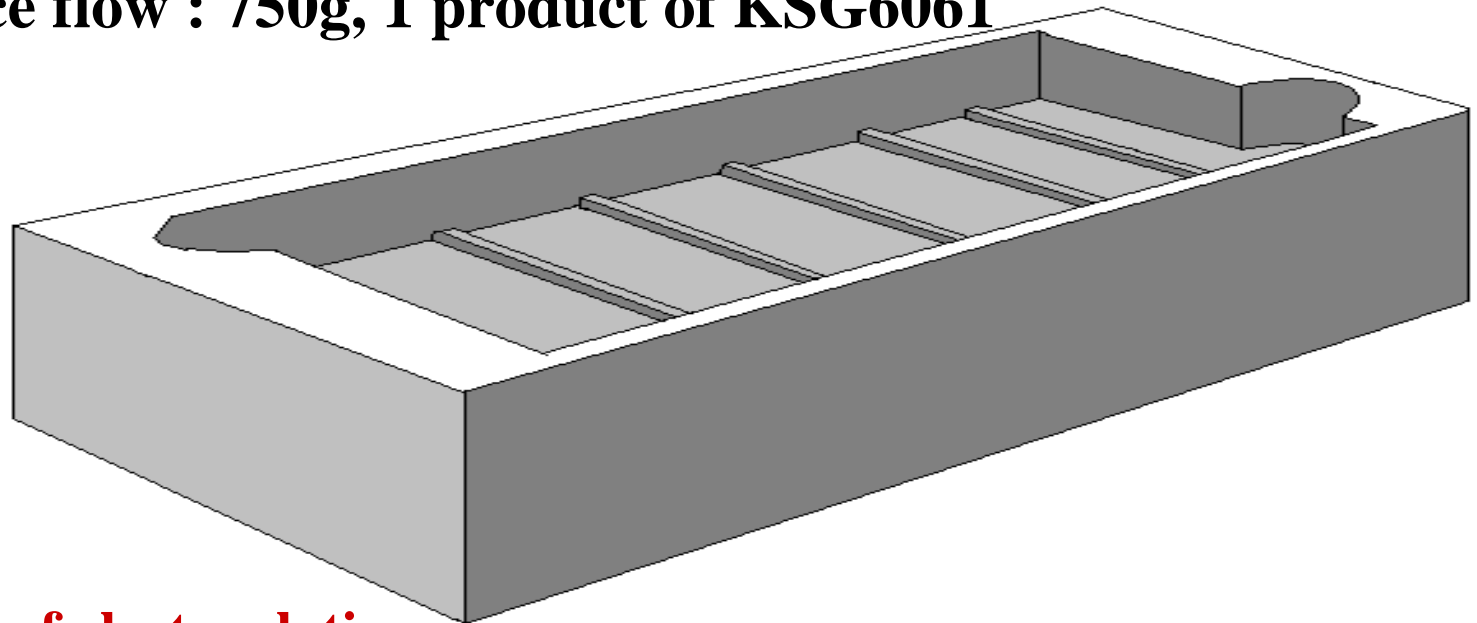
## Results(1)

**LCA** Reference product :

**Function : to hold and connect components electronically  
as a frequency filter for the cellular phone base station**

**Functional unit : aluminum frame electroplated with 5um silver**

**Reference flow : 750g, 1 product of KSG6061**



**Objective of electroplating :  
electroplate silver inside the plate**



## Results(2)

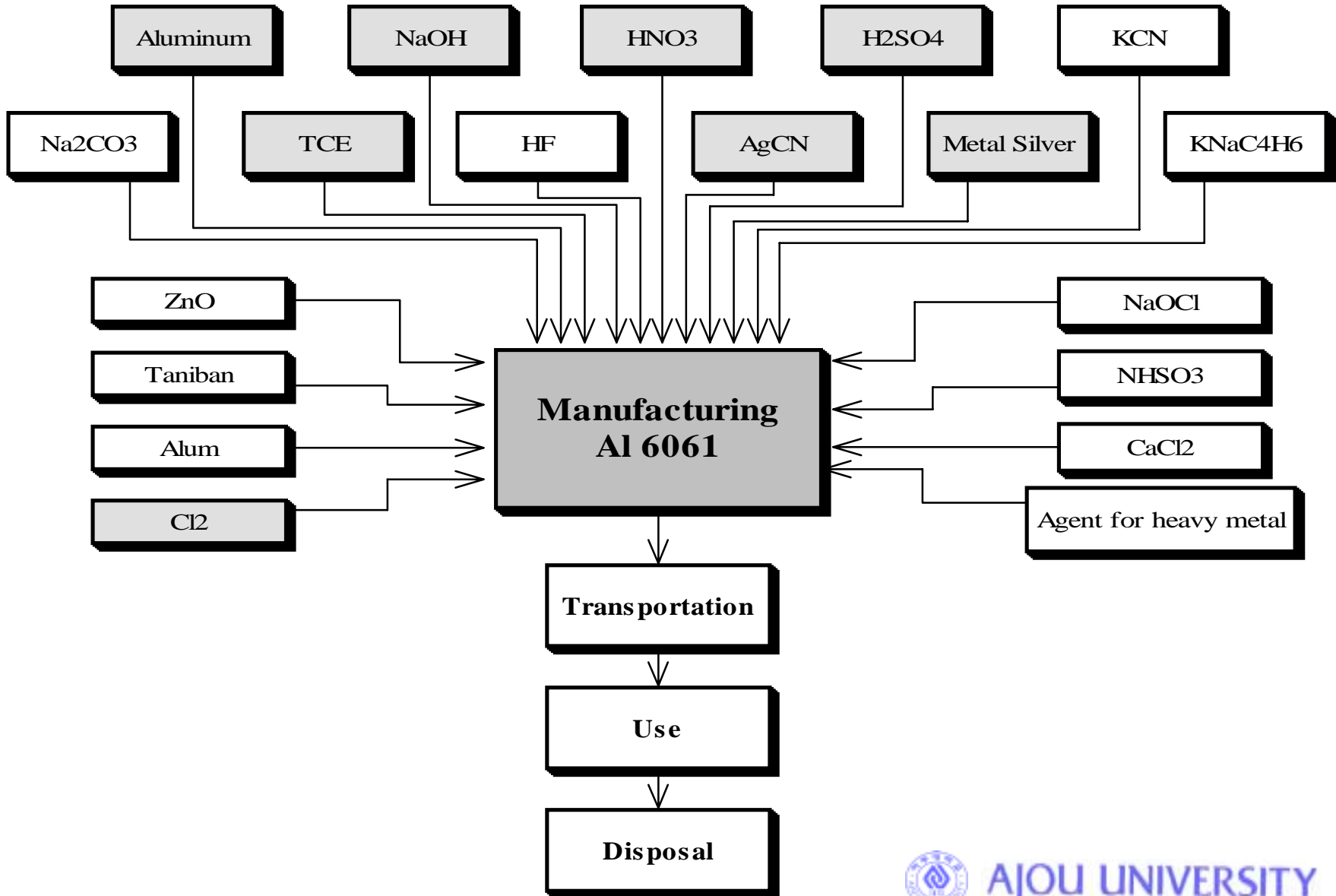
### - Composition

<b>Element</b>	<b>Weight (g)</b>	<b>Weight fraction</b>
<b>Aluminum</b>	<b>735.33</b>	<b>98%</b>
<b>Zinc</b>	<b>0.00085</b>	<b>0%</b>
<b>Silver</b>	<b>13.67</b>	<b>2%</b>
<b>Total</b>	<b>750</b>	<b>100%</b>



# Results(3)

## Process Tree



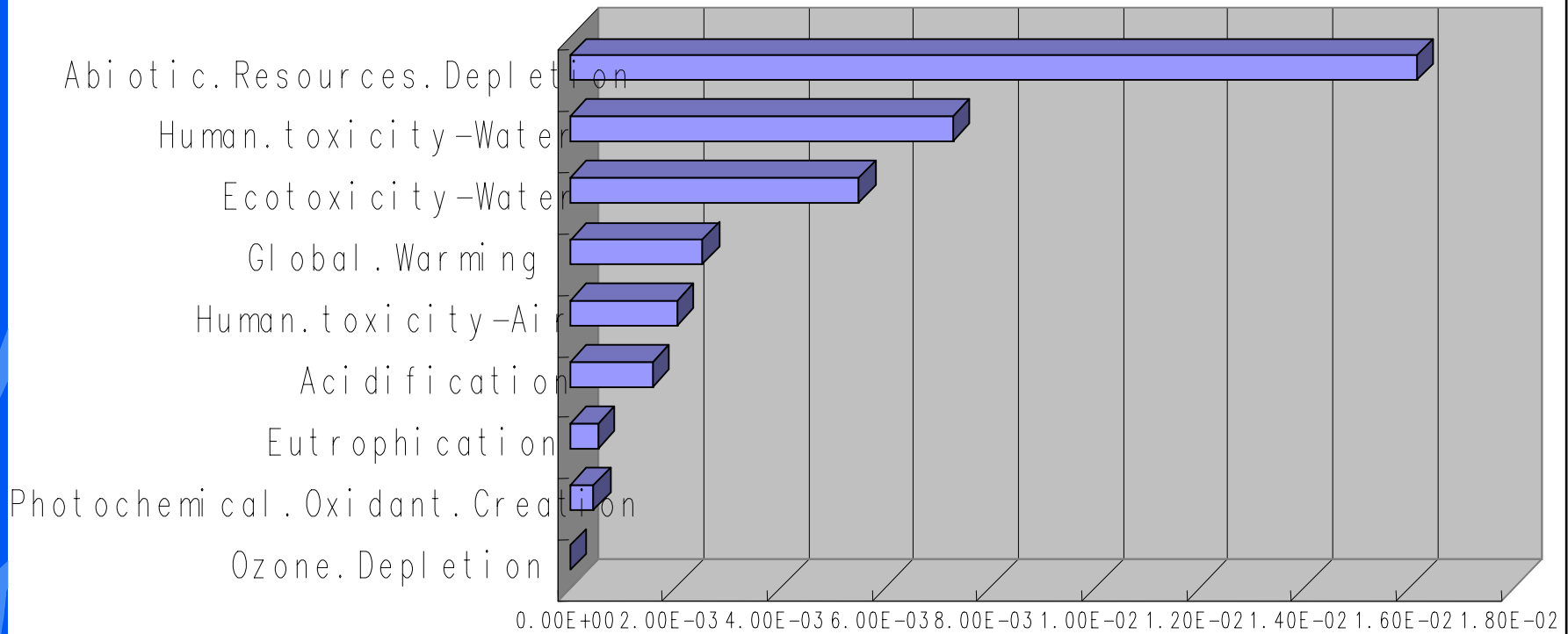
# Key issue: Characterized Impact(CI) basis

Impact Categories	Key issue(activity)	Contribution(%)
<b>Global Warming</b>	Silver cyanide	30
	Metal silver	28
	Aluminum	27
	Manufacturing	8
<b>Ozone Depletion</b>	Aluminum	100
<b>Acidification</b>	Metal silver	30
	Silver cyanide	30
	Aluminum	21
	Manufacturing	8
	Sodium hydroxide	8



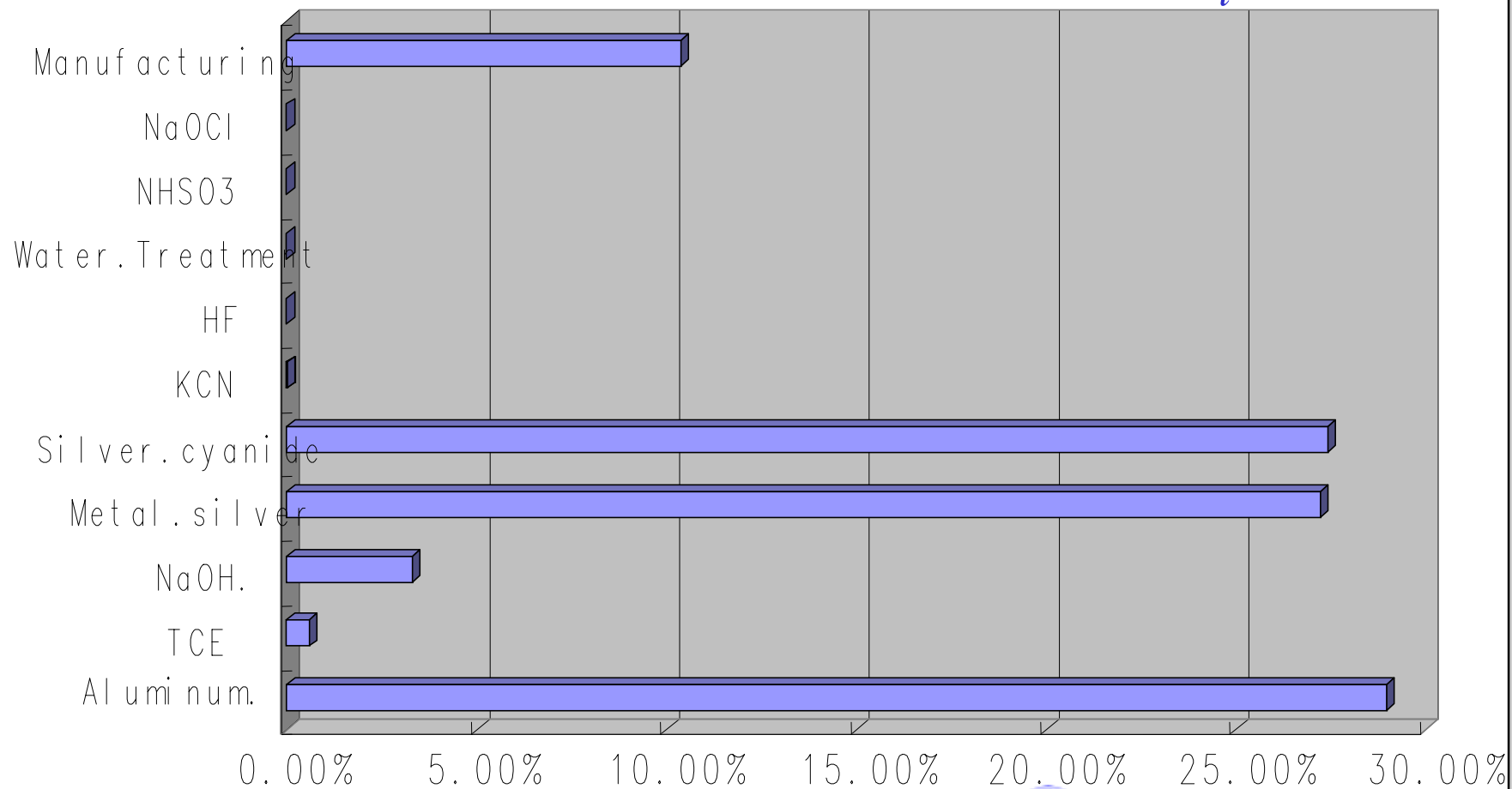
# Normalized Impact (NI)

$$NI_i = \frac{CI_i}{N_i}$$

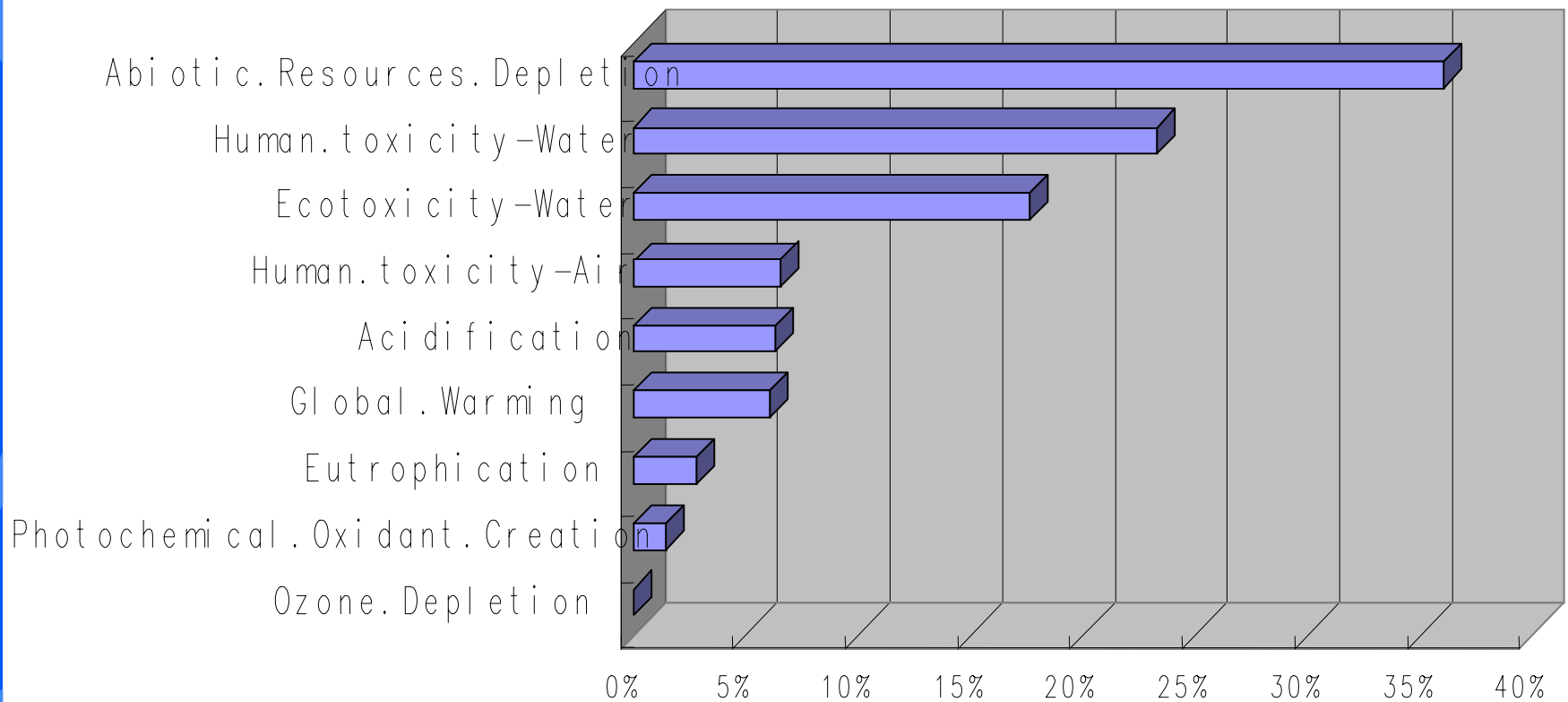


# Key Activity(WI basis)

$$WI_i = \frac{CI_i}{N_i} \frac{N_i}{T_i}$$
$$= \frac{CI_i}{N_i} RF_i$$



# Impact categories (WI basis)



## Key issues: From all impact categories (CI) and WI

- **Aluminum**
- **Metal silver**
- **Silver cyanide**
- **Manufacturing**



## Results(4)

**Key Issue : (e.g.) key impact category and activity  
calculated based on WI basis**

<b>Key impact category</b>	<b>Contribution (%)</b>	<b>Key activity</b>	<b>Contribution (%)</b>
<b>Abiotic Resource Depletion</b>	<b>36</b>	<b>Aluminum</b>	<b>29</b>
		<b>Metal silver</b>	<b>27</b>
<b>Human Toxicity(W)</b>	<b>23</b>	<b>Silver cyanide</b>	<b>27</b>
<b>Ecotoxicity(W)</b>	<b>18</b>	<b>Manufacturing</b>	<b>10</b>

*Basis : Weighted Impact*

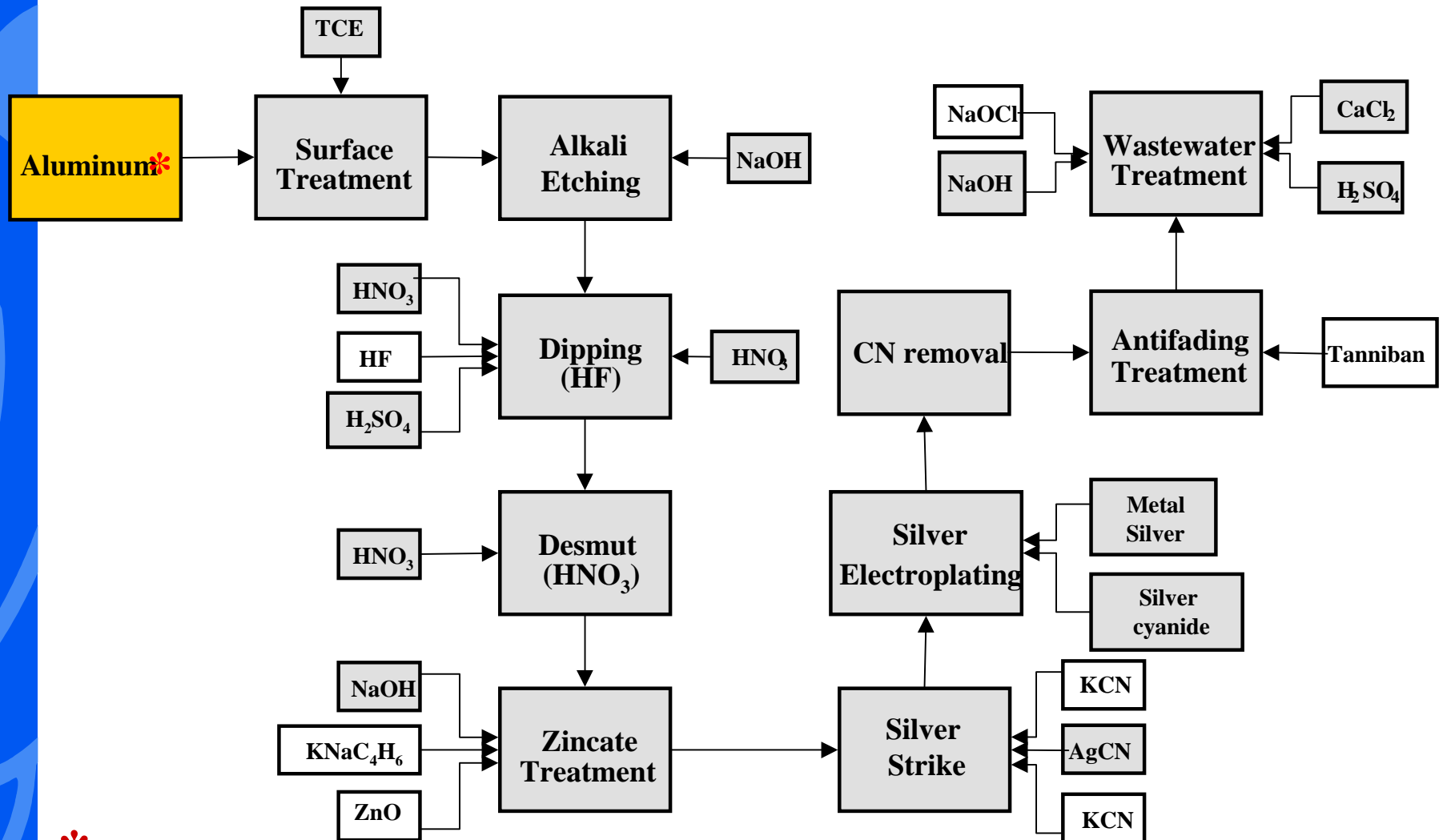


**Focus on manufacturing  
including the use of metal silver and silver cyanide**



# Results(5)

## - Reference manufacturing process



\* Exclude due to uncontrollable nature

□ : process with data gap



## Results(6)

### - LCA result (key unit processes; CI basis )

Impact category	% Contribution of key unit process		
Global warming	G*, 93.5		
Ozone depletion	D, 38.8	C, 30.9	G, 29.6
Acidification	G, 84.8	J, 11.9	
Eutrophication	G, 85.7	J, 10.3	
Photochemical oxidant creation	G, 75.9	J, 21.7	
Ecotoxicity water	G, 68.1	J, 16.7	
Human toxicity air	G, 89.7		
Human toxicity water	G, 69.5	J, 15.9	
Abiotic resource depletion	G, 98.7		

\*A: Surface treatment, B: Alkali etching, C: Dipping, D: Desmut, E: Zincate treatment, F: Silver strike, **G: Silver electroplating**, H: CN removal, I: Antifading treatment, **J: Wastewater treatment**



## Results(7)

### - LCA result (key raw & ancillary materials; CI basis )

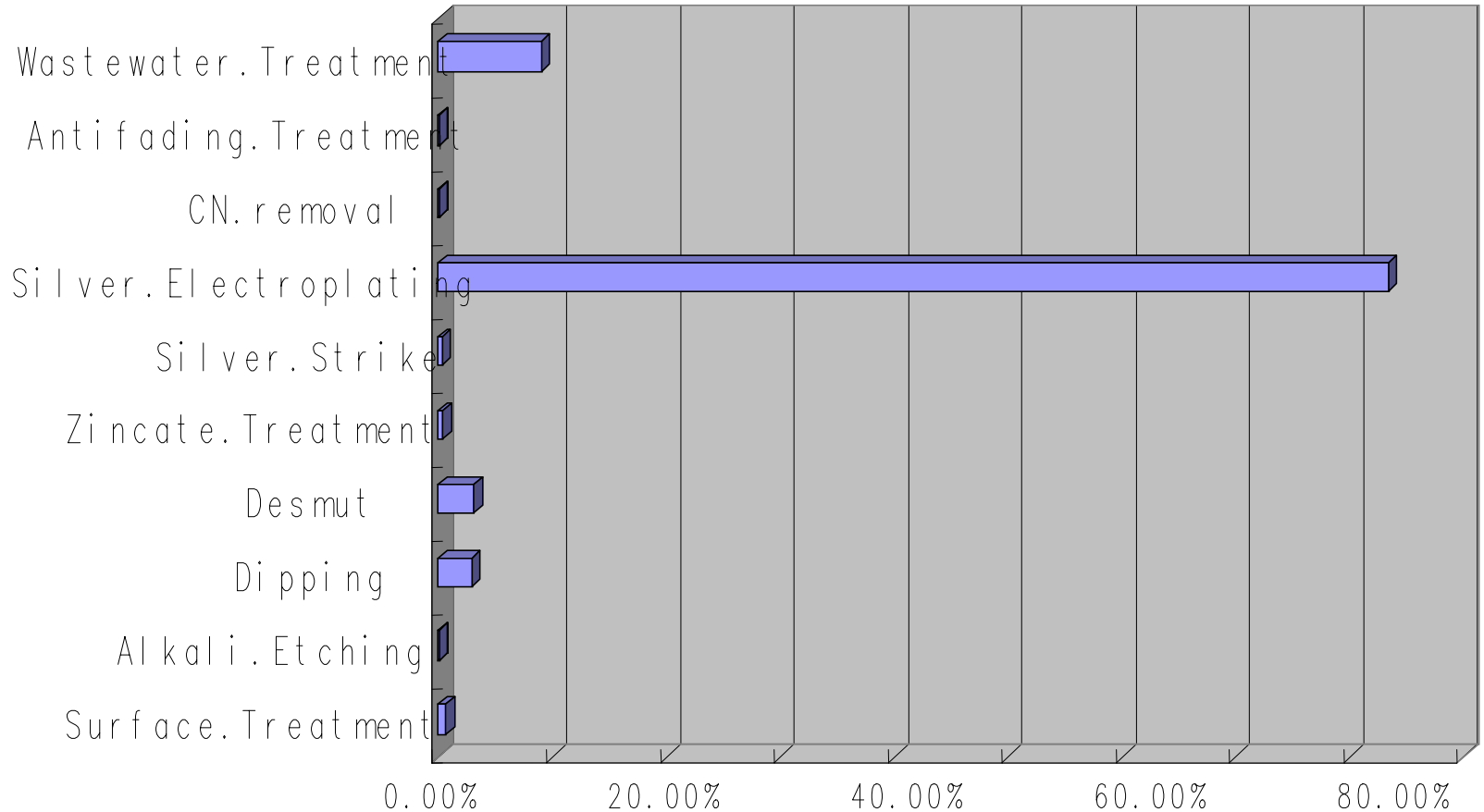
Impact category	% Contribution of key unit process		
Global warming	F, 45.5	E, 45.2	
Ozone depletion	C, 100		
Acidification	E, 42.6	F, 42.1	B, 11.9
Eutrophication	F, 42.9	E, 42.7	B, 10.5
Photochemical oxidant creation	B, 52.7	F, 21.0	E, 20.9
Ecotoxicity water	F, 50.1	E, 49.6	
Human toxicity air	F, 45.1	E, 45.0	
Human toxicity water	F, 47.9	E, 47.6	
Abiotic resource depletion	F, 50.1	E, 49.8	

\*A: TCE, **B: NaOH**, C: Nitric acid, D: Sulfuric acid,  
**E: Metal silver**, **F: Silver cyanide**, G: KCN, H: HF, I: Water, J: NH<sub>2</sub>SO<sub>3</sub>,  
 K: NaOCl



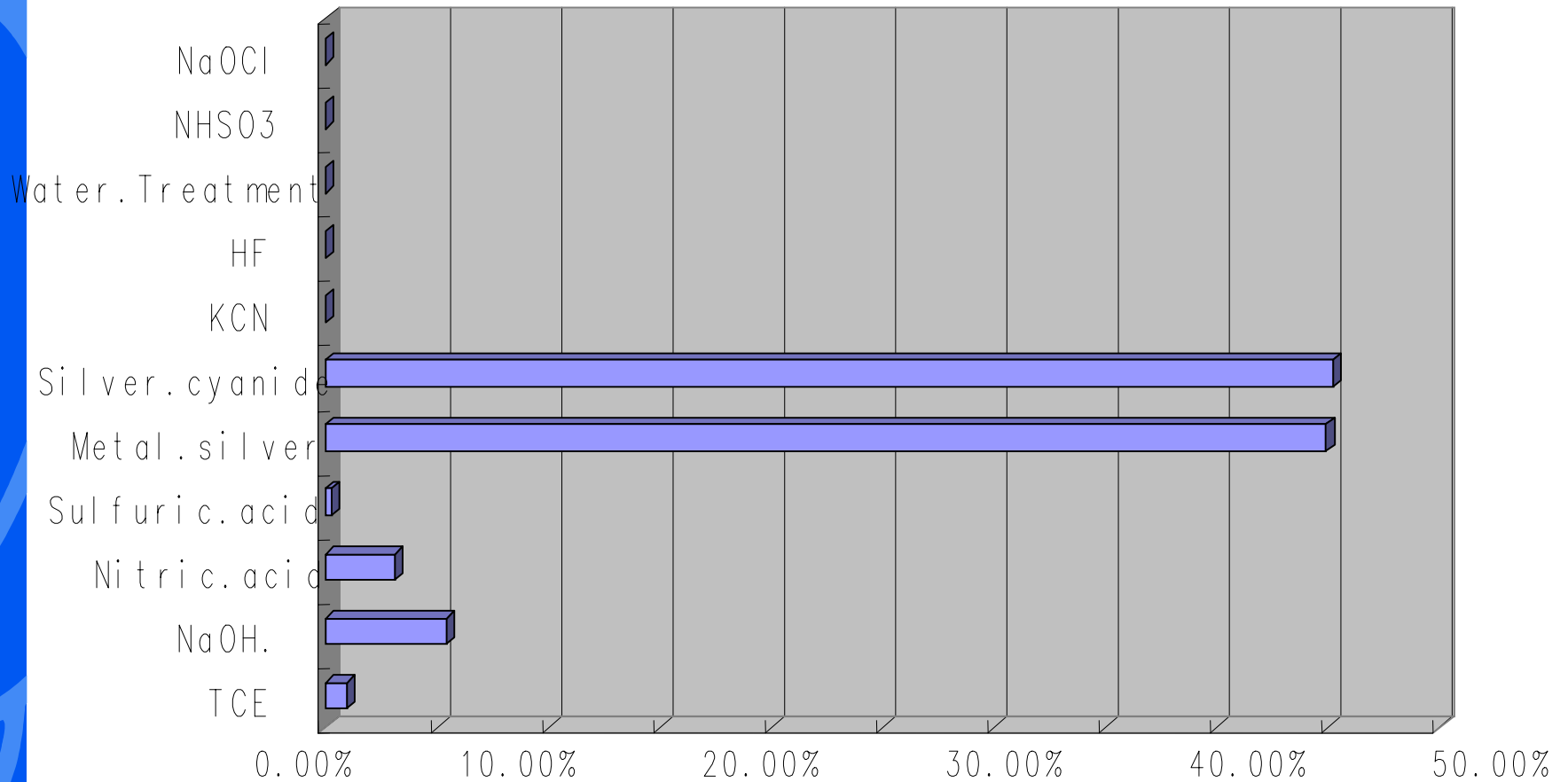
## Results(8)

- *LCA result (key unit processes; WI basis )*



## Results(9)

- LCA result (key raw & ancillary materials; WI basis )



## Results(10)

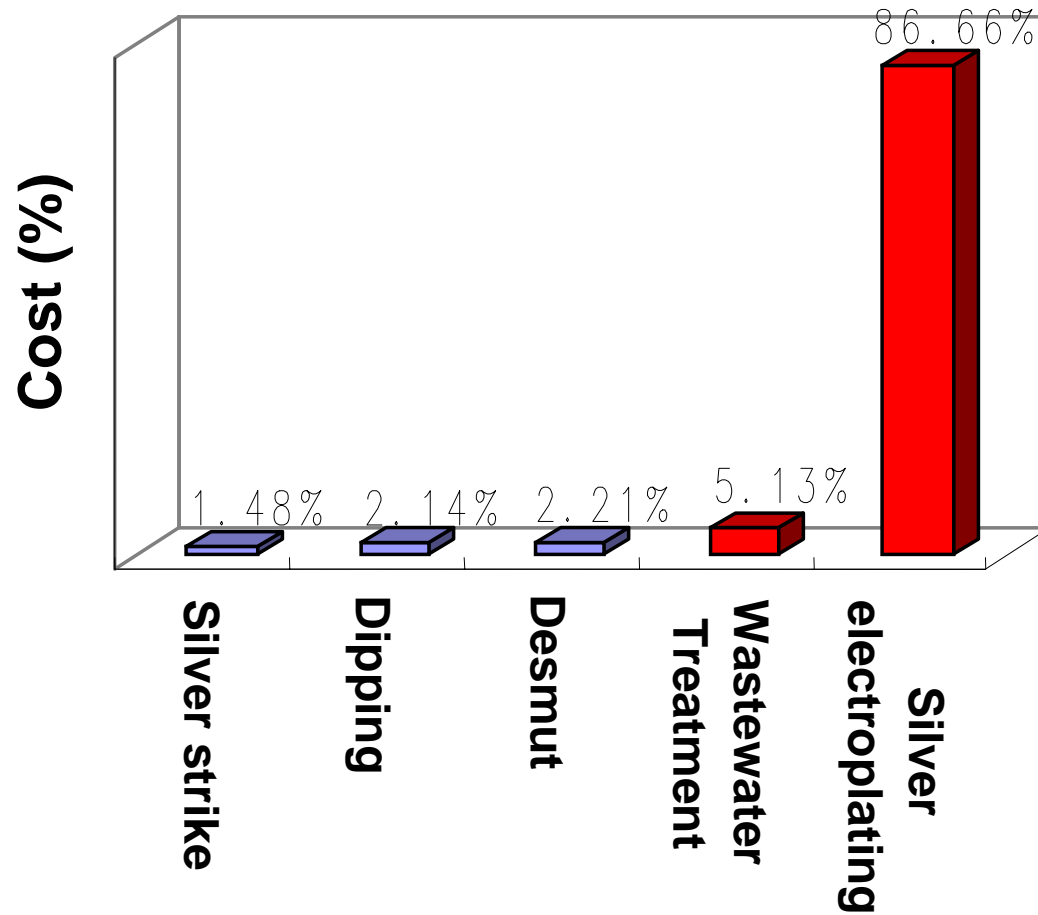
### - Summary of LCA result

	<b>key process</b>	<b>key raw &amp; ancillary material</b>
<b>CI</b>	Silver electroplating Wastewater treatment	Metal silver Silver cyanide NaOH
<b>WI</b>	Silver electroplating Wastewater treatment	Metal silver Silver cyanide NaOH
<b>Both</b>	<b>Silver electroplating</b> <b>Wastewater treatment</b>	<b>Metal silver</b> <b>Silver cyanide</b> <b>NaOH</b>



## Results(11)

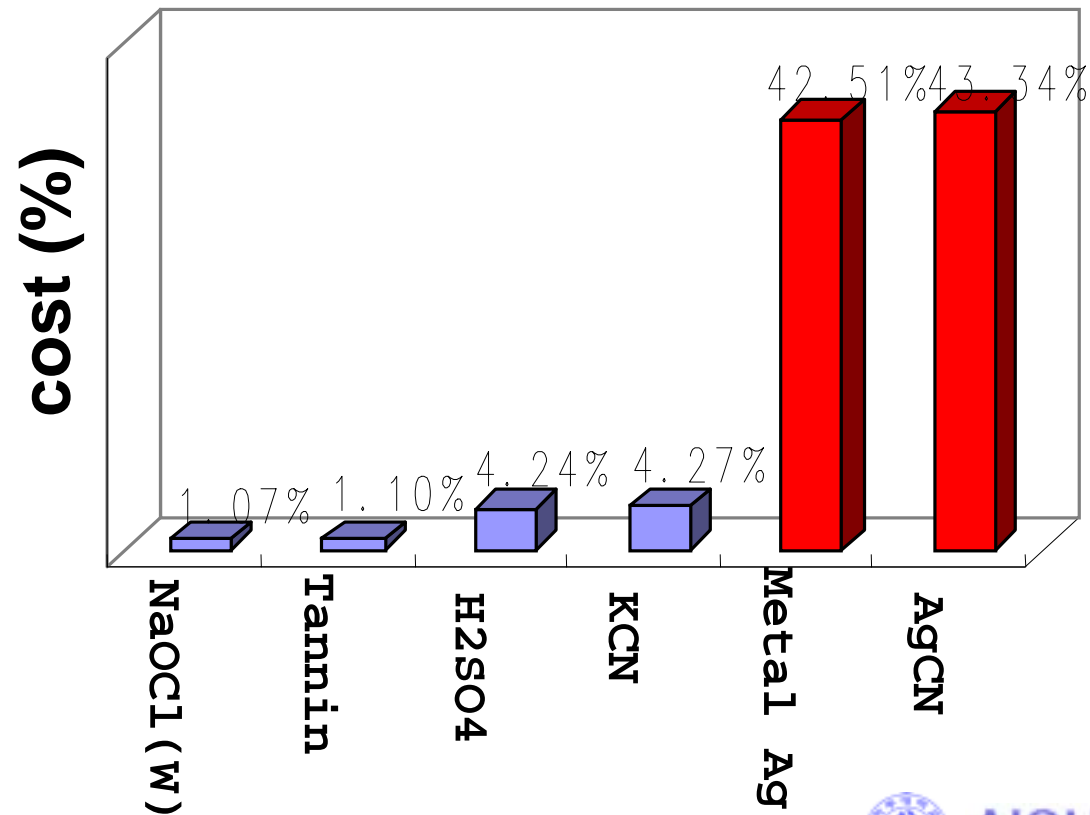
- TCA result (Key cost driver among processes)



## Results(12)

- *TCA result*

*(Key cost driver among raw&ancillary materials)*



## Results(13)

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### *- Summary of TCA result*

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**key process**

**key raw & ancillary material**

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**Silver electroplating**

**Metal silver**

**Wastewater treatment**

**Silver cyanide**

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## PP opportunity

### *-Summary*

**Key issues identified from the environmental and economical aspects**

<b>Process</b>	<b>Raw &amp; ancillary material</b>	<b>PP Opportunity</b>
Silver electroplating	Silver cyanide Metal silver	Reduce excessive use of silver*
Wastewater treatment	Sodium hydroxide	Modification of wastewater treatment

**\*the silver used was about 3.5 times more than that required to meet the spec.**

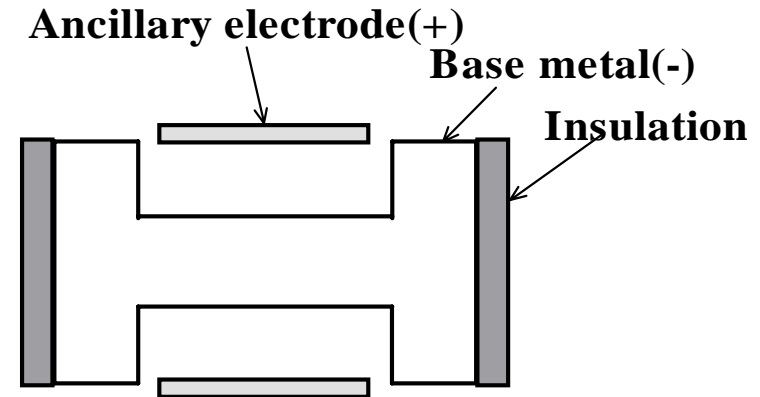


## Alternatives (1)

*-Reduce excessive use of silver*

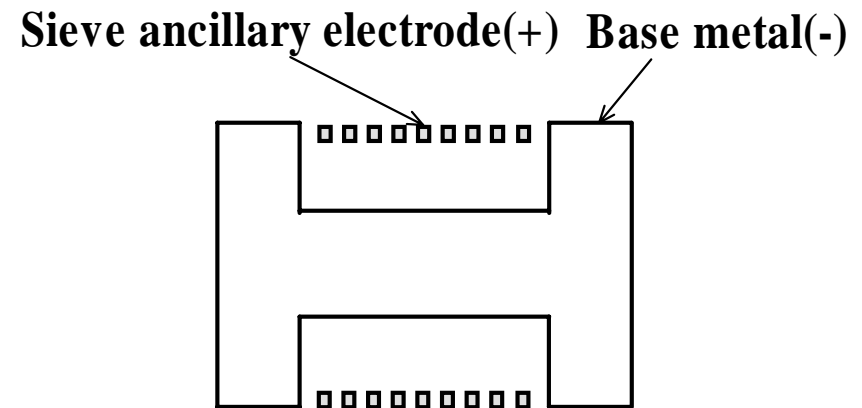
### Alternative A

: Selective electroplating technique  
electroplate selectively



### Alternative B

: Sieve type ancillary anode  
enhance migration of  $\text{Ag}^+$



## Alternatives (2)

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### **Alternative C**

**: Balanced-homogeneous plating technique**  
**apply more electric current inside the plate**

*-Modification of wastewater treatment*

### **Alternative D**

**: Wastewater stream segregation**

**Major pollutants were generated separately from the manufacturing steps.**



# Alternative evaluation(1)

## - feasibility test

PP opportunity	Processes / raw & ancillary materials	Alternatives	Feasibility		
			Regulatory	Technical	Financial
Reduce excessive use of silver	Silver electroplating (Metal silver, Silver cyanide)	A	O	O	O
		B	O	X	O
		C	O	O	O
Modify wastewater treatment	Wastewater stream segregation	D	O	O	O



## Alternative evaluation(2)

### - TCA result

Unit : 1,000won

item	Reference	Alternative		
		A	C	D
Additional capital investment costs		759	29,218	781
Operating costs	288,968	296,148	251,687	288,968
Raw & Ancillary materials costs	591,090	412,480	400,565	591,091
Pollution abatement costs	59,380	59,380	59,380	37,557
Fines	0	-471	-393	-377
<b>Total</b>	<b>939,438</b>	<b>768,307</b>	<b>740,497</b>	<b>916,458</b>

\*interest rate : 5%, inflation rate : 4%



## Alternative evaluation(3)

### - *Ecoscore*

#### Normalized score for alternatives

Alternative	$S_{ENVi}/SR_{ENV}^*$	$S_{COSTi}/SR_{COST}^*$
A	0.750	0.818
C	0.634	0.788
D	0.975	0.976

**\*Weighted Impact Basis**

**\*interest rate : 5%, inflation rate : 4%**



## Alternative evaluation(4)

- *summary*

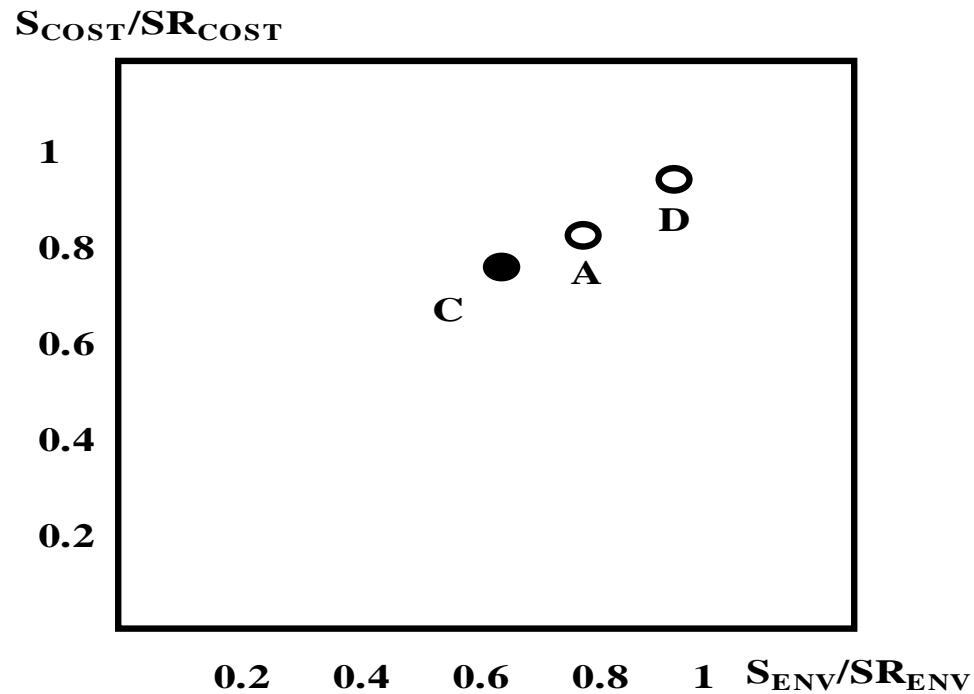
Alternative	Environmental impact	Cost
A	low	low
C	lower	low
D	high	high



# Decision-making(1)

**C** is best followed by A and D.

- C and A → select C
- D is separate



**C is the nondominated solution**



## Decision-making(2)

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*-Two alternatives were selected*

✓ **Alternative C**

**Balanced-homogeneous plating technique**

✓ **Alternative D**

**Wastewater stream segregation**

✓ **Alternative D** may be integrated into **Alternative C**



## Conclusion

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- ✓ *The PP alternatives can be identified based on LCA and TCA*
- ✓ *Ecoscore may be used for the evaluation of the PP alternatives*

