ENVIRONMENTAL SUSTAINABILITY AND SCENARIOS OF URBANIZATION IN ARID AREA
—A Case Study in Wuwei City of Gansu Province

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ABSTRACT: Based on data of questionnaire and field survey and two developing models of Business As Usual (BAU) and the Intensive Urbanization (IU), this article, taking Wuwei City, a medium size city and typical oasis arid area in Gansu Province with very vulnerable and sensitive natural environment but long history of oasis economy, as an example, evaluated the sustainability of its environment and analyzed the scenarios of Wuwei's household energy consumption, waste discharge in transportation industry, primary industry, secondary industry, tertiary industry, by the integration of the systematical dynamics model Stella and Polestar language to simulate the future development of the research area. The results showed that, first, the developing model of IU was propitious to Wuwei City named for oasis economy and vulnerable natural environment. The strategy of "Intensive Urbanization" can change the structure of energy utilization, and improve the efficiency of energy utilization. Second, the proportion of domestic energy consumption will decrease with industrialization and economic development, while that of tertiary industry, secondary industry and transportation will gradually grow up according to strategy of "Intensive Urbanization". Third, the Wuwei City is facing a severe eco-environmental crisis under the conventional patterns of development and a better future under a sustainable urbanization scenario, in the next 10 to 20 years. The different developing trends were clarified and the relative countermeasures were put forward for the policy makers according to the driving forces.

KEY WORDS: impact of urbanization on environment; sustainability of eco-environment; scenario analysis; Wuwei City; arid area

1 INTRODUCTION

The western China is facing growing problems of ecological and economic development. The disparities between the socio-economy of the western and eastern China were enlarging, and the major ecological problems still evolve as past (HU *et al.*, 1995). Too many people concentrated on rural space, exerting great pressure on local ecology and socio-economy. That was the essential barrier impeding the sustainable development (JEROEN, 1996). Wuwei City is one of typical oasis arid areas in Hexi Corridor in developing western China. The eco-system of Wuwei City is very fragile. As we know, the contradiction between economic development and ecological environment in vulnerable area is more and more conspicuous (DONG *et al.*, 1996;

BRENGLE, 1982; SONG *et al.*, 2000). Many cases showed that there are characteristics named Environmental Kuznets Curve between economic development and environment (AGRAS and CHAPMAN, 1999; BERGGREN, 1999; BOULDING, 1966; VINCENT, 1997; TORRAS and BOYCE, 1998). Urbanization is one way to realize eco-economy development in vulnerable area, then we can develop economy and decrease environmental pollution (CONSTANZA, 1991). Urbanization is an important spatial representation of modern society in the aspects of social, economic and cultural behavior (CAMERON, 1993). Urbanization is included in the complex system, which comprises social, economic and ecological factors, and now it becomes one of the driving forces of evolvement of eco-economic system (MALTE *et al.*, 1996). China's average urban-

ization degree has stepped into an accelerating phase, and in the year of 2000, the degree of urbanization was 36.7%. However, in Northwest China's oasis agriculture area the urbanization degree is laggard, and in 2000 the average urbanization degree of Hexi Corridor was only 22.8%, which meant that this area was still in the taking off phase of urbanization. The relative low urbanization degree not only seriously hampered the local social and economic development, but also became the major reason why the eco-environment can not be ameliorated in time. This paper imports the End-Use Analyzing method (EUA) to make a scenario of interactive impact mechanism between the economic, social development and environment on Wuwei City's urbanization. And it is premised in two kinds of developing model, which are Business As Usual (BAU) and Intensive Urbanization (IU) developing models, to analyze the regional environment effectiveness imposed by urbanization.

2 METHOD

2.1 Model Operation Principle

EUA tries to explain the interactive relationship among the human development, nature recourses consumption, and environment quality change. It quantifies the social and economic activities separately, in this way, and calculates macroscopic environment effectiveness by pulsing every predicable and controllable micro behavior's change, thus will offer an operable Decision Support System (DSS) platform for the sustainable development.

First, the model is established according to the interactive mechanism between the local economic social development and the environment effectiveness. It must be tested repetitiously in quality and quantity before operation. In addition, volumes of historical data are needed because they will facilitate quantifying relationships among indexes, and the outputs of historical researches also can be embedded into the model as an inner part to construct a scenario of future development in some aspects. The model is constructed in com-technology, which forecasts the ultimate resources consumption and waste material's emission in every component. So the quantity of total resources consumption and waste emission can be calculated by the following equation:

$$T = \sum_i a_i X_i \qquad (1)$$

where T is the total quantity of resources consumption and waste emission, a_i is corresponding component's end-use or the unit emission level, X_i is intensity of resources consumption or waste emission.

End-use or the unit emission level, i.e. a_i, is determined

by the driving forces, which are the critical dependent variable of system evolution. There are some technical difficulties to get the intensity of resources consumption or waste emission, i.e. X_i. The resources consumption intensity of cardinal year's account is obtained from the average value of survey data. For example, in the modular of per household energy consumption, we use the ratio of population using coal for cooking to the total coal consumption, and then we got the quantity of per capita annual coal consumption by cooking. Here we transform the local coal calorifacient efficiency to the standard unit i.e. joule (J), which is the resources consumption intensity, and this index will be cooperated with another driving force, i.e. growth of population, to determine the total coal consumption in cooking. Another example is the beverage production's power consumption intensity, which is indicated by the number of power consumption per year per unit of production, and the data was still got from the survey practice. The emission intensity of pollution of cardinal year account was got by following two ways. For the energy pollution, we use the China average energy emission intensity, and for the waste water emission intensity, we use the environment quantity data of sampling spot, which were the quantity of special catchment's pollution emission, and the activity level determined primarily by the population and the production value of per unit water consumption.

Establish the EUA database of cardinal year. The cardinal year is the base year of research period, i.e. the start point of scenario. Every EUA index was obtained from the careful field survey to make sure of the accuracy and precision of data. The more multiplex the index, the more real of the scenario, however, the work for gathering the data will be more difficult.

There are two methods in determining the resources consumption intensity and pollution emission intensity. In the BAU module we use the trend forecasting and regression method, which use the change trend of historic data to gain the intensity of resources consumption or the waste water emission. In the intensive development model, we use International Antitheses to get the intensities.

2.2 Management of Database

By questionnaire in field survey and the reading of relative conferences and the consultations of specialists, we got a plenty of data and constructed the database of Wuwei City, which included social, economic and environment datasets. We used the database management software Polestar to organize the datasets. Polestar is the software of SEI to give a scenario of the sustainable fu-

ture, and it had been widely utilized worldwide.

3 RESULTS

3.1 Summary of Scenario

There are two kinds of scenario in this paper, one is under the traditional way—economic, social aspects, and urbanization would develop at present growth rate, i.e. the future society's development will be the prolongation of present state, and abide by the common rule of development, which mainly comprises the general principle restriction and technology restriction. The change of future environment indexes is supposed to be determined by the consuming structure, consumption volumes, investment of amelioration and the environment policy. The other scenario is to stick out of the urbanization strategy, encourages the immigration to the center cities, eliminates the dual social structure and expands the urban civilization. At the same time, within the availability of present technology infrastructure and the economy, there is a scenario of intensive utilization of resources, i. e. the intensity of energy utilization and the pollution emission would be slowed down with the technology improvement and the policy preference.

In the scenario of BAU, the speed of urbanization will be kept at present growth rate. In the IU scenario, the immigration rate of rural area people will grow following the "S" curve in the next 30 years. There are two reasons why there will be a high-speed growth of urbanization in the intensive scenario. The first one is the pulling power from the urban area, and initial help from the government and other regions; the second one is the creative institution, which facilitates the urbanization, will also carry out a large share. The change of rates of urbanization under two different scenarios is shown in Fig. 1.
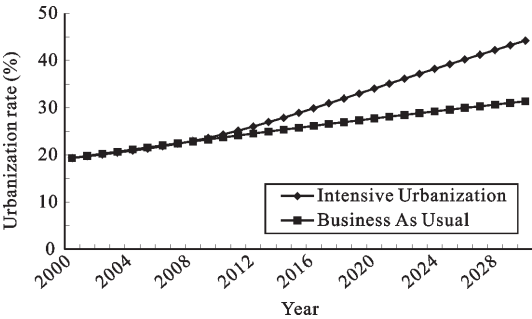

Fig. 1 Urbanization rate under
two different scenarios

3.2 Account of Driving Forces in Cardinal Year

It is pre-defined that the population, GDP and income

distribution are the driving forces, and joined and related to each other terminal unit of consumption. With the changing of driving forces, the quantity changes of social and economic aspects are obvious. To get a more accurate interactive mechanism and the principle of the change of social and economic development, the information about other related indexes are also needed, such as the structure of industry, the production value of each industry, the distribution of income, and the degree of poverty, etc.

Economic statistics as cardinal year of 2000 in Wuwei City are showed in Table 1. The relationship between the driving forces and other indexes is concluded as follows: the population growth will increase the household consumption and agriculture consumption, the need for food and other by products, and the energy consumption of transportation. The increase of GDP will affect the way of traffic and the volume of transportation. The production value of each industry will increase with the development of the industry scale, and the total energy consumption volume, and the total waste emission will be changed if the consumption intensity is not changed. At the same time, the development of economy will facilitate the improvement of the technology. With different improved technology, the intensity of resources utilization and waste emission is different, so the quality of sustainable development will also be different.

Table 1 Economic statistics as cardinal year
of 2000 in Wuwei City

Item	Unit	Value
Population	$\times 10^6$	1.91101
Per capita GDP	yuan (RMB)	3329.5
GDP	$\times 10^9$ yuan	6.3627
Secondary industry adding value	$\times 10^9$ yuan	1.8770
Primary industry adding value	$\times 10^9$ yuan	2.2368
Tertiary industry adding value*	$\times 10^9$ yuan	2.2647
Share of secondary industry adding value	%	29.5
Share of primary industry adding value	%	35.2
Share of tertiary industry adding value	%	35.3
Gini Coefficient	–	0.40
Per capita income	$\times 10^3$ yuan	2.529
Percent of per capita income <625 yuan	%	3
Population with per capita income <625 yuan	$\times 10^3$	57.33

Note: * The data include transportation industry, and do the
same in Table 2, Table 3
Source: Statistical Yearbook of Wuwei City, 2001

3.3 Premise of BAU Model

All of the calculating units of this module are all based on the trend prediction or regression according to the

historical data. And the output of the model indicates that the average nature population growth of Wuwei from 2000 to 2030 will be 0.68‰, which will be a little more in rural areas than the urban areas. The growth rate of GDP will be stable on the level of 8.2% each year. The main growth point of economy will be the secondary and tertiary industries, however, because of the strong foundation of the primary industry, the fundamental statues of agriculture in regional economy will be maintained, but in declined trend. Each industry proportion is planned according to present economic growth trend. The Gini Coefficient is given according to the general rule of the relationship between Gini and economic development. Per capita income and poverty population will be calculated according to the Gini Coefficient. In the model of BAU, each index will change in the following ways (Table 2).

3.4 Premise of IU Model

In this scenario, because the government has adopted inner or outer factors, the urbanization speed will be accelerated, and the immigration from rural areas to urban areas will be continued constantly. For the natural growth rate of urban population is lower than that of rural areas, in this scenario, the total regional population will be smaller than that of the BAU. The average natural growth rate of total population will be 0.67‰ in the first 15 years, and 0.66‰ in the next 15 years. The natural population growth rate of urban areas will be declined to 0.57‰, and that of the rural areas will be 0.75‰. Because of the increase of investment, in the first 15 years, the average growth rate of GDP will be kept the higher speed of 9.0%, and in the next 15 years it will be stabilized at the rate of 8.2%. And the growth speed of proportion of secondary and

Table 2 Driving forces in the BAU scenario

Item	Unit	Value (2015)	Value (2030)
Population	$\times 10^6$	2.1393	2.3906
Per capita GDP	$\times 10^3$ yuan	9.7001	28.3108
GDP	$\times 10^9$ yuan	20.75154	67.67983
Secondary industry adding value	$\times 10^9$ yuan	6.84783	25.04134
Primary industry adding value	$\times 10^9$ yuan	6.22530	15.56624
Tertiary industry adding value	$\times 10^9$ yuan	7.67787	27.07172
Share of secondary industry adding value	%	33	37
Share of primary industry adding value	%	30	23
Share of tertiary industry adding value	%	37	40
Gini Coefficient	−	0.35	0.30
Per capita income	$\times 10^3$ yuan	9.692	32.372
Percent of per capita income <625 yuan	%	1	0.2
Population with per capita income <625 yuan	$\times 10^3$	0	0

tertiary industries will be quicker than that of the BAU model, so the proportion of the primary industry in the economic structure will be declined rapidly and largely (Table 3).

Table 3 Driving forces in the IU scenario

Item	Unit	Value (2015)	Value (2030)
Population	$\times 10^6$	2.1370	2.3835
Per capita GDP	$\times 10^3$ yuan	10.8451	31.7127
GDP	$\times 10^9$ yuan	23.17602	75.5871
Secondary industry adding value	$\times 10^9$ yuan	8.1116	30.23484
Primary industry adding value	$\times 10^9$ yuan	6.25752	13.60568
Tertiary industry adding value	$\times 10^9$ yuan	8.80688	31.74658
Share of secondary industry adding value	%	35	40
Share of primary industry adding value	%	27	18
Share of tertiary industry adding value	%	38	42
Gini Coefficient	−	0.30	0.27
Per capita income	$\times 10^3$ yuan	10.686	36.395
Percent of per capita income <625 yuan	%	0	0
Population with per capita income <625 yuan	$\times 10^3$	0	0

4 SCENARIO ANALYSIS

4.1 Household Energy Consumption

The result of the analyzing of Wuwei resources' press account indicates that, in 2000 the total household energy consumption was 15.00167×10^{15}J, which accounted for 499×10^3t standard coal, and per capita annual energy consumption was 200kg standard coal. Per capita energy consumption in urban area was 8.805×10^9J, that in rural area was 7.364×10^9J.

In the energy consumption structure, as the key energy, the coal consumption accounted for 80% in rural areas, 70% in urban areas, because the infrastructure construction of small towns was relatively slow, and most local residents living energy was still coal. The volume of waste gas produced by daily living energy consumption was totally 1.0936×10^6t, in which rural areas accounted for 937.4×10^3t, and urban areas accounted for 156.2×10^3t. It was impossible to offer centralized warm gas and nature gas through pipelines, as a result that most local farmers could not accept the high-price gas in cans, so the coal was heavily depended on, especially in rural areas. In this module, the waste gas produced by burning coal accounted for 86% of total waste gas.

In the model of BAU, the volume of household energy consumption will increase with the income growth. In energy consumption structure, the consumption intensity of clean fuel such as power, oil will be enhanced increasingly, but which is only confined in urban areas. With the development of economy and growth of income level, some modern house-using equipment will account for more and more proportion, so will the power total consumption volume.

In the large rural areas, it was difficult to utilize the energy in concentrated ways, and the residents' income increase gradually, so coal will continuously account for major proportion. In addition, the energy utilizing efficiency between the rural and urban areas still exists (Table 4).

In IU strategy, the energy consumption volume will

Table 4 Household energy consumption in the BAU scenario of Wuwei City

Item	Energy (Unit)	Rural area (2015)	Urban area (2015)	Rural area (2030)	Urban area (2030)
Population	($\times10^3$)	1679.60	436.30	1762.50	579.10
Proportion	(%)	79.40	20.60	75.30	24.70
Refrigerator	Power ($\times10^{12}$J)	100.80	99.16	158.69	141.70
Lighting	Power ($\times10^{12}$J)	252.00	108.97	264.48	144.59
Air conditioner	Power ($\times10^{12}$J)	0	4.36	0	8.68
Cooking	Coal ($\times10^{12}$J)	4032.06	523.05	4231.74	694.05
	Gas ($\times10^{12}$J)	78.46	182.41	82.34	242.05
	Wood ($\times10^{12}$J)	649.67	40.58	681.84	53.85
Heating water	Coal ($\times10^{12}$J)	2688.04	348.70	2821.16	462.70
	Gas ($\times10^{12}$J)	32.36	147.60	33.85	196.07
	Wood ($\times10^{12}$J)	653.36	0	685.72	0
Warming	Coal ($\times10^{12}$J)	3360.05	653.81	3526.45	867.56
	Gas ($\times10^{12}$J)	0	75.93	0	100.75
	Oil ($\times10^{12}$J)	0	121.00	0	160.56
	Wood ($\times10^{12}$J)	1459.61	0	1531.89	0
Others	Power ($\times10^{12}$J)	168.00	87.18	176.32	115.68

increase with the per capita income's enhancement. The energy consumption structure in urban areas will transform into clean energy with the development of economy and the growth of modernization degree. With the improvement of energy utilization efficiency, intensity of per capita energy consumption will decrease in some degree. In this scenario, the speed of urban population growth will be more rapid than that in the traditional scenario. Affected by the urban household energy consumption structure and the total population tending to be smaller than the traditional scenario, the total energy consumption volume will be less than former scenario (Table 5).

4.2 Household Waste Discharge

According to the classification of household energy consumption, household gas emission of Wuwei is calculated. In BAU model the intensity of water pollution will be kept unchanged, and the total volume of waste discharge will increase with the population growth; in the IU sce-

nario, the total waste volume will be obviously decreased because in the urban areas the disposal and management of waste water is strengthened, and additionally the total population will be smaller than the traditional model (Table 6).

4.3 Traffic and Transportation Industry

In 2000 the total energy consumption of traffic was 5.679173×10^{15} J, while per capita energy consumption intensity was 2.9×10^9 J, the total waste discharge was 336.4975×10^3 t, and the average waste gas emission

Table 5 Household energy consumption in the IU scenario of Wuwei City

Item	Energy (Unit)	Rural area (2015)	Urban area (2015)	Rural area (2030)	Urban area (2030)
Population	($\times 10^3$)	1629.20	483.70	1523.30	807.90
Proportion	(%)	77.10	22.90	65.30	34.70
Refrigerator	Power ($\times 10^{12}$J)	98.40	110.08	156.36	186.86
Lighting	Power ($\times 10^{12}$J)	254.11	120.96	257.94	202.24
Air conditioner	Power ($\times 10^{12}$J)	0	7.26	0	20.22
Cooking	Coal ($\times 10^{12}$J)	3421.00	580.62	3196.77	563.22
	Gas ($\times 10^{12}$J)	152.15	202.49	142.18	437.95
	Wood ($\times 10^{12}$J)	520.69	22.52	588.66	10.30
Heating water	Coal ($\times 10^{12}$J)	2280.66	387.08	2131.18	385.36
	Gas ($\times 10^{12}$J)	62.56	196.83	58.46	383.92
	Wood ($\times 10^{12}$J)	633.54	0	592.01	0
Warming	Coal ($\times 10^{12}$J)	3258.09	665.30	3044.55	736.16
	Gas ($\times 10^{12}$J)	0	134.32	0	311.37
	Oil ($\times 10^{12}$J)	0	150.36	0	224.56
	Wood ($\times 10^{12}$J)	1400.32	0	1322.45	0
Others	Power ($\times 10^{12}$J)	173.66	96.77	152.23	161.79

Table 6 Waste discharge volume in two kinds of scenarios in Wuwei City ($\times 10^3$t)

Emission type	2015 (BAU)	2030 (BAU)	2015 (IU)	2030 (IU)
Coal gas combustion	1088.3222	1418.6134	985.1263	1139.5240
Natural gas combustion	25.3258	31.4657	38.9974	40.5312
Wood combustion	101.6286	83.9610	98.9981	60.3259
Oil combustion	4.4908	5.3909	5.8623	6.5257
BOD in water	15.6576	17.3278	14.3005	15.8993
COD in water	18.8315	20.8402	17.9302	17.8598

intensity was 59×10^9 kg/J.

In both scenarios, with the income increasing, the passenger transportation intensity, especially the average travel distances of urban residents will be enlarged constantly, and the goods transportation volume will be increased with the development of economy, so do the turn-over volumes of both. In the scenario of IU, the rapid growth of urban population accelerates the passenger turn-over volume, the intensity of goods transportation will decrease, however, affected by the economic activities the total goods turn-over transportation volume will increase. In this scenario, contributing to the centralized utilization of energy being emphasized and the quality of vehicles being improved, the energy consumption volume will be declined after 2015, and the trend of this decline is given out by the comparative analysis method. Considering the factors above, it can be concluded that

in both scenarios, the total energy consumption volumes will show the increasing trend, so will the total discharge volume, however, there is still some differences in the increasing degree (Table 7).

4.4 Tertiary Industry

In this paper the tertiary industry is defined as the traditional tertiary industry except the traffic and transportation industry, which includes education, government, administration enterprise, restaurant and hotel, whole sale and retail industry. The energy consumption in tertiary industry is mainly used to lighting, air conditioner cooking, heating, etc. Different urbanization levels affects the driving forces of population, GDP, and income. The change of the driving forces will affect the industry production scale (indicated by the industry additional value), and the terminal energy distribution (indicated by

Table 7 Activity level of traffic and transportation industry and waste discharge volume in Wuwei City

Item	Unit	2015 (BAU)	2030 (BAU)	2015 (IU)	2030 (IU)
Passenger of highway	$\times 10^6$ passage-km	635.50	730.30	655.80	747.00
Passenger of railway	$\times 10^6$ passage-km	289.90	320.80	295.80	334.00
Goods of highway	$\times 10^6$ t-km	2499.90	8724.70	2348.90	8324.50
Goods of railway	$\times 10^6$ t-km	10923.60	38123.30	10657.30	36374.50
Oil consumption (passage transportation)	$\times 10^{15}$J	1134.42	1255.43	1169.27	1330.40
Oil consumption (goods transportation)	$\times 10^{15}$J	11490.95	37560.00	10091.91	37492.03
Waste gas discharge (passage transportation)	$\times 10^3$t	66.49450	81.42710	67.59209	82.93345
Waste gas discharge (goods transportation)	$\times 10^3$t	530.10210	1091.17430	512.30430	9815.75730

the popularization rate of different energy consumption equipments). And the intensity of energy consumption will change with the driving forces and technology innovation. Generally, the intensive utilization degree of energy will be enhanced with the economic development, but this degree will have an obvious improvement in the model of technology innovation (the intensity of energy consumption can be calculated out by the comparative method).   And the possible degree of improvement will depend on the local investment and policy support.   The enlargement of industry scale will affect the change of wastewater,   and the intensity of discharge not only depends on the industry scale,   but also rests on the management and the technology innovation of clean production. Tertiary industry is the main direction of future industry adjustment,   and is also the most rapid growing department in industry adding value.   In the BAU scenario, the energy consumption in tertiary industry will be enlarged constantly because the enhancement of economic activity level,   however,   the intensity of energy consumption and the structure of energy will be maintained as usual for the intensive model of energy utilization is not adopted.   In the IU scenario,   the energy consumption of per unit production value will decrease step by step,   at the same time,   the energy structure will also be major in gas fuel and environment-friendly type. Compared to the traditional model, in the former next 15 years,   the total energy consumption in tertiary industry will be more than that of traditional model,   because of the growth of urban population,   but in the latter next 15 years, the growth rate of energy consumption will be decreased, so will the pollution degree (Table 8).

4.5 Secondary Industry

In 2000 the energy consumption of whole secondary industry was 7.25185×10^{15}J. The waste gas was mainly from coal burning. The industries with highest intensity of energy consumption were paper producing, textile, and non-metal industry, and the ones with highest intensity of waste discharge into waters were also paper producing and textile. Considering from the total gas pollution volume, the non-metal producing industry, which mainly comprises construction industry, is the main source of waste gas, and the next sources are beverage industry, chemical raw material and its production, plastic production and paper producing industry. Considering the wastewater volume, paper-producing industry has much higher discharge than any other industries, and the textile and beverage industries are the next. The energy consumption of per unit production value and intensity of wastewater discharge in the above industries are both high, therefore it is urgent not only to make technology innovation in these industries, but also to think about the developing strategy from the industry adjustment to the industry production's reconstruction and transformation. The beverage, chemical raw material and plastic producing industries have lower energy consumption intensity, but the total volume of waste discharge is huge,

Table 8 Activity level of tertiary industry and waste discharge volume in Wuwei City

Item	Unit	2015 (BAU)	2030 (BAU)	2015 (IU)	2030 (IU)
Adding value	$\times 10^9$ yuan	1.007858	3.957098	1.126281	4.565008
Power	$\times 10^{12}$J	564.40	2191.20	586.67	2215.97
Coal	$\times 10^{15}$J	2.11650	5.30991	1.75700	4.47801
Gas	$\times 10^{12}$J	282.20	1107.99	292.80	2191.20
Oil	$\times 10^{12}$J	1053.35	2239.10	986.00	1799.36
CO_2 discharge	$\times 10^3$t	233.54073	515.33914	201.88321	413.22369
SO_x discharge	$\times 10^3$t	1.44060	3.65630	1.20940	3.03180

so they are also the main units in the environment-friendly technology innovation.

With the processing of urbanization, the speed of the industrialization is accelerated, so the secondary industry's proportion of energy consumption in the whole energy consumption is larger and larger. Because the government has adopted the advantageous industry policy and technology innovation in the clean producing is intensified, the secondary industry has become the most important chain of centralization in regional energy utilization and pollution control. In the BAU scenario the growth speed of industry total production value will continually depend on current booming industry. Under the same energy discharge intension of production value, every industry will maintain its old discharge intension under traditional technology. In the IU scenario, industry value increase will be faster than the former scenario, but the energy consumption per unit will be lower than the traditional scenario. At the same time, it should be paid more attention to the industry structure adjustment and limit some industries' development such as the ones with high-energy consumption and high-pollution. In addition to the increase of technology improvement, there will be a huge decline in the pollution discharge intension and increases in energy consumption intension (Table 9).

4.6 Primary Industry

In the scenario of BAU, the investment in pesticide will be kept growing with the increasing need for food, and the total volume of energy consumption will also increase with the growth of investment in the farming machines. The relationships between the fertilizer and investment of pesticide, the intensity of energy consumption and the economic development degree or planting area, are closely knitted, here it is calculated by their synthetic balanced value. In the IU scenario, the intensity of investment of per unit production value and the energy consumption degree are cut down. At the same time, because the intensive utilization degree of farming machines is improved, the discharge degree of per unit production value is also declined. The consumption of producing material and the change of waste discharge are shown in Table 10.

4.7 Energy

The analysis of cardinal year account indicates that current household energy consumption is the main sources of energy consuming in Wuwei, which accounted for about 54.0% of the total volume. In the structure of energy consumption, coal accounts for 50.1%, in which the household consumption is still the main department of

Table 9 Activity level and waste discharge volume of secondary industry in Wuwei City

Item	2015 (BAU)	2030 (BAU)	2015 (IU)	2030 (IU)
Adding value ($\times 10^9$ yuan)	8.81876	30.77745	9.16741	33.28652
Power ($\times 10^{15}$J)	2.18759	6.05429	2.23050	5.99080
Oil production ($\times 10^{12}$J)	239.16	693.93	300.20	749.40
Coal ($\times 10^{15}$J)	6.85994	9.81360	5.80032	8.00411
CO_2 discharge ($\times 10^3$t)	896.5982	1598.5675	801.3364	1213.3260
CH_4 discharge (t)	9.00	16.40	8.00	12.80
NO_x discharge ($\times 10^3$t)	3.41260	4.01458	2.98870	3.58720
SO_x discharge ($\times 10^3$t)	5.12584	10.13366	4.03250	7.59840
SS discharge ($\times 10^3$t)	21.3396	61.7754	18.9366	56.3222
COD discharge ($\times 10^3$t)	15.18893	46.23381	14.3003	40.5696

Table 10 Activity level and waste discharge volume of primary industry in Wuwei City

Item	2015 (BAU)	2030 (BAU)	2015 (IU)	2030 (IU)
Ammonia fertilizer ($\times 10^3$t)	67.37422	97.78000	64.33020	89.77530
Phosphor fertilizer ($\times 10^3$t)	58.93321	84.35660	57.99380	80.84680
Kalium fertilizer ($\times 10^3$t)	8.69315	12.33150	8.05964	12.00760
Irrigation ($\times 10^6$m^3)	219.6981	235.1062	204.4440	218.7430
Oil ($\times 10^{12}$J)	844.97	1208.70	805.60	1037.90
Power ($\times 10^{15}$J)	2.41759	2.85320	2.21080	2.65430
CO_2 ($\times 10^3$t)	56.17943	61.10050	54.32130	58.93670
SO_x (t)	100.74	128.90	97.20	124.30
NO_x (t)	54.32	70.80	49.90	63.20
CH_4 ($\times 10^3$kg)	1.7666	1.9686	1.7666	1.9686
Waste with NO_2^- and NO_3^- ($\times 10^3$t)	113.2742	138.9723	105.5980	126.7703
Waste with P ($\times 10^3$t)	38.97044	43.55698	369.87440	428.97560

coal consuming, and the traffic and transportation industry is the main department of oil production consumption. Except for the self-supplying areas, all the other regular energies mainly depend on the outer areas' supplying. For the total production volume of coal is relatively huge, in 2000 the regional energy consumption volume was a little smaller than the energy production volume, with a residual of 286.56×10^{12}J. Because the strategic energies such as oil productions and power are non-substituted, the structural lack of energy still exists.

According to the survey data of Wuwei Water Conservancy Administration, the exploitable water energy is 2.628×10^{15}J, of which 121.61×10^{12}J have been exploited, indicating that there are still 2.50639×10^{15}J of potential energy for mining. The proved volume of coal is 427×10^{6}t, and the current exploiting volume is 12×10^{6}t per year, so in short time the coal's total supplying volume will not be declined (Table 11).

Energy will be another limiting factor to the sustainable development of Wuwei in addition to the water resources. And the structural change of energy will be main difference between two kinds of scenarios. In the model of IU, more energy is supplied by clean source and the consumption of coal will decrease. At present, most of energy is from local source. At the end of 2015 in the two models, the external supply will have been main source of energy in this area. At the end of 2030, the self-supplying degree will have been less than 35% in both scenarios.

In the model of BAU scenario, the water level will be lower because of the over-exploitation of urban underground water, grassland will be decreased in the former 15 years, however, the habitant area will increase because of the growing population, especially rural population. The growing pace of desertification will slow down because there will be no land suitable for plantation, and

Table 11　Energy demand volume in two kinds of scenarios (J)

Module	Energy	BAU		IU	
		2015	2030	2015	2030
Household consumption	Coal	11606.06	12630.33	10592.75	10057.24
	Oil	121.00	160.56	150.36	224.56
	Gas	516.76	655.60	748.53	1333.88
	Power	820.47	1010.14	861.24	1137.62
Transportation	Oil	12625.37	38815.43	11261.18	38822.43
Tertiary industry	Coal	2116.50	5309.90	1757.00	4478.01
	Oil	1053.35	2239.10	986.00	1799.36
	Gas	282.20	1107.99	292.80	2192.20
	Power	564.40	2192.20	586.67	2215.97
Primary industry	Oil	844.97	1208.70	805.60	1037.90
	Power	2417.59	2853.20	2210.80	2654.30
Secondary industry	Coal	6859.94	9813.67	5800.32	8044.11
	Oil	239.16	693.93	300.20	749.40
	Power	2187.59	6054.29	2230.50	5999.00
Sum		42255.36	84745.04	38583.95	80745.98

the forest land will be decreased . In the scenario of IU, urban economy will improve, and the urban population will grow, while the rural population will decrease. With the emigration of rural population, water using in the agriculture irrigation will be under control, and at the end of 2009, the stress to underground water will be alleviated. Because of a comparative smaller population in IU model, the inhabitant land will consequently be less. After 2013 the number of stock will decrease, then the bearing stocks per hectare will be less, and after the year 2015, there will be a stable growth of grassland.

5 CONCLUSIONS

(1) The strategy of IU can make change in energy utilization structure, and improve the energy utilization efficiency. In the model of IU the driving forces will continually increase, however, the intensity of resources consumption and the waste discharge will be decreased, at last, the aim of environment protection will be fulfilled. The output of end-using analysis indicates that by 2015, the difference of total emission volume of CO_2 between two kinds of scenarios will have been 300×

Table 12 Total waste discharge in two kinds of scenarios

Total waste	2015 (BAU)	2030 (BAU)	2015 (IU)	2030 (IU)
$CO_2 (\times 10^6 t)$	2.3145800	4.5291592	2.0059695	4.0033276
$CH_4 (\times 10^3 t)$	2.40836	4.61671	2.08724	4.05337
$NO_x (\times 10^3 t)$	8.29971	15.50542	7.15235	13.20433
$SO_x (\times 10^3 t)$	13.31742	26.63485	11.54177	21.30788
COD $(\times 10^3 t)$	30.84653	63.56161	28.6008	56.4689
BOD (Living) $(\times 10^3 t)$	18.8315	20.8402	17.9302	17.8598
SS (Industry) $(\times 10^3 t)$	21.3396	61.7754	18.9366	56.3222
Waste with NO_2^- and NO_3^- $(\times 10^3 t)$	113.2742	138.9723	105.5980	126.7703
Waste with P $(\times 10^3 t)$	38.97044	43.55698	369.8744	428.9756

$10^3 t$; by the year 2030 the difference will have been $500 \times 10^3 t$ (Table 12).

(2) The household energy consumption's proportion to the regional energy consumption will be decreased with the improvement of industrialization level and development of economy, and the proportion of tertiary, secondary and traffic industries will be gradual grow up. In the strategy of IU, the total household energy consumption will be decreased from 54.0% in 2000 to 32.0% in 2015, and till 2030 it will be to 15.8%. In contrast, the proportion of traffic energy consumption will be increased from 20.4% in 2000 to 29.2% in 2015 and 48.0% in 2030. The regional energy consumption's structure will be transformed from the dominant house hold consuming to three units, which are household consuming, traffic and secondary industries.

(3) The intensity of per capita energy consumption in rural area is smaller than that in urban areas, however, the intensity of coal consumption is higher than that in urban areas, and so does the intensity of waste discharge. In 2000 the household daily life's CO_2 emission volume was $937.4 \times 10^3 t$, which accounted for 60.7% of the total volume of whole city's CO_2 emission, and the emission of SO_x in rural areas accounted for 55.9%. The distributed, inefficient utilization style and the energy consumption structure of mainly coal consumption were the reasons why the laggard area's air pollution emissions were relatively higher. For there will be more clean energy utilization like power and gas in household energy consumption, by the year of 2015 compared to the traditional scenario, there will have been $103.1959 \times 10^3 t$ household-consuming waste gas reduced in IU, and by the year of 2030, there will have been $279.0894 \times 10^3 t$ reduced.

(4) The need for the fertilization will be still increased in the next 30 years, and the plane pollution of agriculture will be more serious. The N, P pollution will keep growing, which affects the recycling utilization of groundwater. In the strategy of IU a higher per capita income will be more beneficial for farmers to actively engage in the ecological agriculture and adopt advanced biotechnology. According to the trend that, with the development of economy, the worldwide agriculture is more and more ecological, so the N, P pollution in agriculture will be under control.

(5) The interactive analyzing of economic-social development and the environmental evolvement indicates that, the IU strategy is the basic development strategy for Wuwei's economic development, social advance and environment amelioration. The current phase is still the take-off phase, so it is difficult for Wuwei City to accelerate the industrialization and modernization relying on its own accumulation, and the capital, technology and intelligence supports are all needed. To fundamentally resolve the eco-environment problem, honestly speaking, it can depend on neither planting trees nor planting grass, however, it relies on the western modernization. And it needs large and active progress in industrial structure adjustments, the construction of urban infrastructure, and the construction of intensive resources utilization system, so the IU strategy is the preferable strategy for region's development.

(6) At present, it is difficult for Wuwei City to accelerate the industrialization based on its own accumulation. The supports of capital, technology and intelligence were required. Since the urbanization is a carrier of modernization, the self-innovations of laggard areas, including the innovations of institution, technology, and concept, were the essential conditions for the implementation of "Intensive Urbanization" strategy.

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