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Developing and applying integration system of energy—Economy—Environment control under the perspective of sustainable development

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ABSTRACT

In the energy - economy - environment system, sustainable energy is the foundation, sustainable environment is the condition, sustainable economy is the ultimate goal. Coordinated and sustainable development is the human-oriented scientific development, which requires the stable and healthy development of complex system in energy - economy - environment system. The coordinated development in the whole system is of great significance for the transformation of economic development pattern in China and the sustainable development of the society as a whole. On the basis of balanced and sustainable development theory, the system structure, component element, system function, operating mechanism, causal relation model, feedback loop and so on in energy-economy-environment system is given focused research through the integrated use of qualitative and quantitative method in this paper, so as to strive for providing scientific theoretical basis and the suitable operation method for the balanced and sustainable development of China's energy, economy and environment.

KEYWORDS

Energy - economy - environment; The integration system; The sustainable development.

INTRODUCTION

The main innovation of this study lies in following three points: first, the overall framework of energy -economy -environment system has been constructed. Second, the operation environment and mechanism of energy-economy - environment system has been built. The system running analysis performed in this paper provides an effective method for studying sustainable development of energy-economy- environment system in this paper. The results of this study have certain practical significance to the sustainable development of energy-economy - environment system in our country at present stage, the research mentality and the method of this paper also has reference value for studying some other social and economic issues at the same time[1].

THE CONSTRUCTION OF ENERGY - ECONOMY - ENVIRONMENT SYSTEM

The defining of system

The real world is complex and ever-changing. But examined with abstract perspective, it is nothing but formed by many concrete things and the relationships among all kinds of things. People usually study only a small part of the real world, and call it a system[2]. Generally speaking, the system is composed of some sets of interconnected parts. These parts can be specific material, also can be abstract organization. The process is: inputting material, energy, information, processing in the system; outputting new material, energy, information and using the feedback mechanism of the system for effective control[3]. The process is to exchange material, energy, information with environment in certain circumstances, as shown in Figure 1.

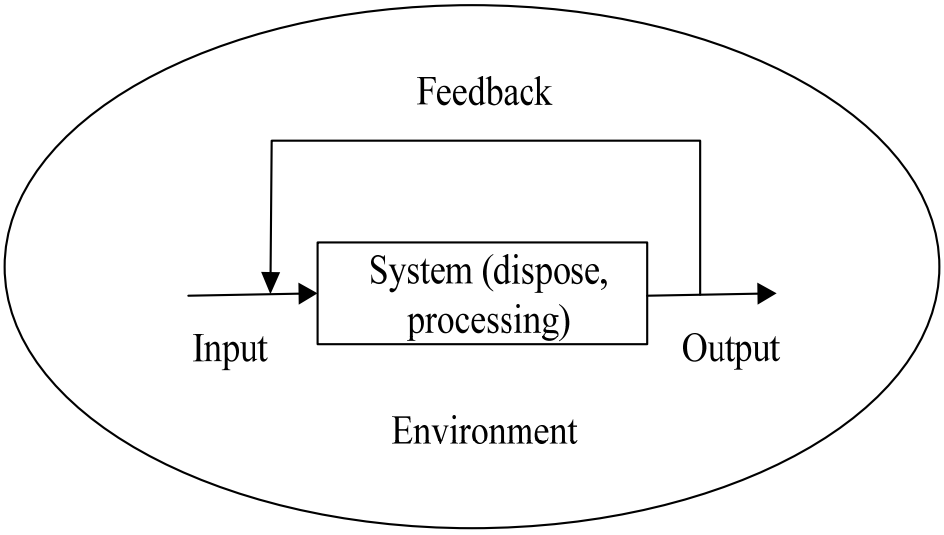

Figure 1 : The definition of system

The system and environment is divided according to the range and objective of problems studied in the field of time and space, thus the system and environment is a relative concept[4]. The environment could be a subsystem, which also can be separated from the larger system at the same time to become an independent system, the rest of original large system will become part of the environment[5]. For the energy - economy - environment system, it includes five subsystems of economic driving subsystem, energy support subsystem, environment bearing subsystem, social development subsystem and policy control system[6]. When considering the energy support system as a subsystem, then economy, environment and society would be the external environment system, which are also the subsystem of energy -economy- environment system at the same time. When we separate the energy or economy subsystem from the big system and design them, environment and social subsystem will be transformed into their environment[7]. The environment referred here is the general name existing outside the system

including the material, energy, information and interpersonal relationship. When we are analyzing energy -economy -environment system, the most important environmental factors associated with the elements of the system are to be discussed. Property change is made through entering measures. On the contrary, the system itself also can change the relevant elements of environment[8].

Energy - economy - environment system refers to the compound system formed by organic integration of various system elements under social, economic, cultural, ecological background. The system consists of several subsystems, these subsystems respectively have different properties[9]. Within energy-economy- environment system, subsystems are of interactive and mutual influence, the internal system could operate the exchange relationship with external environment at the same time. It is visible that energy - economy - environment system is an open complex system with specific function[10].
The connotation of energy-economy- environment system can be represented as:

$$MSIS \subset \{S_1 S_2 .....S_m, E, C_i, F_i, R_{el}, O, R_{st}, T, L\}(m \geq 2)$$

In the type, S_m denotes the m^{th} subsystem; E_i, C_i, F_i denotes the element, structure and function of the i^{th} subsystem respectively; R_{el} is the correlation set of energy - economy - environment system (MSIS), which includes the incidence relation among various subsystems in energy - economy - environment system and association relationship among all internal elements within each subsystem, as well as the correlation between energy - economy - environment system (MSIS) and the sustainable development system of national economy; O is the system target set of in energy - economy - environment system; R_{st} is the limiting constraint set in system; T, L is the time variable and space variable respectively; m is the number of subsystem[11].

Energy - economy - environment system is a typical complex system, it not only involves a variety of natural energy resources (such as coal, oil, wind, solar, tidal, etc.), but also includes a large number of human activities (such as mining, processing, transport, energy conversion and utilization, etc.) and the influence of these activities on the natural environment[12].

Energy-economy-environment system is closely related with each subsystem. On the one hand, subsystem of economic drive proposes the energy demand to energy support subsystem, and then energy support subsystem supplies demanded energy to the economic drive subsystem; on the other hand, the activities of economic system puts forward the demand for economic products, and then economic systems supply these products to the energy system relying on their own activities[13]. While an independent analysis could be performed on energy - economy - environment system, but it is not a closed system, which can't be conducted without big national economy system. Independent analysis could also be conducted on each subsystem of energy - economy - environment system, but due to there is complex relationship among the elements, and each subsystem must be incorporated into a large system[14].

In short, the energy - economy - environment system is the coupling complex and large system composed of economy, energy, society, environment and many other elements[15]. From the angle of system theory, the energy - economy - environment system is a sub-system of the sustainable development system in whole national economy[16].

The framework structure 0f system

System theory thinks that the system behavior is the result of the system structure, the influence of external environment on system behavior model is acted through the internal structure[17]. Structure is the permutations combination mode, interaction form and interconnected rule of various components in space-time continuum. They constitute the specific order for the system. This structural system is the basis of integrity and function[18]. As an open system, energy-economy - environment system includes many elements and control variables, which is a multiple input and multiple output control system, and consists of five subsystems, namely economy drive subsystem, energy support subsystem, environment bearing subsystem, social development subsystem and policy regulation subsystem (see Figure 2). Any

change in subsystem and components of energy-economy-environment system will have impact on other subsystems, thus change the whole system structure and function[19].

The coordination development of energy - economy - environment system depends on the harmonious interaction of economic drive subsystem, energy support subsystem, environment bearing subsystem, social development subsystem, policy regulation subsystem and internal elements. The function of the system is to develop, but the direction of the development is not the certain one, which may be traditional development at the cost of environment, it could also be coordinated sustainable development[20]. Therefore, the output goal of energy-economy- environment system is sustainable development and to promote coordinated development of various factors in incentive system, such components as energy, economy, environment and other factors are needed to be seen as an organic whole, and build up coordinated and sustainable development which could guarantee the economy and energy development, and won't destroy the balanced and sustainable development of resources and environment system. In building energy-economy- environment system, the ecological factors will no longer be the external environment but organic components within the system, each component in the energy-economy - environment system will influence and restrict each other. So we must grasp the influence of various components on the whole system and the relationship among each other, so as to make a scientific and reasonable energy developmental strategy, implement balanced and sustainable development of system[21].

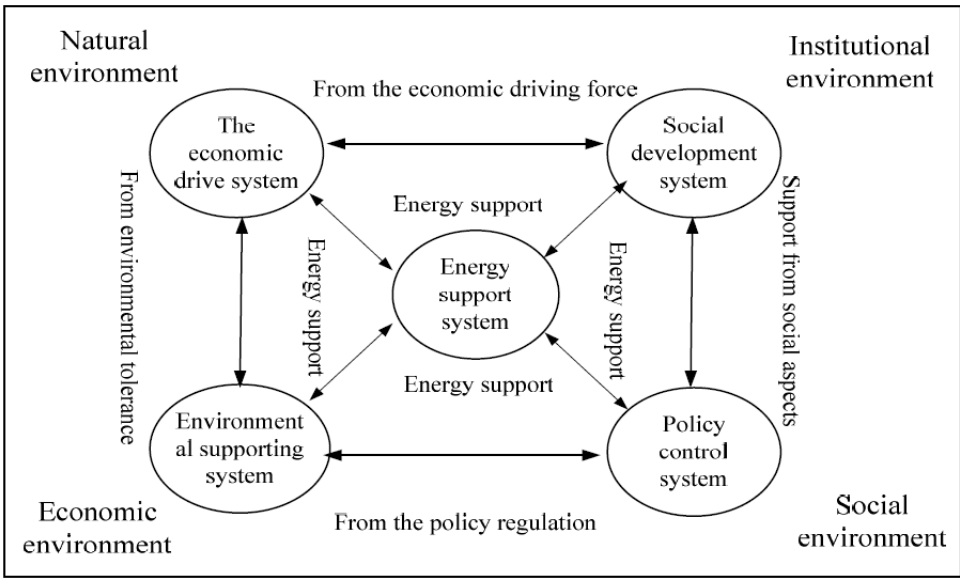

Figure 2 : The interaction diagram of energy - economy - environment system and internal elements

The composition of energy - economy - environment system

Nature and human society constitute the intricate real world, but if look at it from the perspective of system, people usually study only one part of it, and call it a system.

Energy - economy - environment system not only includes the subsystems such as energy, economy, society, environment and policy, but also the connection relationship of all subsystems, namely the relationship between energy - economy - environment system feedback and regulation which makes it as a whole. Although energy - economy - environment system can be independently analyzed, but it is not a closed system, which cannot be analyzed leaving the big system of national economy, and the mutual relationship among links in energy - economy - environment system, energy - economy - environment system and different departments of national economy must be considered. There is close relationship among energy, environment and ecological system at present, the contradiction among resources, environment and economic development is increasingly prominent, energy - economy - environment system is facing many problems such as economic growth, energy utilization and

ecological environment protection. When exploring the system, the relationship among economy, society, technology and environment in the process of energy development and utilization should be comprehensively considered, the relationship and influence among each other should be studied, the organic whole formed by mutual relation, mutual influence and restraint should be regarded as a whole complex system in constant motion and change.

THE DEVELOPMENT AND APPLICATION OF ENERGY - ECONOMY - ENVIRONMENT SYSTEM

System dynamics model

The modeling process of system dynamics could be divided into five steps. The detail is as follows:

(1) Modeling purposes should be cleared. We should know clearly about the problems that the model should study and solve.

(2) The definition of system boundaries. The scope of the research should be determined. The internal system should include all the factors that have a significant impact on system performance, and the part outside the boundary which is associated with system is the system environment.

(3) The analysis of system structure. Namely, the relationship between the system and its components of the system feedback structure should be analyzed, the relationship between the whole and local part should be analyzed, then the causation relationship and the feedback loop should be clear, thus the cause and effect diagram will be formed. Specifics include the following steps:

(1) Determine the variables of model

The first step is determining the model variables and establishing system dynamics model.

First, the state variables should be determined. State variables are regarded as variables with accumulation effect in the system dynamics. The definition:

$$LEV(t) = LEV(t-\Delta t) + \Delta LEV(t-\Delta t) where \qquad \Delta t > 0$$

Second, the rate variable should be determined. Rate variable is the variable reflecting the speed of accumulation effect change. If the state variables LEV (t) and function RAT (t) meets relation :

LEV (t) = LEV (t-Δ t) + Δ t*RAT (t-Δ t), Δ t > 0, then RAT (t-Δt) is the flow rate of LEV (t).

If state variable LEV (t) and function R1 (t), R2 (t) meet

LEV (t) = LEV (t-Δ t) + Δ t (R1 (t-Δ t) - R2 (t-Δ t)), Δ t > 0, there is Ri (t) ≥ 0 in varying range of t, then R1 (t) is the inflow rate of LEV (t), R2 (t) is the outflow rate.

$$RAT(T) = \frac{dLEV(t)}{dt}$$

Third, other auxiliary variables and constants should be determined. Constant is the quantity which will not change over time. Auxiliary variable is the intermediate variable between information source and flow rate. Supplementary variable is the cause and effect diagram, the separation in a feedback loop does not affect any other variables in feedback loop.

(2) Draw diagram of causality system

Causality diagram is the conceptualized and intuitive description of model structure in the first stage, which is to abandon all irrelevant detail and become the relation schema consisting of causal feedback loop of internal mechanism in systematic dynamics process.

In a system, the sequence of closed causal chain is called feedback loop, which is also known as feedback ring, which is shown as Figure 3 : causal relationship between complex feedback loop. In Figure 3, x1→ (t) → y (t) → z (t) → x1(t) is called a feedback loop of this system. A closed feedback system will be influenced by past behaviour, it will takes the history information of system back to itself, thus influence future.

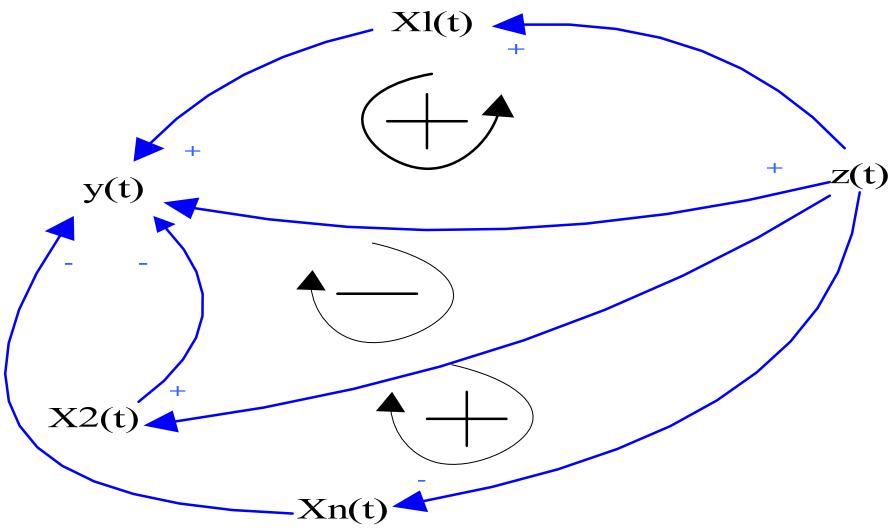

Figure 3 : Causality diagram of complex feedback

(4) The establishment of system dynamics model. The mutual relationship among all variables in system is further depicted through using VENSIM language, the corresponding mathematical equations are established, the parameter value of model is determined through using linear regression method and parameter estimation method, then it will make dynamic flow diagram and dynamics equation of system. System flow chart is the detailed and accurate description of the model.
The general expression is :

$$\frac{dX}{dt} = f(X_i, V_i, R_i, P_i)$$

Its differential form can form: $X(t+\Delta t) = x_{(t)} f(X_i, V_i, R_i, P_i) \bullet \Delta t$. In the type, X is the state variable, V is the instrumental variable, R is the variable of flow rate, P is parameter, t is the simulation time, Δ t is step size of simulation.

System dynamics model is usually composed of several first-order ordinary differential equations, the other also includes the state variable equation, velocity equation, auxiliary variable equation, initial equation and constant equation and the equation of table function, etc.
State variable equations: state variable equation is called horizontal equation, which reflects the accumulative relationship of state; it is integral or differential equation, which reflects the integral process in which the stock is velocity. Horizontal equation form is as follows:

LEVEL.K =LEVEL.J+ DT* (INFLOW.JK-OUTFLOW.JK)

In the type,
LEVEL: state variable (horizontal variable);
LEVEL.K: the value of horizontal variable should be calculated at K time;
LEVEL.J: the value of horizontal variable at the moment before;
DT: the time interval that K experienced from the moment J until now (time unit), namely time step;
INFLOW.JK: the rate of horizontal variable will be added into the time interval of JK (unit/time unit);
OUTFLOW.JK: the rate deducted from horizontal variable in time interval of JK (unit/time unit);
J: represents certain moment in the past
K: represents the moment at present
I: represents the moment in the future

Initial value equation: Initial value equation denotes the initial values of various variables; its function is the initialization value of state variable equations.

Auxiliary equation: auxiliary equation is used to describe how an auxiliary variable changes specifically, which is used to help to build rate equation, namely the static equation. Aided variable denotes the complex causal relationship in expression system; it could not only separate an important concept in the complex ring of causal relationship, but also describes some important external variables.

Rate equation: rate equation is the rule which could reflect how every specific rate changes, we could see in the flow diagram that which variable the information link of pointing rate could represent and how it affects rate.

Constant equation: constant equation is used to assign value for variable, which is usually the proportional coefficient and the assignment of parameter control.

(5) The model application. The simulation is applied with model to verify its authenticity and reliability. Through the analysis of the results, we can find that the defects and deficiencies of system structure, and determine whether to modify the model, and then do the simulation test, until satisfactory results are obtained, and finally, reasonable suggestions would be put forward through policy analysis.

Operating environment

All the things outside the system and associated ones constitute a collection which is called system environment, such as the environment E of the system S refers to all the collection of significant relation and things, namely

Es = {X|X S and it has significant relation with S}

Internal energy-economy-environment system is composed of five interacting subsystems including economic drive subsystem, energy support subsystem, environment bearing subsystem, social development subsystem and policy regulation subsystem, and there exists an external system composed of the ecological environment, economic environment, social environment, institutional environment and other factors (Figure 4).

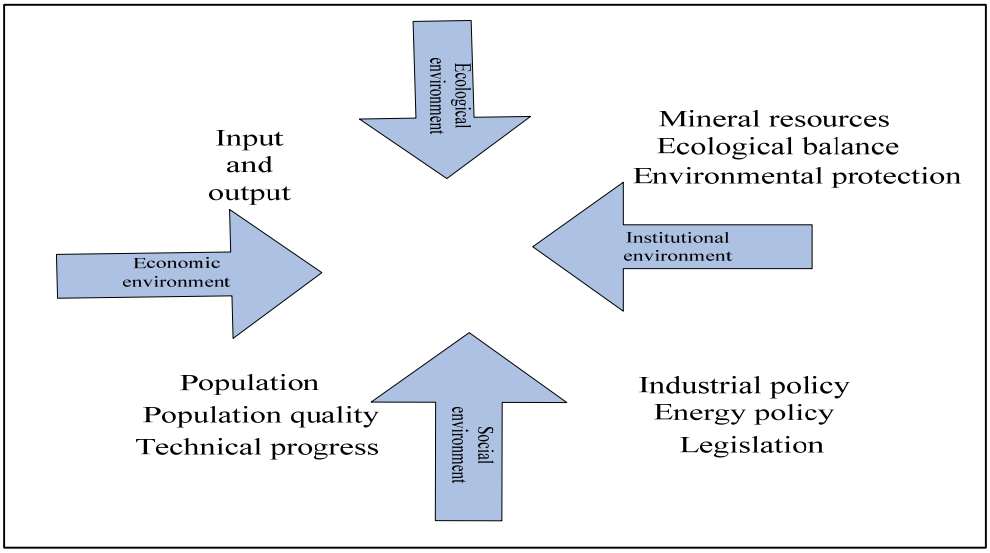

Figure 4 : The operating environment of energy-economy-environment system.

(1) Ecology environment

For all the matter and energy in earth's environment, the ecological factors refers to the things which have direct effect on biological factors in ecology, the sum of ecological factor is called the

ecological environment. Environment can provide all kinds of natural resources which are indispensable to human activity, and perform digestion, absorption and assimilation to the pollutants and waste energy, and offer comfortable living environment for human development at the same time. And the deterioration of environment will not only reduces people's quality of life and damage human itself, it also interferes with the use of resources such as air pollution and water pollution, soil erosion and land desertification, harmful and toxic chemical pollution and so on at the same time, which poses a direct threat to crops and human health, these environmental problems will greatly affect and change the development process of energy - economy - environment system. Due to the environmental capacity is limited, therefore, doing a good job in ecological environmental protection is the key to implementing the strategy of sustainable development.

(2) Economic environment

Compared with other environmental factors, the economic environment has a direct impact on energy - economy - environment system, which is the starting point and driving force for the development of running whole system. As the promotion of economic development, energy intensive industries are of rapid expansion, energy consumption of the second industry is of rising proportion, which has caused the waste of resources and deterioration of ecological environment, these changes in the external environment has posed great threat to the coordinated development of energy - economy - environment system. The adjustment of industrial structure and reducing the proportion of energy-intensive industries, especially the development of the third industry plays an important role in upgrading industrial structure. At the same time, the optimization of the industrial structure can promote the pulling function of consuming on the economy and transform the reliance condition of economic growth on investment, thus improve the quality of economic growth from the aspect of structure; this is of great significance to the optimization of energy - economy - environment system. In addition, factors such as management, information, talents are the indispensable factors in operating energy - economy - environment system; these factors have created a certain economic environment, which has a major impact on energy - economy - environment system.

(3) Social environment

The development of the society needs the participation of people. Social problems are mainly the issue of population, certain population scale and population growth rate has proposed minimum requirement to energy consumption and economic growth, the fast rise in the number of population will accelerates the total energy consumption, which will reduces the share of energy per capita and leads to energy consumption pressure. At the same time, technological progress depends on people's creativity, the certain quantity and quality of the workforce is an essential condition of economic development. In the rapid development of science and technology today, a lot of new and high technology is widely used in the development and utilization of energy, thus improves the efficiency of energy utilization, the new technological revolution has spawned numerous alternative sources of energy, it can be said that the technology innovation determines the sustainable development of energy. Physical properties of the fossil energy determines that it will eventually dries up with the passage of time, the development and utilization of new energy and alternative energy use has provided a material guarantee for the sustainable use of energy and even the entire economic and social sustainable development. It is visible that high-tech moment affects the operation of energy - economy - environment system all the time.

(4) Institutional environment

System is the basic guarantee of economic and social development; the institutional environment has a major impact on energy - economy - environment system. A social economic system is an important determinant in forming the institutional environment. The planning system and market system has essential differences in the allocation of resources, which means that a full market economy and imperfect market economy could make different economic environment, this will affects the running of energy - economy - environment system. At the same time, the administrative intervention, economic policies, laws and regulations also affect the environment system; these will affect the whole system. In the perspective of laws and regulations, any individuals and enterprises must strictly observe the laws and regulations in the process of energy utilization. Laws and regulations are mandatory, stable, and

time sensitive, any economic subjects have to abide by social laws and regulations unconditionally. Economic policy is adjusted with the needs of economic and social development in different periods, and the subject of energy - economy - environment system will adjust its running state according to the change of policy and environment, the intervention of the country is the government's main response to the environmental pollution problem caused by energy use at the present stage.

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