On behalf of

Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Federal Ministry for the Environment, Nature Conservation and Nuclear Safety

of the Federal Republic of Germany

Jiangsu Low Carbon Development Program

江苏低碳发展项目

县市级层面碳减排潜力研究

——以常熟、如皋为例

Carbon Reduction Potential Analysis of GHG Emission at County Level

江苏省发展和改革委员会

Jiangsu Development and Reform Commission

德国国际合作机构

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2012 年 3 月

March 2012

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Abstract

Climate change has become a global problem, and curtailing GHG emissions has been an important way for human to mitigate and adapt to it. This report chooses Changshu and Rugao which are typical South and North Jiangsu counties as study cases, and calculates the energy consumption and carbon emissions of the two counties in 2005-2010. From 2005 to 2010, energy consumption and carbon emissions of Changshu and Rugao have been increasing obviously, respectively, carbon emissions of Changshu increased from 25.10 Mt in 2005 to 36.71 Mt in 2010, and of which Rugao increased from 3.51 Mt in 2005 to 6.49 Mt. What's more, this study develops a set of analysis method of calculating emission reduction potential suitable for county-level city based on scenario analysis. After that we use this calculation method to predict carbon emission trends in the two counties, and obtain differences on developing low-carbon economy between South and North Jiangsu counties. Through analyzing the carbon emission trend during the 12th five-year plan period, till 2015 carbon emissions of two counties will increase year by year. In BAU scenario, carbon emissions of Changshu and Rugao will go up to 49.29 Mt and 10.95 Mt separately, with an annual growth rate 8.95% and 11.57% correspondingly. And in the two integrated reduction scenarios, potential reduction scale will be 5.32 Mt – 10.96 Mt and 1.49 Mt – 2.16 Mt. Changshu's potential reduction is mainly contributed by industrial sector, and its contribution rate is 80.34%; the next is transport sector, coming up to 17.63%. While Rugao's reduction potential is supported by both industrial sector (57.47%) and transport sector (39.46%).

Carbon Reduction Potential Analysis of GHG Emission at County Level

Case of Changshu and Rugao

1 Background Introduction

Global warming is a threat to the living and development of humanity. Meanwhile, the deterioration of the global climate caused by the rising concentration of CO_2 is one of the main environmental problems with the rapid development of cities and the fast growing of population, economy, manufacturing and energy consumption. Climate change is the common challenge internationally, making the development of low-carbon economy the global goal.

The development of low-carbon economy is an effective measure to avoid the threat of climate change, and it is a request for the realization of scientific development and sustainable development. What's more, it is a necessary choice for the relief of energy and environment pressure, the protection of the security of economy, the optimization of industrial structure and the enhancement of national competitive force. As a result, G8 summit on July 9th, 2009, the eight countries committed that they would cut off the international GHG emissions by 50% by the year of 2050 together with other countries, with the goal of controlling global temperature rising within 2℃ based on the level prior to industrialization. They also committed that developed countries would cut off their GHG emissions by 80% based on 1990 or a year after. In November, 2009, before the COP 15 Copenhagen climate change conference, China made a responsible promise to the world that by 2020, the CO_2 emission per GDP would be cut off by 40%-45% compared to 2005.

Jiangsu Province has made a target to cut off CO_2 emission in the 12th five-year plan and has allocated it to the counties within Jiangsu. The 52 counties are playing important roles in carbon reduction as they reporting to the government of Jiangsu directly of their performance. Therefore, carbon reduction potential analysis of GHG emissions at county level is of a high significance.

Taking Changshu, the county in South Jiangsu, and Rugao, the county in North Jiangsu as examples, this research systematically checks their energy consumption and CO_2 emission from 2005 and 2010. Based on scenario analysis, this paper proposes a systematical method applying to the analysis of carbon reduction potential of GHG emissions at county level. We use the method to forecast the trend of carbon emissions of the two counties and try to find out the similarities and differences in the development of low-carbon economy and carbon reduction between counties in North and South Jiangsu.

2 Methodology

2.1 Accounting methods for various sectors

The scope of carbon emissions inventory should be defined clearly to ensure the results are comparable. The objective of this study is to evaluate GHGs emissions from human activities of a county, which include GHGs generated in energy consumption process and un-energy consumption sectors. Energy consumption sectors include industrial, transport, agricultural and household & commercial construction energy, while un-energy consumption sectors include industrial production process and waste treatment, discharging GHGs, such as CO_2 or N_2O, into the air. In this study, carbon emissions are expressed in carbon dioxide equivalents (CO_{2e}). GHGs emissions, including CO_2, CH_4, N_2O, CF_4 and C_2F_6, are transferred into CO_{2e} emissions by multiplying global warming potential (GWP) parameters, which are respectively 1, 21, 310, 6500 and 9200, recommended by IPCC (IPCC, 2006). Fig.1 shows the carbon accounting boundary (within dotted box) and sectors in this study.

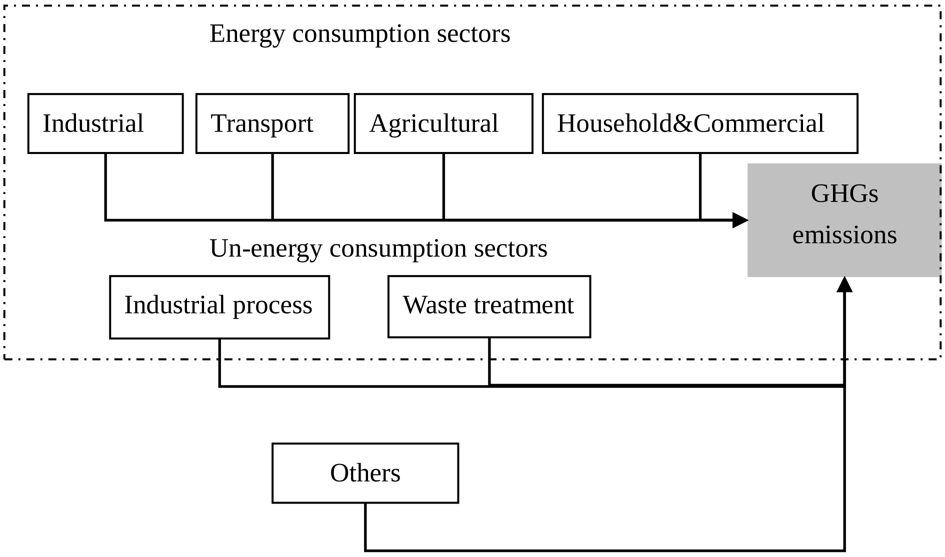

Fig.1 Carbon accounting scope in this study

2.1.1 Industrial energy consumption

The carbon emissions from industrial energy consumption contain two parts: the primary and the second energy consumptions. Carbon emissions from industrial energy consumption sector are calculated through Equation (1).

$$E_I = \sum_{i,j}\left[C_{i,j} \cdot EF_j\right] \tag{1}$$

Where, E_I is carbon emissions from industrial energy consumption sector, t-CO_{2e}; i is industrial sub-sectors (e.g. textile, steel making, and etc); j is energy types (e.g. crude coal, gasoline, nature gas, and etc); $C_{i,j}$ is the amount of energy consumed by industrial sub-sector i in energy type j, unit (ton, m^3, kWh, GJ and etc); EF_j is carbon emission factor of the energy type j (t-CO_{2e} per unit).

2.1.2 Transportation energy consumption

Transportation sector usually includes the on-road, water and air transport. Road transport is the main contributor which account for over 70% of the total carbon emissions in this sector (He et al, 2005). For the lack of information of the water and air transport in China's cities, we only calculate carbon emissions from road transport in this study. The carbon emissions are calculated for each vehicle fleet, such as passenger car, truck (heavy, medium, light and micro), motorcycle and etc, and summed to get the total emissions (Equation 2).

$$E_{\mathrm{T}} = \sum_i \left[VP_i \cdot VMT_i \cdot FE_i \cdot EF_{g/d} \right] \cdot 10^{-6} \tag{2}$$

Where, E_T is carbon emissions from the road transportation sector, t-CO_{2e}; VP_i is the population of vehicle fleet i, vehicles; VMT_i is the annual average kilometers traveled by vehicle fleet i, km/vehicle/year; FE_i is fuel economy of vehicle fleet i, L/km; $EF_{g/d}$ is carbon emission factors for gasoline or diesel, g-CO_{2e}/L.

2.1.3 Household and commercial energy consumption

Household and commercial energy consumption sector includes construction process, commercial energy consumption, and household energy consumption.

2.1.3.1 Construction process

Electricity is the main energy consumption of construction process, carbon emissions are calculated for this sector in this study are shown in equation 3.

$$E_{construction}=C*EF \tag{3}$$

Where, $E_{construction}$ is carbon emissions from construction process, t-CO_2; C is electricity consumption, 10^4 kWh; EF is carbon emission factor for electricity, t-CO_{2e}/10^4 kWh.

2.1.3.2 Commercial energy consumption

Carbon emissions by using electricity are calculated for commercial energy consumption sector in this paper as shown in equation 4.

$$E_C = C \cdot EF \tag{4}$$

Where, E_C is carbon emissions from commercial energy consumption sector,

$t\text{-}CO_{2e}$; *C* is electricity consumption (10^4 kWh); *EF* is carbon emission factor for electricity ($t\text{-}CO_{2e}/10^4$ kWh).

2.1.3.3 Household energy consumption

Carbon emissions from both primary and secondary energy consumption are calculated for the household energy consumption sector in daily life (Equation 5).

$$E_R = \sum_i [C_i \cdot EF_i] \tag{5}$$

Where, E_R is carbon emissions from the household energy consumption sector, $t\text{-}CO_{2e}$; C_i is the amount of energy consumption in type *i*, unit (ton, m^3, kWh, etc); EF_i is carbon emission factors of energy type *i*, $t\text{-}CO_{2e}$ per unit.

2.1.4 Agricultural energy consumption

Electricity consumption during the agricultural activities is the main energy consumption of agriculture, of which carbon emissions for this sector is shown in equation 6.

$$E_{agricultural}=C*EF \tag{6}$$

Where, $E_{agricultural}$ is carbon emissions from construction process, $t\text{-}CO_2$; *C* is the amount of electricity consumption, 10^4 kWh; *EF* is the carbon emission factor for electricity, $t\text{-}CO_{2e}/10^4$ kWh.

2.1.5 Industrial process

There is only one kind of industrial production- cement in one of the counties, so we just account for carbon emissions fromthe process of cement production using Equation （7）.

$$E_c=C*EF \tag{7}$$

Where, E_C is carbon emissions generated from cement production, $t\text{-}CO_{2e}$; *C* is the amount of cement clinker production, ton; *EF* is the emission factor of clinker,

$t-CO_{2e}$/t-clinker.

2.1.6 Solid waste

CH_4 generated from the solid waste landfill accounts for 97% of the total GHGs emissions of the waste treatment sector (IPCC 2006). Solid waste includes two parts which are respectively industrial solid waste and municipal solid waste. In this study, we used IPCC recommended approach of First Order Decay Model to calculate carbon emissions from landfill waste (Equation 8). This approach, however, requires ideally at least 20 or more years of landfill data and good estimates of decay coefficients. The data of industrial solid waste were obtained through the county statistical yearbooks, and municipal solid waste productions were estimated based on the populations of counties. Because there are few studies with GHGs emissions from landfills in Chinese cities, we applied the IPCC's recommended parameters for developing counties.

$$E_W = 21 \cdot \left[\sum_x CH_{4\ x,T} - R_T \right] \cdot (1 - OX_T) \tag{8}$$

Where, E_W is CO_{2e} emission from landfill waste, $t\text{-}CO_{2e}$; $CH_{4\ x,T}$ is the CH_4 production for inventory year T and waste type x, ton; R_T is CH_4 recovery for inventory year, ton; OX_T is the oxidation factor for inventory year T, %; The value 21 is the global warming potential of methane.

2.2 Method of scenario analysis

Referring to the development of economy, society and technology among each county in the 11th five-year plan and the targets of the 12th five-year plan, this research adopts the method of scenario analysis to set three different scenarios to forecast the energy consumption and carbon emission during the 12th five-year. The three scenarios are business-as-usual (BAU) scenario, integrated reduction-low (ITL) scenario and integrated reduction-high (IRH) scenario. We then provide the carbon reduction potential range separately regarding to the 3 scenarios mentioned above.

2.2.1 Industrial energy consumption

The industries are chosen according to the principles below. (1) Industries with enormous energy consumption. (2) Industries with enormous total output value. (3) Main industries involved in the modulation of industrial structure among counties. Industries which correspond to at least one of the three principles would be chosen into the range of scenario analysis. This report mainly considers the 17 industries below: the textile industry; paper and paper products industry; chemical raw materials and chemical products manufacturing; pharmaceutical manufacturing; the chemical fiber industry; the plastic products industry; non-metallic mineral products industry; ferrous metal smelting and rolling processing industry; non-ferrous metal smelting and rolling processing industry; fabricated metal products; general equipment manufacturing; special equipment manufacturing; transportation equipment manufacturing; the manufacturing of electrical machinery and equipment; communications equipment, computers and other electronic equipment; instrumentation and culture, office machinery manufacturing; electricity, steam, hot water production and supply.

The forecast of industrial energy consumption is based on the total output value of industrial departments and the energy consumption per output value. The equation can be summarized as follows:

Industrial energy consumption=Industrial total output value*energy consumption per output value

- **BAU scenario**

Assumption:

1. Industrial structures changed according to the trend of the 11th five-year

plan[1].

2. The levels of industrial technologies changed according to the trend of the 11th five-year plan.

The proportion of the output value for each industry of total industrial output value can be calculated from the industrial structure and the energy consumption per output value can be calculated from the levels of industrial technology. We calculate the output value of each industry and then the energy consumption and carbon emission of each industry according to the forecast of total industrial output value and the proportion of each industry in BAU scenario from the proportion of the 3 industries. Follows are the same.

- **Integrated reduction-low scenario**

Assumptions:

1. Industrial structures changed[2].
2. The levels of industrial technologies changed.

- **Integrated reduction-high scenario**

Assumptions:

1. Industrial structures further changed based on IRL[3].

The levels of industrial technologies further changed based on IRL.

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[1] In BAU scenario, the specific settings of modulus of the two counties ‘ industrial energy consumption are shown in attached table 1-12 ;

[2] In IRL scenario, the specific settings of modulus of the two counties ‘ industrial energy consumption are shown in attached table 13-22 ;

[3] In IRH scenario, the specific settings of modulus of the two counties ‘ industrial energy consumption are shown in attached table 23-32.

2.2.2 Transportation energy consumption

The forecast of transportation energy consumption is based on the population of vehicle fleet and fuel economy. The equation can be summarized as follows:

Transportation energy consumption=population of vehicle fleet*yearly average mileage/fuel economy

This research just takes the changes of the population of vehicle fleet into consideration, assuming yearly average mileage and emission factors being constant. In forecasting the changing trend of future population of vehicle fleet, we use elastic coefficient method, as to consider the population of vehicle fleet is related to GDP. Therefore, we can calculate future population of vehicle fleet according to the trend of future GDP.

- **BAU scenario**

Assumption: The population of vehicle fleet changed according to the trend of the 11^{th} five-year plan, which means that the elastic coefficient would remain the average of during the 11^{th} five-year plan in the range of forecasting years.

- **Integrated reduction-low scenario**

Assumption: The elastic coefficient between the population of vehicle fleet and GDP is 0.8 time multiplying that in the BAU scenario.

- **Integrated reduction-high scenario**

Assumption: The elastic coefficient between the population of vehicle fleet and GDP is 0.5 time multiplying that in the BAU scenario.

This research assumes that the proportion between different types of motorcycles remains the same. Then we calculate the population vehicle fleet of different types based on the total amount and then the energy consumption and carbon emission of each type.

2.2.3 Household and commercial energy consumption

2.2.3.1 Construction period

The forecast of the energy consumption during construction period is based on the augment value during that period and energy consumption per augment value. The equation can be summarized as follows:

Energy consumption during building consumption period=The augment value during building construction*energy consumption per augment value

- **BAU scenario**

BAU scenario only considers the change of the augment value with construction, assuming that energy consumption per augment value is constant. We calculate the energy consumption and carbon emission during building construction period according to the forecast of the augment value in construction in BAU scenario from the proportion of the 3 industries[4].

- **Integrated reduction-low scenario**

Based on BAU scenario and the reduction of energy consumption per GDP in the 12th five-year plan, we assume that the reduction of energy consumption per augment value is 7% yearly for the two counties, and then calculate the energy consumption and carbon emission during construction according to the forecast of the augment value in construction in IRL scenario from the proportion of the 3 industries.

- **Integrated reduction-high scenario**

Based on IRL scenario and the further reduction of energy consumption per augment value, we assume that the reduction of energy consumption per augment

[4] The proportions of the 3 industries are shown in attached table 33-36, and of which primary industry is agriculture, second industry includes industry and building (which means construction process in this report) sectors, and tertiary industry is commercial building.

value is 10% yearly for the two counties, and then calculate the energy consumption and carbon emission during construction according to the forecast of the augment value in construction in IRH scenario from the proportion of the 3 industries.

2.2.3.2 Commercial building operation period

The forecast of the energy consumption during commercial building operation period is based on the augment value during that period and energy consumption per augment value. The equation can be summarized as follows:

Commercial energy consumption=The augment value during commercial building operation*energy consumption per augment value

- **BAU scenario**

According to the trend of energy consumption per augment value for commercial building from 2005-2010, we forecast its energy consumption per augment value from 2011 to 2015. The corresponding decrease for Changshu is 4.22% while the increase for Rugao is 2.19% yearly. We then calculate the energy consumption and carbon emission for each industry according to the forecast of the augment value for the 3rd industry in BAU scenario from the proportion of the 3 industries.

- **Integrated reduction-low scenario**

Based on BAU and the 12th five-year plan for each county, the energy consumption per augment value is reduced. The corresponding decrease for Changshu is 5% while the increase for Rugao is 1% yearly. We then calculate the energy consumption and carbon emission for each industry according to the forecast of the augment value for the 3rd industry in IRL scenario from the proportion of the 3 industries.

- **Integrated reduction-high scenario**

Based on IRL scenario, the energy consumption per augment value is further reduced. The corresponding decrease for Changshu is 7% while the decrease for

Rugao is 1% yearly. We then calculate the energy consumption and carbon emission for each industry according to the forecast of the augment value for the 3rd industry in IRH scenario from the proportion of the 3 industries.

2.2.3.3 Household building operation period

The forecast of energy consumption during household building operation period is based on the total area of household building and the energy consumption per area. The equation can be summarized as follows:

Household energy consumption= total area of household building*energy consumption per area

- **BAU scenario**

The total area for household building from 2011 to 2015 can be forecasted according to the increasing trend from 2005 to 2010. The yearly growth rate for Changshu is 6.02% while for Rugao is 1.50%. Similarly, the energy consumption per area from 2011 to 2015 can be forecasted according to increasing trend. The yearly growth rate for Changshu is 2% while for Rugao is 11%. The household building energy consumption and carbon emission can be calculated afterwards.

- **Integrated reduction-low scenario**

In this scenario, the yearly growth rates of total area of household building for 2 counties are both 8% and the yearly growth rate of energy consumption per area is 1% for Changsu while it is 8% for Rugao. The household building energy consumption and carbon emission can be calculated afterwards.

- **Integrated reduction-high scenario**

In this scenario, the growth rate of total area of household building is further enhanced to 10% for the both counties. And the yearly growth rate of energy consumption per area for Changshu is the same as 2010 while for Rugao it is 5%. The household building energy consumption and carbon emission can be calculated afterwards.

3 Case Analysis

3.1 Country background introduction

3.1.1 Changshu

Changshu, a county of Jiangsu lies in the south-east of the province. It is famous for its long history of culture and humanity, beautiful natural scenery and abundant products and resources. Changshu is in the center of Shanghai economic circle, the most active area of China's economy. With 1263 square km for city area, it has a location advantage, bordering with Shanghai, Suzhou, Wuxi and Yangtze River, with Nantong across Yangtze River. Changshu has a population of 1.07 million in 2010, the majority of which being ethnic Han and the growth rate being -1.7%. The urbanization rate is 51.2%. In the near 20 years, Changshu has maintained its economic growing rate above 15%, with the strikingly enhanced integrated strength. Especially in recent years, export-oriented economy is developing in a dramatic speed and the environment for investment is continuously improving. In September, Changshu won the second place in Forbes county level city in mainland China, being a typical economically powerful county in south Jiangsu.

3.1.2 Rugao

Rugao lies in the north side of Yangtze River delta, with Zhangjiagang across the river. It has a city area of 1477 square km, bordering with Tongzhou district, Rudong county, Haian county, Taixing county and Jingjiang county. Rugao has the population of 1.412 million, with a -0.32% population growing rate. Since the 11th five-year plan, Rugao's economy is developing at a fast speed, with output value continuously growing fast and economic strength being enhanced. In 2010, the output value of Rugao is 43.099 billion, with a growth rate of 14.3% compared to last year; the industrial increase value is 20.795 billion, with a growth rate of 16.2%; the increase value of the 3rd industry is 14.480 billion, with a growth rate of 14.1%. Rugao is in the middle of industrialization, and the heavy chemical industries of high fund and knowledge are basic raw material industries, which contribute significantly to the fast growing economy of the region. Rugao is a typical county in north Jiangsu, with the fast economic growth serving as both a support and challenge for the construction of low-carbon city.

3.2 Energy consumption status

3.2.1 Total energy consumption

Table 1 Energy consumption per GDP and total energy consumption of two counties

Changshu				
Year	**Total energy consumption(10^4 tce)***	**Indices of gross domestic product****	**GDP changeless price(10^8 Yuan)*****	**Energy consumption per GDP(tce/10^4 Yuan)**
2005	1015.08	1.00	678.78	1.50
2006	1205.68	1.15	704.34	1.71
2007	1255.36	1.32	736.13	1.71
2008	1330.27	1.49	772.94	1.72
2009	1452.21	1.67	735.58	1.97
2010	1487.23	1.88	771.59	1.93
Rugao				
Year	**Total energy consumption(10^4 tce)***	**Indices of gross domestic product****	**GDP changeless price(10^8 Yuan)*****	**Energy consumption per GDP(tce/10^4 Yuan)**
2005	132.61	1.00	154.97	0.86
2006	116.63	1.15	166.60	0.70
2007	143.40	1.32	180.67	0.79
2008	166.19	1.49	215.07	0.77
2009	194.53	1.67	212.27	0.92
2010	247.16	1.88	228.78	1.08

Note: *Total energy consumption is summed up by sectoral energy consumption;

** Indices of gross domestic product of 2006-2009 are provided by the statistical yearbook of Jiangsu Province;

*** GDP changeless price are based on the year of 2005, and are stand on the indices of gross domestic product.

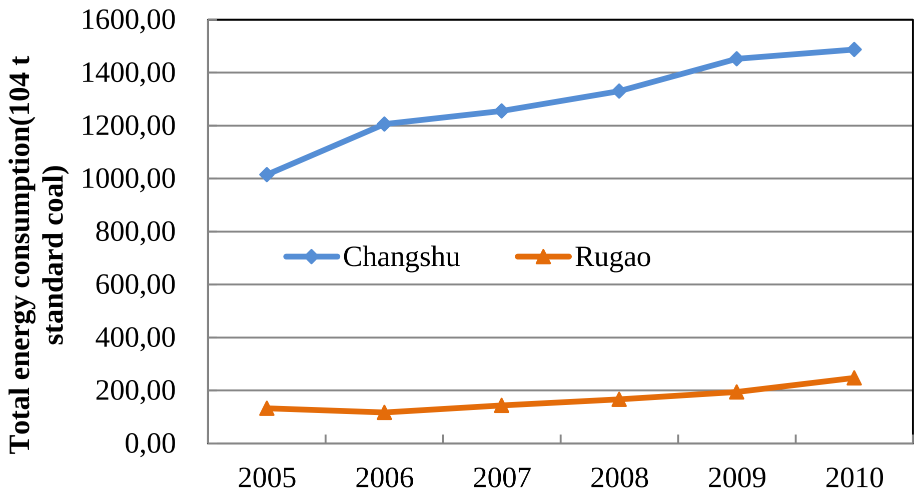

Fig.3 Total energy consumption of two counties, 2005-2010

As shown in Table 1 and Fig.3, Changshu and Rugao's energy consumption per unit GDP increased from 1.50 tce/10^4 Yuan and 0.86 tce/10^4 Yuan in 2005 to 1.93 tce/10^4 Yuan and 1.08 tce/10^4 Yuan in 2010 separately. Generally, it's increasing year by year. At the same time, the total energy consumption of the two counties is rising from 10.15 M tce and 1.33 M tce to 14.87 M tce and 2.47 M tce, with the growth rate of 7.94% and 13.26% separately.

3.2.2 Categorical energy consumption

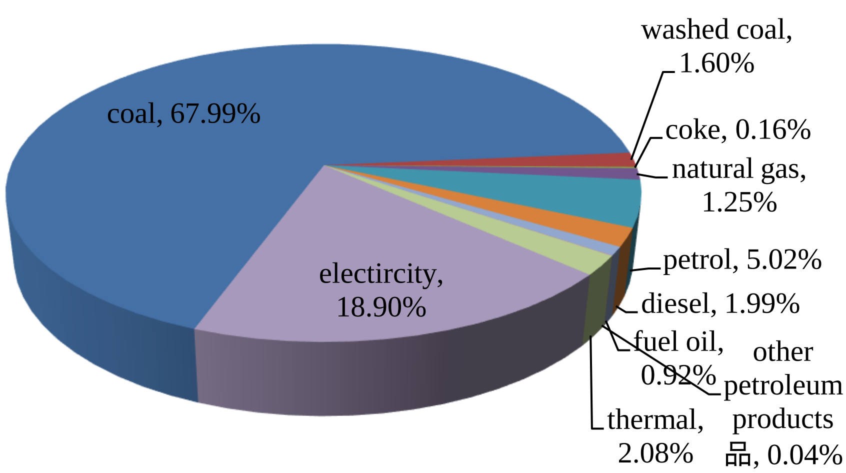

Fig.4 Energy consumption structure of Changshu

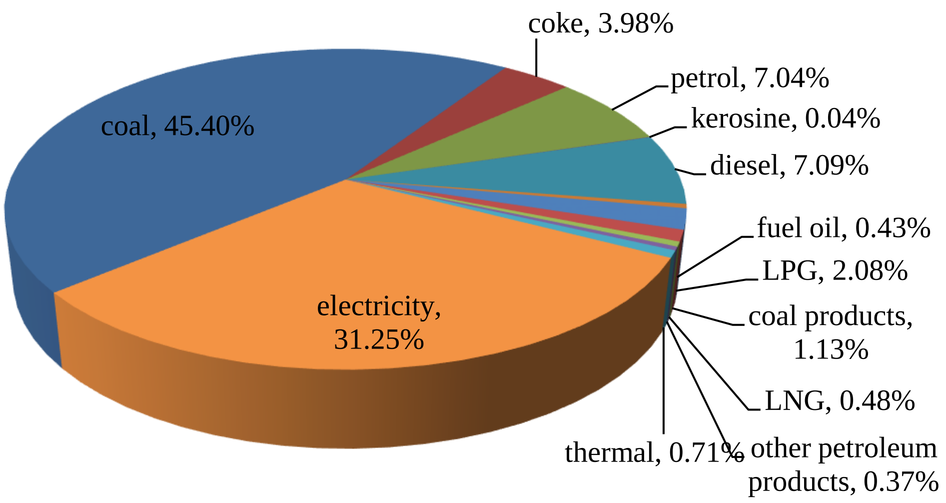

Fig.5 Energy consumption structure of Rugao

From the energy consumption structure of Fig.4 and Fig.5, the energy consumption of Changshu and Rugao is mainly consisted of coal and electricity, particularly in Changshu, the of which percentage of coal and electricity reaches to 86%.

3.2.3 Sectoral energy consumption

Table 2 Sectoral energy consumption of Changshu and Rugao (Unit: 10^4 tce)

Changshu							
Sector \ Year		**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
Industrial	**Above-scale**	847.58	1008.84	1052.54	1109.89	1204.43	1223.25
	Below-scale *	565.05	672.56	701.69	739.93	802.95	815.50
Transportation		34.33	39.47	46.31	51.31	65.68	70.41
Building		37.56	43.80	38.41	44.60	47.10	56.29
Agricultural		1.44	1.47	1.15	1.14	1.18	1.37
Total		1485.96	1766.14	1840.10	1946.87	2121.34	2166.82
Rugao							
Sector \ Year		**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
Industrial	**Above-scale**	60.90	48.70	64.02	74.71	87.19	111.95
	Below-scale **	40.60	32.47	42.68	49.81	58.13	74.63
Transportation		15.65	18.10	21.36	23.52	28.51	34.55
Building		12.67	14.87	13.50	16.66	19.19	24.52
Agricultural		2.78	2.50	1.84	1.49	1.51	1.51

Total	132.60	116.64	143.40	166.19	194.53	247.16

Note:* Changshu's Energy consumption of below-scale enterprises is speculated according to above-scale enterprises. As Suzhou's energy consumption of above-scale accounts for 86% of total industrial energy consumption, and Suzhou's above-scale enterprises are more developed than Changshu, this study assumes that Changshu's energy consumption of below-scale accounts for 90% of total industrial energy consumption;

**Rugao's Energy consumption of below-scale enterprises is also speculated according to above-scale enterprises. According to the telephone survey with Zhu Captain in Industrial Statistics Office of Rugao Municipal Bureau of Statistics, Rugao's above-scale enterprises accounts for 60%-70% of total industrial energy consumption, so this study assumes that Rugao's energy consumption of below-scale accounts for 60% of total industrial energy consumption.

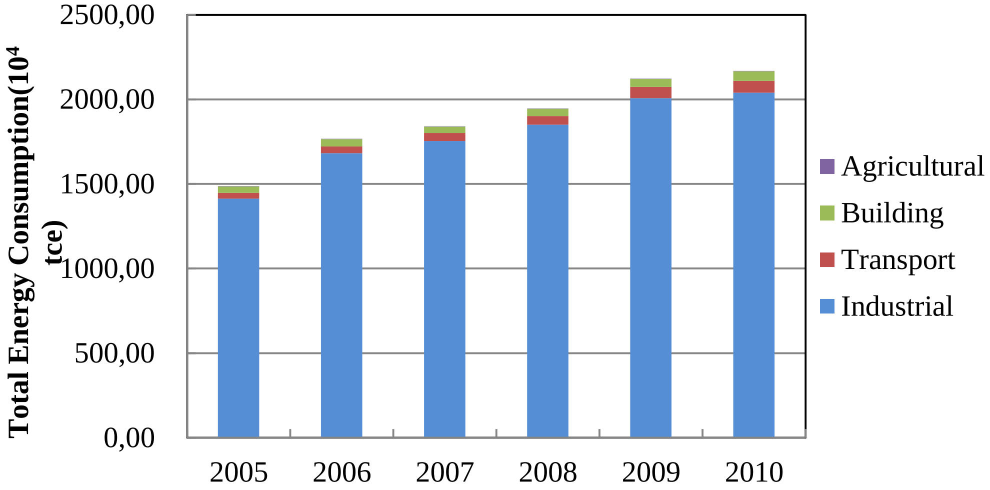

Fig.6 Sectoral energy consumption of Changshu

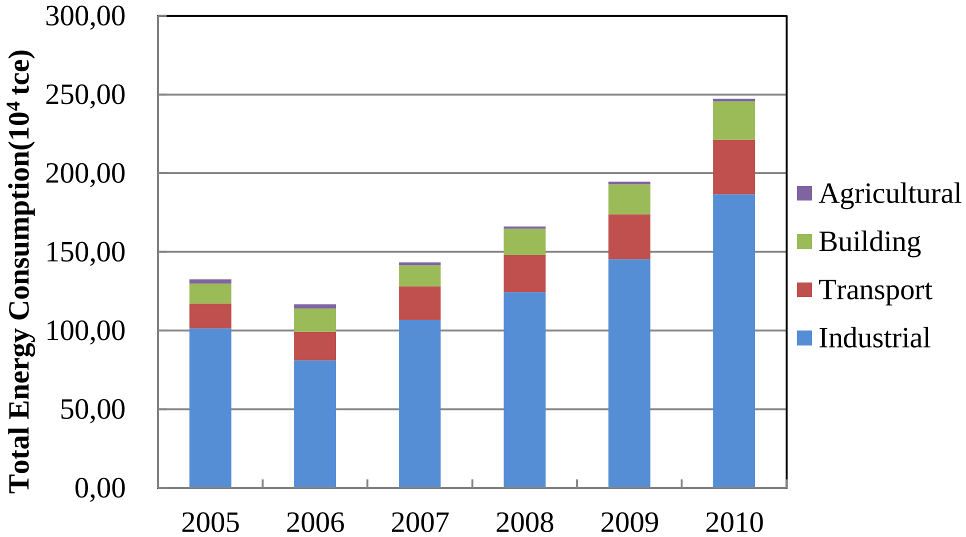

Fig.7 Sectoral energy consumption of Rugao

Through Table 2, Fig.6 and Fig.7, all of the two counties' energy consumption from industrial, transport and building appear the rise tendency. Apparently, Rugao’s growth rate is faster than Changshu. Take the industrial sector as an example, Changshu and Rugao’s annual growth rate is 7.61% and 12.95% separately. While in agricultural sector, Rugao’s agricultural energy consumption annual decrease rate is 11.50%, much larger than Chagnshu.

This shows Rugao is a typical North Jiangsu industrialized mid-term county-level city, and it has a rapid economic and energy consumption development. However, Changshu is a typical South Jiangsu developed county-level city, and its energy consumption keeps a quite high level, with a slower growth rate. For two counties, their industrial energy consumption is the largest sector, and then the transport and building, and the last part is the agricultural sector.

3.3 Carbon emission status

3.3.1 Total carbon emission status

Table 3 Total carbon emission status of two counties(Unit: 10^4 t-CO_{2e})

Changshu									
Year	Industrial	Transport	Building			Agricultural	Production process	Waste	Total
			Construction process	Commercial	Household				
2005	2313.61	84.33	3.48	39.59	49.20	3.54	0.00	16.66	2510.40
2006	2753.81	96.97	3.01	46.09	58.50	3.62	0.00	16.90	2978.90
2007	2873.08	113.78	2.14	41.11	51.10	2.82	0.00	17.21	3101.25
2008	3029.64	126.05	2.12	48.87	58.58	2.80	0.00	17.41	3285.47
2009	3287.69	161.36	2.37	53.45	59.89	2.89	0.00	17.47	3585.12
2010	3339.05	172.99	0.62	64.02	73.64	3.36	0.00	17.51	3671.18

Rugao									
Year	Industrial	Transport	Building			Agricultural	Production process	Waste	Total
			Construction process	Commercial	Household				
2005	249.37	38.45	0.52	6.17	24.44	6.84	4.52	20.92	351.22
2006	199.40	44.47	0.71	7.74	28.09	6.13	6.40	21.03	313.97
2007	262.11	52.49	0.73	7.74	24.70	4.52	11.92	21.12	385.35
2008	305.90	57.77	1.69	10.22	29.01	3.67	19.80	21.20	449.27
2009	356.99	70.04	2.82	12.18	32.14	3.72	28.59	21.28	527.76
2010	458.38	84.87	5.17	16.19	38.88	3.71	20.13	21.34	648.68

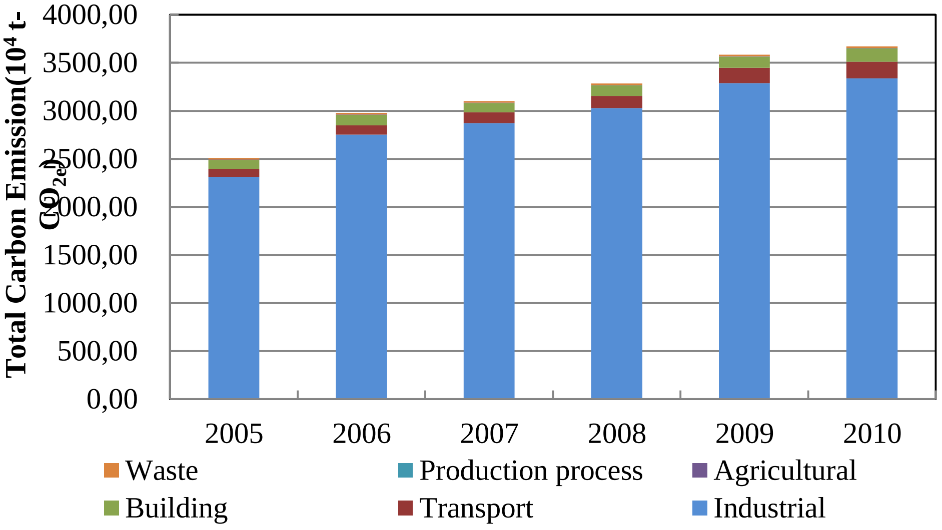

Fig.8 Sectoral carbon emission of Changshu

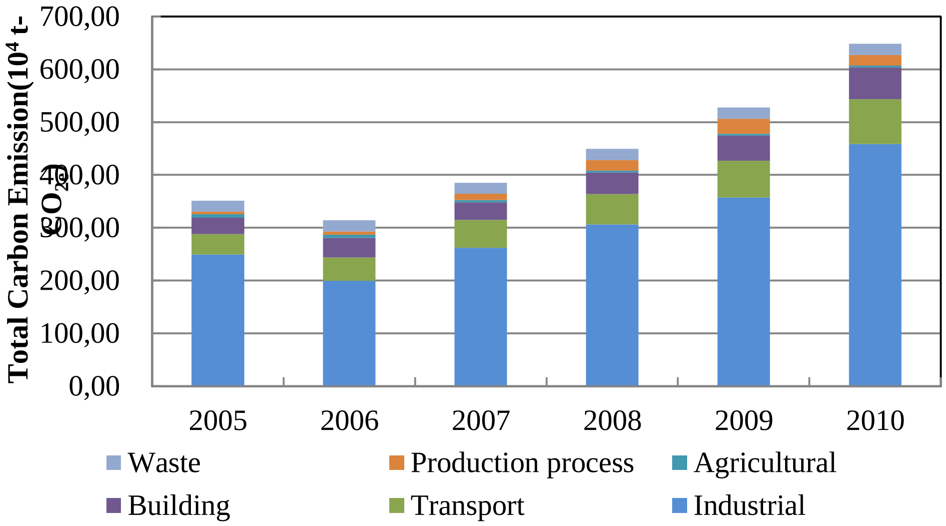

Fig.9 Sectoral carbon emission of Rugao

As shown in Table 3, Fig.8 and Fig.9, Changshu and Rugao's total carbon emissions are increasing year by year. Total carbon emissions of Chagnshu increases from 25.10 Mt in 2005 to 36.71 Mt in 2010, and its growth rate is 7.90%; while in Rugao, Total carbon emissions increases from 3.51 Mt in 2005 to 6.49 Mt, of which growth rate is 13.06%, higher than that in Changshu because of a larger economic growth rate in Rugao.

What's more, the two pictures show that carbon emissions of industrial sector of

Changshu accounts for 90% of its total emissions, while of Rugao accounts for 70% of its total emissions. Both of the two counties' industrial sector account for the largest proportion, which shows industry is still the leading part of economy. The percentage of Rugao's industrial sector is around 70%, while the percentage of Changshu's industrial sector is decreasing year by year (from 92.16% in 2005 to 90.95% in 2010), which shows the work of industrial transformation and upgrading in Changshu is much better than Rugao.

Both the carbon emissions of Changshu and Rugao's transport sector are ranked second, which are about 5% and 13% separately, with a trend of increasing. The increasing of carbon emissions of transport sector relates with economic development and the improvement of living standard, which lead to the increasing of the volume of motor vehicles. As Rugao's economic development is larger than Changshu, its transport sector's carbon emission is larger than Changshu.

Carbon emissions of the two counties' agricultural and waste management sector basically maintain at a quite low level. Carbon emissions percentage of Rugao's industrial production process increased during 2005-2009, while decreased a little in 2010, which has matter with controlling high emissions in industrial enterprises.

3.3.2 Carbon intensity status

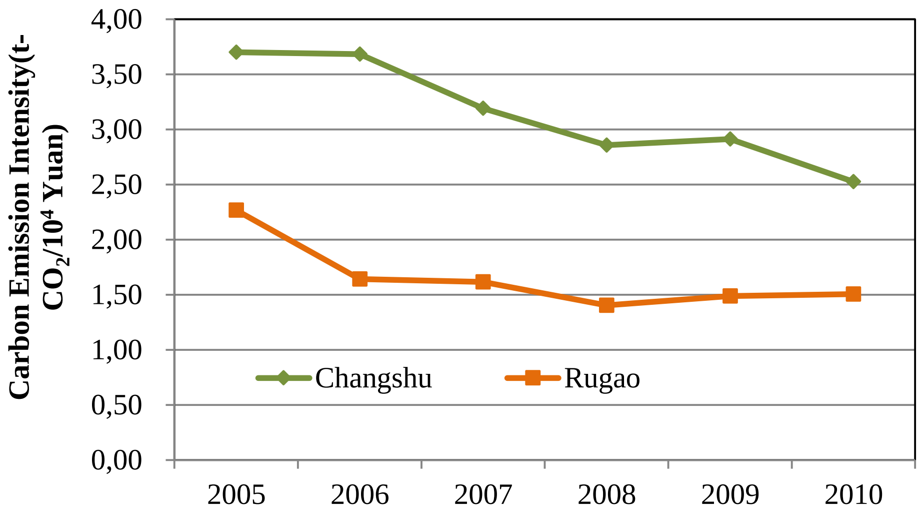

Fig.10 Carbon emission intensity of two counties

From Fig.10 we can find that both the counties' carbon emission intensities keep a trend of decreasing. The carbon emission intensity of Changshu decreased from 3.70 t/ 10^4 Yuan in 2005 to 2.53 t/ 10^4 Yuan in 2010, of which reduction rate was 7.35%; at the same time, the carbon emission intensity of Rugao decreased from 2.27 t/ 10^4 Yuan to 1.51 t/10^4 Yuan, with a reduction rate 7.86%.

3.4 Emission reduction potential analysis

3.4.1 Trend of country carbon emission

Table 4 Sectoral carbon emission trend of Changshu (Unit: 10^4 t-CO_{2e})

BAU scenario								
Year	**Agricultural**	**Building**			**Industrial**	**Transport**	**Un-energy consumption**	**Total emission**
		Construction process	Commercial	Household				
2011	1.66	2.17	30.68	40.48	3158.84	246.45	17.68	3497.16
2012	1.91	3.71	34.15	43.77	3419.86	319.91	17.86	3839.47
2013	2.19	5.92	38.01	47.34	3713.38	393.37	18.04	4215.52
2014	2.52	9.33	42.30	51.19	3976.12	466.83	18.22	4562.62
2015	2.90	13.57	47.07	55.36	4250.28	540.29	18.40	4922.66
Integrated reduction-low scenario								
Year	**Agricultural**	**Building**			**Industrial**	**Transport**	**Un-energy consumption**	**Total emission**
		Construction process	Commercial	Household				
2011	1.66	2.81	30.59	40.83	3038.17	229.00	17.68	3357.50
2012	1.91	4.24	33.95	44.53	3239.84	285.01	17.86	3620.57
2013	2.19	5.83	37.66	48.58	3452.40	341.02	18.04	3895.07
2014	2.52	8.05	41.78	52.99	3629.05	397.04	18.22	4134.74
2015	2.90	10.50	46.33	57.80	3807.22	453.05	18.40	4376.65
Integrated reduction-high scenario								
Year	**Agricultural**	**Building**			**Industrial**	**Transport**	**Un-energy consumption**	**Total emission**
		Construction process	Commercial	Household				
2011	1.66	3.09	30.18	41.17	2947.36	207.12	17.68	3244.14

2012	1.91	4.52	33.03	45.29	3062.79	241.25	17.86	3398.04
2013	2.19	5.98	36.13	49.82	3177.97	275.39	18.04	3552.01
2014	2.52	7.69	39.51	54.80	3268.97	309.52	18.22	3682.38
2015	2.90	9.45	43.17	60.28	3354.38	343.65	18.40	3807.55

Table 5 Sectoral carbon emission trend of Rugao (Unit: 10^4 t-CO_{2e})

BAU scenario								
Year	**Agricultural**	**Building**			**Industrial**	**Transport**	**Un-energy consumption**	**Total emission**
		Construction process	Commercial	Household				
2011	**1.92**	**2.83**	**8.65**	**20.45**	**521.20**	**110.02**	**41.56**	**704.58**
2012	2.30	3.89	10.73	23.04	581.89	135.16	41.64	794.31
2013	2.76	5.37	13.31	25.95	653.53	160.30	41.73	895.99
2014	3.31	7.58	16.51	29.24	712.43	185.45	41.82	986.37
2015	3.98	10.44	20.48	32.94	774.43	210.59	41.91	1081.37

Integrated reduction-low scenario								
Year	**Agricultural**	**Building**			**Industrial**	**Transport**	**Un-energy consumption**	**Total emission**
		Construction process	Commercial	Household				
2011	**1.92**	**2.93**	**8.67**	**21.17**	**496.55**	**102.08**	**41.56**	**671.93**
2012	2.30	3.74	10.79	24.69	543.20	119.29	41.64	739.27
2013	2.76	4.69	13.40	28.80	587.06	136.49	41.73	804.53
2014	3.31	6.00	16.65	33.59	624.17	153.70	41.82	864.12
2015	3.98	7.51	20.67	39.18	661.75	170.90	41.91	925.27

Integrated reduction-high scenario								
Year	**Agricultural**	**Building**			**Industrial**	**Transport**	**Un-energy consumption**	**Total emission**
		Construction process	Commercial	Household				
2011	**1.92**	**2.96**	**8.62**	**20.96**	**487.33**	**92.46**	**41.56**	**652.82**
2012	2.30	3.69	10.66	24.21	526.21	100.04	41.64	702.33
2013	2.76	4.47	13.15	27.97	567.99	107.63	41.73	755.34
2014	3.31	5.42	16.19	32.30	606.88	115.22	41.82	806.28
2015	3.98	6.45	19.93	37.31	646.60	122.80	41.91	858.92

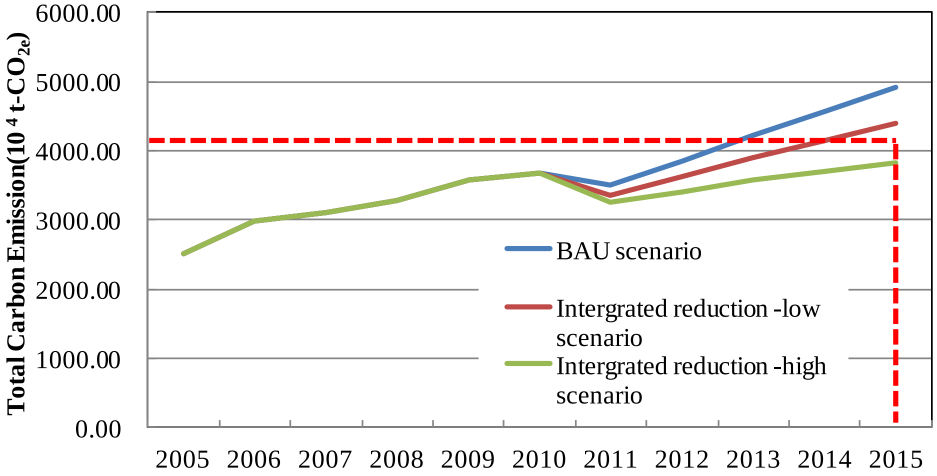

Fig.11 Carbon emission trend of Changhsu

Note: The dotted line in Fig.11 is the carbon reduction target value of Changshu in 2015, which is calculated according to national carbon emission intensity in 2015 relatively dropping 17% compared to 2010, the same below.

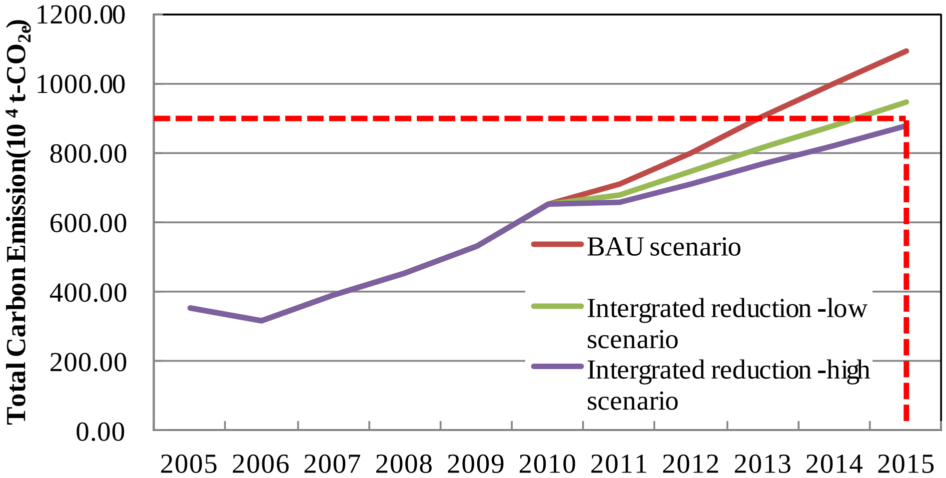

Fig.12 Carbon emission trend of Rugao

As shown in Table 4, Table 5, Fig.11 and Fig.12, during the 12th five-year plan period, carbon emissions of Changshu and Rugao will be increasing year by year. In BAU scenario, carbon emissions of Changshu will increase from 36.71 Mt in 2010 to 49.28 Mt in 2015, with an annual growth rate 8.95%. In IRL and IRH scenarios, carbon emission will increase from 43.96 Mt and 38.32 Mt separately, correspondingly, the annual growth rate will be 6.94% and 4.22%. In BAU scenario, carbon emissions of Rugao will increase from 6.49 Mt in 2010 to 10.95 Mt in 2015, with an annual growth rate 11.57%. In IRL and IRH scenarios, carbon emission will increase from 9.26 Mt and 8.79 Mt separately, correspondingly, the annual growth rate will be 8.81% and 7.60%

Rugao as a typical North Jiangsu county, is still in a high economic development period, while Changshu as a typical South Jiangsu developed county, its economic development has reach a quite high level, thus during the 12th five-year plan period, carbon emissions of Rugao will keep far behind Changshu, however, its annual growth rate will larger than Changshu.

- Industrial sector

In BAU scenario, industrial carbon emissions of two counties in 2015 will arrive at 42.50 Mt and 7.74 Mt separately, in IRL scenario, it will get up to 38.07 Mt and 6.62 Mt, and in IRH scenario, it will come to 33.54 Mt and 6.47 Mt, which proves the industrial carbon emissions in Changshu will be much higher than that in Rugao. Consequently, Changshu, at the turning point of industry dominated, should reduce the carbon emissions brought by the unit industrial output as much as possible, also, Rugao should reduce its energy consumption and curtail carbon emission.

- Transport sector

Transport sector emission is the second contributor of the two counties separately. Considering the continuous influx of foreign population, the levels of residents' income, the consumption rising steadily, and the living quality improving one step further, the number of residents' trips will increase substantially, both passenger and freight transport demand will improve significantly, and the number of private car will increase further, thus, carbon emissions of transport sector will still show a rapid growth trend.

In BAU scenario, the transport sector's carbon emissions of Changshu and Rugao will reach 5.40 Mt and 2.11 Mt separately in 2015, in IRL scenario, it will arrive at 4.53 Mt and 1.71 Mt, and in IRH scenario, it will come to 3.44 Mt and 1.23

Mt.

➢ Building sector

In BAU scenario, Building sector's carbon emissions of Changshu and Rugao will reach 1.16 Mt and 0.64 Mt separately in 2015, in IRL scenario, it will arrive at 1.15 Mt and 0.67 Mt, and in IRH scenario, it will come to 1.13 Mt and 0.64 Mt.

Among the building sector, Changshu's commercial predicted carbon emissions are much higher than Rugao's, which is caused by the difference of economic development of two counties, and what's more, Changshu is at the point of turning industrial dominated county into tertiary industry dominated one.

Although household carbon emissions are small now, it's increasing rapidly because of the rapid economic development and the residents' increasing demand of energy. As a result, the government should enhance the public education and publicity of energy saving and emission reduction to achieve the goal of curtail GHG emissions.

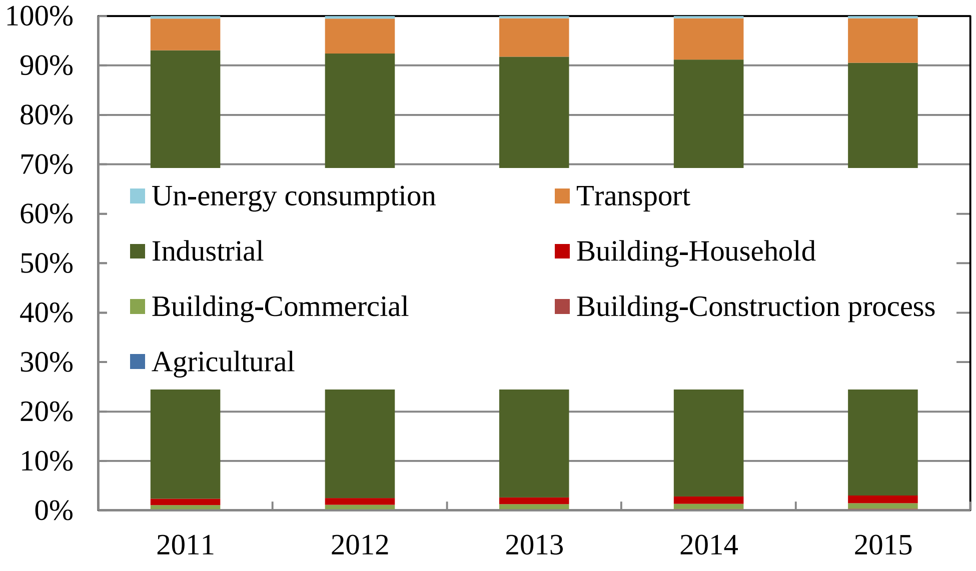

Fig.13 Changshu sectoral proportion of carbon emission (IRH scenario)

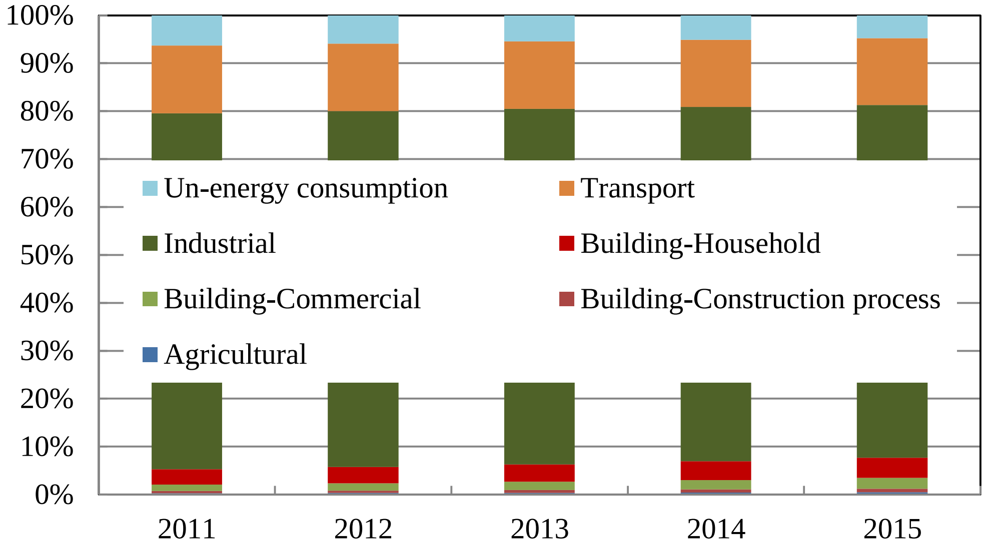

Fig.14 Rugao sectoral proportion of carbon emission (IRH scenario)

As shown in Fig.13 and Fig.14, during the 12th five-year plan period, in ITH scenario, industrial carbon emissions of two counties will still be the biggest contributors. With further adjustment of industrial structure, industrial emission proportion will decrease year by year. Changshu and Rugao's industrial emission percentages will decrease from 90.95% and 70.66% in 2010 to 87.53% and 73.56% in 2015 separately. It's worth noticng that transport emission percentage will be increasing from 4.71% and 13.08% in 2010 to 8.97% and 13.97% in 2015 separately.

3.4.2 Potential of country emission reduction

Table 6 Carbon reduction potential of two counties (Unit: 10^4 t-CO_{2e})

Changshu			
Year	BAU scenario	ITL scenario	IRH scenario
2011	3497.96	3360.74	3248.26
2012	3841.17	3627.35	3406.65
2013	4218.25	3905.72	3565.51
2014	4566.52	4149.63	3701.23
2015	4927.88	4396.19	3832.23
Reduction	-	531.69	1095.65
Rugao			
Year	BAU scenario	ITL scenario	IRH scenario
2011	706.61	674.87	655.81

2012	798.65	745.65	708.76
2013	902.96	814.94	765.70
2014	996.35	879.24	821.14
2015	1094.76	945.90	878.96
Reduction	-	148.86	215.79

Till 2015, carbon reduction potential section of Changshu is 5.32 Mt – 10.96 Mt, and Rugao is 1.49 Mt – 2.16 Mt.

The reason why Changshu has larger reduction potential is Changshu as South Jiangsu developed county, whose need for energy is more huge. If Changshu optimizes the industrial structure, eliminates high energy consumption and high emission of industrial enterprises, promotes energy saving technologies, and vigorously promotes energy saving policy, it will have huge reduction potential. While Rugao is in a catch-up period, each industry is in a stage of vigorous development. Although its need of energy is increasing fast, it has a much smaller base than Changshu, thus it has a smaller reduction potential.

3.4.3 Comparison of emission reduction

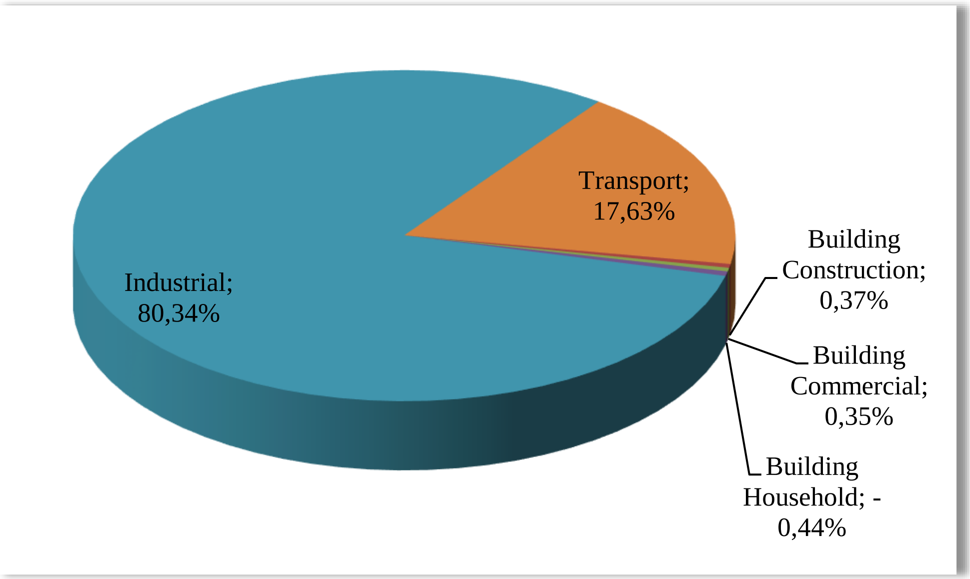

Fig.15 Sectoral reduction contribution of Changshu

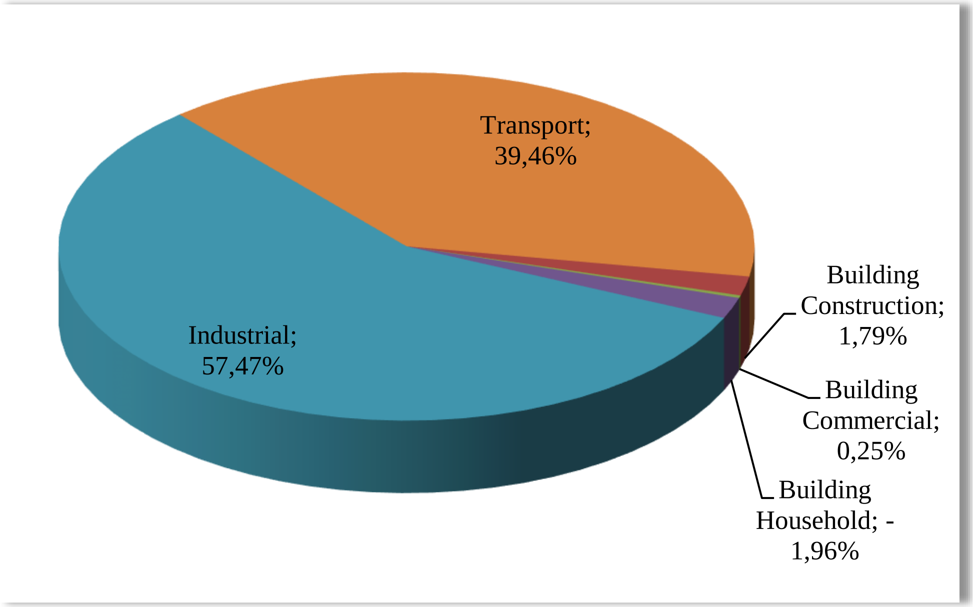

Fig.16 Sectoral reduction contribution of Rugao

As shown in Fig.15 and Fig.16, two counties' sectoral reduction contribution from largest to smallest in turn is industrial sector, transport sector, construction process, commercial sector and household sector.

As Changshu and Rugao are still industrial dominated counties, industrial reduction potential is the largest. The contributions of two counties' industrial reduction are 80.34% and 57.47% separately. Thus it can be seen that during the 12th five-year plan, two counties should put center in the industrial sector. On one hand, the government should adjust industry structure to speed up the development of service dominated industry, and make it being the leading industry gradually; on the other hand, they should apply new technologies to improve energy efficiency, do work to reduce energy consumption, phase out the high pollution and high emission business, and support strategic emerging industries.

At the same time, car ownership brought by economic development in future is increasing rapidly, resulting in transport carbon emission reduction should also receive attention. According to the predicting data, emission reduction potential of transport sector is quite huge simultaneously, especially for Rugao, its transport sector reduction contribution will come to 39.46%. Therefore on one hand, they should construct and imply public transportation with great exertion, and encourage the public to choose green traffic positively; on the other hand, they should improve vehicle engine technologies to improve energy efficiency, switch to clean energy, and promote the electric vehicle market actively.

For service industry (which is commercial sector in this report) now contributes not big enough, while the reduction of tertiary industry sector cannot be ignored with the development and carbon emission growth trend of tertiary industry, and encouragement policies of government..

With the improvement of residents' living standard, household sector carbon emission will still increase significantly. Its contribution to the whole society is negative, and Rugao's modulus is bigger than Changshu, because Changshu is South Jiangsu typical county, and it has strengthened the education of energy saving, as well as the technological transformation of household energy consumption facilities.

4 Conclusion

From 2005 to 2010, energy consumption and carbon emissions of Changshu and Rugao has been increasing obviously, specifically, carbon emissions of Changshu increased from 25.10 Mt in 2005 to 36.71 Mt in 2010, and carbon emissions of Rugao increased from 3.51 Mt in 2005 to 6.49 Mt. Through analyzing the carbon emission trend during the 12th five-year plan period, till 2015 carbon emissions of two counties will increase year by year. In BAU scenario, carbon emissions of Changshu and Rugao will go up to 49.29 Mt and 10.95 Mt separately, and its annual growth rates are 8.95% and 11.57% correspondingly. And in the two integrated reduction scenarios, reduction potential will be 5.32 Mt – 10.96 Mt and 1.49 Mt – 2.16 Mt. Changshu's potential reduction is mainly contributed by industrial sector, and its contribution rate is 80.34%; the next is transport sector, coming up to 17.63%. While Rugao's potential reduction is supported by industrial sector (57.47%) and transport sector (39.46%).

As a conclusion, the carbon emissions of North and South Jiangsu counties will be increasing during the 12th five-year plan period, and among which the growth rate of North Jiangsu county is much higher than South Jiangsu, which is related with high growth rate of economy in North Jiangsu.

The shortcomings of this study are: (1) Energy consumption statistical data are from the two counties' statistical yearbooks. As we know, statistical yearbook only compiles above-scale enterprises, thus in this study, below-scale enterprises are estimated according to above-scale ones. In a word, there are quite large uncertainties. (2) The energy consumption in energy consumption per unit GDP of this study is the sum of all parts, not the comprehensive energy consumption of the whole society in strict sense, thus it cannot be used as the index to measure the goal of energy-saving.

For next step, on one hand, the government should strengthen the accuracy of statistics, and especially do well the statistical work of below-scale industrial energy consumption. On the other hand, South Jiangsu counties should put focus on adjusting industrial structure, phasing out high pollution, high emission businesses, and supporting strategic emerging industries; while North Jiangsu counties should construct and imply public transportation with great exertion, and encourage the public to choose green traffic positively on the basis of adjusting industry sector.