

# Green Development Model for Resource-based Cities on the Basis of Circular Economy

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**Abstract:** The selection of resource development mode is one of the important content of economic transformation and sustainable development for resource-based cities. Based on the theory of circular economy and green economy, this paper proposes green development model of resource for resource-based cities, and analyzes the economic and social benefits generated by the model. By implementing green development model of resource, on the one hand, it could reduce the waste emissions and the ecological damage, on the other hand, it can take full advantage of resources and reduce the requirements of resources in the follow-up production, so it is good to realize sustainable development for resource-based cities.

**Key words:** Circular economy; Resource-based cities; Resource development; Green economy

## 1 Introduction

Resource-based cities are the supply places of basic energy and raw materials in China for a long time, they have made outstanding contributions to China's economic development and social stability. But because of the backward production technology and extensive industrial development model in the resource extraction process, there emerged a series of problems like resource depletion, environmental pollution and ecological damage, which have seriously hampered the sustainable development of resource-based cities. Begin from 1940s, the economic transformation and sustainable development of resource-based cities has become a major issues which troubled government and academia.

The material base of sustainable development of resource-based cities is non-renewable energy and mineral resources, regardless of how much reserve resources will be explored and how long it will last, sustainable use of resources is ultimately limited. Therefore, if the resources are exploited uncontrolled and the city doesn't have a very good transition mechanism, the city maybe decomposed as the failure of mineral. In addition, resource development and ecological environmental protection is a pair of prominent contradictions in the development of resource-based cities, resource exploration will inevitably affect ecological environment to some extent. Resource-based cities have extensive explored resources for a long time, the urban landscape is seriously damaged, and the water, air, biological and human production and life are affected seriously<sup>[1]</sup>.

Therefore, the traditional resource development model can not meet the demand for sustainable development of resource-based cities, it is necessary to explore new resource exploration model which suitable for resource-based cities.

## 2 Literature Review

### 2.1 Literature review on circular economy

Circular economy refers to a series of basic questions of sustainable development like economic, social, culture and environment, which has transformed to the integration and optimization of complex ecosystem of economic - social - nature from the purely economic and management.

Many scholars began to study the operation mechanism of circular economy, which is mainly about the occurrence, development and current situation of circular economy<sup>[2]</sup>. With in-depth study of circular economy theory, scholars turn to research achieve conditions and development barriers to operation mechanism of circular economy. Gao Hongshen et al. (2007) posit that one important aspect of circular economy is to coordinate the relationship between man and nature, and realize the translation from "anthropocentrism" to "biocentrism" and "ecocentrism"<sup>[3]</sup>. In addition, many scholars intensively study the evaluation of the traditional circular economy like material flow analysis and energy analysis.

With gradual deepening of theory research of circular economy, the practical research of circular economy is gradually deepening. Qin Shusheng (2007) presented that research model of circular economy mainly expands from three levels: macro-level, meso-level and micro-level<sup>[4]</sup>.

**2.2 Literature review on green economy**

“Green economy” was proposed by Peirce in “Blue Book of Green Economy” published in 1989. Yuan Xiaoling et al. (2007) note that green economy is a new economic form, which is market-oriented and based on ecological economy and knowledge economy, aimed at harmony and sustainable development of economy and environment<sup>[5]</sup>. Heriberto Cabezas et al. (2005) posit that the nature of the green economy is a mode of economic development, whose core is the coordinated development of ecology and economy, whose characteristic is maintaining the human environment and protect the resources and energy<sup>[6]</sup>.

**2.3 Literature review on resource development model of resource-based cities**

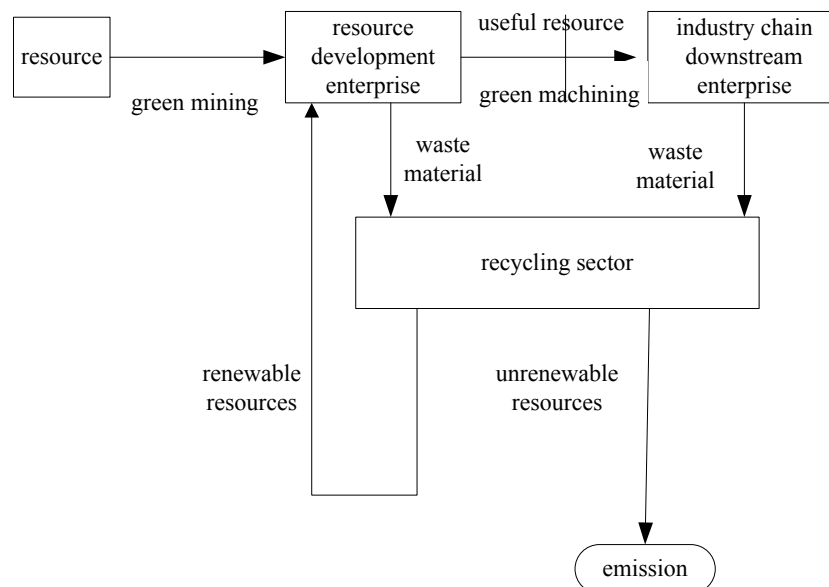
The research on the model of resource development in resource-based urban is mainly from Canada, Australia and the United States. In 1931, Hotelling published a paper about the economics of exhaustible resources in the journal of political economy, and he pointed out that the formation and development of resource-based cities is dependent of local resources and is restricted with the resource reserves, which shows that it conforms to the unique development rule<sup>[7]</sup>. In 1971, R. A. Lucas put forward four phases of the development of resource-based cities<sup>[8]</sup>. Bradbury (1998) researched further in theory and practice on the resource-based cities in Canada. He developed Lucas’s life cycle theory of the single resource-based city and put forward the ascending phase and declining phase<sup>[9]</sup>.

In china, the research mainly focused on putting forward policies and proposals for resource-based cities, especially coal and oil city. Some research focused on evolution and evolutionary mechanism of resource-based cities, others focused on transition costs, risk assessment and ecological city construction of resource-based cities. The research on the social psychology and behavior of urban residents is seldom, which also shows the difference between China’s resource-based cities and foreign resource-based towns. Foreign researches focus on solving social problems, but researches in China focus on both economic and social issues, relatively speaking, the research on economic transformation is more often in China<sup>[10]</sup>.

Based on the theory of circular economy and green economy, the paper proposes green development model of resource on the basis of circular economy for resource-based cities, and analyzes the economic and social benefits generated by the model.

**3 Green Development Model of Resource on the Basis of Circular Economy**

Green development model of resource takes green development as guide, based on the current economic and social development and environmental carrying capacity of resources, emphasizes “low extraction, high use, low emissions”, in accordance with cleaner production, comprehensive utilization of resources and waste. The model is shown in Figure 1.



**Figure 1 The Process of Resource Green Development on the Basis of Circular Economy**

The processes of resource green development based on circular economy are divided into three

main stages.

Firstly, at the stage of resource green mining, it is realized to transform backward production method, raise the level of mining mechanization, and increase power of exploiting symbiotic and associated resources by introducing high-tech. On the one hand it can reduce the waste of resources; on the other hand it can reduce the pressure on the environment exercised by waste resources.

Secondly, at the stage of resource green machining, it is achieved to extend the industry chain of original resource extraction and primary processing greenly, improve the use efficiency of resources, and turn the production processes into the cycle process of changing waste into valuables, guide resource-consuming production mode transforming to resources recycling production mode, to get the target of expansion of economic output while reducing energy and material consumption. The alternatives are developed like natural gas, wind energy, solar energy and other clean, renewable energy adaptation to local conditions. By using high-tech research and develop new uses of mineral resources, it can ease the demand for mineral resources and reduce environmental pollution and ecological destruction.

Thirdly, at the stage of resources recycling, by comprehensively utilizing all available resources, increasing the capacity of exploiting and using resources, it can improve the environment, prevent pollution and achieve harmony between economic development and environmental protection.

## 4 Benefit Analysis of Green Development Model of Resource on the Basis of Circular Economy

### 4.1 Assumptions

Resource-based urban develop circular economy aims to achieve social and economic development and ecological environment, rather than sacrifice environment at great cost for temporary economic development, economic system and environmental system are two interaction systems. In order to analyze conveniently, the following assumptions are put forward:

(1) There are two economic entities in resource development, they are resource development enterprise and industry chain downstream enterprise;

(2) Enterprises in the resource development process will produce waste, these wastes are not discharged directly to the surrounding environment, but first processing waste, then return to the company in the form of resources and reuse them;

(3) The resource products of industry chain downstream enterprise provided by resource development enterprise are consisted of two parts: the one is resource products by utilizing original resources, another is by recycling of reusable resources, these two are no diffidence in meeting needs, and the resource products of enterprise can be purchased by downstream firms;

(4) The circular economy of resource development industry focus on two links, they are the process of resource exploitation and resource recycling<sup>[11]</sup>.

### 4.2 Circular economy benefit in resource mining process

The circular economy process for resource mining is as follows: resource mining enterprises develop new resources, useful resources enter industry chain downstream enterprise, there also produces waste during resource development process, and these waste is processed by the recycling sector rather than discharged to the environment directly. After treatment, some waste is converted to reusable resources, the rest unavailable waste is discharged to the environment by dealing with environmental protection.

In the traditional economic model, suppose that the production function is Cobb-Douglas function:

$$Q_t = AK^\alpha L^\beta \quad (\alpha + \beta = 1) \quad (1)$$

Suppose that the returns to scale unchanged,  $Q_t$  is the output in the traditional economic model;  $L$  is the amount of labor input,  $K$  is the amount of capital invested.  $R$  is all productive resources invested by enterprise (except labor), then  $K = RP_r$ ,  $P_r$  ( $P_r > 0$ ) is the resource price, type it into the equation (1), can be drawn:

$$Q = AL^{1-\alpha} P_r^\alpha R^\alpha = A_0 R^\alpha \quad (\text{order } AL^{1-\alpha} P_r^\alpha = A_0) \quad (2)$$

At this point, the total receipts of resource development for the enterprise are:  $TR_t = P \times Q_t = A_0 R^\alpha P$ ,  $P$  is product price, the total cost  $TC_t = C_0$ .

In the mode of circular economy, through a treatment process of reclamation, the waste produced in

resource development transforms to resource. The amount of waste produced in development process is  $S, S = a_1 R$ ,  $a_1$  ( $0 < a_1 < 1$ ) is waste generation rate of unit resources.  $a_2$  ( $0 < a_2 < 1$ ) is the conversion rate of the waste produced in resource development transforming to new resource by the treatment of reclamation, and the amount of unit of waste transforming to resource, therefore,  $R_1 = a_2 S = a_2 a_1 R$ ,  $R_1$  is the amount of waste transforming to resource. By equation (2), the amount of  $R_1$  transforming to new resource is  $Q_1 : Q_1 = A_0 R_1^\alpha = A_0 a_1^\alpha a_2^\alpha R^\alpha$ , then the amount  $Q_c$  of circular economy mode is:

$$Q_c = Q_i + Q_1 = A_0 R^\alpha + A_0 a_1^\alpha a_2^\alpha R^\alpha = A_0 R^\alpha (1 + a_1^\alpha a_2^\alpha) \quad (3)$$

Then the total business income is:  $TR_c = P \times Q_c = A_0 R^\alpha P (1 + a_1^\alpha a_2^\alpha)$ . In terms of cost, because of taking circular economy mode, the cost of waste disposal is increased, order  $a_3$  ( $0 < a_3 < 1$ ) is the disposal cost of unit of waste, then the total cost  $TC_c = C_0 + a_3 a_1 R$ .

Compared to the traditional economic model, circular economy benefits of resource development  $\pi_1$  are the difference between revenue generated by the circular economy and input costs. The costs of resource development company implementing circular economy are investment transforming the waste to new resource, revenue is mainly from the increase of enterprise production by reclamation of waste.

$$\pi_1 = TR_c - TC_c = A_0 R^\alpha P (1 + a_1^\alpha a_2^\alpha) - (C_0 + a_3 a_1 R) \quad (4)$$

In the above formula, because the size of  $A_0$ ,  $a_1$  only related to the level of production technology, under the condition of the level of enterprise technology is established, its value is more stable, so the level of effectiveness of resource development enterprise implementing circular economy only related to  $a_2, a_3$ .

The paper mainly analyzes the relationship between circular economy benefit  $\pi_1$  with the rate of reclamation  $a_2$ . Derivation  $a_2$  on both sides of equation (4), the following formula can be drawn:

$$\frac{d\pi}{da_2} = \alpha A_0 R^\alpha P a_1^\alpha a_2^{\alpha-1} > 0 \quad (5)$$

Derivation  $a_2$  on both sides of equation (5),  $\frac{d^2\pi}{da_2^2} = \alpha(\alpha-1)A_0 R^\alpha P a_1^\alpha a_2^{\alpha-2} > 0$

These show:  $\frac{d\pi}{da_2} > 0$ ,  $\frac{d^2\pi}{da_2^2} > 0$

Through the model analysis above, it shown that circular economy benefit of resource development process is increasing with the exaltation of the rate of reclamation, furthermore, under the condition of other parameters unchanged, its growth rate is increased. Combined with current state, if discharge the waste produced in the resource development process to the environment, it may great impact on the environment and increase the waste of resources. Conversely, if resource the waste, on the one hand it improves the eco-efficiency, reduces environmental pollution, with the increase of the rate of reclamation, the waste discharge to the environment is declining, and the eco-efficiency is improving; on the other hand, it has good economic benefits, circular economy could get more new resources, then reduces the need of number of resources.

### 4.3 Circular economy benefit in resource recycling process

The process of circular economy of resource recycling in resource development enterprise is: the useful resources developed by the resource development enterprises enter to downstream industry chain enterprises, the waste produced after processing is processed by recycling sector, some unavailable waste discharged to the environment by dealing with environmental protection, the rest waste converted to re-use of resources, and looped back into the enterprise.

The circular economy benefit of resource recycling process for resource development enterprise is the difference between revenue generated by the circular economy and input costs. The revenue is from the new resource by recycling waste, the costs are recycling cost and cost of processing products. Assume that the enterprise has produced resource the number of  $Q_0$ , and it has sold out. According to production function we could know that  $Q_0 = A_0 R^\alpha$ . Assume that the rate of recycling waste is  $b_1$

( $0 < b_1 < 1$ ), the number of recyclable waste is  $b_1 Q_0$ . Order the rate of reclamation of unit waste is  $b_2$  ( $0 < b_2 < 1$ ), then the number of transforming recycled products to new resource is  $b_2 b_1 Q_0$ . The number of new product by transforming recovered reusable resources is  $Q_r$ :

$$Q_r = A_0 (b_2 b_1 Q_0)^\alpha$$

The recycling revenue of recycling and reuse of resources is  $Q_r P = A_0 (b_2 b_1 Q_0)^\alpha P_0$ . The processing cost of unit of resource waste is  $b_3$  ( $b_3 > 0$ ), the recovery and processing cost is  $b_3 b_2 b_1 Q_0$ . Therefore, The circular economy benefit of resource recycling process = the recycling revenue of recycling and reuse of resources - the recovery and processing cost, by substituting these equations above, it can be drawn the circular economy benefit of recycling resource is  $\pi_2$ :

$$\pi_2 = A_0 (b_2 b_1 Q_0)^\alpha P - b_3 b_1 Q_0 \quad (6)$$

The following mainly analysis the relationship between circular economy benefit  $\pi_2$  and the rate of reclamation of unit waste  $b_2$ . Derivation  $b_2$  on both sides of equation (6), then:

$$\frac{d\pi}{db_2} = \alpha A_0 (b_1 Q_0)^\alpha P b_2^{\alpha-1} > 0 \quad (7)$$

Derivation  $b_2$  on both sides of equation (7):

$$\frac{d^2\pi}{db_2^2} = \alpha(\alpha-1)A_0(b_1Q_0)^\alpha P b_2^{\alpha-2} > 0$$

$$\text{These show: } \frac{d\pi}{db_2} > 0, \frac{d^2\pi}{db_2^2} > 0$$

Through the model analysis above, it shows that the circular economy benefits of resource recycling by resource development enterprises is proportional to the rate of reclamation of unit waste, and it is increasing with the improve of the rate of reclamation of unit waste. Under the condition of other parameters unchanged, its growth rate is increased<sup>[12]</sup>.

## 5 Conclusion

By constructing theoretical models of circular economy for resource development enterprises and in-depth analyzing the model using the method of marginal analysis, then get some basic conclusions as follows:

In the stage of developing resource products, even though the waste recycling needs some cost, the rate of reclamation of unit waste  $a_1$  promotes the circular economy benefit  $\pi_1$ , and under the condition of other parameters unchanged, its growth rate is increased. In the stage of resource recycling, the circular economy benefits  $\pi_2$  of resource development enterprises are proportional to the rate of reclamation of unit waste  $b_2$ , and under the condition of other parameters unchanged, its growth rate is increased. Therefore, in the process of developing resource, it is very important to improve the efficiency of waste. By implementing circular economy, on the one hand, it could reduce the waste emissions and the ecological damage; on the other hand, it can take full advantage of resources and reduce the requirements of resources in the follow-up production, so it is good to realize sustainable development for resource-based cities. Thus it can be seen that developing the resources greenly and developing circular economy, not only bring in social benefits, but also good economic efficiency.

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