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# The effect of energy construction adjustment on the dynamical evolution of energy-saving and emission-reduction system in China ☆

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## HIGHLIGHTS

- Use nonlinear method to model the ESER system with multiple variable constraints.
- Energy construction adjustment could effectively control energy intensity.
- ESER system will crash with improper economic input or energy construction adjustment.
- Economic input is the key variable affecting energy construction adjustment and ESER.

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## ABSTRACT

This paper attempts to explore the effect of energy construction adjustment on the energy-saving and emission-reduction (ESER) dynamical evolution system. Based on the nonlinear dynamics theory, the dynamic behavior of the novel system is discussed. The quantitative coefficients of the actual system are identified with the aid of genetic algorithm-back propagation neural network. Scenario analysis results show that, energy construction adjustment could effectively control energy intensity. To clarify this further, an example of 4D ESER system with new energy constraints is demonstrated. Investigation results show that, government control can effectively control energy intensity, while brings inhibiting impact on economic growth and people's livelihood. Economic investment is the key variable affecting energy construction adjustment and ESER, the ESER system will crash when the investment is too low. Energy construction adjustment could effectively reduce energy intensity. However, the ESER system will also crash if the development of energy construction adjustment is too fast. The interesting thing is that the ESER system should be pulled back to steady state as the investment getting bigger. Energy intensity could be controlled in expected range by taking adequate measures. Full use of the role of energy structure adjustment should be made to promote the development of new energy, while government control is used only when necessary.



## 1. Introduction

Greenhouse gas emissions pose a significant threat to human survival and the sustainable development of social economy [1,2]. In the research of tackling climate change, it is gradually aware that energy-saving and emission-reduction (ESER) is the ideal choice of attaining the low-carbon targets [3,4]. The ESER system should seek truth of ESER facts and keep pace with the times. The smooth development of ESER can achieve the objectives of protecting the environment and achieving an emission trajectory to a low emission economy [5], which could build a resource conserving and environment-friendly society [6]. The constructing of holistic ESER system is fundamental work for how to do well in ESER [7], and will form a good outset for further development of ESER [8].

ESER system is a complex nonlinear coupling system includes many variables [9,10]. Making clear the measure index of ESER system [11–13], finding these sensitive variables of reducing greenhouse gas emissions in ESER system are becoming a hot topic of relative academic researches [14]. Energy construction adjustment is an efficient measure among the policy instruments of ESER sys-

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tem, which could promote ESER targets to be more easily achieved to a certain extent [15,16]. Coordinating the relationship between energy construction adjustment, technological progress and other variables are helpful to overcome constraints of the internal alternative energy and energy supply structure [17]. The scientific and effective utilization of energy construction adjustment could perfectly control energy intensity [18,19], and there is no obvious suppression effect on economic growth.

Energy construction adjustment has great influence on future energy pattern and economic development trend [20]. In addition, energy construction adjustment can promote the current energy system revolution process [21]. In a sense, energy construction adjustment is driven by economy. They influence and control each other. Therefore, energy construction should be adjusted when the economic structure changes. New energy plays an important role in the progress of energy construction adjustment [22]. The development of new energy industry is the important direction of energy industry adjustment in the future. New energy industry has bright development prospect, while it is restricted by technology, cost, system of organization and other factors [23–26]. Beyond that, government control plays a key role in ESER system [27], which also has effect on energy construction adjustment.

Cambero and Sowlati [28] proposed numerous optimization models to study the economic and environmental design of biomass-to-bioenergy or biofuel supply chains. Ju et al. [29] constructed a multi-objective optimization model for DERs CCHP system under four optimizations. Take Guangzhou Higher Education Mega Center (GHEMC) in China for example, the authors discussed the optimization program. Olsthoorn et al. [30] reviewed the recent advancements in modeling and optimization of the DHS. The research results showed that the recent studies of DHS were classified in accordance with the optimization objectives. Wu et al. [31] developed a multi-objective MILP model for the optimization of a distributed energy network. The model is applied to a low carbon community. Simulation results showed the total capacity of distributed generations was increased, and the overall performances of the local area were enhanced.

Growing attention has been focused on nonlinear dynamics theory [32–34]. The reference [35] proposed a novel 3D ESER chaotic system, and provide sound theoretical basis for the present study. This paper introduces energy construction adjustment into the 3D ESER dynamics system. The dynamic evolution behavior of the energy intensity and economic growth are put forward vividly, the coefficients which affect the peak value and stable value are discussed systemically. Further, this paper introduces new energy and government control into the 3D ESER system. Take the novel 4D ESER system for example. The effect of energy construction adjustment on ESER is investigated further. Existing literatures on energy construction adjustment studies are multifarious, while lack the theory strut. The dynamic method is an innovative research method for energy construction adjustment. Compared with the previous studies, evolution analysis and theoretical basis in this paper are more persuasive. The findings of this paper are more consistent with the reality of energy construction adjustment.

The rest of this paper is organized as follows. Section 2 provides a brief description of the model. Section 3 is about parameter identification of the actual system based on China's statistical data. A scenario analysis of the actual system is presented in Section 4. Section 5 presents policy enlightenment. Conclusions and further perspectives are presented in Section 6.

## 2. Establishment of the model

Among the variables that influence ESER system, energy construction adjustment is one of the effective methods to promote the development of ESER. Drawing on the successful experience of developed countries, energy construction adjustment (optimization) is the effective way to solve the problems of resources and environment issues. In response to the challenges of climate change and new energy integration, America has taken a series of measures to tackle the problem of energy infrastructure, energy storage, transportation and transmission. The European Union has issued a series of directives on energy policy after entering the 21st century, such as "EU Energy 2020" and "EU Energy Roadmap 2050". The different paths and alternative options of energy construction optimization are explored, which aims to build up a sustainable EU energy system.

Energy construction adjustment is the nub of solving the current energy, resources and environmental issues. Study on the ESER problem should comply with the situation. In one sense, energy construction adjustment is driven by economic means under the current circumstances, and the investment of economic to energy construction adjustment has effect on economic growth. Based on the previous successful experience and the relationship between these variables, the dynamic evolution system with energy construction adjustment constraints can be described by the following differential equations:

$$\begin{cases} \dot{x} = a_1 x(y/M - 1) - a_2 y + a_3 z \\ \dot{y} = -b_1 x + b_2 y(1 - y/C) + b_3 z(1 - z/E) - b'_4 z \cdot (d/1 - (1+d)^{-t}) \\ \dot{z} = c_1 x(x/N - 1) - c_2 y - c_3 z - c_4 z \end{cases} \tag{1}$$

In Eq. (1), $x(t)$ is the time-dependent variable of ESER; $y(t)$, of carbon emissions; $z(t)$, of economic growth (GDP). For the explanation of the formulas, please see [35,36]. $-b'_4 z \cdot (d/1 - (1+d)^{-t})$ is time-dependent energy construction adjustment, $b'_4$ is the coefficient of energy construction adjustment, $d$ is effective rate of discount, $t$ is the period, $t \in I$, $I$ is a given economic period. To facilitate the discussions, let $b'_4 \cdot (d/1 - (1+d)^{-t}) = b_4$. Based on the reality of China, energy construction adjustment is driven by economic means under the current circumstances. So energy construction adjustment is simplified as the direct effect of economic growth ($b_4 z$). The investment in energy construction adjustment will have a certain effect on $z(t)$, and $-c_4 z$ represents the effect ($c_3 = c'_3 - c''_3$. $c'_3 z$ is the inhibition effects of ESER on economic growth; $c''_3 z$, positive effects of ESER on economic growth. Similarly, $c_4 = c'_4 - c''_4$. $c'_4 z$ is the inhibition effects of energy construction adjustment on economic growth, and $c''_4 z$ is the positive effects of energy construction adjustment on economic growth. These coefficients represent different meanings, and each of them could not be replaced by another).

The system presented in Eq. (1) is a macroscopic model, which reflects the complicated evolutionary relationship between ESER, carbon emissions, economic growth and energy construction adjustment. Energy construction adjustment plays a very important role in this model, which contains the adjustment of energy sector in segments of production, transmission, distribution, and consumption of all usable forms of energy. On the basis of obtaining the micro data, the model presented in Eq. (1) could also be used to explore energy construction adjustment of the specific sector.

In the second and third formula in Eq. (1), integrate $\dot{y}(dy/dt)$ and $\dot{z}(dz/dt)$ about $t$, the energy consumption (carbon emissions) and GDP (economic growth) could be deduced as $y^*(t) = \phi_1(x, ky, z, t)$, $z(t) = \phi_2(x, y, z, t)$. The time-dependent energy intensity during a given period can be depicted as $U(t) = \phi_1(x, ky, z, t)/\phi_2(x, y, z, t)$, $t \in I$. Energy intensity reflects the comprehensive results of carbon emissions and economic growth. When energy measures or policies change, i.e. the constrained vari-