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Evaluation of industry eco-industrialization: Case study of Shaanxi, China

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The rapid development of industry brings great pressure on resource and environment, forcing people to explore the road of ecological development. In China, the level of regional industry ecological development differs from each other due to different economic level of regions. This paper establishes eco-industrialization index system from aspects of resource consumption, pollution emission, pollution abatement, economic and social development to reveal the connotation and characteristics of industry eco-industrialization, taking Shaanxi Province as an example, and adopts the principal component analysis to evaluate the industry eco-industrialization level of 2001-2015 in Shaanxi. The study shows that the level of industry eco-industrialization in Shaanxi Province is steadily improving, but the environmental protection and pollution control work still needs to be further strengthened. The current development process of industry eco-industrialization still faces hindrances from imperfection of environmental laws, insufficiency of government supervision, shortage of environmental protection planning, high energy consumption and ineffective implementation of cleaner production. Aiming at the hindrances, the paper suggests that Shaanxi should enhance the level of industry eco-industrialization by accelerating the construction of industrial ecological system, establishing environmental planning pilot system, improving resource utilization and promoting the key technological innovation and system integration of industry eco-industrialization.

Keywords: Industry eco-industrialization; Principal component analysis; Evaluation

1. INTRODUCTION

Natural ecological environment is the basis and prerequisite for human survival and development. The economic growth paradigm of "mass production, large consumption, a large number of abandoned" has been restricted by the natural environment and economic development. Therefore, the realization of ecological development has become the consensus and potential impetus to economic development of all countries. Nowadays, China's industry is largely belongs to traditional extensive waste industrial development pattern, the mode of "high input, high consumption and high pollution". Uneven regional development also makes the level of industry eco-industrialization differ from region to region. Therefore, it is realistic and inevitable to make industrial ecology development strategies according to different regional characteristics. As one of the old industrial bases in China, which is located in the western, Shaanxi Province has an important strategic position in the western development of China and *the Belt and Road Strategy.* Depending on resource advantage, Shaanxi makes industrial economy as the main engine to promote economic development. However, the rapid development of industry has also formed a negative ecological effect, which makes the development of industry eco-industrialization in Shaanxi Province imminent.

Industry eco-industrialization is the combination of different types of enterprises and industries to form an ecological chain, through establishing industrial system of low consumption and low pollution to reduce the impact of production activities on the natural environment, and promoting the transformation and upgrading of industrial economy. The evaluation of industry eco-industrialization level is a basic work to promote the development of eco-industrialization. It is not only an evaluation on the effect of the early ecological policy, but also the direction of the next ecological adjustment, which has become the concern of many scholars. Western scholars are more inclined to evaluate the industry's ecological effects from the perspective of sustainable development, such as the physical evaluation represented by ecological footprint[1], and the national green account based on monetary analysis[2]. Bartsev(2012) argued that industrial ecological assessment should take the effects of green production technologies into account and pointed out that over-reliance on cleaner production, recycling, and other technologies also have ecological negative effects[3]. Ohnishia(2017) used material flow analysis, carbon footprint method and energy analysis method to evaluate the ecological level of urban industrial system in Kawasaki City, Japan, and found that the single evaluation method could lead to the one-sidedness of the evaluation results[4]. Salmanighabeshi(2015) assessed the risk of industrial pollution in the five major industrial areas of Chile by measuring the distribution of soil elements[5]. It can be seen from the literature that the research of scholars mainly focuses on the definition of evaluation scope and the evaluation method, and pays more attention on the objectivity of evaluation results. In China, scholars mainly follow closely the applicability of evaluation methods and the construction of evaluation indexes(Liu Chuanjiang,2016;Wang Rusong,2014)[6−7], and based on the data, evaluating the eco-industrialization level of specific industrial park (Fan Yupeng,2016;Wang Jianjun,2015)[8−9], specific area (Liu Jingru,2016;Ma Yong 2015;Gu Pinghua,2016;Lu Qiang)[10−13] and specific industry (An Jing,2014;Wang Zhongya,2013;Wang Lei,2015)[14−16]. Throughout the existing literature on eco-industrialization evaluation, there still are some common defects: the selection of index is more one-sided, only from points of industrial pollution and economic efficiency not fully reflecting the situation of regional industry eco-industrialization; some studies adopt expert scoring and questionnaire survey to empower indexes, with a certain subjectivity and lacking of quantitative study on regional eco-industrialization. Thus this paper based on sustainable development theory uses the principal component analysis to quantitatively evaluate the industry eco-industrialization level of Shaanxi Province, analyzes the constraints, and puts forward the corresponding countermeasures and suggestions to provide reference for the Shaanxi provincial government making ecological development planning and related policies.

2. THE CONSTRUCTION OF ECO-INDUSTRIALIZATION INDEX SYSTEM

To fully reflect the connotation and characteristics of eco-industrialization, the index system should set up indexes from several aspects: the principle of low consumption, low emission and high efficiency; the principle of scientific, systematic and representative. Learning form analytic hierarchy process (AHP), the index system is divided into three levels: target layer, criterion layer and index layer. The level of eco-industrialization is the target layer, and the criterion layer is comprised of the level of resource consumption (A_1), the level of pollution (A_2), the level of pollution abatement (A_3) and the level of economic and social development (A_4), respectively to reflect the level of energy consumption, the intensity of pollutant emissions, environmental protection and industrial contribution to the local economic and social development. Considering the availability of data, index layer is composed of 14 individual indexes (B_1-B_{14}) that can reflect economic, environmental and social benefits. The specific indexes of eco-industrialization are shown in Table 1.

3. EVALUATION OF INDUSTRY ECO-INDUSTRIALIZATION IN SHAANXI PROVINCE

3.1 Data sources and processing

The data mainly are from *China Environmental Statistical Yearbook* and *Shaanxi Province Statistical Yearbook*. The index system consists of positive indexes and contrary indexes. To avoid the influence of contrary indexes, formula (1) is used to deal with contrary indexes. To eliminate the effects of different dimensions, the Z-Score method is used to standardize the data, the standardized indexes is marked as ZB_i showed in table 2.

$$y_i = \frac{\max x_i + \min x_i - x_i}{\max x_i} \tag{1}$$

Max x_i: the maximum value of the x_i index sample data from 2001 to 2015;
Min x_i as the minimum value of the x_i index sample data from 2001 to 2015;

3.2 Research Method and Applicability Test

As the eco-industrialization index system contains a large number of indexes, The empowerment of the indexes concerns the rationality of the evaluation results. Mainstream weight granting methods include subjective weighting methods (i.e., specialist-scored method, paired comparison method and analytic hierarchy process) and objective weighting methods (i.e., standard deviation method, entropy weight method and CRITIC method). Considering the objectivity of evaluation, the paper is intended to apply principal component analysis to empower indexes with the information carried by the data. This method not only could assess the level of eco-industrialization, but also can effectively avoid the interference of subjective factors, which is suitable for the study.

After normalization of the original data, Kaiser-Meyer-Olkin test of sampling adequacy and Bartlett test of sphericity are utilized to examine the correlation between the indexes. By using SPSS19.0 to process the sample data, the KMO value is 0.772 (KMO $\geqslant 0.7$, indicating that it is suitable for principal component analysis), and the significant level is 0.000, which is less than the given significant level of 0.05, indicating that there is a significant difference in the correlation coefficient matrix. The correlation test shows that sample data are relevant and are suitable for principal component analysis.

Table 1 Industry Eco-industrialization Index System.

target layer	criterion layer	index layer	
		Name	Calculation formula
The level of eco-industrialization	A_1 the level of resource consumption	B_1 Industrial energy consumption per unit of gross industrial production	Total industrial energy consumption/Gross industrial output value
		B_2Industrial electricity consumption per unit of gross industrial production	Total industrial electricity consumption /Gross industrial production
		B_3 Volume of industrial water per unit of gross industrial production	Total volume of industrial water/ Gross industrial production
	A_2 the level of pollution	B_4 Volume of industrial waste water discharged per unit of gross industrial production	Total volume of industrial waste water discharged/ Gross industrial production
		B_5Volume of industrial waste gas emission per unit of gross industrial production	Total volume of industrial waste gas emission / Gross industrial production
		B_6Volume of industrial solid waste produced per unit of gross industrial production	Total volume of industrial solid waste produced / Gross industrial production
	A_3 the level of pollution abatement	B_7 Ammonia Nitrogen discharge by industrial waste water per unit of gross industrial production	Ammonia Nitrogen discharge by industrial waste water / Gross industrial production
		B_8Volume of Sulphur Dioxide emission by industry per unit of gross industrial production	Total volume of Sulphur Dioxide emission by industry / Gross industrial production
		B_9Percentage of industrial solid waste utilized	[Volume of industrial solid wastes utilized/(Volume of industrial solid wastes produced+ Comprehensive utilization stored quantity in early years)]$\times$100%
		B_{10}Volume of industrial soot emission per unit of gross industrial production	Total volume of industrial soot emission / Gross industrial production
		B_{11}Investment completed industrial pollution control projects	The actual investment invested by an enterprise in environmental management projects
		B_{12}"Three wastes" comprehensive utilization of product output	Production value utilizing "three wastes" as the main raw material
	A_4 the level of economic and social development	B_{13}Ratio of industrial enterprises above designed size total assets to industrial output value	[(Total profits +Total taxes+ Interest expense)/Average total assets]$\times$100 %
		B_{14}Total profits and taxes of industrial enterprises above designed size	Product sales taxes and other taxes+ Total profits

3.3 Principal Component Analysis

It can be seen from Table 3 that the eigenvalues of the first two principal component factors are 10.503 and 2.713, respectively, and the cumulative variance contribution rate is 94.401%$>$ 85%, which can represent most of the original data. Therefore, the paper extracts the first two principal component factors for analysis.

The correlation coefficient between the original variable and the two principal components can be characterized by the loading value, and the variable with large loading value can be regarded

Table 2 The standardized indexes from 2001 to 2015.

year	ZB1	ZB2	ZB3	ZB4	ZB5	ZB6	ZB7	ZB8	ZB9	ZB10	ZB11	ZB12	ZB13	ZB14
2,001	-1.22767	-1.31041	-1.70573	-1.88716	-2.15329	-1.47796	0.84760	-0.33056	-1.34766	-0.46097	-1.02806	-1.08959	-1.61969	-1.10657
2002	-1.49801	-1.55684	-1.87376	-1.52789	-1.55292	-2.50527	0.79920	-0.28264	-1.10759	-0.23479	-1.01437	-1.11190	-2.08302	-1.10413
2,003	-1.20353	-1.21538	-1.59868	-1.20765	-1.11240	-1.04145	-0.16937	-0.50067	-1.15217	-0.56166	-1.00876	-1.03504	-1.46110	-0.95560
2,004	-1.04520	-1.19968	-1.12810	-0.63782	-0.11419	-0.67754	-0.58073	-0.72948	-1.15217	-0.81300	-1.00876	-1.03504	-.31055	-0.94359
2,005	-0.99889	-0.78695	0.29806	-0.75945	-0.31431	-0.02294	-0.42512	-0.90039	-1.23791	-2.37219	-1.00107	-0.98591	0.08748	-0.79255
2,006	-0.49740	-0.40805	0.43442	-0.14181	0.17969	0.00408	-1.14719	-1.87793	-0.31191	-1.24056	-1.06943	-0.68932	0.46686	-0.65815
2,007	-0.14434	-0.14391	0.52576	-0.05955	0.43270	0.16781	-1.23501	-1.26098	-0.11756	-1.61200	-0.95822	-0.31431	0.67520	-0.48966
2,008	0.21308	0.25794	0.55455	0.30921	-0.19171	0.46793	-1.29920	-1.42280	-0.19187	-1.36897	-0.51211	-0.52675	0.68453	-0.31428
2,009	0.32826	0.51886	0.59695	0.43119	-0.16887	0.91355	-1.17903	-0.72756	0.58952	-0.52101	0.07454	-0.15786	-0.46603	-0.01617
2,010	0.77078	0.72301	0.60585	0.74159	0.06491	0.62255	-0.45799	0.26182	0.62896	-0.47166	0.69266	0.07761	0.62545	0.44793
2,011	1.00153	0.88448	0.64066	0.57848	0.39364	0.67723	0.16239	0.73243	0.94163	0.48762	0.78854	0.37761	1.16341	0.93157
2,012	1.10999	1.03266	0.65531	0.93001	1.08716	0.74071	0.72679	1.05828	1.00794	0.97235	0.95208	0.59724	0.91153	1.10663
2,013	1.16975	1.10393	0.66238	0.78588	1.13043	0.72248	1.15766	1.22200	1.13541	0.92201	1.05967	0.77761	0.28028	1.13098
2,014	1.16500	1.09829	0.66500	1.24428	1.22839	0.74982	1.19515	1.31025	1.10168	0.87166	1.39334	1.20516	0.17766	1.24177
2015	0.85667	1.00205	0.66735	1.20069	1.09077	.65900	1.28048	1.39148	1.21372	1.09584	1.55592	1.34197	0.86799	1.66740

Table 3 Total Variance Explained.

Component	Initial Eigenvalues			Extraction Sums of Squared loadings			Rotation Sums of Squared loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance)	Cumulative %
1	10.503	75.020	75.020	10.503	75.020	75.020	8.254	58.957	58.957
2	2.713	19.381	94.401	2.713	19.381	94.401	4.962	35.444	94.401
3	0.288	2.059	96.461						
4	0.171	1.225	97.685						

as the main influencing factor of the principal component. Table 4 shows the initial factors loading corresponding to the two principal components. For identifying factors more easily, the initial factor load matrix is rotated by the maximum variance method. The factor loading with rotation is shown in Table 5.

From Table 5, we can see that the first main component has a larger loading in B_3, B_6, B_{13}, B_4, B_2, B_5, B_1, $B_{14}$and B_9, which reflects the comprehensive situation of resource consumption, economic contribution, industrial waste discharge and comprehensive utilization in Shaanxi province. Among these indexes, B_3, the volume of industrial water per unit of gross industrial production has the maximum loading, 0.965. Because of most indexes which has larger loading in the first principal component reflecting the level of resource consumption, the first principal component can be considered as resource consumption factor.

The second principal component has a large loading in B_8, B_7, B_{10}, B_{12} and B_{11}, reflecting the comprehensive situation of pollutant discharge intensity, pollutant recycling, pollution control investment and corporate profitability in Shaanxi Province. Since five of the six indexes represent the environmental impact of Shaanxi's industrial development, the second principal component can be considered as the environmental impact factor.

In order to comprehensively evaluate the level of industry eco-industrialization in Shaanxi Province, it is necessary to calculate the comprehensive score of 14 indexes, calculating the scores of the principal components by using the eigenvector values in Table 3 as the weights of the indexes, then calculating the industry eco-industrialization comprehensive score by using variance contribution rates in Table 3 as the weights of the principal component factors. The score expression is:

$$\begin{aligned} y_1 = {} & 0.302ZB_1 + 0.302ZB_2 + 0.252ZB_3 + 0.297ZB_4 \\ & - 0.276ZB_5 + 0.262ZB_6 + 0.110ZB_7 + 0.225ZB_8 \\ & + 0.301ZB_9 + 0.212ZB_{10} + 0.293ZB_{11} \\ & + 0.299ZB_{12} + 0.235ZB_{13} + 0.303ZB_{14} \end{aligned} \tag{2}$$

$$\begin{aligned} y_2 = {} & -0.043ZB_1 - 0.074ZB_2 - 0.327ZB_3 - 0.129ZB_4 \\ & - 0.139ZB_5 - 0.285ZB_6 + 0.540ZB_7 + 0.396ZB_8 \\ & + 0.002ZB_9 + 0.407ZB_{10} + 0.165ZB_{11} \\ & + 0.104ZB_{12} - 0.327ZB_{13} + 0.101ZB_{14} \end{aligned} \tag{3}$$

$$y = 75.020\% \times y_1 + 19.381\% \times y_2 \tag{4}$$

From the formula (2), the formula (3) and the formula (4) calculating the level of industry eco-industrialization comprehensive score from 2001 to 2015 in Shaanxi Province, the results shown in Table 6. The Trend of Industrial Ecology in Shaanxi Province in 2001-2015 is showed in Figure 1.

3.4 Results

As can be seen from Table 6 and Figure 1, the first principal component score has an upward trend, and can be divided into three stages. The first stage is the slow development stage of 2001-2005.In this period, B_1, B_2 and B_3 decrease significantly, B_4, B_5, B_6 and B_9 also decrease slightly, but B_{13} is on the rise. The fact showing the industry development of Shaanxi focuses on energy conservation, but lacks attention on industrial waste disposal and utilization, there still has room for the development of industry eco-industrialization. The second stage is the rapid growth stage of 2006-2010. B_1, B_2 and B_3 decrease significantly compared with the first stage. B_4 and B_6 respectively reduced in different degrees, although B_5 shows a slight increase in 2008

Table 4 Initial Factor Loading and Eigenvector.

	Initial Factor Loading		Eigenvector	
	a_1	a_2	t_1	t_2
ZB_1	0.980	-0.071	0.302	-0.043
ZB_2	0.979	-0.122	0.302	-0.074
ZB_3	0.818	-0.538	0.252	-0.327
ZB_4	0.962	-0.213	0.297	-0.129
ZB_5	0.893	-0.229	0.276	-0.139
ZB_6	0.849	-0.470	0.262	-0.285
ZB_7	0.356	0.890	0.110	0.540
ZB_8	0.728	0.652	0.225	0.396
ZB_9	0.977	0.004	0.301	0.002
ZB_{10}	0.688	0.671	0.212	0.407
ZB_{11}	0.950	0.271	0.293	0.165
ZB_{12}	0.970	0.171	0.299	0.104
ZB_{13}	0.760	-0.538	0.235	-0.327
ZB_{14}	0.982	0.167	0.303	0.101

Table 5 Factor Loading with Rotation.

	Factor Loading with Rotation	
	a_1	a_2
ZB_1	0.865	0.466
ZB_2	0.891	0.423
ZB_3	0.979	-0.014
ZB_4	0.926	0.338
ZB_5	0.876	0.287
ZB_6	0.969	0.060
ZB_7	-0.178	0.942
ZB_8	0.264	0.941
ZB_9	0.821	0.529
ZB_{10}	0.220	0.935
ZB_{11}	0.656	0.739
ZB_{12}	0.726	0.666
ZB_{13}	0.930	-0.045
ZB_{14}	0.738	0.669

and 2009, but overall is stable. It is noteworthy that B_9 begins to rise in this stage, and B_{13} keeps increasing, which reflects that enterprise is committed to industrial waste management, and the contribution of industrial development to economic and social benefits in this stage is improved, more specifically, reflecting the unity of economic, social and environmental benefits. The third stage is the steady growth stage of 2011-2015. B_{13} in this stage has been significantly improved compared with the second stage, B_4, B_5 and B_6 steadily reducing, which indicates the implementation of energy-saving emission reduction measures in Shaanxi is remarkably effective. The industry development has gradually shifted from extensive to intensive.

The second principal component score fluctuates greatly and is divided into two stages. It can be seen that in the first stage of 2001-2007, B_7, B_8 and B_{10} increase year by year, at the same time, B_{11} and B_{12} also increase year by year but the rate is far less than B_7, B_8 and B_{10}. It shows that with the rapid industrial economy growth in Shaanxi Province, the substantial increase in gross industrial production and the continuous expansion of production scale have led to the gradual increase in investment in pollution control, whereas the control of pollutant emission and energy consumption still need to be further improved. Shaanxi Province in pollution control investment and industrial output value does not form a dynamic balance, pollution control still lagging behind the formation of pollution. In the second stage of 2007-2015, the increase of pollution indicator value like B_7, B_8 and B_{10} has been controlled, and the economy indicator value like B_{11} and B_{12} keeping increasing. Thus it can be known that the government funds is the condition for the realization of industry eco-industrialization, and the government investment needs to keep up with the pace of industry development in to ensure the continuous improvement of the level of industry eco-industrialization.

In general, from 2001 to 2015, the level of industry eco-industrialization development in Shaanxi Province showed an upward trend. The stage of 2001-2005 increased slowly, and since 2006, the level of industry eco-industrialization has risen faster. The main reason for the level of industry eco-industrialization improved rapidly is that Shaanxi supports high-tech industry to stimulate the development of eco-industrialization. In the subsequent development stage, Shaanxi Province should insist on strengthening the protection of the environment and improving the level of resource utilization, realizing the unity of economy, society and environment.

Compared Shaanxi with other provinces in China, it can be seen that there are following issues in the industry eco-industrialization development of Shaanxi:

1. The imperfection of the environmental legal system prevents the government from conducting effective supervision. In China, the State Council and the National Development and Reform Commission has repeatedly issued to speed up the implementation of cleaner production and energy saving, But in Shaanxi there is no specific implementation method and standard, nor the establishment of energy utilization analysis system and sewage enterprise announcement system. The legal blank also makes it impossible for administration to manage enterprises, to a certain extent hindered the advancement of industry eco-industrialization in Shaanxi Province.

2. Shaanxi lacks scientific environmental protection plan, which couldn't provide infrastructure guarantee for the development of industry eco-industrialization. In the overall development plan of Shaanxi Province, mainly making economic development as a prerequisite for planning, environmental planning lacks convergence with socio-economic development planning and land planning. When environmental goals conflict with economic development goals, it usually requires coordination between different departments and leads to mutual deduction of responsibility. The result is often that environmental goals make concessions for economic development.

3. The proportion of heavy industry in the secondary industry is too large resulting in high energy consumption. In the heavy industry of Shaanxi Province, energy chemical industry and equipment manufacturing industry annually consume more than two-thirds of the total industrial en-

Table 6 The Score and Rank of Industry Eco-industrialization in Shaanxi from 2001 to 2015.

Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
y_1	-4.57	-4.75	-3.91	-3.07	-2.72	-1.67	-0.97	-0.61	0.36	1.61	2.66	3.42	3.48	3.89	4.18
y_2	1.94	2.43	0.86	-0.41	-1.78	-2.43	-2.54	-2.57	-1.53	-0.94	-0.18	0.42	0.95	1.05	1.15
Y	-3.05	-3.09	-2.76	-2.38	-2.38	-1.72	-1.22	-0.96	-0.03	1.03	1.96	2.65	2.79	3.12	3.36
Rank	13	14	12	11	11	10	9	8	7	6	5	4	3	2	1

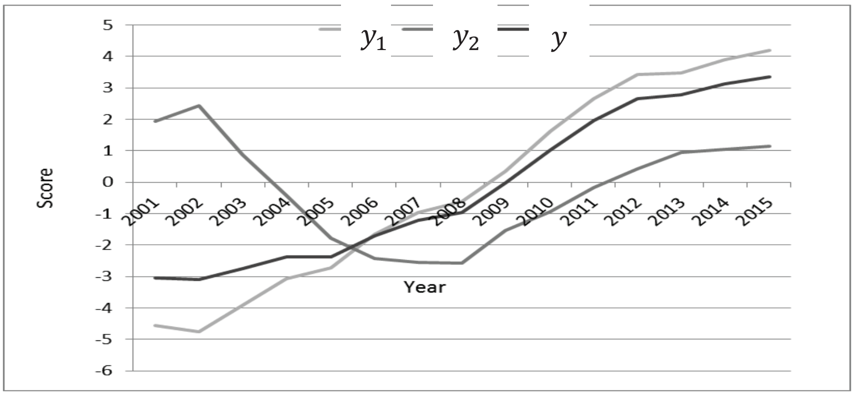

Figure 1 the development trend of industry eco-industrialization level and principal component score in Shaanxi from 2001 to 2015.
y_1: resource consumption factor
y_2: environmental impact factor
y: the score of industry eco-industrialization.

ergy consumption of raw coal, crude oil and hydropower resources, at the same time, these high energy-consuming industries also discharge waste water, waste gas and industrial solid waste, hindering the process of energy saving.

4. The production technology lags behind and fails to promote cleaner production effectively. The majority of industrial enterprises in Shaanxi couldn't fully utilize production resource, consuming large amounts of resources, and the waste from industrial production also posing hazard for environment. Especially in steel industry and nonferrous metals industry of Shaanxi, the situation that the technology for desulfurization and denitrification of flus gas has not been widely implemented makes the transformation of cleaner production mode can't be achieved.

4. SUGGESTIONS

Targeting at the issues of industry eco-industrialization in Shaanxi Province, the administration may take the following measures:

1. The government should further improve the legal system of industry eco-industrialization. In order to achieve industry eco-industrialization effectively, the government should strengthen legislation and enforcement of environmental protection and avoid environmental damage and resource waste from uneconomical external behavior and unsustainable social behavior. Based on *the Energy Conservation Law of the People's Republic of China* and *the Cleaner Production Promotion Law*, for the industrial layout of Shaanxi Province, the city manager should develop specific and feasible clean production standards and forced recycling of waste recycling methods, implement sewage enterprise announcement system, from the source to eliminate industrial pollution. In addition, this legislative initiative also is essential to the reinforcement of public environmental awareness.

2. The government should accelerate the promotion of industrial ecology among industrial enterprises. As the subject of microeconomics, the enterprise also as the practical basis and promoter of industrial ecological theory, is a crucial link in the promotion of industry eco-industrialization. Therefore, the administration should encourage enterprises to establish environmental management system, and technical cooperation among enterprises in the production of raw materials, so as to truly control industrial pollution from the source. At the same time, with the transformation of industrial ecological development mode, the improvement of market mechanism, environmental costs and pollution costs gradually reflecting in the price of resources, the motivation of reducing production costs will make industrial enterprises actively seek advanced energy saving technology, thus forming a benign cycle of industrial ecological development.

3. City management department should give priority to environment planning among numerous development plans. The urban planning should be comprehensive to incorporate eco-environmental protection plan, taking account of resource conditions, location factors, industrial structure and regional development strategies of different place. In the part of eco industrial park, the planer should use ecological principle and systematic methods to design the upstream

and downstream industry chain in the park, consequently to formulate a plan suiting for the local situation.

4. Promote energy conservation to reduce resource consumption. Industry eco-industrialization requires the dematerialization of industrial products and economic activities. In other words, that is in the same or even less material to obtain more services and products, simply to improve the productivity of resources. Shaanxi as China's mineral resources province, enhancing mineral resources mining recovery rate, concentration recovery rate and comprehensive utilization rate is an important part of promoting the development of industry eco-industrialization. Strengthening the construction of mining rights market and the management of petroleum, chemical, electricity, steel, nonferrous metals, building materials and other high energy consumption industries, using advanced energy-saving technologies and products, thereby, it can continuously reduce energy consumption per unit of product.

5. Accelerate the research and development of core technologies of industry eco-industrialization to make a significant technological progress. Shaanxi should encourage the application in traditional industries, combine produce process with research process, and put the industrial development point on high value-added and high-tech industrial products. Meanwhile, for irreplaceable characteristic industries of Shaanxi, like energy and chemical industry, equipment manufacturing and nonferrous metallurgy, should rely on the existing core enterprises, strengthen industrial technology development and innovation, focus on developing energy-saving and clean production and other key support technology, accordingly to improve the comprehensive utilization of energy, extend the industrial chain and further promote industry eco-industrialization.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflicts of interest.

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REFERENCES

1. Rees W, Wackernagel M. Urban ecological footprints: why cities cannot be sustainable and why they are key to sustainability[G].Environmental Impact Assessment Review. 1996.
2. Monfreda C, Wackernagel M, Deumling D. Establishing national natural capital accounts based on detailed ecological footprint and biological capacity assessments[J].Land Use Policy . 2004.
3. Bartsev S.I, Degermendzhi A.G, et.al. An Integrated Approach to the Assessment of an Ecological Impact of Industrial Products and Processes[C].Procedia Environmental Sciences, Volume 13, 2012, Pages 837-846
4. Ohnishia S, Dong HJ, Geng Y. A Comprehensive Evaluation on Industrial & Urban Symbiosis by Combining MFA, Carbon Footprint and Emergy Methods—A Case of Kawasaki, Japan[J]. Ecological Indicators, Volume 73, February 2017, Pages 513-524.
5. Salmanighabeshi S, Bernalte E, et.al. Long-term Assessment of Ecological Risk from Deposition of Elemental Pollutants in the Vicinity of the Industrial Area of Puchuncaví-Ventanas, Central Chile[J]. Science of The Total Environment, Volumes 527–528, 15 September 2015, Pages 335-343.
6. Liu Chuanjiang, Wu Hanhan, Wu Wei. Analysis on the Transformation of China's Industrial Ecology Using the IOOE Model: Empirical Analysis Based on the Industrial Sector's Data in 2003-2012[J]. China Population, Resources and Environment, 2016, Volumes 26, 119-128.
7. Wang Rusong, Li Feng, Hang Baolong, et.al. Urban Eco-comlpex and Eco-space Management[J]. Acta Ecologica Sinica. 2014, 34 (1): 1-11.
8. Fan Yupeng, Qiao Qi. Research on Environmental Management of Industrial Parks Based on Industrial Ecological Construction[J]. Chinese Journal of Environmental Management, 2016, (05):80-84.
9. Wang Jianjun, Kang Yiru, Li Zhixia. Study on the Evaluation of Industrial Ecology in the Park-A Case Study of Qinghai Qaida Circular Economy Experimental Zone [J]. Qinghai Social Sciences, 2015, (05):190-196.
10. Liu Jingru,Yan Yuting, Nie Xinrui. The application of life cycle assessments to the evaluation of the environmental benefits of industrial symbioses: re-search progress and challenges[J].Acta Ecologica Sinica,2016,36(22):7202-7207.
11. Ma Yong, Liu Jun. Efficiency Evaluation of Regional Industrial Ecology of the Yangtze River Middle Reaches Urban Agglomerations [J]. Economic Geography, 2015, 06: 124-129.
12. Gu Pinghua. Study on Evaluation of Industrial Ecology Level [J].Seeker, 2016, 05: 83-88.
13. Lu Qiang, Wu Qinghua, et.al. Industry Green Development Evaluation Index System and Its Application to the Regional Assessment of Guangdong Province in China [J]. Ecology and Environmental Sciences, 2013, 22(3): 528-534.
14. An Jing, Xue Xiangxin. Study on Ecological Development Strategies of Boron Industry in China [J]. Ecological Economy, 2014, (01):88-90.
15. Wang Zhongya. Research on the Development of Industrial Ecology of Typical Resource-based Cities of China [J]. Research on the Development of Industrial Ecology of Typical Resource-based Cities of China,2013,(02):54-58.
16. Wang Lei, Chen Jun, Wang Taixiang. The Level and Evolution of Ecological Development of Resource-based Industry-A Case Study of Xinjiang [J]. Forum on Science and Technology in China, 2015, (05):96-101.