

# Exploring Coal and Power Industries Integrated System in China

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## Abstract

*Differences of market force of coal and power industries caused this contradiction "market for coal, electricity for plans". C&P (Coal and power) industries issues around dual pricing system seriously hampered the development of C&P industries. This paper used the System Dynamics method to analyze the composition, characteristics and ways to build of the C&P industries integrated energy system, building feedback causal relationships of the C&P industries integrated energy system and their subsystems. Finally, this article established System Dynamics flow diagram. The analysis showed that C&P industries need rational planning, coordinating collaboration; strengthen the government's guide and regulation, continuously improve the transport capacity between enterprises.*

**Keywords:** C&P industries, energy system, system dynamics, Vensim

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## 1. Introduction

The contradictions around coal price between power enterprise and coal enterprise are escalating, since coal price has become market-oriented from 2002. On the one hand, coal has achieved market-based pricing, on the other; electricity price set by power generation companies is under the government control. Dual pricing system "Market for coal, electricity for plans" causes the current impasse in the coal-power industry relationship [1].

In recent years, scholars at home and abroad have made a lot of suggestions and solutions for the C&P industries contradictions. Among it, "vertical integration of coal and power industries" is an important architecture pattern to mitigate C&P industries contradictions and promote the development of C&P energy. Liu Jing-song (2007) analyzed the key issues in the vertical relationship of C&P industries then offered some policy recommendations to ease the conflicts from the perspective of the "coal, electricity rent". Yang Hui-xin (2007) pointed out institutional arrangements of division in the industrial chain, including enterprise division, quasi-integration contract division and market division in "Vertical Relations of Industry Chain versus Integration of Institutional Arrangement on Division of Labor". Comparison of costs and benefits is the main factor to determine the institutional arrangements of division, and changes in costs and benefits determine the further integration of institutional arrangements of division. Lin Wei-bin (2007) thought the causes of C&P contradictions rooted in the dual pricing system, and the fundamental approach to resolve the conflicts was breaking vertical governance model that is collective bargaining on the key coal contracts, so the C&P enterprises could sign a long-term contract based on independent negotiations. Jacek Kamiński (2008) examined the relationships among the degree of vertical integration between power enterprises and coal enterprises, long-term contracts and spot market transactions in "The impact of liberalization of the electricity market on the hard coal mining sector in Poland".

## 2. Analysis on Coal and Power Industries Integrated Energy System

### 2.1. C&P Industries' Contradictions

Due to the different market forces, C&P industries played a game on the issue of thermal coal price, while the end result: C&P enterprises acted of their own free will and hold different views [4]. Both sides in the game cooperated in the inter-industries from their own interests. The trading activity of two sides is bound to appear opportunistic behavior in

psychological egoism and such uncertainty behavior brings enormous risks and harm to contracting parties in performing and selecting contracts and bilateral trade [2-4].

## 2.2. Analysis on Integrated Energy System's Structure, Characteristic and Cause and Effect

C&P industries integrated energy system is composed of six subsystems: C&P energy supply system, C&P energy transport system, C&P energy transform system, C&P energy policy system, C&P energy socio-economic system and C&P energy environment system [5-7].

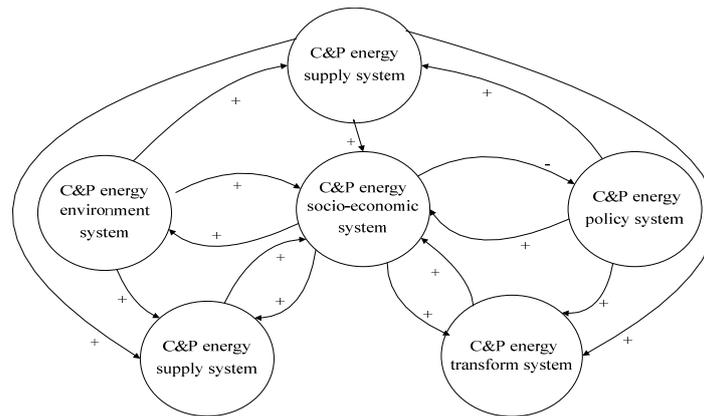


Figure 1. C&P industries integrated energy system's cause and effect analysis graph

Each subsystem of the C&P industries integrated energy system is interrelated, mutual support, collaborative operated, working together to build a dynamic, constantly developing giant system [8-11].

## 2.3. Building Integrated Energy System

C&P industries integrated energy system belongs to the scope of vertical integration of enterprises in theory. The vertical integration has two meanings: 1) Enterprise status: meaning that individual enterprise extends to production side or sales side on a product. 2) Enterprise behavior: meaning that an enterprise enters another processing or marketing stage through vertical integration or establishing a new production or sales organization.

C&P industries integrated energy system combines the existing industries or enterprises in the upstream and downstream of coal-power industries chain according to the production processes with market mechanism. That's to say that putting the production processes of coal and power enterprises into one system and making the unnecessary market behaviors internalized. The integrated energy system is conducive to prevent opportunistic market behavior, reduce enterprises' transaction cost incurred by asset specificity, uncertainty, information trading and extensive coordination, internalize the external economy, avoid government regulation and taxation, improve productivity and competitiveness [12].

From a macro and dynamic point of view, the construction of vertically integrated C&P industries has four dimensions: 1) Coal enterprises dimension; 2) Power enterprises dimension; 3) Government dimension; 4) Market dimension. At first, the construction begins from the development of coal enterprise dimension. The changes in the competition and cooperation modes of node enterprises in coal enterprises dimension cause its improvements and result in agglomeration effects and technology synergies within the region. Finally, all these lead to the rising coal industry. The rising coal industry promotes the development of power enterprises dimension at the same time, such as technology innovating, building Smart Grids, etc. While coal and power enterprises are evolving in the above two directions, they realize a collaborative and interactive development in the government and market dimensions simultaneously.

A "dynamic network structure construction path" of C&P industries integrated energy system is formed in the interaction of coal, power, government and market [6, 7].

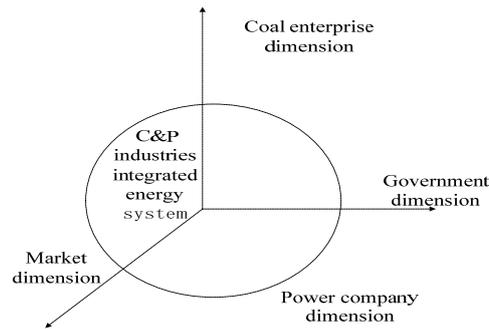


Figure 2. Dynamic multidimensional construct of vertically integrated C&P industry graph

#### 2.4. Integrated Energy System' S Boundary

Coase and Williams have both researched on the optimal boundary of vertically integrated enterprises. The optimal boundary is the intersection of the marginal costs of market and corporate transactions.

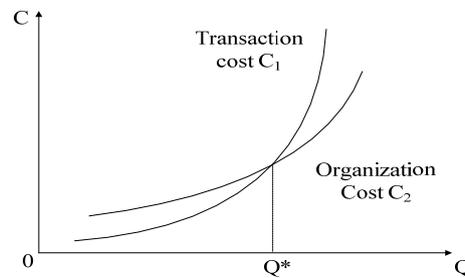


Figure 3. Transaction cost, organization cost graph of the C&P industries integrated energy system

#### 2.5. Integrated Energy System's Target

First, establishing integrated energy system can expand the business scale and enhance the market force of system. A large system helps to play the learning effect, achieve technology spillover and technical diffusion, realize economies of scale and lower production costs, increase consumer surplus and social welfare.

Second, integrated energy system can reduce transaction costs. Uncertainty transaction and asset specificity lead to the high spot market transaction costs. The integrated energy system turns the collaborators into the internal organizations and fixes trade terms in the form of "contract". Then the opportunistic behaviors may be eliminated, and transaction cost is reduced [12].

#### 3. Analysis About Subsystem's Feedback Loop

As it can be seen from the above analysis, the C&P industries integrated energy system's feedback loop is composed of six subsystems. Here is the detailed analysis of these six subsystems [13-15].

##### (1) C&P energy policy system

C&P energy policy system can largely determine the future development direction of integrated energy system. Adopting incentive policies can increase the support for integrated energy system as well as market information.

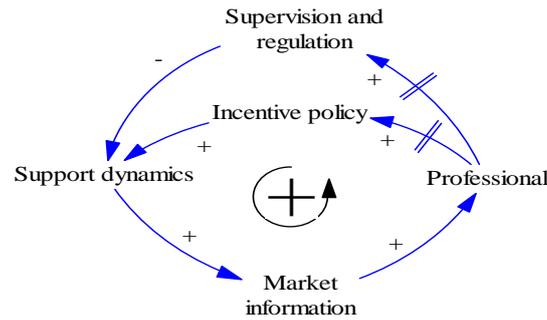


Figure 4. C&P energy policy system feedback graph

(2) C&P energy transform system

C&P energy transform system is an energy conversion process, namely "Thermal energy-Kinetic energy-Mechanical energy-Electrical energy". There is an obvious "Path dependence" phenomenon in the energy transform system. Variables in the system together make up a large positive feedback loop.

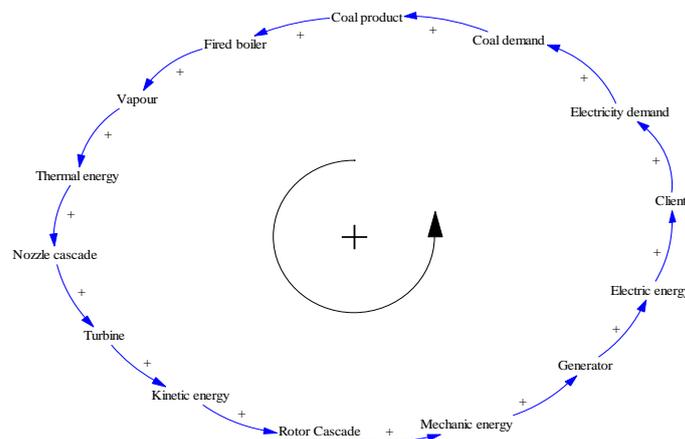


Figure 5. C&P energy transform system feedback graph

(3) C&P energy supply system

C&P energy supply system contains thermal power plant and coal yard. The coal yard provides the primary system energy-coal for C&P industries integrated energy system.

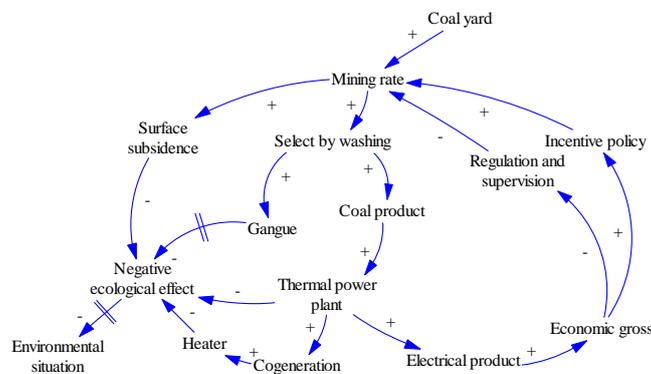


Figure 6. C&P energy supply system feedback graph

(4) C&P energy transport system

The excavated coal will be transported to power plants through road, railway or waterway. After that, electricity could be assigned to each client through the power grid. Customer's demand for power product has led to the coal resource demand of upstream power enterprises, which promotes the development of C&P energy transportation system. "Path dependence" phenomenon is obvious in C&P energy transport system [18, 19].

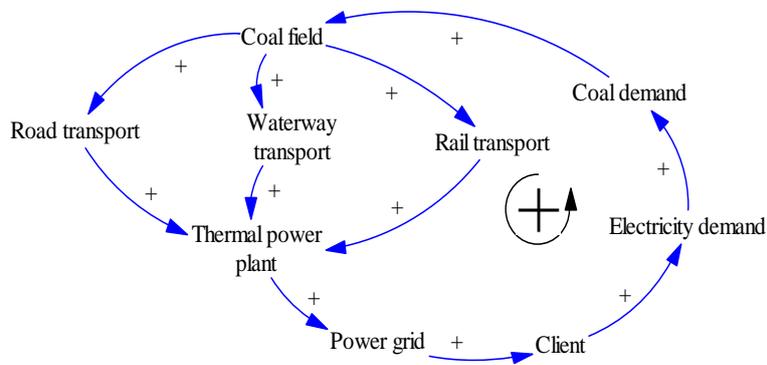


Figure 7. C&P energy transport system feedback graph

(5) C&P energy socio-economic system

C&P energy socio-economic system is the core of C&P industries integrated energy system. Contradictions of C&P dual pricing lead to the integrated energy system program directly. C&P industries integration indirectly affects the transaction costs through quasi-integration behaviors and the alternative forms [20].

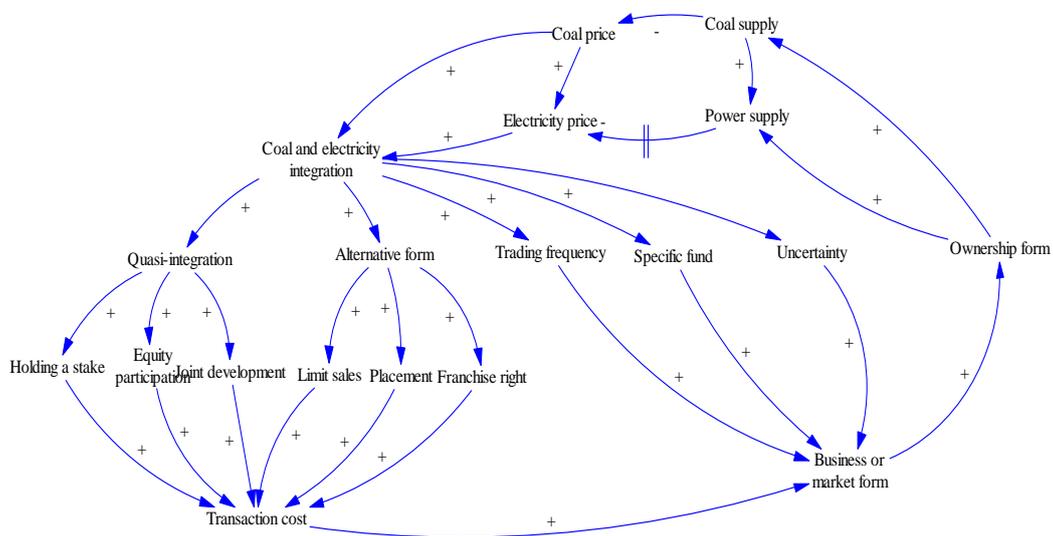


Figure 8. C&P energy socio-economic system feedback graph

(6) C&P energy environment system

Coal mining process will produce waste "gangue" and coal and cause the surface subsidence at the same time. After that coal is transported to the thermal power plants. CO<sub>2</sub>, SO<sub>2</sub>, NO<sub>x</sub>, etc. pollutants are generated in this process.

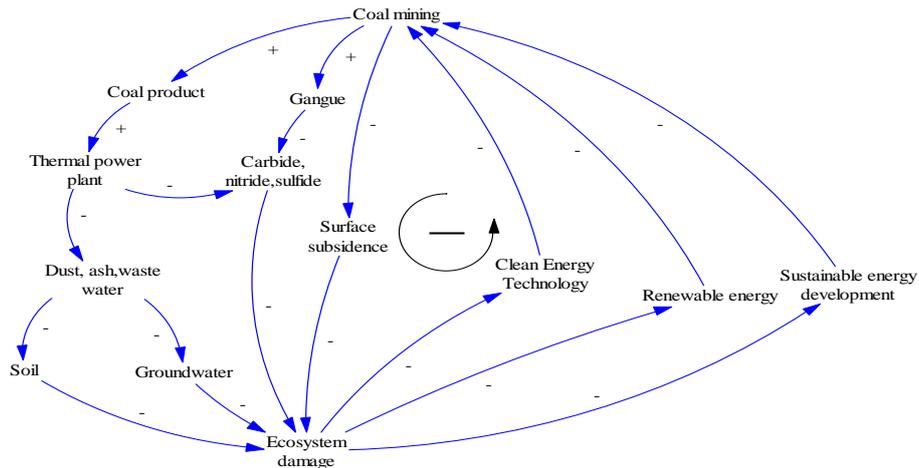


Figure 9. C&P energy environment system feedback graph

**4. System Dynamics Flow Diagram of C&P Industries Integrated Energy System**

In order to further describe the development of C&P industries integrated energy system, we established System Dynamics flow diagram of the system in Vensim [21-23].

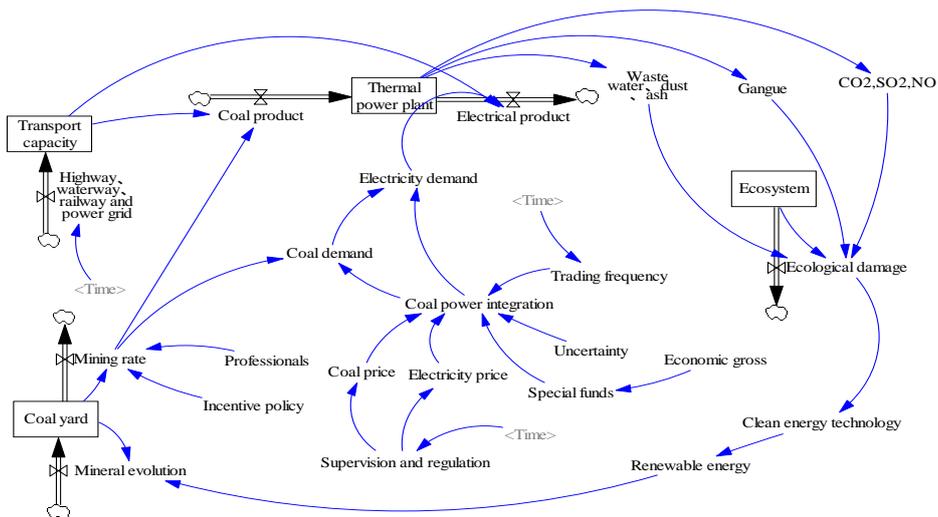


Figure 10. System Dynamics flow diagram of C&P industries integrated energy system

**5. Simulation and analysis**

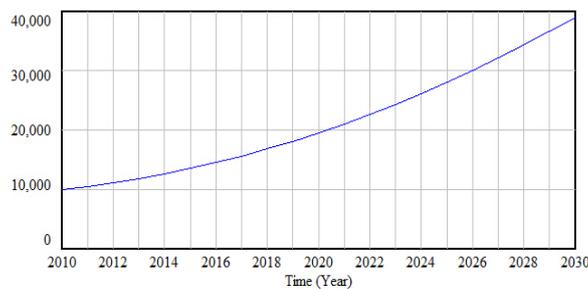


Figure 11. Simulation analysis on transportation capacity

The increasing transport capacity of C&P industries integrated energy system in the next 20 years will greatly promote the development of the system.

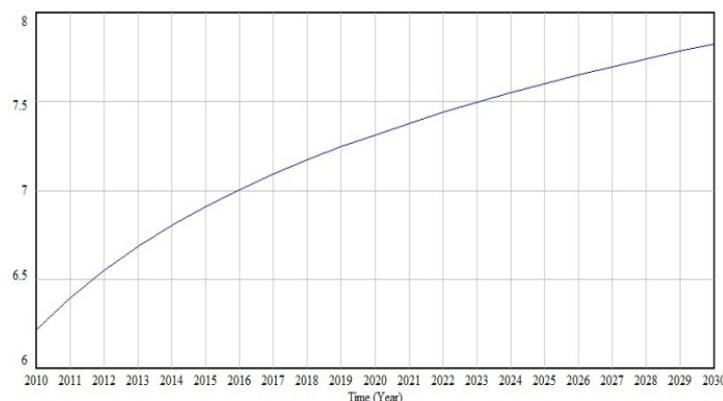


Figure 12. Power Grid operational capacity simulation

With the gradual improvement of grid operational ability, gradually enhancing the integrated energy system, the system begins to show superiority and a good development trend. The integrated effects begins to show their huge advantages.

## 6. Conclusion

1) Strengthening coordinated planning about the C&P industries, developing clear industrial policy.

The C&P industries integrated energy system is a complicated large system, which need government and enterprises' harmonization and overall planning at the macro level. Set low energy consumption, high-yield, sustainable development as the goal of integrated energy system, make efforts to reduce transaction cost and production cost, and promote the C&P industries' vigorous development in the end.

2) Vigorously developing transportation system, significantly enhance the energy transport capacity.

Transport capacity of coal resource has become a constraint barrier, restricting industries' development. Transportation capacity of the system has been a crucial key to the development of C&P industries integrated energy system.

3) Steadily promoting electricity market reform.

"Market for coal, electricity for plans" dual pricing has seriously affected the production and business activities of C&P enterprises. Steadily promoting the electricity market reform, and gradually forming a scientific, rational pricing mechanism make the price fully reflect cost and the supply and demand on the market, literally weaken government mandatory management measures.

4) Establishment of national and regional trading platform.

Encourage and promote the merger of electricity, coal, shipping and sales, gradually achieving multi-industry win-win situation in coal, power generation, rail transportation. etc. Encourage C&P companies to sign long-term contracts, establishing long-term partnerships, and achieving long-term cooperation among enterprises.

## Acknowledgements

The authors gratefully acknowledge the financial support from the National Natural Science Fund of China (No. 71471061).

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