# Linkage between Natural Resources-Primary Energy-Power Generation-Economy-Environment

## —Modeling for Integrated Planning of Electricity Company

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**ABSTRACT:** The discussion of linkage analysis for human economy activity and the nature (natural resources and environment) under the framework of sustainable development has received increased attention by the international society, since the report of the World Commission on Environmental and Development was published in 1987. This heightening interest led to the proposal contained in Agenda 21 of the United Nations Conference on Environmental and Development (Rio de Janiero Earth Summit 1992) to encourage making integrated analysis for human economy activity and natural resources and environment, not only from the macro-level (the world or the state level) but also from the micro-level (enterprise or company level) . In this paper, we try to make an such micro-level analysis for one kind of special and important company——power company on the basis of our integrated input-output accounting model of natural resources-economy-environment. In detail, we try to establish one perfect and effective model with which we can make integrated analysis for power company's planning based on the linkage analysis of nature resource-economy-environment (Lei,1998,1999) and the theory of marginal opportunity cost (MOC) (Pearce, et al., 1989), in this paper.

**Keywords:** Power, Environmental Engineering,

Energy Management System, Modeling

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Abstract: Based on the theory of marginal opportunity cost, one kind of input-output table and models of power company be put forward in this paper. As application, analysis of integrated planning, cost analysis, pricing of the Power Company be also given.

Keywords: Power, Environmental Engineering, Energy Management System, and Modeling

The discussion of linkage analysis for human economy activity and the nature (natural resources and environment) under the framework of sustainable development has received increased attention by the international society, since the report of the World Commission on Environmental and Development was published in 1987. This heightening interest led to the proposal contained in Agenda 21 of the United Nations Conference on Environmental and Development (Rio de Janeiro Earth Summit 1992) to encourage making integrated analysis for human economy activity and natural resources and environment, not only from the macro-level (the world or the state level) but also from the micro-level (enterprise or company level). In this paper, we try to make an such micro-level analysis for one kind of special and important company ——power company on the basis of our integrated input-output accounting model of natural resources-economy-environment. In detail, we try to establish one perfect and effective model with which we can make integrated analysis for power company's planning based on the linkage analysis of nature resource-economy-environment (Lei,1998,1999) and the theory of marginal opportunity cost (MOC) (Pearce, et al., 1989), in this paper.

### 1 Basic Analysis

As we mentioned in our former analysis, there is one negative feedback system existing between human economy activities and natural resource/environmental (Fig.1) since the existence of economy externality. The cost of any kind of human economy activities not only contains the consumption of all production factors (labor, capital etc.), but also the cost resulted from external diseconomy caused by human activities. So does the Power Company. For the Power Company, firepower generation usually results in some negative effects on ecological environment especially atmosphere such as resulting in acid rain by $SO_2$ emission, hydropower usually cause the ecological damage nearby etc.. On the other hand, the usage of un-renewable natural resources such as, coal resources as fuels, in power station can also result in exhaustion of these resources. Similar to our former analysis, here, we also classify the resources (natural resource) into physical resource and environmental resource two kinds in light of its function, obviously, the external cost (exhaustion/damages) brought by the power company can also be divided into two main parts (Fig. 1). One is the ecology damage caused by the over-exploitation of nature resources resulting from the un-renewable resources used as fuels in power station, which mainly refers to the temporary or eternal exhaustion of physical resource in amount, or in the other words, is a disappearance of some kinds of physical resources, such as coal, petroleum, and natural gas etc., temporarily or eternally. Another is the ecology damage caused by the pollutant emission, such as $SO_2$, $CO_2$ etc., produced in the power generation and supply, which mainly refers to the quality decreasing of environmental resources (worsened in quality), means the service-quality of environmental falls down, such as globe warming, acid rain etc..

That means the cost of any kind of power generation & supply not only contains traditional production costs (labor, fuels, fixed assets etc.), but also the cost resulted from external diseconomy accompany with power generation & supply.

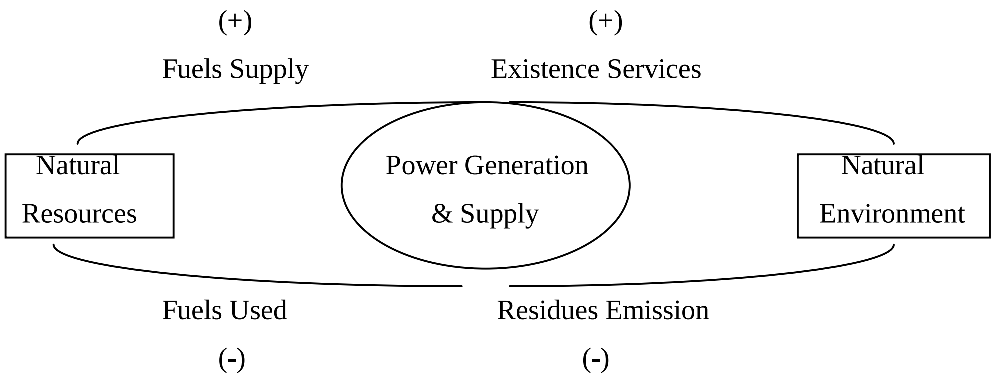


Fig. 1

## 2 Basic Table

In light of our above analysis on the negative feedback system between power generation & supply and the nature including natural resource and natural environment, one kind input-output table of power company behavior analysis be put forward as follows,

**Table 1**

| Output / Input | | Resources Recovery Dept. | Fuels Dept. | Non-Fuels' Materials Dept. | Power Dept. | | Pollution Abatement Dept. | Final Demand | Total Output |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Power Generation | Power Supply | | | |
| Resources Used | | $R^{e}_{ij}$ | $F^{e}_{ij}$ | $F^{enf}_{ij}$ | $G^{e}_{ij}$ | $S^{e}_{ij}$ | $W^{e}_{ij}$ | $Y^{e}_{ij}$ | $X^{e}_{i}$ |
| Fuels | | $R^{f}_{ij}$ | $F^{f}_{ij}$ | $F^{fnf}_{ij}$ | $G^{f}_{ij}$ | $S^{f}_{ij}$ | $W^{f}_{ij}$ | $Y^{f}_{ij}$ | $X^{f}_{i}$ |
| Non- Fuels' Materials | | $R^{nf}_{ij}$ | $F^{nf}_{ij}$ | $F^{nfnf}_{ij}$ | $G^{nf}_{ij}$ | $S^{nf}_{ij}$ | $W^{nf}_{ij}$ | $Y^{nf}_{ij}$ | $X^{nf}_{i}$ |
| Power | Power Generation | $R^{g}_{ij}$ | $F^{g}_{ij}$ | $F^{gnf}_{ij}$ | $G^{g}_{ij}$ | $S^{g}_{ij}$ | $W^{g}_{ij}$ | $Y^{g}_{ij}$ | $X^{g}_{i}$ |
| | Power Supply | $R^{s}_{ij}$ | $F^{s}_{ij}$ | $F^{snf}_{ij}$ | $G^{s}_{ij}$ | $S^{s}_{ij}$ | $W^{s}_{ij}$ | $Y^{s}_{ij}$ | $X^{s}_{i}$ |
| Pollution Emitted | | $R^{w}_{ij}$ | $F^{w}_{ij}$ | $F^{wnf}_{ij}$ | $G^{w}_{ij}$ | $S^{w}_{ij}$ | $W^{w}_{ij}$ | $Y^{w}_{ij}$ | $X^{w}_{i}$ |
| Value-added | | $N^{e}_{j}$ | $N^{f}_{j}$ | $N^{fnf}_{j}$ | $N^{g}_{j}$ | $N^{s}_{j}$ | $N^{w}_{j}$ | | |
| Total Input | | $Z^{e}_{j}$ | $Z^{f}_{j}$ | $Z^{fnf}_{j}$ | $Z^{g}_{j}$ | $Z^{s}_{j}$ | $Z^{w}_{j}$ | | |
| Man-made Assets | Fixed Assets | $W_1^{e}$ | $W_1^{f}$ | $W_1^{nf}$ | $W_1^{g}$ | $W_1^{s}$ | $W_1^{e}$ | | |
| Natural | Physical Resources | | | | $t_{ij}^{e}\left(X_i^{e}-Z_i^{e}\right.$ | | | | |
| Assets | Environmnntal Assets | | | | $t_{ij}^{w}\left(X_i^{w}-Z_i\right.$ | | | | |

(where $R^{e}_{ij}$ -- the amount of natural resource i consumed by resource recovering department j; $R^{f}_{ij}$ -- the amount of fuel i consumed by resource recovering department j; $R^{nf}_{ij}$ -- the amount of non-fuel material i consumed by resource recovering department j; $R^{g}_{ij}$ -- the amount of i'th kind power (power generation) consumed by resource recovering department j; $R^{s}_{ij}$ -- the amount of i'th kind power (power supply) consumed by resource recovering department j; $R^{w}_{ij}$ -- the amount of pollution i emitted by resource recovering department j; $F^{e}_{ij}$ -- the amount of resource i consumed by fuels department j (such as coal resources, petroleum resources, natural gas resources, water resources etc.); $F^{f}_{ij}$ -- the amount of fuel i consumed by fuels department j; $F^{nf}_{ij}$ -- the amount of non-fuel material i consumed by fuels department j; $F^{g}_{ij}$ -- the amount of i'th kind power (power generation) consumed by fuels department j; $F^{s}_{ij}$ -- the amount of i'th kind power (power supply) consumed by fuels department j; $F^{w}_{ij}$ -- the amount of pollution i emitted by fuels department j; $F^{enf}_{ij}$ -- the amount of resource i consumed by non-fuels materials department j (such as coal resources, petroleum resources, natural gas resources, water resources etc.); $F^{fnf}_{ij}$ -- the amount of fuel i consumed by non-fuels materials department j; $F^{nfnf}_{ij}$ -- the amount of non-fuel material i consumed by non-fuels materials department j; $F^{gnf}_{ij}$ -- the amount of i'th kind power (power generation) consumed by non-fuels materials department j; $F^{snf}_{ij}$ -- the amount of i'th kind power (power supply) consumed by non-fuels materials department j; $F^{wnf}_{ij}$ -- the amount of pollution i emitted by non-fuels materials department j; $G^{e}_{ij}$ -- the amount of resource i consumed by power generation department j; $G^{f}_{ij}$ -- the amount of fuel i consumed by power generation department j (such as coal, petroleum, natural gas, nuclear materials etc.); $G^{nf}_{ij}$ -- the amount of non-fuel material i consumed by power generation department j; $G^{g}_{ij}$ -- the amount of i'th kind power (power generation) consumed by power generation department j (such as electricity be consumed by the power generation plant/station itself etc.); $G^{s}_{ij}$ -- the amount of i'th kind power (power supply) consumed by power generation department j (such as electricity of different kind of voltages be consumed by the power generation plant/station etc.); $G^{w}_{ij}$ -- the amount of pollution i emitted by power generation department j; $S^{e}_{ij}$ -- the amount of resource i consumed by power supply department j; $S^{f}_{ij}$ -- the amount of fuel i consumed by power supply department j (such as oil be used in the electricity transform machine etc.); $S^{nf}_{ij}$ -- the amount of non-fuel material i consumed by power supply department j ; $S^{g}_{ij}$ -- the amount of i'th kind power (power generation) consumed by power supply department j (such as electricity be consumed by all equipment of power supply etc.); $S^{s}_{ij}$ -- the amount of i'th kind power (power supply) consumed by power supply department j (such as electricity of different kind of voltages be consumed by all equipment of power supply etc.); $S^{w}_{ij}$ -- the amount of pollution i emitted by power supply department j; $W^{e}_{ij}$ -- the amount of resource i consumed by pollution abatement department j; $W^{f}_{ij}$ -- the amount of fuel i consumed by pollution abatement department j; $W^{nf}_{ij}$ -- the amount of non-fuel material i consumed by pollution abatement department j; $W^{g}_{ij}$ -- the amount of i'th kind power (power generation) consumed by pollution abatement department j; $W^{s}_{ij}$ -- the amount of i'th kind power (power supply) consumed by pollution abatement department j; $W^{w}_{ij}$ -- the amount of pollution i emitted by pollution abatement department j; $Y^{e}_{ij}$ -- the amount of resource i consumed by final user j; $Y^{f}_{ij}$ -- the amount of fuel i consumed by final user j; $Y^{nf}_{ij}$ -- the amount of non-fuel material i consumed by final user j; $Y^{g}_{ij}$ -- the amount of i'th kind power (power generation) consumed by final user j; $Y^{s}_{ij}$ -- the amount of i'th kind power (power supply) consumed by final user j; $Y^{w}_{ij}$ -- the amount of pollution i emitted by final user j; $X^{e}_{i}$ -- the total amount of consumption of resource i; $X^{f}_{i}$ -- the total amount of consumption of fuel i; $X^{nf}_{i}$ -- the total amount of consumption of non-fuel material i; $X^{g}_{i}$ -- the total amount of consumption of i'th kind power (power generation); $X^{s}_{i}$ -- the total amount of consumption of i'th kind power (power supply); $X^{w}_{i}$ -- the total emission of pollutant i; $N^{e}_{j}$--the value-added (labor wage, net social income, etc.) created by recovering department j (including the depreciation in fixed assets); $N^{f}_{j}$--the value-added (labor wage, net social income, etc.) created by fuels department j (including the depreciation in fixed assets); $N^{nf}_{j}$--the value-added (labor wage, net social income, etc.) created by non-fuels materials department j (including the depreciation in fixed assets); $N^{g}_{j}$--the value-added (labor wage, net social income, etc.) created by power generation department j (including the depreciation in fixed assets); $N^{s}_{j}$--the value-added (labor wage, net social income, etc.) created by power supply department j (including the depreciation in fixed assets); $N^{w}_{j}$--the value-added (labor wage, net social income, etc.) created by pollution abatement department j (including the depreciation in fixed assets); $Z^{e}_{j}$ -- the total amount of resource j recovered; $Z^{f}_{j}$ -- the total consumption by fuel department j; $Z^{nf}_{j}$ -- the total consumption by non-fuel materials department j; $Z^g_j$ -- the total consumption by power generation department j; $Z^s_j$ -- the total consumption by power supply department j; $Z^w_j$ -- the total amount of pollutant j eliminated)

Like to our former Integrated Input-output Table of Natural Resources-Economy-Environment, there are two noticeable characters existing in this table:

1) The table is designed based on the complete analysis of full external cost of human economy activities (here is only focus on the power generation & supply) and the relevant pricing theory of marginal opportunity cost , not the traditional basement——the production cost pricing theory;
2) The table is extended from tow side compare with traditional input-output table, i.e. not only the pollution emission & abatement but the natural resources exhaustion & recovery, though W. Leontief considered about and do the work but only the former extended side in his environmental-economy analysis (1972).

## 3 Basic Model

### 3.1 Physical Model

According to the basic relationship of table 1 (row), the following physical balancing equations can be gotten as,

1) Natural Resources

$$\sum_{j=1}^{N} R^e_{ij} + \sum_{j=1}^{n} F^e_{ij} + \sum_{j=1}^{m} G^e_{ij} + \sum_{j=1}^{l} S^e_{ij} + \sum_{j=1}^{k} F^{enf}_{ij} + \sum_{j=1}^{M} W^e_{ij} + Y^e_i = X^e_i \qquad (1)$$

2) Fuels

$$\sum_{j=1}^{N} R^f_{ij} + \sum_{j=1}^{n} F^f_{ij} + \sum_{j=1}^{m} G^f_{ij} + \sum_{j=1}^{l} S^f_{ij} + \sum_{j=1}^{k} F^{fnf}_{ij} + \sum_{j=1}^{M} W^f_{ij} + Y^f_i = X^f_i \qquad (2)$$

3) Non-Fuels

$$\sum_{j=1}^{N} R^{nf}_{ij} + \sum_{j=1}^{n} F^{nf}_{ij} + \sum_{j=1}^{m} G^{nf}_{ij} + \sum_{j=1}^{l} S^{nf}_{ij} + \sum_{j=1}^{k} F^{nfnf}_{ij} + \sum_{j=1}^{M} W^{nf}_{ij} + Y^{nf}_i = X^{nf}_i \qquad (3)$$

4) Power Generation

$$\sum_{j=1}^{N} R^g_{ij} + \sum_{j=1}^{n} F^g_{ij} + \sum_{j=1}^{m} G^g_{ij} + \sum_{j=1}^{l} S^g_{ij} \quad \sum_{j=1}^{k} F^{gnf}_{ij} + \sum_{j=1}^{M} W^g_{ij} + Y^g_i = X^g_i \qquad (4)$$

5) Power Supply

$$\sum_{j=1}^{N} R^s_{ij} + \sum_{j=1}^{n} F^s_{ij} + \sum_{j=1}^{m} G^s_{ij} + \sum_{j=1}^{l} S^s_{ij} + \sum_{j=1}^{k} F^{snf}_{ij} + \sum_{j=1}^{M} W^s_{ij} + P^s_i = X^s_i \qquad (5)$$

6) Pollutants

$$\sum_{j=1}^{N} R^w_{ij} + \sum_{j=1}^{n} X^w_{ij} + \sum_{j=1}^{m} E^w_{ij} + \sum_{j=1}^{l} T^w_{ij} + \sum_{j=1}^{k} F^{wnf}_{ij} + \sum_{j=1}^{M} W^w_{ij} + Y^w_i = X^w_i \qquad (6)$$

where N is the number of natural resources, n is the number of fuels (such as coal, petroleum, natural gas, hydro, nuclear materials etc.), k is the number of non-fuels materials, m is the number of power generation departments (unit: power plant/station), l is the number of power supply department (includes electricity transportation department, electricity transform department, electricity distribution department etc. or high voltage’s , medium voltage’s, lower voltage’s etc.), M is the number of pollution abatement department.

**3.2 Value Model**

According to the basic relationship of table 1 (column), the following value balancing equations can be get as following:

1）Natural Resources

$$\sum_{i=1}^{N} P^e_i R^e_{ij} + \sum_{i=1}^{n} P^f_i R^f_{ij} + \sum_{j=1}^{k} P^{nf}_i R^{nf}_{ij} + \sum_{i=1}^{m} P^g_i R^g_{ij} + \sum_{i=1}^{l} P^s_i R^s_{ij} + \sum_{i=1}^{M} P^w_i R^w_{ij} + N^e_j = P^e_j Z^e_j \qquad (6)$$

2) Fuels

$$\sum_{i=1}^{N} P^e_i F^e_{ij} + \sum_{i=1}^{n} P^f_i F^f_{ij} + \sum_{j=1}^{k} P^{nf}_i F^{nf}_{ij} + \sum_{i=1}^{m} P^g_i F^g_{ij} + \sum_{i=1}^{l} P^s_i F^s_{ij} + \sum_{i=1}^{M} P^w_i F^w_{ij} + N^f_j = P^f_j Z^f_j \qquad (7)$$

3) Non-Fuels

$$\sum_{i=1}^{N} P^e_i F^{enf}_{ij} + \sum_{i=1}^{n} P^f_i F^{fnf}_{ij} + \sum_{j=1}^{k} P^{nf}_i F^{nfnf}_{ij} + \sum_{i=1}^{m} P^g_i F^{gnf}_{ij} + \sum_{i=1}^{l} P^s_i F^{snf}_{ij} + \sum_{i=1}^{M} P^w_i F^{wnf}_{ij} + N^{nf}_j = P^{nf}_j Z^{nf}_j \qquad (8)$$

4) Power Generation

$$\sum_{i=1}^{N} P^e_i G^e_{ij} + \sum_{i=1}^{n} P^f_i G^f_{ij} + \sum_{j=1}^{k} P^{nf}_i G^{nf}_{ij} + \sum_{i=1}^{m} P^g_i G^g_{ij} + \sum_{i=1}^{l} P^s_i G^s_{ij} + \sum_{i=1}^{M} P^w_i G^w_{ij} + N^g_j = P^g_j Z^g_j \qquad (9)$$

5) Power Supply:

$$\sum_{i=1}^{N} P^e_i S^e_{ij} + \sum_{i=1}^{n} P^f_i S^f_{ij} + \sum_{j=1}^{k} P^{nf}_i S^{nf}_{ij} + \sum_{i=1}^{m} P^g_i S^g_{ij} + \sum_{i=1}^{l} P^s_i S^s_{ij} + \sum_{i=1}^{M} P^w_i S^w_{ij} + N^s_j = P^s_j Z^s_j \qquad (10)$$

6) Pollutants

$$\sum_{i=1}^{N} P^e_i W^e_{ij} + \sum_{i=1}^{n} P^f_i W^f_{ij} + \sum_{j=1}^{k} P^{nf}_i W^{nf}_{ij} + \sum_{i=1}^{m} P^g_i W^g_{ij} + \sum_{i=1}^{l} P^s_i W^s_{ij} + \sum_{i=1}^{M} P^w_i W^w_{ij} + N^w_j = P^w_j Z^w_j \qquad (11)$$

where $P^f_i$, $P^{nf}_i$, $P^g_i$, $P^s_i$, are the cost per unit of fuel i (i=1,2,…,n), non-fuels materials i (i=1,…,k), electricity (power generation) i (i=1,2,…,m) and electricity (power supply) i (i=1,2,…,l) respectively, $P^e_i$, $P^w_i$, are the natural resources compensation fee per unit natural resources i (i=1,2,…,N) used and the pollution abatement fee per unit pollutant i (i=1,2,…,M) emitted.

## 4 Applied Analysis

### 4.1 Decision Making——Production Planning

Obviously, another important application of our input-output table and model is the production (power generation & supply) decision making or plan making. Similar to all kinds of application of production plan making based on the input-output table and model, here the production (power generation & supply) plan of the power company/enterprise can be made based on the final demand on the power, by means of our above physical input-output model.

Let $r^e_{ij} = R^e_{ij}/Z^e_j$, $f^e_{ij} = F^e_{ij}/Z^f_j$, $f^{enf}_{ij} = F^{enf}_{ij}/Z^{nf}_j$, $g^e_{ij} = G^e_{ij}/Z^g_j$, $s^e_{ij} = S^e_{ij}/Z^s_j$, $w^e_{ij} = W^e_{ij}/Z^w_j$

where $r^e_{ij}$ is direct consumption coefficient of natural resources recovery department j to natural resource i; $f^e_{ij}$ is direct consumption coefficient of fuel department j to natural resource i; $f^{enf}_{ij}$ is direct consumption coefficient of non-fuel materials department j to natural resource i; $g^e_{ij}$ is direct consumption coefficient of power generation department j to natural resource i; $s^e_{ij}$ is direct consumption coefficient of power supply department j to natural resource i; $w^e_{ij}$ is direct consumption coefficient of pollution abatement department j to natural resource i;

Then equation (1) can be written as,

$$\sum_{j=1}^{N} r^e_{ij} Z^e_j + \sum_{j=1}^{n} f^e_{ij} Z^f_j + \sum_{j=1}^{m} g^e_{ij} Z^g_j + \sum_{j=1}^{l} s^e_{ij} Z^s_j + \sum_{j=1}^{k} f^{enf}_{ij} Z^{nf}_j + \sum_{j=1}^{M} w^e_{ij} Z^w_j + Y^e_i = X^e_I$$

Let $r^f_{ij} = R^f_{ij}/Z^e_j$, $f^f_{ij} = F^f_{ij}/Z^f_j$, $f^{fnf}_{ij} = F^{fnf}_{ij}/Z^{nf}_j$, $g^f_{ij} = G^f_{ij}/Z^g_j$, $s^f_{ij} = S^f_{ij}/Z^s_j$, $w^f_{ij} = W^f_{ij}/Z^w_j$

where $r^f_{ij}$ is direct consumption coefficient of natural recovery department j to fuels i; $f^f_{ij}$ is direct consumption coefficient of fuel department j to fuels i; $f^{fnf}_{ij}$ is direct consumption coefficient of non-fuel materials department j to fuels i; $g^f_{ij}$ is direct consumption coefficient of power generation department j to fuels i; $s^f_{ij}$ is direct consumption coefficient of power supply department j to fuels i; $w^f_{ij}$ is direct consumption coefficient of pollution abatement department j to fuels i;

Then equation (2) can be written as,

$$\sum_{j=1}^{N} r^f_{ij} Z^e_j + \sum_{j=1}^{n} f^f_{ij} Z^f_j + \sum_{j=1}^{m} g^f_{ij} Z^g_j + \sum_{j=1}^{l} s^f_{ij} Z^s_j + \sum_{j=1}^{k} f^{fnf}_{ij} Z^{nf}_j + \sum_{j=1}^{M} w^f_{ij} Z^w_j + Y^f_i = X^f_I$$

Let $r^{nf}_{ij} = R^{nf}_{ij}/Z^e_j$, $f^{nf}_{ij} = F^{nf}_{ij}/Z^f_j$, $f^{nfnf}_{ij} = F^{nfnf}_{ij}/Z^{nf}_j$, $g^{nf}_{ij} = G^{nf}_{ij}/Z^g_j$, $s^{nf}_{ij} = S^{nf}_{ij}/Z^s_j$, $w^{nf}_{ij} = W^{nf}_{ij}/Z^w_j$

where $r^{nf}_{ij}$ is direct consumption coefficient of natural recovery department j to non-fuels materials i; $f^{nf}_{ij}$ is direct consumption coefficient of fuel department j to non-fuels materials i; $f^{nfnf}_{ij}$ is direct consumption coefficient of fuel department j to non-fuels materials i; $g^{nf}_{ij}$ is direct consumption coefficient of power generation department j to non-fuels materials i; $s^{nf}_{ij}$ is direct consumption coefficient of power supply department j to non-fuels materials i; $w^{nf}_{ij}$ is direct consumption coefficient of pollution abatement department j to non-fuels materials i;

Then equation (3) can be written as,

$$\sum_{j=1}^{N} r^{nf}_{ij} Z^{e}_{j} + \sum_{j=1}^{n} f^{nf}_{ij} Z^{f}_{j} + \sum_{j=1}^{m} g^{nf}_{ij} Z^{g}_{j} + \sum_{j=1}^{l} s^{nf}_{ij} Z^{s}_{j} + \sum_{j=1}^{k} f^{nfnf}_{ij} Z^{nf}_{j} + \sum_{j=1}^{M} w^{nf}_{ij} Z^{w}_{j} + Y^{nf}_{i} = X^{nf}_{I}$$

Let $r^{g}_{ij} = R^{g}_{ij}/Z^{e}_{j}$, $f^{g}_{ij} = F^{g}_{ij}/Z^{f}_{j}$, $f^{gnf}_{ij} = F^{gnf}_{ij}/Z^{nf}_{j}$, $g^{g}_{ij} = G^{g}_{ij}/Z^{g}_{j}$, $s^{g}_{ij} = S^{g}_{ij}/Z^{s}_{j}$, $w^{g}_{ij} = W^{g}_{ij}/Z^{w}_{j}$ where $r^{g}_{ij}$ is direct consumption coefficient of natural resource recovery department j to power (power generation) i; $f^{g}_{ij}$ is direct consumption coefficient of fuel department j to power (power generation) i; $f^{gnf}_{ij}$ is direct consumption coefficient of non-fuel materials department j to power (power generation) i; $g^{g}_{ij}$ is direct consumption coefficient of power generation department j to power (power generation) i; $s^{g}_{ij}$ is direct consumption coefficient of power supply department j to power (power generation) i; $w^{g}_{ij}$ is direct consumption coefficient of pollution abatement department j to power (power generation) i;

Then equation (4) can be written as,

$$\sum_{j=1}^{N} r^{g}_{ij} Z^{e}_{j} + \sum_{j=1}^{n} f^{g}_{ij} Z^{f}_{j} + \sum_{j=1}^{m} g^{g}_{ij} Z^{g}_{j} + \sum_{j=1}^{l} s^{g}_{ij} Z^{s}_{j} + \sum_{j=1}^{k} f^{gnf}_{ij} Z^{nf}_{j} + \sum_{j=1}^{M} w^{g}_{ij} Z^{w}_{j} + Y^{g}_{i} = X^{g}_{I}$$

Let $r^{s}_{ij} = R^{s}_{ij}/Z^{e}_{j}$, $f^{s}_{ij} = F^{s}_{ij}/Z^{f}_{j}$, $f^{snf}_{ij} = F^{snf}_{ij}/Z^{nf}_{j}$, $g^{s}_{ij} = G^{s}_{ij}/Z^{g}_{j}$, $s^{s}_{ij} = S^{s}_{ij}/Z^{s}_{j}$, $w^{s}_{ij} = W^{s}_{ij}/Z^{w}_{j}$ where $r^{s}_{ij}$ is direct consumption coefficient of natural resource recovery department j to power (power supply) i ; $f^{s}_{ij}$ is direct consumption coefficient of fuel department j to power (power supply) i; $f^{snf}_{ij}$ is direct consumption coefficient of non-fuel materials department j to power (power supply) i; $g^{s}_{ij}$ is direct consumption coefficient of power generation department j to power (power supply) i; $s^{s}_{ij}$ is direct consumption coefficient of power supply department j to power (power supply) i; $w^{s}_{ij}$ is direct consumption coefficient of pollution abatement department j to power (power supply) i;

Then equation (5) can be written as,

$$\sum_{j=1}^{N} r^{s}_{ij} Z^{e}_{j} + \sum_{j=1}^{n} f^{s}_{ij} Z^{f}_{j} + \sum_{j=1}^{m} g^{s}_{ij} Z^{g}_{j} + \sum_{j=1}^{l} s^{s}_{ij} Z^{s}_{j} + \sum_{j=1}^{k} f^{snf}_{ij} Z^{nf}_{j} + \sum_{j=1}^{M} w^{s}_{ij} Z^{w}_{j} + Y^{s}_{i} = X^{s}_{I}$$

Let $r^{w}_{ij} = R^{w}_{ij}/Z^{e}_{j}$, $f^{w}_{ij} = F^{w}_{ij}/Z^{f}_{j}$, $f^{wnf}_{ij} = F^{wnf}_{ij}/Z^{nf}_{j}$, $g^{w}_{ij} = G^{w}_{ij}/Z^{g}_{j}$, $s^{w}_{ij} = S^{w}_{ij}/Z^{s}_{j}$, $w^{w}_{ij} = W^{w}_{ij}/Z^{w}_{j}$ where $r^{w}_{ij}$ is direct emission coefficient of pollutant i in natural resources recovery department j; $f^{w}_{ij}$ is direct emission coefficient of pollutant i in fuel department j; $f^{wnf}_{ij}$ is direct emission coefficient of pollutant i in non-fuel materials department j; $g^{w}_{ij}$ is direct emission coefficient of pollutant i in power generation department j; $s^{w}_{ij}$ is direct emission coefficient of pollutant i in power supply department j; $w^{w}_{ij}$ is direct emission coefficient of pollutant i in pollution abatement department j;

Then equation (6) can be written as,

$$\sum_{j=1}^{N} r^{w}_{ij}Z^{e}_{j}+\sum_{j=1}^{n} f_{ij}^{w}Z_{j}^{f}+\sum_{j=1}^{m} g_{ij}^{w}Z_{j}^{g}+\sum_{j=1}^{l} s_{ij}^{w}Z_{j}^{s}+\sum_{j=1}^{k} f^{wnf}_{ij}Z^{nf}_{j}+\sum_{j=1}^{M} w^{w}_{ij}Z^{w}_{j}+Y^{w}_{i}=X^{w}_{I}$$

Let $R^* = (r^*_{ij})^T$, $F^* = (f^*_{ij})^T$, $G^* = (g^*_{ij})^T$, $S^* = (s^*_{ij})^T$, $W^* = (w^*_{ij})^T$,

$Z^* = (Z^*_1, Z^*_2, \ldots, Z^*_k)^T$,

$Y^* = (Y^*_1, Y^*_2, \ldots, Y^*_k)^T$,

$X^* = (X^*_1, X^*_2, \ldots, X^*_k)^T$

for * as e, f, *nf*, g, s, w, and k = LL, n, *k*,m, l, M, the upper-symbol "T" indicates transferred matrix

And let $\alpha_i = Z^e_i / X^e_i$ is proportion of natural resources-recovery, $\beta_i = Z^w_i / X^w_i$ is proportion of pollution-abatement, $\underline{\alpha} = \mathrm{diag}(\alpha_1, \alpha_2, \ldots, \alpha_L)$, $\underline{\beta} = \mathrm{diag}(\beta_1, \beta_2, \ldots, \beta_N)$,

then we have,

$$R^e\ \underline{\alpha} X^e + F^e X^f + F^{enf} X^{nf} + G^e X^g + S^e X^s + W^e \underline{\beta} X^w + Y^e = X^e$$
$$R^f\ \underline{\alpha} X^e + F^f X^f + F^{fnf} X^{nf} + G^f X^g + S^f X^s + W^f \underline{\beta} X^w + Y^f = X^f$$
$$R^{nf}\ \underline{\alpha} X^e + F^{nf} X^f + F^{nfnf} X^{nf} + G^{nf} X^g + S^{nf} X^s + W^{nf} \underline{\beta} X^w + Y^{nf} = X^{nf}$$
$$R^g\ \underline{\alpha} X^e + F^g X^f + F^{gnf} X^{nf} + G^g X^g + S^g X^s + W^g \underline{\beta} X^w + Y^g = X^g$$
$$R^s\ \underline{\alpha} X^e + F^s X^f + F^{snf} X^{nf} + G^s X^g + S^s X^s + W^s \underline{\beta} X^w + Y^s = X^s$$
$$R^w\ \underline{\alpha} X^e + F^w X^f + F^{wnf} X^{nf} + G^w X^g + S^w X^s + W^w \underline{\beta} X^w + Y^w = X^w$$

hence
$$\begin{bmatrix} \alpha R^e & F^e & F^{enf} & G^e & S^e & \beta W^e \\ \alpha R^f & F^f & F^{fnf} & G^f & S^f & \beta W^f \\ \alpha R^{nf} & F^{nf} & F^{nfnf} & G^{nf} & S^{nf} & \beta W^{nf} \\ \alpha R^g & F^g & F^{gnf} & G^g & S^g & \beta W^g \\ \alpha R^s & F^s & F^{snf} & G^s & S^s & \beta W^s \\ \alpha R^w & F^w & F^{wnf} & G^w & S^w & \beta W^w \end{bmatrix} \begin{bmatrix} X^e \\ X^f \\ X^{nf} \\ X^g \\ X^s \\ X^w \end{bmatrix} + \begin{bmatrix} Y^e \\ Y^f \\ Y^{nf} \\ Y^g \\ Y^s \\ Y^w \end{bmatrix} = \begin{bmatrix} X^e \\ X^f \\ X^{nf} \\ X^g \\ X^s \\ X^w \end{bmatrix}$$

let
$$A = \begin{bmatrix} \alpha R^e & F^e & F^{enf} & G^e & S^e & \beta W^e \\ \alpha R^f & F^f & F^{fnf} & G^f & S^f & \beta W^f \\ \alpha R^{nf} & F^{nf} & F^{nfnf} & G^{nf} & S^{nf} & \beta W^{nf} \\ \alpha R^g & F^g & F^{gnf} & G^g & ,S^g & \beta W^g \\ \alpha R^s & F^s & F^{snf} & G^s & S^s & \beta W^s \\ \alpha R^w & F^w & F^{wnf} & G^w & S^w & \beta W^w \end{bmatrix}, \quad Y = \begin{bmatrix} Y^e \\ Y^f \\ Y^{nf} \\ Y^g \\ Y^s \\ Y^w \end{bmatrix}, \quad X = \begin{bmatrix} X^e \\ X^f \\ X^{nf} \\ X^g \\ X^s \\ X^w \end{bmatrix}$$

then $AX + Y = X$

$$X = (I - A)^{-1} Y$$

Since the natural resources used directly by the final user and the pollutants emitted directly by the final user has nothing to do with the power company production planning, and there are obviously there is no natural resources directly used and no pollutants directly emitted by the final user when they use the power company's product——electricity. I addition, it's obviously the final user can not and will not use the fuels supplied by the fuels department since here the fuels department is only the fuels department belongs to the power company. Hence, the power generation & supply can be made as following as the final demand on the power generation & supply $Y^g$ , $Y^s$ by different users are given,

$$\begin{bmatrix} X^e \\ X^f \\ X^{nf} \\ X^g \\ X^s \\ X^w \end{bmatrix} = (I - \begin{bmatrix} \alpha R^e & F^e & F^{enf} & G^e & S^e & \beta W^e \\ \alpha R^f & F^f & F^{fnf} & G^f & S^f & \beta W^f \\ \alpha R^{nf} & F^{nf} & F^{nfnf} & G^{nf} & S^{nf} & \beta W^{nf} \\ \alpha R^g & F^g & F^{gnf} & G^g & S^g & \beta W^g \\ \alpha R^s & F^s & F^{snf} & G^s & S^s & \beta W^s \\ \alpha R^w & F^w & F^{wnf} & G^w & S^w & \beta W^w \end{bmatrix}) \begin{bmatrix} 0 \\ 0 \\ 0 \\ Y^g \\ Y^s \\ 0 \end{bmatrix}$$

From here, not only the gross production (power generation & supply) plan——total power generation and supply of the power company/enterprise can be made based on the final demand on the power , but the relevant total amount of natural resources used/exhausted and total amount of pollutants emitted can be known if the production plan be carried out.

**4.2 Cost Analysis**

In in the traditional power generation & supply planning analysis, cost analysis is usually done by two important index ——the Cost of Per Unit Power Generation & the Cost of Per Unit Power Supply. Here we try to give an same analysis on the basis of our input-output model.

As we know, as definition, the Cost of Per Unit Power Generation plant/station and the Cost of Per Unit Power Supply are defined as follows,

Cost of Per Unit Power Generation (KW)

$$= \frac{total \quad cost \quad of \quad power \quad generation \quad plant / station}{power \quad generation \quad of \quad power \quad plant / station}$$

Cost of Per Unit Power Supply (KW)

$$= \frac{total \quad cost \quad of \quad power \quad supply \quad department}{total \quad power \quad supply \quad of \quad power \quad supply \quad department}$$

Suppose the Cost Per Unit Power Generation in power generation department (plant/station) j is $P_j^f$ (thousand US$/KW)（j=1,2,…,m), the Cost Per Unit Power Supply in power supply department j is $P_j^f$ (thousand US$/KW)（j=1,2,…,l), and let $d_j$ is the depreciation rate of fixed assets in department i， $\text{И}_{ij}^{g}$, $\text{И}_{ij}^{s}$ are direct occupancy of fixed assets i per unit product of power generation department j and direct occupancy of fixed assets i per unit product of power supply department j，respectively,

$$\text{И}_{ij}^{g} = W_{ij}^{g} / X_j^{g} \quad (i,j=1,2,\cdots,m), \quad \text{И}_{ij}^{s} = W_{ij}^{s} / X_j^{s} \quad (i,j=1,2,\cdots,m)$$

where $W_{ij}^{g}$, $W_{ij}^{s}$ are total occupancy of fixed assets i of power generation department j and total occupancy of fixed assets i of power supply department j，respectively.

$\text{И}_{ij}^{e}$ , $\text{И}_{ij}^{w}$ are direct occupancy of fixed assets i per unit product of natural resources recovery department j and direct occupancy of fixed assets i per unit product of pollutant abatement department j，respectively,

$$\text{И}_{ij}^{e} = \frac{W_{ij}^{e}}{X_j^{e}}, \text{И}_{ij}^{w} = \frac{W_{ij}^{w}}{X_{ij}^{w}}$$

where $W_{ij}^{e}, W_{ij}^{w}$ are total occupancy of fixed assets i of natural resources recovery department j and total occupancy of fixed assets i of pollutant abatement department j，respectively.

According to our analysis above，power generation is the core of activities in the power company and the other relevant activities (natural resources recovery and pollutant abatement) are obviously accused by power generation. So all consumption of natural assets are supposed belong to the power generation department here.

Let $T_{ij}^{e}$ is the consumption coefficient of natural physical assets i results from power generation in power generation department j（can be estimated on the basis of apportion of the difference between total amount of natural resources used and total amount of natural resources recovered), $T_{ij}^{w}$ is the consumption coefficient of natural environmental assets i results from power generation in power generation department j（can be estimated on the basis of apportion of the difference between total amount of pollutants emitted and total amount of pollutants abated).

$$\mathrm{T} = \frac{t\ (X\ \ - Z\ )}{X}, \mathrm{T}\ = \frac{t\ (X\ \ - Z\ )}{X}$$

where $t_{ij}^{e} = \frac{u_{ij}^{p}}{X_i^{e}}$ is the share of power generation department j in the consumption of natural physical assets i， $t_{ij}^{w} = \frac{e_{ij}^{p}}{X_i^{w}}$ is the share of power generation department j in the consumption of natural environmental assets i.

Then on the basis our value input-output model we have，

$$\sum_{i=1}^{N} P^e_i G^e_{ij} + \sum_{i=1}^{N} P^e_i t^e_{ij}\left(X^e_i - Z^e_i\right) + \sum_{i=1}^{k} P^{nf}_i G^{fnf}_{ij} + \sum_{i=1}^{n} P^f_i G^f_{ij} + \sum_{i=1}^{m} P^g_i d_i \text{И}_{ij}^{g} + \sum_{i=1}^{m} P^g_i G^g_{ij} + \sum_{i=1}^{l} P^s_i G^s_{ij} + \sum_{i=1}^{M} P^w_i G^w_{ij} + \sum_{i=1}^{M} P^w_i t^w_{ij}\left(X^w_i - Z^w_i\right) + D^g_j + V^g_j + M^g_j = P^g_j Z^g_j \qquad (j=1,2,\ldots,m)$$

$$\sum_{i=1}^{N} P^e_i S^e_{ij} + \sum_{i=1}^{k} P^{nf}_i G^{fnf}_{ij} + \sum_{i=1}^{n} P^f_i S^f_{ij} + \sum_{i=1}^{m} P^g_i S^g_{ij} + \sum_{i=1}^{m} P^s_i d_i \text{И}_{ij}^{s} + \sum_{i=1}^{l} P^s_i S^s_{ij} + \sum_{i=1}^{M} P^w_i S^w_{ij} + D^s_j + V^s_j + N^s_j = P^s_j Z^s_j \qquad (j=1,2,\ldots,l)$$

where $D^g_j$, $V^g_j$, $M^g_j$ are the depreciation of the fixed assets of power generation department j, the salary of power generation department j and the operation surplus (taxes and profit) of power generation department j respectively.

From our I-O table, let

$g1^e_{ij} = \frac{G^e_{ij}}{X^e_i}$ is direct distribution coefficient of natural resources i in power generation department j;

$s1^e_{ij} = \frac{S^e_{ij}}{X^e_i}$ is direct distribution coefficient of natural resources i in power supply department j;

$g1^f_{ij} = \frac{G^f_{ij}}{X^f_i}$ is direct distribution coefficient of fueling i in power generation department j;

$s1^f_{ij} = \frac{S^f_{ij}}{X^f_i}$ is direct distribution coefficient of fueling i in power supply department j;

$g1^g_{ij} = \frac{G^g_{ij}}{X^g_i}$ is direct distribution coefficient of power (power generation) i in power generation department j;

$s1^g_{ij} = \frac{S^g_{ij}}{X^g_i}$ is direct distribution coefficient of power (power generation) i in power supply department j;

$g1^s_{ij} = \frac{G^s_{ij}}{X^s_i}$ is direct distribution coefficient of power (power supply) i in power generation department j;

$s1^s_{ij} = \frac{S^s_{ij}}{X^s_i}$ is direct distribution coefficient of power (power supply) i in power supply department j;

$g1_{ij}^{w} = \dfrac{G_{ij}^{w}}{X_{i}^{w}}$ is direct distribution coefficient of pollutant i emitted by power generation department j;

$s1_{ij}^{w} = \dfrac{S_{ij}^{w}}{X_{i}^{w}}$ is direct distribution coefficient of pollutant i emitted in power supply department j;

Then the above equations can be rewritten as，

$$\sum_{i=1}^{N} P^e_i g1^e_{ij} X^e_i + \sum_{i=1}^{N} P^e_i T^e_{ij} X^f_i + \sum_{i=1}^{n} P^f_i g1^f_{ij} X^f_i + \sum_{i=1}^{k} P^{nf}_i g1^{nf}_{ij} X^{nf}_i + \sum_{i=1}^{m} P^g_i g1^g_{ij} X^g_i +$$

$$\sum_{i=1}^{l} P^s_i g1^s_{ij} X^s_i + \sum_{i=1}^{M} P^w_i g1^w_{ij} X^w_i + \sum_{i=1}^{M} P^w_i T^w_{ij} X^f_i + D^g_j + V^g_j + M^g_j = P^g_j X^g_j \qquad (i=1,2,\ldots,m)$$

$$\sum_{i=1}^{N} P^e_i s1^e_{ij} X^e_i + \sum_{i=1}^{n} P^f_i s1^f_{ij} X^f_i + \sum_{i=1}^{k} P^{nf}_i s1^{nf}_{ij} X^{nf}_i + \sum_{i=1}^{m} P^g_i s1^g_{ij} X^g_i +$$

$$\sum_{i=1}^{l} P^s_i s1^s_{ij} X^s_i + \sum_{i=1}^{M} P^w_i s1^w_{ij} X^w_i + D^s_j + V^s_j + N^s_j = P^s_j X^s_j \qquad (i=1,2,\ldots,l)$$

Let $G1^e = (g1^e_{ij})$, $S1^e = (s1^e_{ij})$, $G1^f = (g1^f_{ij})$, $S1^f = (s1^f_{ij})$, $G1^g = (g1^g_{ij})$, $S1^* = (s1^g_{ij})$, $G1^s = (g1^s_{ij})$, $S1^s = (s1^s_{ij})$, $G1^w = (g1^w_{ij})$, $S1^w = (s1^w_{ij})$,

$$P^f = (P_1^f, P_2^f, \ldots, P_m^f)^T$$

$$P^s = (P_1^s, P_2^s, \ldots, P_m^s)^T$$

$D^* = (D^*_1, D^*_2, \ldots, D^*_k)^T$,

$V^* = (V^*_1, V^*_2, \ldots, V^*_k)^T$,

$M^* = (M^*_1, M^*_2, \ldots, M^*_k)^T$

then we can rewrite the above equations in the following matrix form,

$$P^{eT}X^{\wedge e}G1^e + P^{eT}X^{\wedge f}T^{e} + P^{fT}X^{\wedge f}G1^f + P^{nfT}X^{\wedge nf}G1^{nf} + P^{gT}X^{\wedge g}G1^g + P^{sT}X^{\wedge s}G1^s + P^{wT}X^{\wedge w}G1^w + P^{wT}X^{\wedge f}T^w + D^g + V^g + M^g = P^{gT}X^{\wedge g}$$

$$P^{eT}X^{\wedge e}S1^e + P^{fT}X^{\wedge f}S1^f + P^{nfT}X^{\wedge nf}S1^{nf} + P^{gT}X^{\wedge g}S1^g + P^{sT}X^{\wedge s}S1^s + P^{wT}X^{\wedge w}S1^w + D^s + V^s + M^s = P^{sT}X^{\wedge s}$$

where $\widehat{X}^g = diag(X_1^g, X_2^g, \ldots, X_m^g)$, $\widehat{X}^s = diag(X_1^s, X_2^s, \ldots, X_l^s)$

hence

$$P^{gT}(I-G1^g)X^{\wedge g} - P^{sT}X^{\wedge s}G1^s = P^{eT}X^{\wedge e}G1^e + P^{eT}X^{\wedge f}T^{e} + P^{fT}X^{\wedge f}G1^f + P^{nfT}X^{\wedge nf}G1^{nf} + P^{wT}X^{\wedge w}G1^w + P^{wT}X^{\wedge f}T^w + D^g + V^g + M^g$$

$$-P^{gT}X^{\wedge g}S1^g + P^{sT}(I-S1^s)X^{\wedge s} = P^{eT}X^{\wedge e}S1^e + P^{fT}X^{\wedge f}S1^f + P^{nfT}X^{\wedge nf}S1^{nf} + P^{wT}X^{\wedge w}S1^w + D^s + V^s + M^s$$

$$(P^{gT}, P^{sT})\begin{pmatrix} (I - G1^g)\widehat{X}^g & -\widehat{X}^s G1^s \\ -\widehat{X}^g S1^g & (I - S1^s)\widehat{X}^s \end{pmatrix} =$$

$$\begin{pmatrix} P^{eT}\hat{X}^e G1^e + P^{eT}\hat{X}^f T^e + P^{fT}\hat{X}^f G1^f + P^{nfT}\hat{X}^{nf} G1^{nf} + P^{wT}\hat{X}^w G1^w + P^{wT}\hat{X}^f T^w + D^g + V^g + M^g \\ P^{eT}\hat{X}^e S1^e + P^{fT}\hat{X}^f S1^f + P^{nfT}\hat{X}^{nf} S1^{nf} + P^{wT}\hat{X}^w S1^w + D^s + V^s + M^s \end{pmatrix}^T$$

from here, we get $P^{gT}, P^{sT}$ as follows,

$$(P^{gT}, P^{sT}) = \begin{pmatrix} P^{eT}\hat{X}^e G1^e + P^{fT}\hat{X}^f G1^f + P^{wT}\hat{X}^w G1^w + D^g + V^g + M^g \\ P^{eT}\hat{X}^e S1^e + P^{fT}\hat{X}^f S1^f + P^{wT}\hat{X}^w S1^w + D^s + V^s + M^s \end{pmatrix}^T \Phi$$

where $$\Phi = \begin{pmatrix} (I - G1^g)\hat{X}^g & -\hat{X}^s G1^s \\ -\hat{X}^g S1^g & (I - S1^s)\hat{X}^s \end{pmatrix}^{-1} = \begin{pmatrix} \Phi_{11} & \Phi_{12} \\ \Phi_{21} & \Phi_{22} \end{pmatrix}$$

and then, we get the cost of per unit electricity production (generation & supply), it is equal to the average cost per unit power generation $\dfrac{\sum_{j=1}^{m} P_j^g}{m}$ plus the average cost per unit power supply $\dfrac{\sum_{j=1}^{l} P_j^s}{l}$ as follows,

$$\frac{\sum_{j=1}^{m} P_j^g}{m} + \frac{\sum_{j=1}^{l} P_j^s}{l}$$

**4.3 Theoretical price of electricity.**

For Power Company, electricity pricing is the key and though the electric power system is a single product economy system, the price of electric is complex. Usually, the electric prices are different from different users in practice. For example, agriculture sector usually enjoys the more preferential treatment——lower electricity price in prices; two different kinds of prices are often adopted within the industrial sector; for some special products, the prices of electricity is very cheaper and in for those sectors such as communication and transportation, municipal construction, broadcast, scientific research, the price of electric is sole, etc.. Here we only discuss the theoretical price because the actual price is on the basis of theoretical price and adjusted by the government policies.

As well known, there are two well-considered principles in the electricity pricing 1.cost principal; 2. fair-share of users principal.

Principle 1 is audio-visual and easy to count. It means that any electricity price should be determined based on the cost of power generation & supply. In an another word, electricity supplied to the users should pricing in light of the production cost of power (power generation & supply). Though there are different electricity prices for different users in practice, the average electricity price over all users shouldn't lower than the cost of per unit electricity production (generation & supply), which can be calculated in our Input-output model as 4.2. This principle is the first and basic principle in power production (power generation & supply) just like others industrials. As to principle 2, it is not so easy or a little more complex compare with principle 1.

Considering different users consume electricity with different electric voltage and further more different equipment is used to form different electricity of different voltage, therefore in order to realize fair-share of the electricity price in different kind of users, the cost of electricity is usually divided into two parts——fixed cost and flexible cost in the traditional power generation & supply planning analysis. There, what is called fixed cost is the cost, which is un-changeable with the electricity produced/generated & supplied, but flexible cost is the cost, which is changeable with the electricity produced/generated & supplied.

Usually, fixed cost includes all the fixed assets investment such the construction investment which includes the dam construction of hydro-power station, nuclear reaction-pile build of nuclear power station etc., special coal mine for coal-power plant investment, power generation equipment which includes electricity generation machine, electricity transform machine etc., power transportation wire net investment, natural resources recovery factory/equipment investment, pollutants abatement factory/equipment investment, all employees wage etc. Flexible cost includes fuels fee, the natural resources compensation fee, the pollution abatement fee and operation surplus of the whole power company which includes all departments of the company such as natural resources department, power generation department, power supply department and pollution abatement department etc..

In the traditional power generation & supply planning analysis, the fixed cost sharing in the users has to consider the following 3 factors,

1) the maximum demand for electricity per year per kind of users.
2) the total electricity consumption of per year per kind of users.
3) the load at the peak-load tine of electricity system per kind of users

As to the flexible cost sharing of users, only the total electricity consumption per year should be considered.

Here, users are divided into K kinds (such as agriculture, industry, lighting, etc.) and the style of power supply are assumed only three kinds i.e. high voltage, medium voltage, lower voltage etc..

Let

$$\sigma^e = \sum_{i=1}^{N}\left(\frac{\sum_{j=1}^{l} G_{ij}^e}{\sum_{j=1}^{m} G_{ij}^e + \sum_{j=1}^{l} S_{ij}^e}\right) \qquad \tau^e = \sum_{i=1}^{N}\left(\frac{\sum_{j=1}^{l} S_{ij}^e}{\sum_{j=1}^{m} G_{ij}^e + \sum_{j=1}^{l} S_{ij}^e}\right) \qquad \sigma^f = \sum_{i=1}^{n}\left(\frac{\sum_{j=1}^{l} G_{ij}^f}{\sum_{j=1}^{m} G_{ij}^f + \sum_{j=1}^{l} S_{ij}^f}\right)$$

$$\tau^f = \sum_{i=1}^{n}\left(\frac{\sum_{j=1}^{l} S_{ij}^f}{\sum_{j=1}^{m} G_{ij}^f + \sum_{j=1}^{l} S_{ij}^f}\right) \qquad \sigma^{nf} = \sum_{i=1}^{k}\left(\frac{\sum_{j=1}^{l} G_{ij}^{nf}}{\sum_{j=1}^{m} G_{ij}^{nf} + \sum_{j=1}^{l} S_{ij}^{nf}}\right) \qquad \tau^{nf} = \sum_{i=1}^{k}\left(\frac{\sum_{j=1}^{l} S_{ij}^{nf}}{\sum_{j=1}^{m} G_{ij}^{nf} + \sum_{j=1}^{l} S_{ij}^{nf}}\right)$$

$$\sigma^{w}=\sum_{i=1}^{M}\left(\frac{\sum_{j=1}^{l}G_{ij}^{w}}{\sum_{j=1}^{m}G_{ij}^{w}+\sum_{j=1}^{l}S_{ij}^{w}}\right)\qquad \tau^{w}=\sum_{i=1}^{M}\left(\frac{\sum_{j=1}^{l}S_{ij}^{w}}{\sum_{j=1}^{m}G_{ij}^{w}+\sum_{j=1}^{l}S_{ij}^{w}}\right)$$

Then, according the definition on the power production (power generation and power supply) fee in traditional power planning analysis, fixed fee can be calculated as following,

**(1) Fixed cost/fee**

$$\sum_{j=1}^{m}(D_j^g+V_j^g+\sum_{i=1}^{h}P_i^g d_i \mathrm{N}_{ij}^g)+\sum_{j=1}^{n}\sigma^f(D_j^f+V_j^f+\sum_{j=1}^{h}P_i^f d_i \mathrm{N}_{ij}^f)+\sum_{j=1}^{k}\sigma^{nf}(D_j^{nf}+V_j^{nf}+$$
$$\sum_{i=1}^{h}P_i^{nf} d_i \mathrm{N}_{ij}^{nf})+\sum_{j=1}^{N}\sigma^e(D_j^e+V_j^e+\sum_{i=1}^{h}P_i^e d_i \mathrm{N}_{ij}^e)+\sum_{j=1}^{M}\sigma^w(D_j^w+V_j^w+\sum_{i=1}^{h}P_i^w d_i \mathrm{N}_{ij}^w)=FC_g$$

a) Fixed fee of power generation:

b) Fixed fee of power supply

i) Fixed fee of high voltage power supply

$$\sum_{j=1}^{l_1}(D_j^s+V_j^s+\sum_{i=1}^{h}P_i^s d_i \mathrm{N}_{ij}^s)+\sum_{j=1}^{n}\tau^f(D_j^f+V_j^f+\sum_{i=1}^{h}P_i^f d_i \mathrm{N}_{ij}^f)+\sum_{j=1}^{k}\tau^{nf}(D_j^{nf}+V_j^{nf}+$$
$$\sum_{i=1}^{h}P_i^{nf} d_i \mathrm{N}_{ij}^{nf})+\sum_{j=1}^{N}\tau^e(D_j^e+V_j^e+\sum_{i=1}^{h}P_i^e d_i \mathrm{N}_{ij}^e)+\sum_{j=1}^{M}\tau^w(D_j^w+V_j^w+\sum_{i=1}^{h}P_i^w d_i \mathrm{N}_{ij}^w)=FC_{t_1}$$

ii) Fixed fee of medium voltage power supply

$$\sum_{j=1}^{l_2}(D_j^s+V_j^s+\sum_{i=1}^{h}P_i^s d_i \mathrm{N}_{ij}^s)+\sum_{j=1}^{n}\tau^f(D_j^f+V_j^f+\sum_{i=1}^{h}P_i^f d_i \mathrm{N}_{ij}^f)+\sum_{j=1}^{k}\tau^{nf}(D_j^{nf}+V_j^{nf}+$$
$$\sum_{i=1}^{h}P_i^{nf} d_i \mathrm{N}_{ij}^{nf})+\sum_{j=1}^{N}\tau^e(D_j^e+V_j^e+\sum_{i=1}^{h}P_i^e d_i \mathrm{N}_{ij}^e)+\sum_{j=1}^{M}\tau^w(D_j^w+V_j^w+\sum_{i=1}^{h}P_i^w d_i \mathrm{N}_{ij}^w)=FC_{t_2}$$

iii) Fixed fee of low voltage power supply

$$\sum_{j=1}^{l_3}(D_j^s+V_j^s+\sum_{i=1}^{h}P_i^s d_i \mathrm{N}_{ij}^s)+\sum_{j=1}^{n}\tau^f(D_j^f+V_j^f+\sum_{i=1}^{h}P_i^f d_i \mathrm{N}_{ij}^f)+\sum_{j=1}^{k}\tau^{nf}(D_j^{nf}+V_j^{nf}+$$

$$\sum_{i=1}^{h}P_i^{nf}d_i \mathrm{N}_{ij}^{nf})+\sum_{j=1}^{N}\tau^e(D_j^e+V_j^e+\sum_{i=1}^{h}P_i^e d_i \mathrm{N}_{ij}^e)+\sum_{j=1}^{M}\tau^w(D_j^w+V_j^w+\sum_{i=1}^{h}P_i^w d_i \mathrm{N}_{ij}^w)=FC_{t_3}$$

**(2) Flexible cost/fee**

a) Flexible fee of power generation：

$$\sum_{j=1}^{m}[S_j^g+M_j^g+\sum_{i=1}^{N}P_i^e G_{ij}^e+\sum_{i=1}^{N}P_i^e t_{ij}^e(X_i^e-Z_i^e)+\sum_{i=1}^{M}P_i^w G_{ij}^w+\sum_{i=1}^{M}P_i^w t_{ij}^w(X_i^w-Z_i^w)]+$$

$$\sum_{j=1}^{n}\sigma^f(S_j^f+M_j^f+\sum_{i=1}^{N}P_i^e F_{ij}^e+\sum_{i=1}^{n}P_i^f F_{ij}^f+\sum_{i=1}^{k}P_i^{nf}F_{ij}^{nf}+\sum_{i=1}^{M}P_i^w F_{ij}^w+P_j^f Y_j^f)+$$

$$\sum_{j=1}^{k}\sigma^{nf}(S_j^{nf}+M_j^{nf}+\sum_{i=1}^{N}P_i^e F_{ij}^{enf}+\sum_{i=1}^{n}P_i^f F_{ij}^{fnf}+\sum_{i=1}^{k}P_i^{nf}F_{ij}^{nfnf}+\sum_{i=1}^{M}P_i^w F_{ij}^{wnf}+P_j^{nf}Y_j^{nf})+$$

$$\sum_{j=1}^{N}\sigma^e(S_j^e+M_j^e+\sum_{i=1}^{N}P_i^e R_{ij}^e+\sum_{i=1}^{n}P_i^f R_{ij}^f+\sum_{i=1}^{k}P_i^{nf}R_{ij}^{nf}+\sum_{i=1}^{M}P_i^w R_{ij}^w+P_j^e Y_j^e)+$$

$$\sum_{j=1}^{M}\sigma^w(S_j^w+M_j^w+\sum_{i=1}^{N}P_i^e W_{ij}^e+\sum_{i=1}^{n}P_i^f W_{ij}^f+\sum_{i=1}^{k}P_i^{nf}W_{ij}^{nf}+\sum_{i=1}^{M}P_i^w W_{ij}^w+P_j^w Y_j^w)=MC_g$$

b) Flexible fee of power supply：

i) Flexible fee of high voltage power supply：

$$\sum_{j=1}^{l_1}(S_j^s+M_j^s+\sum_{i=1}^{N}P_i^e S_{ij}^e+\sum_{i=1}^{M}P_i^w S_{ij}^w)+\sum_{j=1}^{n}\tau^f(S_j^f+M_j^f+\sum_{i=1}^{N}P_i^e F_{ij}^e+\sum_{i=1}^{n}P_i^f F_{ij}^f+$$

$$\sum_{i=1}^{k}P_i^{nf}F_{ij}^{nf}+\sum_{i=1}^{M}P_i^w F_{ij}^w+P_j^f Y_j^f)+\sum_{j=1}^{k}\tau^{nf}(S_j^{nf}+M_j^{nf}+\sum_{i=1}^{N}P_i^e F_{ij}^{enf}+\sum_{i=1}^{n}P_i^f F_{ij}^{fnf}+$$

$$\sum_{i=1}^{k}P_i^{nf}F_{ij}^{nfnf}+\sum_{i=1}^{M}P_i^w F_{ij}^{wnf}+P_j^{nf}Y_j^{nf})+\sum_{j=1}^{N}\tau^e(S_j^e+M_j^e+\sum_{i=1}^{N}P_i^e R_{ij}^e+\sum_{i=1}^{n}P_i^f R_{ij}^f+$$

$$\sum_{i=1}^{k}P_i^{nf}R_{ij}^{nf}+\sum_{i=1}^{M}P_i^w R_{ij}^w+P_j^e Y_j^e)+\sum_{j=1}^{M}\tau^w(S_j^w+M_j^w+\sum_{i=1}^{N}P_i^e W_{ij}^e+\sum_{i=1}^{n}P_i^f W_{ij}^f+$$

$$\sum_{i=1}^{k}P_i^{nf}W_{ij}^{nf}+\sum_{i=1}^{M}P_i^w W_{ij}^w+P_j^w Y_j^w)=MC_{t_1}$$

ii) Flexible fee of medium voltage power supply:

$$\sum_{j=1}^{l_2}(S_j^s + M_j^s + \sum_{i=1}^{N} P_i^e S_{ij}^e + \sum_{i=1}^{M} P_i^w S_{ij}^w) + \sum_{j=1}^{n} \tau^f (S_j^f + M_j^f + \sum_{i=1}^{N} P_i^e F_{ij}^e + \sum_{i=1}^{n} P_i^f F_{ij}^f +$$
$$\sum_{i=1}^{k} P_i^{nf} F_{ij}^{nf} + \sum_{i=1}^{M} P_i^w F_{ij}^w + P_j^f Y_j^f) + \sum_{j=1}^{k} \tau^{nf} (S_j^{nf} + M_j^{nf} + \sum_{i=1}^{N} P_i^e F_{ij}^{enf} + \sum_{i=1}^{n} P_i^f F_{ij}^{fnf} +$$
$$\sum_{i=1}^{k} P_i^{nf} F_{ij}^{nfnf} + \sum_{i=1}^{M} P_i^w F_{ij}^{wnf} + P_j^{nf} Y_j^{nf}) + \sum_{j=1}^{N} \tau^e (S_j^e + M_j^e + \sum_{i=1}^{N} P_i^e R_{ij}^e + \sum_{i=1}^{n} P_i^f R_{ij}^f +$$
$$\sum_{i=1}^{k} P_i^{nf} R_{ij}^{nf} + \sum_{i=1}^{M} P_i^w R_{ij}^w + P_j^e Y_j^e) + \sum_{j=1}^{M} \tau^w (S_j^w + M_j^w + \sum_{i=1}^{N} P_i^e W_{ij}^e + \sum_{i=1}^{n} P_i^f W_{ij}^f +$$
$$\sum_{i=1}^{k} P_i^{nf} W_{ij}^{nf} + \sum_{i=1}^{M} P_i^w W_{ij}^w + P_j^w Y_j^w) = MC_{t_2}$$

iii) Flexible fee of low voltage power supply:

$$\sum_{j=1}^{l_3}(S_j^s + M_j^s + \sum_{i=1}^{N} P_i^e S_{ij}^e + \sum_{i=1}^{M} P_i^w S_{ij}^w) + \sum_{j=1}^{n} \tau^f (S_j^f + M_j^f + \sum_{i=1}^{N} P_i^e F_{ij}^e + \sum_{i=1}^{n} P_i^f F_{ij}^f +$$
$$\sum_{i=1}^{k} P_i^{nf} F_{ij}^{nf} + \sum_{i=1}^{M} P_i^w F_{ij}^w + P_j^f Y_j^f) + \sum_{j=1}^{k} \tau^{nf} (S_j^{nf} + M_j^{nf} + \sum_{i=1}^{N} P_i^e F_{ij}^{enf} + \sum_{i=1}^{n} P_i^f F_{ij}^{fnf} +$$
$$\sum_{i=1}^{k} P_i^{nf} F_{ij}^{nfnf} + \sum_{i=1}^{M} P_i^w F_{ij}^{wnf} + P_j^{nf} Y_j^{nf}) + \sum_{j=1}^{N} \tau^e (S_j^e + M_j^e + \sum_{i=1}^{N} P_i^e R_{ij}^e + \sum_{i=1}^{n} P_i^f R_{ij}^f +$$
$$\sum_{i=1}^{k} P_i^{nf} R_{ij}^{nf} + \sum_{i=1}^{M} P_i^w R_{ij}^w + P_j^e Y_j^e) + \sum_{j=1}^{M} \tau^w (S_j^w + M_j^w + \sum_{i=1}^{N} P_i^e W_{ij}^e + \sum_{i=1}^{n} P_i^f W_{ij}^f +$$
$$\sum_{i=1}^{k} P_i^{nf} W_{ij}^{nf} + \sum_{i=1}^{M} P_i^w W_{ij}^w + P_j^w Y_j^w) = MC_{t_3}$$

Suppose the following date have gotten from the relevant materials:

1) the maximum demand for electricity per kind of users all over the year $a_j$ (j=1,2,…,K)

2) the total electricity consumption of per kind of users all over the year $b_{uj}$ (u=1,2,…,l; j=1,2,…,K)

$$b_{1j} = \sum_{i=1}^{l_1} R_{ij} \quad \text{(high voltage)}$$

$$b_{2j} = \sum_{i=l_1+1}^{l_2} R_{ij} \quad \text{(medium voltage)}$$

$$b_{3j} = \sum_{i=l_2+1}^{l} R_{ij} \quad \text{(high voltage)}$$

3) the load at the peaking-time of electricity system per kind of users $c_j$ （j=1,2,…,K）

Then the share-coefficients of power generation fixed cost of each kind of users is,

$$\alpha_{uj} = \frac{2a_j + b_{uj} + c_j}{\sum_{j=1}^{K}\sum_{u=1}^{m}(2a_j + b_{uj} + c_j)} \qquad \text{(u=1,2,…,m; j=1,2,…,K)}$$

the share-coefficients of power generation flexible cost of each kind of users is,

$$\beta_{uj} = \frac{b_{uj}}{\sum_{j=1}^{K}\sum_{u=1}^{m} b_{uj}} \qquad \text{(u=1,2,…,m; j=1,2,…,K)}$$

the share-coefficients of power supply fixed cost of each kind of users is,

$$\gamma_{uj} = \frac{2a_j + b_{uj} + c_j}{\sum_{j=1}^{K}(2a_j + b_{uj} + c_j)} \qquad \text{(u=1,2,…,l; j=1,2,…,K)}$$

the share-coefficients of power supply fixed cost of each kind of users is,

$$\varphi_{uj} = \frac{b_{uj}}{\sum_{j=1}^{K} b_{uj}} \qquad \text{(u=1,2,…,l; j=1,2,…,K)}$$

where the sum of every elements in matrix $\alpha = (\alpha_{uj})$ is equal 1，the sum of every elements in matrix $\beta = (\beta_{uj})$ is also equal 1, the sum of elements in each column in matrix $\gamma = (\gamma_{uj})$ is equal 1，the sum of elements in each column in matrix $\varphi = (\varphi_{uj})$ is also equal 1。

The total cost share matrix of all kind of users can be wrote as follows,

$$(C_{uj})_{l\times K} = FC_g\alpha + MC_g\beta + \hat{F}C_t\gamma + \hat{M}C_t\varphi$$

where $\hat{F}C_t = diag(FC_{t_1}, FC_{t_2}, FC_{t_3})$

$$\hat{M}C_t = diag(MC_{t_1}, MC_{t_2}, MC_{t_3})$$

Hence, the theoretical price of electricity is,

$$P_{uj} = C_{uj} / b_{uj} \qquad \text{(u=1,2,3)}$$

where $P_{1j}$ is the theoretical price of high voltage electricity to user j，$P_{2j}$ is the theoretical price of medium voltage electricity to user j，$P_{3j}$ is the theoretical price of low voltage electricity to user j

The above prices are just so called theoretical sale prices of electricity. For the actual price of electricity，it can be made on the basis of theoretical price and adjusted in light of the preferential policy for different users, but the average price of all over the users shouldn't lower than the cost of per unit electricity production (generation & supply) as we mentioned above as principle 1of electricity pricing.

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