

Research on Low-carbon Consumption Level of Urban Residents

—Take Tianjin as an example

Hu Biao^{1,a,*}, Yuan Kai^{1,b}

Tianjin University of Technology, Tianjin 300384

Keywords: low carbon consumption; ecological civilization; DPSIR model; Tianjin; guidance strategy

Abstract: Based on the development of Tianjin, this paper establishes a DPSIR evaluation model and uses the improved TOPSIS algorithm to calculate and analyze the 30 evaluation indicators under the driving force, pressure, status, impact, and response system. The results show that from 2006 to 2016, the overall level of low-carbon consumption of urban residents in Tianjin continued to increase, and the driving forces, status, influence, and response systems showed a good development trend, and the pressure gradually decreased. Based on this, practical and feasible guidance strategies are formulated to provide a strong institutional guarantee for the construction of an ecologically-civilized society.

1. Introduction

Under the current status of the ecological environment, efforts to develop a low-carbon recycling economy has become the main choice for governments of all countries to cope with the deterioration of the ecological environment. Formulating low-carbon economy strategies that are in line with their own national conditions has become an important task for people and governments of all countries in the world^[1]. Consumers constitute the main players in the low-carbon recycling economy. Scientifically and effectively assessing residents' low-carbon consumption levels has very important reference value for the construction of ecological civilization and the development of low-carbon economy.

In recent years, low-carbon consumption has become the focus of research by experts and scholars which they^[2-4] discusses the dialectical relationship between urban ecological environment and human social economic activities and environmental protection from the perspective of ecological civilization and adopts methods of investigation and analysis. Johnston and Kamas pointed out that improving the ecological environment requires changing the energy consumption structure and establishing a scientific low-carbon emission system^[5-7]. The above research puts forward different viewpoints on the development of low-carbon economy and the improvement of residents' low-carbon consumption level, but there are shortcomings. The data collection of the Probit-logit-LPM combination model is in the form of a questionnaire. It has strong subjectivity and randomness, and it is incomplete coverage. Therefore, this article refers to the "Tianjin City Yearbook" and "Tianjin National Economic and Social Development Statistical Communiqué" and

other literature materials, uses the DPSIR model to construct 30 specific evaluation indicators and adopts improved TOPSIS Calculated and analyzed, to find out the gap between low-carbon consumption level and the “positive and negative ideal state” of urban residents in Tianjin from 2006 to 2016. Analyze the results and formulate corresponding guiding strategies to build the ecological civilization in Tianjin.

2. Research Method

2.1 Construction of Evaluation Index System

Based on the DPSIR model of Driving Force, Pressure, State, Impact, and Response, a comprehensive evaluation system for low-carbon consumption levels of urban residents in Tianjin was constructed. The system consists of three indicator layers. The first layer is a comprehensive indicator layer, which includes comprehensive evaluation indicators for low-carbon consumption levels of urban residents in Tianjin. The second layer is the system layer, which is subdivided into five system layers: driving force, pressure, status, influence, and response. The third level is the indicator level. It is subdivided into 30 specific indicator items on the basis of the above five system layers, and measures the level of low-carbon consumption of urban residents in Tianjin.

2.2 Method Selection

The TOPSIS method calculates the gap between the corresponding index and the "positive ideal solution" and "negative ideal solution" according to the weight of the evaluation index, so as to further obtain the relative degree of closeness between each evaluation object and the "ideal solution".

Step 1 Data Collection

The relevant research data of this article are mainly derived from the Tianjin Statistical Yearbook 2006-2016, the Statistical Communiqué of Tianjin National Economic and Social Development, the Tianjin Economic Census Yearbook, the China Statistical Yearbook, Tianjin Statistical Information Network, and Tianjin Municipal public data report on environmental pollution and governance.

Step 2 Standardization of evaluation indicators

For evaluating positive indicators, the calculation formula is:

$$y_{ij} = [x(i, j) - x_{\min}(j)] / [x_{\max}(j) - x_{\min}(j)] \quad (1)$$

For evaluating negative indicators, the formula is:

$$y_{ij} = [x_{\max}(j) - x(i, j)] / [x_{\max}(j) - x_{\min}(j)] \quad (2)$$

In the formula: $X_{(i,j)}$, $i=1, \dots, m$; $j=1, \dots, n$ is the i th evaluation index value of the year; m, n are the number of years and the evaluation index number.

Step 3 Calculation of Indicator Weights

This paper uses entropy weight method to calculate the weight of the evaluation index. The formula is:

(1) Indicator information entropy

$$H_j = -k \sum_{i=1}^m p_{ij} \ln(p_{ij}) \quad (3)$$

In the formula: $k = \frac{1}{\ln m}$ and; \ln is the natural logarithm; $p_{ij} = y_{ij} / \sum_{i=1}^m y_{ij}$ (assuming that, when $p_{ij} = 0$, $p_{ij} \ln p_{ij} = 0$).

(2) Calculate the difference coefficient of the j th evaluation index: G_j

$$G_j = 1 - H_j \quad (4)$$

(3) Calculate indicator weights: W_j

$$W_j = G_j / \sum_{j=1}^n G_j, n = 1, 2, 3 \dots 30 \quad (5)$$

Step 4 Establish Weighted Normalized Moment V

$$V = |V_{ij}|_{m \times n} = W_j \times Y_{ij} \quad (6)$$

The standardized matrix.

Step 5 Determine positive and negative ideal solutions

The maximum and minimum values in the weighted normalized decision matrix V are respectively taken as the "positive ideal solution" and "negative ideal solution" of the evaluation index.

The formula for the positive solution is:

$$V^+ = \{ \max v_{ij} | i = 1, 2, \dots, m \} \quad (7)$$

The negative ideal solution formula is:

$$V^- = \{ \min v_{ij} | i = 1, 2, \dots, m \} \quad (8)$$

Step 6 Calculate the distance between the evaluation indicators in different years to the "positive ideal solution" D^+ and the "negative ideal solution" D^-

$$D_i^+ = \sqrt{\sum_{j=1}^n (V_{ij} - V_j^+)^2} \quad (i = 1, 2, \dots, m) \quad (9)$$

$$D_i^- = \sqrt{\sum_{j=1}^n (V_{ij} - V_j^-)^2} \quad (i = 1, 2, \dots, m) \quad (10)$$

The smaller the value of D^+ , the closer the evaluation index is to the "positive ideal solution", the lower the level of low-carbon consumption is, the smaller the indicator is, and the closer the evaluation index is to the "negative ideal solution", the lower the carbon consumption level.

Step 7 Calculate the closeness between each evaluation index and the "ideal solution"

$$C_i = \frac{D_i^-}{D_i^+ + D_i^-} \quad (11)$$

When it is between 0 and 1, the greater the value, the higher the level of low-carbon consumption of urban residents in Tianjin in the i -th year.

2.3 Establish a Criterion for Low-carbon Consumption Levels

After consulting the relevant literature and research results and consulting with relevant experts, according to the actual development level of Tianjin, The level of low-carbon consumption in townships was evaluated (Table 1).

Table 1 The low-carbon consumption level standards of Tianjin urban residents

C	[0.0,0.2]	[0.2,0.4]	[0.4,0.6]	[0.6,0.8]	[0.8,1.0]
consumption levels	extremely low	low	medium	high	extremely high

3. Results Analysis

3.1 Index Weight Analysis

By collecting relevant data of Tianjin from 2006 to 2016 and standardizing it, and using the entropy weight method to calculate the index values, the weights of each index and the comprehensive weight values of various system layers are obtained (see Table 2). From the indicator level, D1, D2, D3, D4, P2, P3, S2, I1, I3, I4, R3,R4, R5, R6, R8 are relatively high, indicating that the above factors are The main factors for the low-carbon consumption level of urban residents in Tianjin include economic factors, social factors, environmental factors, and resource factors, and involve various aspects of residents' lives. D1, D2, and D3 are the main economic factors that directly reflect the current level of economic development of the society, the income of residents, and then directly affect the level of consumption of residents. P2, P3, S2, I1, I3, I4, R4, and R5 belong to the category of resource and environmental factors and directly reflect the current situation of environmental pollution and treatment, resource utilization and recycling in Tianjin. The level of urbanization (D4) and the rate of new energy development and penetration are social factors, which also affect the level of low-carbon consumption of residents.

3.2 Analysis of the development of low-carbon consumption level of urban residents in Tianjin

Through calculations and analysis of the results, the overall level of low-carbon consumption of urban residents in Tianjin during 2006-2016 showed a good development trend and continued to increase. Among them, the D^+ decreased continuously from 0.155 in 2006 to 0.104, a decrease of 0.051, showed a tendency towards a "positive ideal solution" gradually; D^- overall increased continuously from 0.092 in 2006 to 0.131 in 2016, an increase of 0.039, showing a gradual trend towards "negative ideals" Solution" trend. The degree of closeness C rose from 0.175 in 2003 to 0.510 in 2013. The level of low-carbon consumption of urban residents has increased from the original low level to the current moderate level, indicating that the level of low-carbon consumption of urban residents in Tianjin is gradually increasing and gradually adapting to Tianjin. City's requirements for developing a low-carbon economy strategy (Figure 1, Figure 2).

Observing the pattern, we can see that the degree of closeness from 2006 to 2008 is relatively low (both below 0.2), and the level of low-carbon consumption of urban residents is at a very low level. The reason is that in 2006-2008, Tianjin over-pursued GDP, and the production process Excessive resources, excessive resource consumption, higher product consumption, higher carbonization, and low awareness of low-carbon environmental protection among residents, the

government has not formulated specific regulations and policies to guide residents' low-carbon consumption, which has led to this phenomenon. Since 2008, the degree of closeness has gradually increased from the original 0.158 and has continued to rise to 0.450 in 2013. This shows that Tianjin has begun to change its economic development model, shifting from extensive production to environmental protection and resource-saving production methods, and gradually strengthening environmental protection. Education guides residents' low-carbon consumption. From 2013 to 2014, the degree of closeness decreased by 0.139, and the level of low-carbon consumption dropped from the original middle to a lower level. After consulting the development report of Tianjin and consulting relevant experts, the decline in the level of household consumption and the implementation of Tianjin were implemented. The bottleneck encountered in the process of low-carbon economic strategy is related. Mainly manifested in the residents of the recognition of new energy products is not high, some residents did not completely change the traditional concept of consumption and the low penetration rate of low-carbon education and other phenomena lead to the above phenomenon. Since 2014, the level of closeness has increased from 0.311 to 2.510 in 2016 and has continued to rise. The level has also reached an intermediate level. In general, while Tianjin is striving to develop a low-carbon economy, transform its economic development strategy, and adjust its industrial development structure, residents' low-carbon consumption has also risen to a new level.

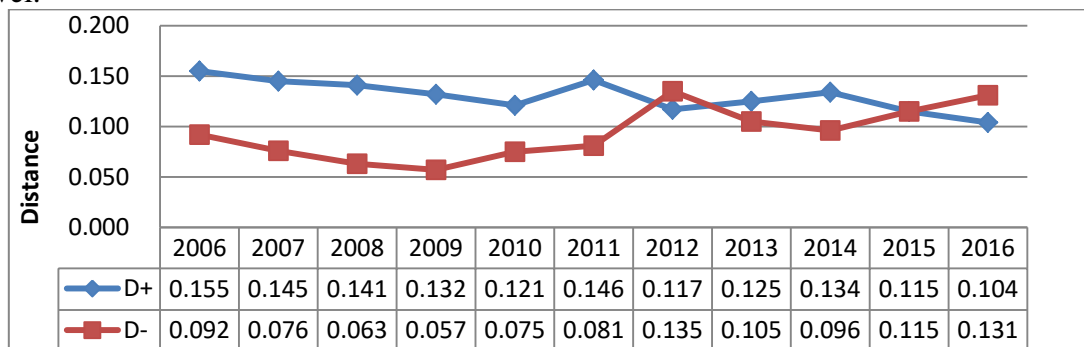


Figure. 1 The low carbon consumption level D^+ and D^- of Tianjin urban residents in 2006-2016

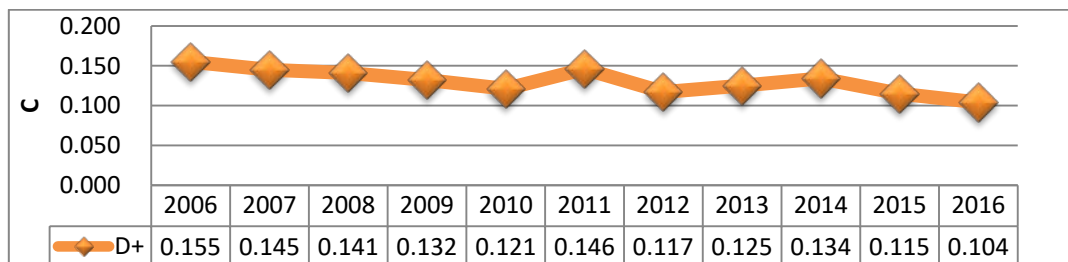


Figure. 2 The low carbon consumption level of Tianjin urban residents in 2006-2016

3.3 Analysis of low carbon consumption of subsystems in DPSIR model

The weighted average method was used to calculate the degree of closeness between each system layer and the “ideal solution” from 2006 to 2016. After the consolidation, the line graphs of the system level indicators affecting low-carbon consumption levels of urban residents in Tianjin from 2006 to 2016 were plotted using EXCEL software., As shown in Figure 3.

(1) From the perspective of the driving force system, the degree of closeness rose from 0.255 in 2006 to 0.845 in 2016, and the level of household consumption rose from very low to very high. Per capita GDP increased from 51,000 in 2006 to 17.4 in 2016. Ten thousand yuan, GDP growth rate rose from 14.8% to a maximum of 17.4%, urban disposable income rose from 10,000 yuan in 2006

to 33,000 yuan in 2016, an increase of 23,000 yuan, the increase in per capita consumer spending from the original From 8.3% to 11.4%, the increase in per capita disposable income, consumer price index, and Engel's coefficient have improved substantially. The above data fully shows that the economic development of Tianjin promotes an increase in per capita disposable income, and the number of residents spending also increases. The phenomenon of high carbonization in the consumption process is also becoming more and more prominent. The weak awareness of low-carbon consumers directly restricts the development of the living environment.

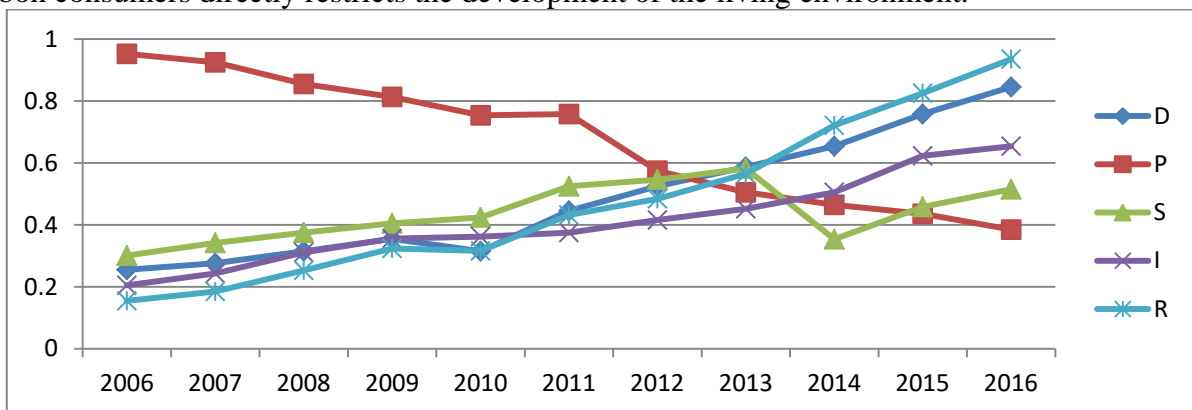


Figure. 3 The evaluation of each subsystem of low-carbon consumption level degree of Tianjin urban residents

(2) From the point of view of the pressure system, the closeness of the pressure system's degree of decline has been relatively fast, falling from 0.952 in 2006 to 0.385 in 2016, indicating that the pressure system layer has a role in influencing the low-carbon consumption level of urban residents in Tianjin. The per capita carbon content of consumer goods in Tianjin dropped from 99.1 tons to 45.5 tons in 2013. However, the growth rate of industrial carbon consumption rose from 6.4% to 16.1% in 2010, and then fell to 7.5% in 2016, which is still an increase. The main reason for the numerical change in the indicator level is that due to the excessive reliance on GDP growth in Tianjin to complete the economic indicators in 2006-2011, the consumption of coal has increased, the pace of life of residents has accelerated, and the consumption of high-carbon products has increased. This has seriously polluted the ecological environment.

(3) From the state system level, the degree of closeness of the state system layer rose from 0.310 in 2006 to 0.515 in 2016. The rating was raised from the very low to the medium level, and the degree of closeness as a whole showed a fluctuating upward trend. 2006- In 2009, it was at a relatively low level. 2009-2013 was at a medium level, but during the period from 2013 to 2014, the closeness degree dropped to a lower level. The analysis shows that this is mainly due to the implementation of the low-carbon economy strategy in Tianjin. The bottleneck encountered is related. After 2014, the closeness of the state has been at a moderate level and has progressed toward a better level.

(4) About the impact system level, as the status system improves, the closeness of the impacted system has increased from 0.205 in 2006 to 0.654 in 2016, which fully shows that the level of low-carbon consumption of urban residents in Tianjin has significantly increased. With the improvement of people's environmental awareness, people's awareness of environmental protection is gradually improving. Residents pay more and more attention to low-carbon consumption, and they are apt to consume new-type green products. The concept of energy saving and emission reduction has penetrated into them.

(5) About the response system level, the degree of closeness has increased by 0.78 from 2006 to 2016, and the rating level has risen from extremely low to very high. In the indicator system of the

response system, the R1, R2, R3, R4, R5, R6, R7, R8 all have significant changes. The changes in these indicators directly reflect the strong recognition of low-carbon consumption by urban residents in Tianjin and actively fulfill the responsibilities and obligations of low-carbon environmental protection. Therefore, the level of low-carbon consumption of urban residents in Tianjin has reached a new level, in line with Tianjin's requirements for building an ecological and civilized society.

4. Conclusion and Suggestions

As a manufacturing center in the north, a regional economic center in the Bohai Sea, an ecological city, and an international port city, Tianjin has a very important influence in China's economic construction. Research shows that from 2006 to 2016, Tianjin has made significant progress in developing a low-carbon economy and implementing low-carbon consumption. Residents have gradually shifted to low-carbon and green consumption in the way they consume, and they are gradually adapting to the development of low-carbon consumption. trend. The improvement of low-carbon consumption needs both the supervision of the government and society and the self-consciousness of the residents themselves.

The government must optimize the industrial structure and build a low-carbon industrial system. Since 2006, Tianjin is still dominated by secondary industries with high energy consumption and high carbon emissions, which has added tremendous pressure on the development of Tianjin's low-carbon economy. Therefore, the Tianjin Municipal Government vigorously develops the tertiary industry, encourages support for technological innovation, introduces new technologies to develop new environmental protection products, minimizes the carbon content of industrial products, and strengthens the promotion and popularization of low-carbon products and green products. When formulating relevant policies, the government should base on the natural conditions and economic background of the relevant regions. Strengthen environmental protection propaganda and education. For government agencies, schools, companies, individuals, etc., to provide in-depth explanations and guidance, gradually change their traditional concept of consumption, establish a “government, society, individual” trinity of supervision mechanisms, for advanced collectives and individuals, reward and support for The malicious and disruptive collectives and individuals have given punishment, continuously deepened environmental protection awareness, transformed residents' traditional consumption concepts, and gradually increased residents' low-carbon consumption levels. In the context of Tianjin's strategy of vigorously developing a low-carbon economy, the Group and individuals actively responded to the government's call, strengthened their awareness of low-carbon environmental protection.

Acknowledgments

This work was financially supported by National Key Research and Development Program Funding Project (2016YFF0201603)fund .

References

- [1] Yu Xiaozhong, Hou Chunhua, Wang Xiaomei. *Study on Low Carbon Consumption Behavior Patterns and Guiding Strategies of Different Regional Types [J]. Soft Science, 2013, 27(6): 79-82.*
- [2] Zhao Min. *Discussion on ways to realize low carbon consumption [J]. Exploration of Economic Issues, 2011(2):33-37.*
- [3] Chen Kai, Li Huajing. *Influencing factors of low-carbon consumer behavior and analysis of intervention strategies [J]. China Science and Technology Forum, 2012 (9): 42-47.*
- [4] Zhang Yaxin, Zhang Pingyu. *Evaluation of Low Carbon Economic Development Level in Jilin Province[J]. Journal*

of *Arid Land Resources and Environment*, 2011, 25(6): 43-48.

[5] Hansla A, Gamble A, Juliusson A, Tommy Garling. *Psychological Determinants of Attitude towards and Willingness to Pay for Green Electricity*[J]. *Energy Policy*, 2008, 36(2): 768-774.

[6] Xin Ling. *Evaluation Index System and Comprehensive Evaluation Model of Low-carbon Consumption Mode*[J]. *Statistics and Decision*, 2011(11): 31-34.

[7] Yang Bo. *Analysis of Factors Affecting Residents' Cognition Status and Consumer Willingness of Low-Carbon Commodities: An Empirical Study Based on Resident Survey Data* [J]. *Economic Survey*, 2012(1): 122-126.

Table 2 The evaluation index weight of low carbon consumption level of Tianjin urban residents

Comprehensive indicator level	System level weigh	Indicator level	Indicator weight	
Tianjin Urban Residents Low-carbon Consumption Evaluation Index	D	GDP per capita (D1)	0.031	
		0.281	GDP growth rate (D2)	0.036
			Per capita disposable income of urban and rural areas (D3)	0.0351
			Urbanization level (D4)	0.0325
			Engel's number (D5)	0.0263
	P	0.2506	Population Growth Rate (P1)	0.0158
			Carbon consumption per unit of GDP(P2)	0.0307
			Unit industrial added value carbon consumption(P3)	0.0313
			Per capita product consumption carbon content(P4)	0.0189
			Percentage of carbon-containing products(P5)	0.0203
	S	0.2376	Per Capita Carbon Emissions(S1)	0.0191
			Carbon emissions per unit of GDP(S2)	0.0315
			Tertiary Industry Contribution Rate (S3)	0.0256
			Consumed product ratio of green products(S4)	0.0278
			Per capita green product consumption ratio(S5)	0.0275
	I	0.241	The average temperature change rate of (I1)	0.0304
			Urban air quality compliance rate(I2)	0.0201
			Urban Water Pollution Rate(I3)	0.0315
			The average comprehensive pollution rate of the town(I4)	0.031
			Per capita incidence of respiratory diseases(I5)	0.0295
	R	0.2675	Consumption of Low-carbon Products for Urban Residents (R1)	0.0285
			Urban residents' environmental education(R2)	0.0287
			New energy development penetration rate(R3)	0.0418
			Per capita low-carbon consumption growth rate(R4)	0.0351
			Comprehensive Utilization of Industrial Waste(R5)	0.0332
			Per capita public green area(R6)	0.031
			Forest Coverage (R7)	0.0284
			Low carbon product consumption growth rate(R8)	0.0311