

# Research on Analysis Model of Resource Value Flow for Electrolytic Aluminum Enterprise

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**Abstract**—Beginning with material flow analysis, through the trace of resources input, output of positive products, negative products and environmental load, a complete model of resource value flow for manufacturing industry is constructed. By taking into account the volume and monetary measurement, cost of resource flows, the internal loss - external damage cost and industrial output value are required to be analyzed layer by layer in the model. Taking an electrolytic aluminum enterprise for example, an application of the model is studied. It presents that Model of Resources Value Flow is applicable to decision-making of balancing economic and environmental interest.

**Keywords**- Resource value flow; Electrolytic aluminum enterprise; Environmental management; Model

## 1. Introduction

To promote establishment of resource-saving and environment-friendly society, China government introduces the environmental regulation on heavy polluting industries continually. It is important to analyze economic and environmental benefit in Electrolytic Aluminum Enterprise which belongs to industry of intensive resource consumption. There are energy value and material flow analysis which base on resource efficiency research [1-2]. However, these tools lack of value analysis information which lead to difficulty in measurement and analysis the value of internal resources. Additionally, the tools don't quantify the negative value of environmental impact and can't provide effective support of economic and environmental decision-making.

Resource flow is the transformation process of shape, function and value in the movement of original state of the resource, processing, consumption, waste [3]. Resource flow includes material and value ones. Based on material flow analysis, Resource value flow focus on value changes in the chain, ring, net et al, which belong to the value concept of economic - environmental system [4]. Resource value flow analysis helps decision makers balance the contradiction between economic development and environmental protection. Started by material flow analysis and through the trace of resource input, output of positive products, negative products and environmental loads, this paper integrates monetary measurement to the model effectively and studies cost of resource flow, the internal loss - external damage Cost and industrial output value progressively.

## 2. Theoretical basis of analysis model of resource value flow

### 2.1. Material flow analysis

Material flow analysis is a tool to understand and describe a specific substance (usually elements, compounds or substances, etc.) at a specific flow conditions within a special system [5-6]. Based on material balance principle, Material flow analysis quantifies the input and output of substances or a class ones and the internal flow in a particular system or storage conditions, establishing quantitative relationship between economy and the environment in system. According to classification of material elements, Udo de Haes et al.(1997)[6]select a main element in the material flow, further refine it to element flow analysis. Specific to the material flow analysis in Electrolytic Aluminum Enterprise, Material flow analysis studies the flow of aluminum element in production processes, which can find the key area where the management level of resource use and energy savings may be improved.

## 2.2. Cost analysis of resource flow

Cost analysis of resource flow, which is based on material flow analysis, considers the cost value including labor, depreciation and other costs into the production system, and allocates them to positive and negative products<sup>1</sup>. Specific is shown in figure 1.

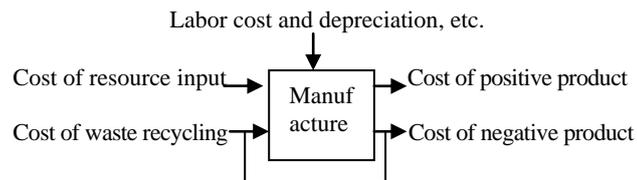


Figure 1. Cost analysis of resource flow

The use of cost analysis of resource flow is to appraise the effective use of resources, loss of value and cost waste, and improve the potential area when diagnosis. It also applicable to evaluate the product design, environmental management, technological innovation and other economic benefits.

## 2.3. Analysis of internal loss-external damage cost

Analysis of internal loss mainly investigates the loss of element(such as aluminum element in Electrolytic Aluminum manufacture ) in the major production areas of resource input and output, while that of external damage cost focuses on the impact of eternal damage generated by production which is calculated with monetary unit. The purpose of internal loss-external damage cost analysis is to take into consider the interest of produce process and external damage, and to adjust the future directions of improvement.

## 2.4. Analysis of industrial output value

When based on cost analysis of resource flow and incorporating profit in analysis, industrial output value will be divided into transferred value, industrial added value and profit. According to element attribution, transferred value is partitioned into cost of positive product and negative ones. Analysis of industrial output value will contributes to evaluate production and sales impacts on internal, external and community stakeholders which include positive and negative ones. Specific is shown in figure 2.

<sup>1</sup> Positive Product means what manufacturers are expected, while negative product are not, such as wastewater, waste gas and solid waste.

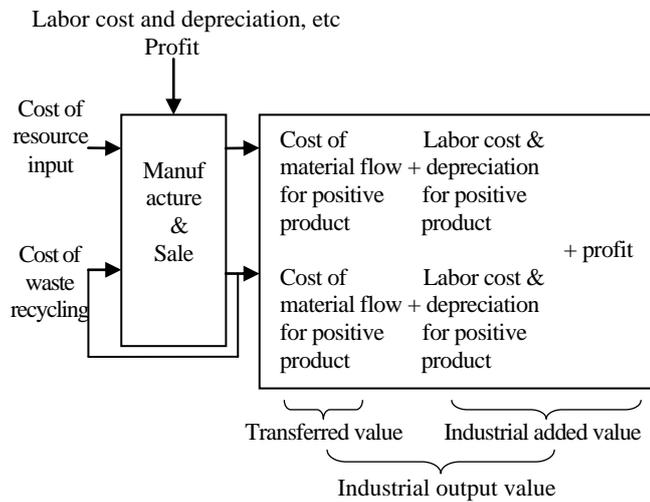


Figure 2. Analysis of industrial output value

### 3. Case study of resource value flow in electrolytic aluminum enterprise

A company which is located in China is engaged principally in the exploration and mining of bauxite, the production and sales of alumina, primary aluminum and aluminum-fabricated products and related research activities. The principal products of the Group include alumina, primary aluminum, aluminum fabricated products, gallium and carbon-related products, etc. this paper takes the plate of electrolytic aluminum for example, analyze its resource flow. Due to datum open, datum of year 2006 are studied and the processes omitted.

#### 3.1. material flow analysis of electrolytic aluminum production

A company's aluminum production in 2006 is 229 million tons, covering ordinary aluminum ingots, aluminum and other dozens of products. Main raw materials for aluminum production include alumina, cryolite, anode, fluoride, etc. Consumption of primary aluminum per ton is 1.94 tons of alumina. Main energy is electricity consumption and electricity consumption per ton of primary aluminum is 14,700 kwh.

Anodes in the electrolysis process and roasting process will produce fluoride and waste water also includes it. Exhaust gas also contains fluoride and carbon monoxide produced by electrolysis gases and perfluorocarbons. Solid waste is mainly spent anode and aluminum slag. Material flow analysis of electrolytic aluminum production for company A is shown in table 1.

Table 1. material flow analysis

process	type	name	unit	quantity
input	material	alumina	10000tons	443
		cryolite	10000tons	0.96
		Fluoride salt	10000tons	6
		carbon anode	10000tons	97
	energy	alternating current	100000000Kwhs	338
output	product	primary aluminium	10000tons	229
	waste	Gas & aluminum slag (loss of aluminum)	10000tons	8

#### 3.2. Resource flow cost analysis of electrolytic aluminum production

Primary aluminum sales price is 17,492 Yuan per ton, cost of it be 15156.87 Yuan per ton. Cost of raw material accounts for 57.99% of primary aluminum, fuel and power cost does 31.48% and 10.53% for other cost. Du to can not access the production ratio of maintenance and repair and other specific datum, this article gives other cost to labor costs and depreciation. Specific is shown in table 2.

It should be noted that profit of related party transactions is removed from cost of material due to elated party transactions such as carbon anode and alumina.

### 3.3. Internal loss-external damage cost analysis of electrolytic aluminum production

Primary Air pollutions are sulfur dioxide and fluoride when electrolytic aluminum produced. Solid wastes include waste (waste tank lining) and electrolytic smelting slag.

Table 2. Resource flow cost analysis

Industrial output value		Amount (10000Yuan)	Sub- ratio	Total- ratio
Industrial added value	Accumulated profit	535646.84	59%	13%
	Labor cost and depreciation	366104.77	41%	9%
	subtotal	901751.6	100%	22%
Value of effective utilization		2995352.58		75%
Loss value		115321.08		3%
summation		4012425.26		100%

Reference to "discharge fee collection standards and methods of computation" drawn up by State Development Planning Commission, Ministry of Finance, State Environmental Protection Administration and State Economic and Trade Commission in 2003, the standard pollution equivalent discharged is charged of 0.6Yuan, and sulfur dioxide pollution equivalent value of 0.95 (kg), fluoride pollution equivalent do of 0.87 (kg). Air pollution damage cost is calculated as followed in table 3.

Table 3. Damage costs of air pollutant

Waste	Amount (Kg)	Equivalent	Charge per equivalent (Yuan)	Damage cost (Yuan)
	(1)	(2)	(3)	(4)=(2)*(3)
sulfur dioxide	25350000	26684211	0.6	16010526
fluoride	2562000	2944828	0.6	1766896
summation				17777423

For the damage cost of solid waste, due to lack of calculation standard in China, LIME standard in Japan is used for analysis. LIME Coefficient Of anode scrap is 1.18 (JPY/ kg) while aluminum slag be 0.591 (JPY/kg).The exchange rate is 6.563:1 at the end of year 2006.Damage cost of solid waste is calculated as followed in table 4.

Table 4. Damage costs of solid waste

Waste	Amount (Kg)	LIME coefficient (JPY/Kg)	Damage cost (Yuan)
	(1)	(2)	(3)=(1)*(2)/100
anode scrap	24014480	1.18	1849114.96
aluminum slag	88313730	0.59	3419657.75
summation			5268772.71

### 3.4. Industrial output value analysis of electrolytic aluminum production

Industrial output value of electrolytic aluminum amounts to 40124252600 Yuan. Gross profit reaches 5356468400 Yuan and industrial added value does 9017516100 Yuan which includes Labor cost and depreciation, etc attributed to positive and negative product.

Value of effective utilization includes material and energy cost of positive product, while loss value does materials and energy cost of negative product. Specific is shown in table 5.

Table 5. Industrial output value analysis

Input (alumina)	material amount (10000tons)	443.73
	material cost(10000Yuan,the same below)	2016183.81
	Of which: cost of carry-over from negative product	108017.83
	of which:profit of carry-over from related party transactions	543319.36
	net cost of material	1364846.62
	energy cost	1094489.85
	Labor cost and depreciation	366104.77
	summation	3476778.42
Output (positive product)	material amount (10000tons)	229.38
	material cost (10000Yuan,the same below)	1941438.43
	Of which: cost of carry-over from negative product	104013.32
	of which:profit of carry-over from related party transactions	523177
	net cost of material	1314248.11
	energy cost	1053914.15
	Labor cost and depreciation	352532.28
	summation	3347884.86
Output (negative product)	material amount (10000tons)	8.83
	material cost (10000Yuan,the same below)	74745.38
	Of which: cost of carry-over from negative product	4004.51
	of which:profit of carry-over from related party transactions	20142.32
	net cost of material	50598.55
	energy cost	40575.7
	Labor cost and depreciation	13572.49
	summation	128893.57

#### 4. Conclusions

Based on analysis of resource value flow, this paper find that company A control efficiently aluminum loss when producing, loss of aluminum element being only 3.7% ( $= 8.83 / (229.38 + 8.83)$ ).Energy and material cost of negative product is higher than labor cost and depreciation that means that the potential area of resource saving is still in the consumption of energy and materials. Damage cost of major air pollutants occupies only 0.05% of total cost ( $= 1777.74/3476778.43$ ) and probable reason is low charge standard of pollution in China; damage cost of major solid waste makes up 0.015% of total cost ( $= 526.87/3476778.43$ ), indicating that company A has high level of environmental governance. In respect of industrial added value, manufacture and sale of aluminum contributes 22.47% industrial output value added while dedication to enterprises, employees and community and other stakeholders keeps general level.

#### 5. References

- [1] G. M. Niu, "Establishment of the Recycling Economic Assessment Indicator System," *Urban Environment & Urban Ecology*, vol.18, pp.4-7, Feb ruary 2005.
- [2] H. Liu, Q. Wang and Y. Song, "Evaluating Regional Circular Economy based on Emergy Theory:A Case Study in Liaoning Province," *Resources Science*, vol.20, pp.192-198, February 2008.
- [3] L. Shen and X. J. Liu, "Discussion on Theories and Methods of Resources Flow," *Resources Science*, vol.28, pp.9-16, March 2006.
- [4] W. X. Lin and X. Xiao, *Management of environmental cost*, China Financial and Economic Publishing House:Beijing, 2006.

- [5] H.A. Udo de Haes, E. Voet and R. Kleijn, Substance flow analysis ( SFA) , an analytical tool for integrated chain management // Bringezu S, eds . Regional and National Material Flow Accounting: From Paradigm to Practice of Sustainability, Institute for Climate, Environment and Energy:Wuppertal, 1997.
- [6] E. Van der Voet, R. Kleijn, L. Oers, R. Heijungs, R. Huele and P. Mulder, "Substance flow through the economy and environment of a region. Part I: systems definition," Environmental Science and Pollution Research, vol.2, pp.89-96, February 1995.