American Journal of Climate Change, **2012, 1, 64-103**
http://dx.doi.org/10.4236/ajcc.2012.12007 Published Online June 2012 (http://www.SciRP.org/journal/ajcc)

Development of a Low Carbon Economy in Wuxi City

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Received April 6, 2012; revised May 6, 2012; accepted May 18, 2012

ABSTRACT

The development of a Low Carbon Economy is a vital instrument to encounter climate change and take into account the growing challenges of an increasing urbanization in China. Wuxi City in East China's Jiangsu Province is starting to implement a Low Carbon City Plan for safeguarding a sustainable development of the city until 2020 and beyond. This paper aims at estimating the impact of the Low Carbon City plan for Wuxi's energy demand and CO_2-emissions until 2050. Using an econometric energy supply and demand model to estimate and forecast the Wuxi energy and CO_2-balance aggregates until 2050, it compares a scenario without specific Low Carbon City measures to reduce sectoral CO_2-intensities to a Low Carbon scenario implementing these measures according to the Low Carbon City Plan until 2020 and beyond. The decomposition of the Kaya-identity reveals that the increase of per capita income has the largest impact on the growth of CO_2-emissions and the decrease of energy intensity of Gross Value Added the largest impact on the reduction of CO_2-emissions in Wuxi. A decrease of population and CO_2-intensity of Primary energy supply only have average contributions. The decrease of energy intensity of Gross Value Added is due to energy efficiency gains in the single economic sectors, but to a large extent due to structural changes of the economy away from energy intensive sectors such as iron and steel, chemical industry or cement industry towards the energy extensive service sectors. A growing residential sector also reduces the industrial share of energy demand. Only following the assumed national trend with a shift from CO_2-intensive industries to a CO_2-extensive service economy, the Low Carbon goal of a 50% reduction of CO_2-intensity of Gross Value Added compared to 2005 cannot be reached in Wuxi. Specific sectoral CO_2-intensity goals have to be successfully observed by the economic sectors in Wuxi, especially by the industry. The promotion of combined heat and power generation also has to contribute to the specific activities in Wuxi.

Keywords: Climate Change; Low Carbon Economy in Cities; China; Carbon Intensity; Combined Heat and Power Generation

1. Introduction

Increasing urbanization and climate change are one of the greatest challenges in the 21st Century [1-5]. Cities cover only 1% of the Earth's surface, but host about 50% of the Earth's population, soon it will reach 60%. Hence, cities are highly vulnerable to the impact of climate change (sea level rise, droughts, extreme weather events etc.) especially in coastal regions. As cities use about three quarters of all energy and emit about 80% of the greenhouse gases, they are also one focal point of climate change mitigation measures, in recent times in Low Carbon City concepts and strategies all over the world [6-10].

Wuxi is a city on the Yangtze River with 6.4 Mill. inhabitants (2010) between Suzhou and Nanjing, located in the south of Jiangsu Province, half way between the cities of Shanghai and Nanjing, with Shanghai 128 km to its east and Nanjing 183 km to its west. In the south of Wuxi is Lake Tai (*Tai hu*) and to its north Yangtse River. Wuxi covers an overall area of 4787.6 km^2. The urban district occupies an area of 216.5 km^2 with 973 inhabitants per km^2. This implies that Wuxi is densely populated, comparable to Beijing (1167.3 inhabitants per km^2). Average population density in Jiangsu Province is 753 inhabitants per km^2, the Chinese average is only 135 per km^2. Wuxi's economy has witnessed a considerable increase in recent years. The per capita GDP was 575.8 billion RMB in 2010, doubling that of 2005 and with an average annual growth rate of 13.5%. Per capita GDP (based on resident population) was over US $13,000 (90,355 RMB) [7].

In order to emphasize the high importance of urban areas for a low carbon development, the National Development and Reform Commission (NDRC) has selected five provinces and eight cities as low carbon pilot regions. These pilots include five provinces (Guangdong, Liaoning,

Hubei, Shaanxi, Yunnan), and eight cities (Tianjin, Chongqing, Shenzhen, Xiamen, Hangzhou, Nanchang, Guiyang and Baoding), covering a total population of 350 million. Wuxi is not part of this initiative, but is part of the low carbon eco-city pilot initiative of the national Ministry of Housing and Urban-Rural Development (MOHURD), involving regulation for massive energy saving in buildings. In March 2010, Wuxi city government developed a Low Carbon City Plan in cooperation with Wuxi Low Carbon City Development Research Centre (WLCDRC) of Jiangnan University [12]. The Plan constitutes the key document for low carbon development in Wuxi and outlines, in line with strategies in other Chinese cities, strategic milestones and goals for the following sectors:

- Agriculture;
- Industry;
- Transport;
- Buildings (cooling, heating, ventilation, dehumidification, lighting);
- Residential consumption (hot water, cooking, electric appliances etc.).

For these sectors, the city government adopts different strategies. Quantitative aim of Wuxi government is to reduce CO_2-emissions per unit GDP by 50% in 2020 compared to 2005. This is going even beyond the national goal of 40% - 45% formulated by the central government.

Aim of this paper is to compare the development of CO_2-emissions in Wuxi in a Low Carbon City scenario to a Business as Usual (BAU) scenario without specific Low carbon measures in the city, only following the trend in China. Chapter 1 describes the model and the sectoral development of energy consumption and CO_2-emissions between 1994 and 2010. Chapter 2 analyses the Business as Usual scenario, Chapter 3 compares it to the Low Carbon City scenario. Chapter 4 summarizes the article.

2. Model Description and Development until 2010

2.1. Overview

Basis of the analysis is the energy balance of Wuxi City between 1994 and 2010. Data used is the Wuxi City Statistical Yearbook [13]. The energy balance is forecasted with an econometric model. The energy demand and supply in China had been modeled by using different approaches [14-16]. Söderholm [17] gives an overview of different models used.

Basis is the econometric bottom-up estimation of the final energy demand, transformation and primary energy supply (in PJ) in Wuxi (**Table 1**). Estimation approaches are based on Ordinary Least Squares (OLS)-regressions [18] and the Augmented Dickey-Fuller-Test on stationarity [19].

Between 1994 and 2010, total primary energy supply more than five-folded (478%) from 138 PJ to 798 PJ. Transformation of primary to secondary energy in Wuxi increased so that total primary energy imports grew slower (451%). Total final consumption in Wuxi increased by 396%, higher in the secondary (463%) and tertiary sector (810%), but slower in the residential sector (324%). Final energy consumption in the primary sector even decreased by 67% (**Table 1**). Within the industry sector, the largest increase of energy consumption was both in light industry (Clothes, Shoes and Hats Products: 4825%; Electric Equipment and Machinery Manufacturing: 4661%, Telecommunications, Computers and other Electronic Equipments Products: 1568%) and heavy industry (Chemical Fiber Manufacturing: 1979%; Plastic Products: 1898%; Smelting and Pressing of Nonferrous Metals: 1667%). Within the tertiary sector, all branches increased energy consumption more or less around the sector average. In the residential sector, the catching up of the rural areas in terms of income lead to a considerably higher growth of energy consumption (430%) compared to urban areas (271%). Non energy use of crude oil by chemical industry decreased from 4.864 PJ in 1994 to 2.319 PJ in 2010. In 2010, the primary energy supply mix was as follows: 80.8% coal, 9.3% imported coke, 3.2% oil, 3.1% gas, 3.0% imported electricity and 0.7% recovery of heat energy in combined heat and power generation.

In 2010, 99.9% of power generation input was coal, only a small fragment (0.4%) are diesel aggregates. Since 2009, coking gas is also used for power generation, but currently only to a very small extent (0.2%). Process heat (thermopower) is 100% coal generated. In 2010, the petroleum refineries in Wuxi can produce the city's kerosene demand. The consumption of diesel has to a large extent be supplemented by imports (60.6%). Gasoline and fuel oil, however, are also produced for interregional exports.

In 2010, the final energy mix was 36.7% coal, 14.5% coke, 2.7% oil, 4.5% gas, 29.6% imported electricity and 12.1% heat energy

The energy related CO_2-emissions in Wuxi are calculated using the factors shown in **Table 2**.

The energy-related CO_2-emissions in Wuxi follow the trend of energy consumption (**Table 3**). Between 1994 and 2010, total CO_2-emissions of primary energy supply in Wuxi increased by 358% from 16.8 Mt to 77.0 Mt CO_2. In 2010, 79.1% of CO_2-emissions are coal, 2.2% oil, 1.8% gas and 0.8% recovery of heat energy. 9.2% total CO_2 in the primary energy balance is imported coke, 6.8% imported electricity. To include imported secondary energy (also relevant for petroleum products) provides the problem of possible double counting, if the

Table 1. Wuxi energy balance (1994-2010, in PJ).

	1994	2000	2005	2010
Total Primary Energy Supply	138.018	267.730	573.669	797.687
Indigenous Production	0.000	0.000	0.000	0.000
Indigenous Production—Hydro Power	0.000	0.000	0.000	0.000
Indigenous Production—Nuclear Power	0.000	0.000	0.000	0.000
Indigenous Production—Renewable Energy	0.000	0.000	0.000	0.000
Recovery of Energy	0.000	0.000	0.000	5.460
Interprovincial Imports (+)	144.120	274.478	605.891	793.665
Import (+)	0.000	0.000	0.000	0.000
Chinese Vessels Refueling Abroad (+)	0.000	0.000	0.000	0.000
Interprovincial Exports (−)	0.000	0.000	−3.502	0.000
Export (−)	−6.102	−6.748	−1.195	−1.437
Foreign Vessels Refueling in China (−)	0.000	0.000	0.000	0.000
Stock Change (increase: −; decrease: +)	0.000	0.000	−27.525	0.000
Total Transformation (input: −; output: +)	−21.287	−72.133	−135.404	−224.417
Thermal Power	−18.748	−58.304	−125.139	−195.332
Heating Supply	−1.397	−2.800	−5.794	−19.133
Coal Washing	0.000	0.000	0.000	0.000
Coking	−2.539	−1.526	−1.099	−1.032
Petroleum Refineries	−0.079	−9.503	−3.372	−8.947
Gas Works	1.476	0.000	0.000	0.027
Gas Works—Coke Input	0.000	0.000	0.000	0.000
Briquettes	0.000	0.000	0.000	0.000
Losses in Transformation	0.000	0.000	0.000	0.000
Total Final Consumption	116.731	195.597	438.264	573.270
Agriculture	1.749	1.978	0.623	0.580
Secondary Industry	96.410	180.779	416.285	537.892
Industry	96.245	180.543	415.575	536.978
Coal Mining	0.108	0.000	0.000	0.000
Non-Metal Mining and Processing	0.190	0.084	0.122	0.000
Agriculture and Non-Staple Food Processing	0.328	1.059	0.577	0.358
Food Production	1.353	0.836	3.759	2.239
Beverage Production	0.371	0.491	0.272	1.099
Textile Industry	11.218	30.783	58.583	44.192
Clothes. Shoes and Hats Products	0.288	1.862	9.921	14.176
Leather. Fur. Down and Related Products	0.151	0.172	0.217	0.323

Continued

Timber Processing. Bamboo. Cane. Palm	0.127	0.259	0.165	0.168
Furniture Manufacturing	0.015	0.002	0.010	0.036
Papermaking and Paper Products	0.878	3.703	7.126	9.389
Printing and Record Medium Reproduction	0.051	0.250	0.420	0.584
Stationery. Educational and Sports Goods Products	0.010	0.105	0.368	0.152
Petroleum. Coking and Nuclear Fuel Processing	1.708	0.550	1.217	2.276
Raw Chemical Materials and Chemical Products	21.505	39.300	66.392	89.035
Medical and Pharmaceutical Products	1.473	3.206	2.017	2.022
Chemical Fiber Manufacturing	1.277	9.680	23.803	26.545
Rubber Products	0.929	0.981	3.217	2.361
Plastic Products	0.267	2.475	5.465	5.315
Non-Metallic Mineral Products	13.505	25.793	33.771	43.971
Smelting and Pressing of Ferrous Metals	15.739	31.427	134.912	188.052
Smelting and Pressing of Nonferrous Metals	0.821	3.668	7.146	14.518
Metal Products	1.944	4.738	10.297	10.696
General Purpose Equipment Manufacturing	2.497	5.470	9.082	17.004
Special Purpose Equipment Manufacturing	0.902	1.941	1.798	5.661
Transportation Equipment Manufacturing	0.327	1.003	3.255	6.554
Electric Equipment and Machinery Manufacturing	0.548	2.079	7.264	26.083
Telecommunications. Computers and Other Electronic Equipments Products	1.344	1.471	7.088	22.414
Instruments. Meters. Culture and Office Machinery Manufacturing	0.221	0.196	0.317	0.665
Handicraft Articles and Others Manufacturing	1.524	0.290	0.928	0.939
Recycling and Disposal of Waste	0.000	0.000	0.000	0.241
Electricity and Heating Power Production and Supply	2.821	3.915	12.218	15.504
Gas Production and Supply	0.022	0.004	0.011	0.072
Water Production and Supply	0.342	0.334	0.502	0.690
Construction	0.166	0.236	0.710	0.914
Tertiary Sector	1.678	3.661	7.950	15.270
Transportation. Telecommunications. Postal	0.138	0.262	0.494	1.279
Commerce. Hotel and Catering Service	0.475	1.137	3.084	4.537
Other	1.065	2.262	4.372	9.454
Residential Consumption	4.610	9.178	13.406	19.528
Residential Consumption—Rural	2.597	6.550	9.407	13.751
Residential Consumption—Urban	1.556	2.505	3.935	5.777
Statistical Difference	0.000	0.000	0.000	0.000

Source: [13], own calculation.

Table 2. CO_2-emission factors.

Fuel Types	Low Heating Value (MJ/kg)	CO_2-Factor (kg CO_2/MJ)
Raw Coal	20.91	0.094600
Fine Coal	26.34	0.094600
Other Coal	29.31	0.094600
Lump Coal	29.31	0.094600
Coke	28.44	0.095700
Coking Gas	17.00	0.044367
LNG	46.06	0.064200
Crude Oil	41.82	0.073333
Gasoline	43.07	0.069300
Kerosene	43.07	0.071867
Diesel Oil	42.65	0.074067
Fuel Oil	41.82	0.077367
LPG	50.18	0.063067
Natural Gas	38.93	0.056100

Source: [11,20].

analysis boundary would be widened e.g. on a provincial scale, as primary energy was used in other regions to produce the secondary energy in question. As we here only focus on Wuxi, it may be rational to account for produced and consumed secondary energy. 90% of CO_2-emissions of final energy are in the secondary sector as described above for energy consumption in the different branches.

The Econometric Wuxi energy and CO_2 model is a bottom-up estimation of the Wuxi City energy balance disaggregated by 17 energy sources and the 46 sectors listed above (including the sums for total final energy demand and final energy demand in the primary, secondary, tertiary and residential sector). Based on assumptions on input factors in the petroleum refinery sector and coking as well as capacities of petroleum refineries, electricity and heat generation, final energy demand is determining the production of oil products, heat and electricity in Wuxi City as well as the demand and supply for primary energy in terms of intra-provincial imports and exports. Based on assumed political goals for total primary energy CO_2-intensity of Gross Value Added in Wuxi,

- Excess heat demand is produced with co-generation (recovery of energy);
- A further reduction of CO_2-intensity down to the required level through the generation of renewable electricity.

As data on the mix of renewable energy is missing, only the total renewable energy generation is calculated.

For the estimation of the future energy balance, bunkers (refuelling of Chinese and foreign vessels, stock changes) are assumed to be zero as a net-value.

Statistical differences are calculated as: Primary Energy Supply + Total Transformation − Final Energy Consumption, e.g. for coal as:

$$WX\_SD02 = WX\_PES02 + WX\_IT02 - WX\_TFC02 \quad (1)$$

2.2. Final Energy Demand

Generally, final demand (WX_FC) of energy (i) of the different sectors (j) in the year (t) is estimated as

$$\begin{aligned} WX_{FC_{i,j,t}} = {} & c + \alpha \cdot CO2INT_{j,t} + \beta \cdot GVA_{j,t} \\ & + \gamma \cdot POPWX_{j,t} WX_{FC_{i,j,t}} \\ & + \delta \cdot T_t + \vartheta \cdot D_t + \mu_x \cdot OUTP_{x,t} + \varepsilon_t \end{aligned} \quad (2)$$

with:

- CO2INT = assumed CO_2-intensity goal of Gross Value Added (PJ/1000 RMB);
- GVA = Gross Value Added (Mill. RMB);
- POPWX = Population Wuxi (1000 inhabitants);
- T = Linear technical progress trend;
- OUTPx = Selected physical output of product x;
- D = Dummy variable (being 1 in year t and 0 in the other years).

A similar model for the estimation of the energy demand in China had been developed in [21]. For some sectors, in the estimated function, some coefficients (α, ···, ϑ) may be zero. The variable $CO2INT_{j,t}$ stands for political carbon intensity goals of sector (j) in Wuxi given in the observed time (t) until 2010 and set by the central government for the future. For 2020, Wuxi plans a reduction of the CO_2-intensity of GDP by 50% compared to 2005. Until 2050 it is assumed to be gradually reduced further (65% by 2030, 70% by 2040, and 75% by 2050).

The variable GVA (**Table 4**) is a variable determining the value of the output in the different sectors (j) in Wuxi, whereas OUTP_x is the physical output of selected products (x).

In the model, the nominal output value had been deflated with the Wuxi city producer price index taking the base year of 2005. In 2010, Total Gross Value Added of 493,589 bn. RMB was dominated by Wholesale and Retail (72,278 bn. RMB), Telecommunications, Smelting and Pressing of Ferrous Metals (35,178 bn. RMB), Computers and Other Electronic Equipments Products (32,714 bn. RMB), Electric Equipment and Machinery Manufacturing (32,591 bn. RMB), Real Estate (30,889 bn. RMB), Transportation Equipment Manufacturing (25,322 bn. RMB), Raw Chemical Materials and Chemical Products (17,425 bn. RMB), Textile Industry (13,990

Table 3. Wuxi CO_2 balance (1994-2010, in Mt CO_2).

	1994	2000	2005	2010
Total Primary Energy Supply	16.838	26.307	58.474	77.049
Indigenous Production	0.000	0.000	0.000	0.000
Indigenous Production—Hydro Power	0.000	0.000	0.000	0.000
Indigenous Production—Nuclear Power	0.000	0.000	0.000	0.000
Indigenous Production—Renewable Energy	0.000	0.000	0.000	0.000
Recovery of Energy	0.000	0.000	0.000	0.627
Interprovincial Imports (+)	17.066	26.416	60.982	76.525
Import (+)	0.000	0.000	0.000	0.000
Chinese Vessels Refueling Abroad (+)	0.000	0.000	0.000	0.000
Interprovincial Exports (−)	0.000	0.000	−0.421	0.000
Export (−)	−0.584	−0.645	−0.083	−0.103
Foreign Vessels Refueling in China (−)	0.000	0.000	0.000	0.000
Stock Change (increase: −; decrease: +)	0.000	0.000	−2.526	0.000
Total Transformation (input: −; output: +)	4.340	3.613	4.067	−0.766
Thermal Power	0.000	0.000	0.000	−0.003
Heating Supply	0.000	0.000	0.000	0.000
Coal Washing	0.000	0.000	0.000	0.000
Coking	−0.231	−0.195	−0.180	−0.118
Petroleum Refineries	−0.006	−0.705	−0.265	−0.646
Gas Works	0.065	0.000	0.000	0.001
Gas Works—Coke input	0.000	0.000	0.000	0.000
Briquettes	0.000	0.000	0.000	0.000
Losses in Transformation	0.000	0.000	0.000	0.000
Total Final Consumption	26.930	30.067	63.002	76.190
Agriculture	1.095	0.691	0.176	0.127
Secondary Industry	15.561	26.089	58.011	68.418
Industry	15.457	26.007	57.810	68.217
Coal Mining	0.034	0.000	0.000	0.000
Non-Metal Mining and Processing	0.030	0.015	0.009	0.000
Agriculture and Non-Staple Food Processing	0.074	0.147	0.077	0.048
Food Production	0.247	0.136	0.487	0.303
Beverage Production	0.055	0.067	0.038	0.143
Textile Industry	2.992	4.594	8.655	5.727
Clothes. Shoes and Hats Products	0.056	0.257	1.005	1.647
Leather. Fur. Down and Related Products	0.025	0.026	0.033	0.043

Continued

Timber Processing. Bamboo. Cane. Palm	0.013	0.034	0.028	0.030
Furniture Manufacturing	0.003	0.001	0.002	0.007
Papermaking and Paper Products	0.286	0.562	1.077	1.074
Printing and Record Medium Reproduction	0.015	0.066	0.086	0.104
Stationery. Educational and Sports Goods Products	0.004	0.015	0.051	0.024
Petroleum. Coking and Nuclear Fuel Processing	0.150	0.118	0.152	0.195
Raw Chemical Materials and Chemical Products	3.055	4.025	7.319	9.751
Medical and Pharmaceutical Products	0.339	0.432	0.325	0.279
Chemical Fiber Manufacturing	0.613	1.458	3.265	3.609
Rubber Products	0.165	0.155	0.442	0.347
Plastic Products	0.069	0.459	0.994	0.887
Non-Metallic Mineral Products	2.189	2.953	4.210	4.713
Smelting and Pressing of Ferrous Metals	3.946	4.442	16.110	21.315
Smelting and Pressing of Nonferrous Metals	0.472	0.703	1.125	1.911
Metal Products	0.818	0.887	2.185	1.729
General Purpose Equipment Manufacturing	0.560	0.862	1.481	2.429
Special Purpose Equipment Manufacturing	0.198	0.316	0.368	0.930
Transportation Equipment Manufacturing	0.107	0.188	0.609	1.119
Electric Equipment and Machinery Manufacturing	0.140	0.417	1.357	3.514
Telecommunications, Computers and other Electronic Equipments Products	0.405	0.283	1.649	4.268
Instruments, Meters, Culture and Office Machinery Manufacturing	0.041	0.040	0.058	0.130
Handicraft Articles and Others Manufacturing	0.152	0.038	0.193	0.183
Recycling and Disposal of Waste	0.000	0.000	0.000	0.039
Electricity and Heating Power Production and Supply	1.746	1.307	3.329	2.600
Gas Production and Supply	0.002	0.001	0.002	0.013
Water Production and Supply	0.210	0.115	0.141	0.150
Construction	0.104	0.082	0.201	0.201
Tertiary Sector	1.050	1.278	2.251	3.354
Transportation. Telecommunications. Postal	0.086	0.091	0.140	0.281
Commerce. Hotel and Catering Service	0.297	0.397	0.873	0.997
Other	0.667	0.790	1.238	2.077
Residential Consumption	1.537	2.775	3.635	4.290
Residential Consumption—Rural	0.866	1.980	2.551	3.021
Residential Consumption—Urban	0.642	0.787	1.081	1.269
Statistical Difference	0.000	0.000	0.000	0.000

Source: [13], own calculations.

Table 4. Real gross value added (1994-2010, in Mill. RMB and prices of 2005).

	1994	2000	2005	2010
Total	**86388**	**125059**	**280381**	**493589**
Primary Sector	**4928**	**4925**	**5212**	**9348**
Secondary Sector	**53597**	**73279**	**169595**	**273191**
Industry	50177	68603	158773	254919
Non-Metal Mining and Processing	3	5	11	0
Agriculture and Non-Staple Food Processing	133	182	421	342
Food Production	273	373	864	949
Beverage Production	33	45	104	309
Textile Industry	5394	7376	17070	13990
Clothes, Shoes and Hats Products	1408	1924	4454	8888
Leather, Fur, Down and Related Products	84	115	266	259
Timber Processing, Bamboo, Cane, Palm	85	116	269	357
Fiber and Straw Products	8	11	26	136
Furniture Manufacturing	0	0	0	0
Papermaking and Paper Products	346	474	1096	1602
Printing and Record Medium Reproduction	231	316	730	1174
Stationery , Educational and Sports Goods Products	68	93	215	257
Petroleum, Coking and Nuclear Fuel Processing	293	400	926	1291
Raw Chemical Materials and Chemical Products	4275	5845	13527	17425
Medical and Pharmaceutical Products	406	555	1285	2747
Chemical Fiber Manufacturing	2735	3740	8656	9428
Rubber Products	316	432	999	1498
Plastic Products	1220	1668	3860	3906
Non-Metallic Mineral Products	976	1334	3088	4430
Smelting and Pressing of Ferrous Metals	9737	13313	30811	35178
Smelting and Pressing of Nonferrous Metals	2038	2787	6449	14114
Metal Products	2650	3623	8384	10745
General Purpose Equipment Manufacturing	2690	3678	8511	14796
Special Purpose Equipment Manufacturing	1521	2080	4814	10900
Transportation Equipment Manufacturing	2343	3203	7413	25322
Electric Equipment and Machinery Manufacturing	3795	5189	12009	32591
Telecommunications, Computers and Other Electronic Equipments Products	5883	8043	18614	32714
Instruments, Meters, Culture and Office Machinery Manufacturing	353	482	1117	3793
Handicraft Articles and Others Manufacturing	103	141	326	367

Continued

Recycling and Disposal of Waste	0	0	0	78
Electricity and Heating Power Production and Supply	665	910	2106	4437
Gas Production and Supply	49	67	155	685
Water Production and Supply	62	85	196	210
Construction	3420	4676	10822	18272
Tertiary Industry	**27863**	**46855**	**105574**	**211050**
Transportation, Storage and Post	2271	3819	8606	11131
Information Transmission, Computer and Software Services	1237	2080	4686	7728
Wholesale and Retail	10846	18239	41096	72278
Catering Trade	1377	2315	5216	12368
Real Estate	2393	4024	9068	30889
Hiring and Commercial Services	1470	2472	5569	12790
Community Services and Others	916	1540	3469	1971
Health Care, Social Ensure and Social Welfare	746	1254	2826	4767
Culture, Sports and Entertainment	331	557	1256	2127
Others	3547	5965	13440	36563
Other Tertiary	2729	4590	10342	18439

Source: [13].

bn. RMB) and Smelting and Pressing of Nonferrous Metals (14,114 bn. RMB) (**Table 5**).

Between 1994 and 2010, total population in Wuxi grew by 25.4% from 5.084 Mill. in 1993 to 6.376 Mill. in 2010 (**Table 6**). During the same period of time, urbanization increased considerably. Urban population grew by 190%, whereas rural population decreased by 22%.

According to the Population Census Wuxi, permanent population is calculated including migrant workers and their families from other regions not having a formal residence (*hukou*) in Wuxi.

Total Final Energy demand, e.g. for raw coal (WX_TFC02) is defined as:

$$WX\_TFC02 = WX\_FCA02 + WX\_FCI02 + WX\_FCN02 + WX\_FCV02 + WX\_FCW02 + WX\_FCZ02 + WX\_FCR02 \quad (3)$$

with

WX_FCA02 = Agriculture (PJ);
WX_FCI02 = Industry (PJ);
WX_FCN02 = Construction (PJ);
WX_FCV02 = Transportation, Telecommunications, Postal (PJ);
WX_FCW02 = Commerce, Hotel and Catering Service (PJ);
WX_FCZ02 = Other Tertiary (PJ);
WX_FCR02 = Residential (PJ).

2.3. Transformation of Primary Energy

In the energy balance model, primary energy inputs in the transformation sectors are calculated as follows:

- Primary energy inputs for power generation are calculated on the basis of their input factors or partial efficiencies (EFFIC_POWER_RAWCOAL). e.g. the input of raw coal (WX_ITTP02) is calculated as

$$WX\_ITTP02 = (WX\_ITTP22 / (EFFIC\_POWER\_RAWCOAL/100)) * -1 \quad (4)$$

Output of electricity generated in Wuxi (WX_ITTP22) is calculated as the product of the capacity of power generation (CAPTP_22), the utilization hours per year (8760 h * 0.7) and the calculation of TWh to PJ (1/8.141)/1000 * 29.308) as:

$$WX\_ITTP22 = CAPTP\_22 * 8760 * 0.7 * (1/8.141)/1000 * 29.308 \quad (5)$$

Excess electricity demand in Wuxi has to be "imported" from the East China Grid.

- The same rationale applies for the coal input of heat generation (WX_ITHS02) and the heat output (WX_IHS02) calculated with the heat generation capacity (CAPHP_21) and the parameters mentioned above:

$$WX\_ITHS02 = (WX\_ITHS21 / (EFFIC\_HEAT\_RAWCOAL/100)) * -1 \quad (6)$$

Table 5. Output of selected industrial products (1994-2010, in physical units).

			1994	2000	2005	2010
		Ferrous and Non-Ferrous Metal				
OUTP_Coke	Coke	(Mill. tons)	0.278	0.299	0.334	0.336
OUTP_Steel	Steel	(Mill. tons)	0.914	1.248	3.270	11.484
OUTP_Steelmat	Steel Material	(Mill. tons)	2.204	4.672	11.681	21.930
OUTP_Coppermat	Copper Material	(Mill. tons)	0.000	0.155	0.430	0.820
OUTP_Alummat	Aluminium Material	(Mill. tons)	0.000	0.109	0.174	0.571
		Building Material and Forestry Products				
OUTP_Cement	Cement	(Mill. tons)	3.318	4.341	9.490	16.729
OUTP_Granite	Granite Board Material	(Mill. sq·m)	0.000	0.060	0.008	0.450
OUTP_Firerest	Fire-Resistant Material Products	(Mill. tons)	0.500	0.216	0.308	0.579
		Light Industry and Grain Products				
OUTP_Wheatpowder	Wheat Powder	(Mill. tons)	0.000	0.144	0.066	0.101
OUTP_Vegoil	Edible Vegetable Oil	(Mill. tons)	0.000	0.083	0.084	0.021
OUTP_Milk	Milk	(ton)	0	48	465	207
OUTP_Wine	Beverage Wine	(Mill. litres)	88	765	973	1184
OUTP_Shoes	Leather Shoes	(Mill. pairs)	3.485	1.846	1.703	0.302
OUTP_Paperboard	Machine-Made Paper Board	(Mill. tons)	0.179	0.288	0.041	0.854
OUTP_Paperprod	Paper-Made Products	(Mill. tons)	0.000	0.072	0.118	0.196
OUTP_Board	Man-Made Board	(Mill. cu.m)	0.007	0.000	0.041	0.045
OUTP_Compoundfl	Compound Floor	(Mill. sq.m)	0.000	0.000	0.258	0.044
OUTP_Plasticprod	Plastic Products	(Mill. tons)	0.241	0.397	0.877	1.489
OUTP_Plasticfilm	Plastic Film	(Mill. tons)	0.000	0.070	0.245	0.343
OUTP_Motorcycle	Motorcycle	(Mill. units)	0.393	0.586	0.416	0.503
OUTP_Bicycle	Bicycle	(Mill. units)	0.918	0.232	0.564	0.116
OUTP_Washer	Household Washer	(Mill. units)	0.639	1.545	1.522	3.325
OUTP_Fridge	Household Refrigerator	(Mill. units)	0.000	0.135	0.334	0.877
OUTP_Shower	Electric Shower-Bath Device	(Mill. units)	0.000	0.331	0.832	1.841
OUTP_Lamp	Lamp	(Mill. units)	17.898	1.025	0.085	0.716
		Textile				
OUTP_Yarn	Yarn	(Mill. tons)	0.128	0.203	0.354	0.619
OUTP_Cloth	Cloth	(Mill. m)	524.6150	551.1969	607.0395	500.2073
OUTP_Cottincloth	Cotton Cloth	(Mill. m)	206.2000	288.7388	301.2626	273.8920
OUTP_Blendfabrics	Blend Fabrics	(Mill. m)	0.000	174.532	244.683	176.691
OUTP_Chemicalfiber	Pure Chemical-Fibre Cloth	(Mill. m)	146.075	87.926	61.094	49.625

Continued

OUTP_Prontingcloth	Printing and Dyeing Cloth	(Mill. m)	392.505	892.474	1122.001	895.140
OUTP_Curtain	Curtain Cloth	(Mill. tons)	0.000	0.008	0.010	0.021
OUTP_Knittingwool	Knitting Wool	(Mill. tons)	0.047	0.027	0.023	0.026
OUTP_Woolfabrics	Wool Fabrics	(Mill. m)	23.505	65.138	65.267	120.955
OUTP_Silk	Silk	(ton)	32.065	20.737	21.470	8.262
OUTP_Silkfabrics	Silk Fabrics	(Mill. m)	79.120	61.222	43.167	3.734
OUTP_Clothing	Clothing	(Mill. units)	150.735	155.637	250.512	586.376
OUTP_ShuttleCloth	Shuttle-Woven Clothing	(Mill. units)	0.000	72.986	122.883	201.412
OUTP_KnittedCloth	Knitted Clothing	(Mill. units)	0.000	82.620	127.630	384.964
OUTP_ChemFibre	Chemical Fibre	(Mill. tons)	0.187	0.496	1.415	3.077
OUTP_Synthetigfibre	Synthetic Fibre	(Mill. tons)	0.000	0.476	1.383	3.001
		Petro-Chemical and Pharmaceuticals Products				
OUTP_Crude oil	Crude Oil Processing	(Mill. tons)	0.123	0.175	0.170	0.400
OUTP_Petroleum	Petroleum	(Mill. tons)	0.000	0.051	0.084	0.064
OUTP_Diesel	Diesel Oil	(Mill. tons)	0.000	0.066	0.031	0.044
OUTP_Lubricant	Lubricating Oil	(Mill. tons)	0.000	0.063	0.117	0.388
OUTP_Fuel oil	Fuel Oil	(Mill. tons)	0.000	0.030	0.052	0.167
OUTP_LPG	Liquefied Petroleum Gas	(Mill. tons)	0.000	0.011	0.025	0.016
OUTP_Sulphuricacid	Sulphuric Acid	(Mill. tons)	0.064	0.245	0.291	0.139
OUTP_Saltacid	Salt Acid	(Mill. tons)	0.068	0.074	0.025	0.056
OUTP_CausticSoda	Caustic Soda	(Mill. tons)	0.093	0.104	0.141	0.121
OUTP_SnthFertilizer	Synthetic Ammonia	(Mill. tons)	0.071	0.160	0.271	0.373
OUTP_ChemFertilizer	Chemical Fertilizer	(Mill. tons)	0.072	0.143	0.223	0.335
OUTP_Urea	Urea	(Mill. tons)	0.000	0.111	0.194	0.262
OUTP_ChemPesticide	Chemical Pesticide	(Mill. tons)	0.008	0.016	0.005	0.018
OUTP_Pesticides	Pesticides	(tons)	0.000	71.580	16.830	6.739
OUTP_Dye	Dye	(Mill. tons)	0.020	0.029	0.034	0.020
OUTP_FormPlastic	Pmimary-Form plastic	(Mill. tons)	0.000	0.000	0.340	0.945
OUTP_Polymers	Synthetic Fiber Polymers	(Mill. tons)	0.000	0.000	0.919	1.896
OUTP_Medicchemicals	Medicinal chemicals	(ton)	9.520	99.364	33.967	29.083
		Machinery Products				
OUTP_Industryboiler	Industrial-Boiler	(evaporative capacity:ton)	70.270	75.639	115.350	139.578
OUTP_Powerstatboiler	Power-Station Boiler	(evaporative capacity:ton)	30.400	37.150	199.400	219.554
OUTP_Engine	Engine	(Mill. kilowatt)	0.000	7.767	23.736	51.236
OUTP_Metalcutmach	Metal-Cutting Machine Tool	(unit)	42.350	23.490	32.720	53.641

Continued

OUTP_Metalformmach	Metal Forming Machine	(unit)	0.000	0.003	0.002	8.996
OUTP_Pump	Pump	(Mill. units)	0.094	0.273	0.033	0.025
OUTP_Gaspressmach	Gas-Pressing Machine	(unit)	133.720	74.030	88.790	431.312
OUTP_Porttool	Power-Driven Portable Tool	(Mill. units)	0.000	1.011	2.616	0.126
OUTP_Kolling	Kolling Bearing	(Mill. sets)	14.040	168.903	233.361	163.723
OUTP_Liquidpress	Liquid-Pressed Part	(Mill. units)	0.000	0.141	0.293	0.061
OUTP_Pneumpart	Pneumatic Part	(Mill. units)	0.000	0.000	0.104	0.196
OUTP_Harvester	Harvester	(unit)	0.000	37.410	5.410	56.017
OUTP_ACMach	A.C. Machine	(Mill. kw)	2.067	2.305	5.477	7.354
OUTP_Transformer	Transformer	(Mill. kv·a)	4.131	2.161	5.035	1.466
OUTP_ElectCable	Electric Cable	(Mill. km)	0.004	0.076	0.400	1.293
OUTP_telcomcable	Telecommunications Cable	(Mill. km)	0.000	6.719	5.391	1.153
OUTP_Oilpump	Oil Pump	(Mill. yuan)	193.160	827.690	1556.450	4222.907
		Communications. Electronics and Transportation Product				
OUTP_Telephone	Telephone	(Mill. units)	0.000	1.079	2.289	2.164
OUTP_Display	Display Machine	(Mill. units)	0.000	1.487	32.998	0.927
OUTP_Notebook	Notebook Computer	(Mill. units)	0.000	0.000	0.171	0.251
OUTP_semicondpart	Semiconduction Separating Part	(Mill. units)	363.465	1945.285	11725.575	25122.325
OUTP_IC	IC	(Mill. pieces)	88.053	717.038	3867.646	9142.479
OUTP_Camera	Numerical Camera	(Mill. units)	0.000	0.000	48.560	9.028
OUTP_ElectrInstr	Electronic Instrument and Meter	(Mill. units)	0.000	1.773	0.634	1.045
OUTP_HardDisk	Hard Disk Storage Device	(Mill. units)	0.000	8.485	44.692	73.771
OUTP_Reinstcar	Reinstalled Automobile	(Mill. unit)	7.185	112.290	113.780	121.235
OUTP_ship	Civil Steel Ship	(Mill. complex ton)	121.065	605.510	1552.470	6263.726
		Products of Electric Power. Tap Water and Gas				
OUTP_Electricity	Electricity Generation Volume	(Mill. kw·h)	0.327	1.093	2.026	4.102
OUTP_Heat	Heat supply	(million kJ)	0.000	6.223	19.370	64.615
OUTP_Gas	Gas Production	(Mill. m^3)	0.000	69.640	106.810	36.362
OUTP_Tap water	Tap Water Production	(Mill. m^3)	0.000	371.188	458.545	654.342

Source: [13].

Table 6. Population Wuxi (1994-2010, in 1000).

Year	1994	2000	2005	2006	2007	2008	2009	2010
Total	5105	5180	5747	5867	5990	6116	6245	6376
Urban	1145	1347	2900	2977	3061	3128	3216	3304
Rural	3960	3833	2847	2890	2930	2988	3029	3072

Source: [13].

and

$$WX\_ITHS21 = CAPHP\_21 * 8760 * 0.58 * (1/8.141)/1000 * 29.308 \quad (7)$$

Excess heat demand in Wuxi is modeled to be generated with combined heat and power generation (recovery of energy).

- The input of coal for the production of coke (WX_ITC02) is calculated on the basis of its input factor (IC_02_06) for the output of coke (WX_ITC06) as

$$WX\_ITC02 = WX\_ITC06 * IC\_02\_06 * -1 \quad (8)$$

- The output of petroleum products (gasoline, kerosene, diesel, fuel oil, LPG) from refineries, are calculated on the basis of their output factors (or the reverse of their input factors), e.g. for fuel oil (WX_ITPR15) as

$$WX\_ITPR15 = WX\_ITPR11 * (1/IC\_11\_15) * -1 \quad (9)$$

The capacities of the oil refineries (CAP_ITPR11) and their capacity factor (Capfactor_ITPR11) determine the amount of petroleum products which can be produced in Wuxi city as:

$$WX\_ITPR11 = CAP\_ITPR11 * CAPFACTOR\_ITPR11 * -1 \quad (10)$$

Excess demand of petroleum products has to be imported from other regions in China. As Wuxi does not produce crude oil, 100% of crude oil has to be imported from other regions in China. Imports from other countries are neglected here.

Total transformation, e.g. of raw coal (WX_IT02) is defined as

$$\begin{aligned} WX\_IT02 = {} & WX\_ITTP02 + WX\_ITHS02 \\ & + WX\_ITCW02 + WX\_ITC02 \\ & + WX\_ITPR02 + WX\_ITGW02 \\ & + WX\_ITCI02 + WX\_OTBQ02 \\ & + WX\_LOSS02 \end{aligned} \quad (11)$$

with

WX_ITTP02 = Transformation Input Thermal Power (PJ);

WX_ITHS02 = Transformation Input Heating Supply (PJ);

WX_ITCW02 = Transformation Input Coal Washing (PJ);

WX_ITC02 = Transformation Input Coking (PJ);

WX_ITPR02 = Transformation Input Petroleum Refineries (=0) (PJ);

WX_ITGW02 = Transformation Input Gas Works (=0) (PJ);

WX_ITCI02 = Gas Works − Coke input (=0) (PJ);

WX_OTBQ02 = Transformation Input Briquettes (=0) (PJ);

WX_LOSS02 = Losses in Transformation (PJ).

Transformation output of the input factor coal e.g. is realized in power and heat generation (see above).

Primary energy supply

Primary energy supply, e.g. of coal (WX_PES02) is calculated as

$$\begin{aligned} WX\_PES02 = {} & WX\_PESIP02 + WX\_PESREC02 \\ & + WX\_PESIIP02 + WX\_PESIMP02 \\ & + WX\_PESCAS02 + WX\_PESIEXP02 \\ & + WX\_PESEXP02 + WX\_PESFAS02 \\ & + WX\_PESFC02 \end{aligned} \quad (12)$$

with:

WX_PESIP02 = Indigenous Production (PJ);

WX_PESREC02 = Recovery of Energy (PJ);

WX_PESIIP02 = Interprovincial Imports (+) (PJ);

WX_PESIMP02 = Import (+) (PJ);

WX_PESCAS02 = Chinese Vessels Refueling Abroad (+) (PJ);

WX_PESIEX02 Interprovincial Exports (−) (PJ);

WX_PESEXP02 = Export (−) (PJ);

WX_PESFAS02 = Foreign Vessels Refueling in China (−) (PJ);

WX_PESFC02 = Stock Change (increase: −; decrease: +) (PJ).

Indigenous production of electricity in Wuxi (WX_PESIP22) is the sum of the production of nuclear power (WX_PESNP22), hydro power (WX_PESHP22) and other renewable energy (WX_PESREN22).

$$WX\_PESIP22 = WX\_PESHP22 + WX\_PESNP22 + WX\_PESREN22 \quad (13)$$

Excess demand of electricity from the final energy sectors (WX_TFC22) which cannot be generated in thermal (WX_ITTP22) or non-fossil (WX_PESIP22) power plants in Wuxi has to be imported from other regions in China (WX_PESIIP22).

$$WX\_PESIIP22 = WX\_TFC22 - WX\_ITTP22 - WX\_PESIP22 \quad (14)$$

Excess demand of heat from the final energy sectors (WX_TFC21) which cannot be generated in thermal (WX_ITHP21) or non-fossil (WX_PESIP21 = 0) heat plants in Wuxi has to be produced by co-generation (WX_PESREC21).

$$WX\_PESREC21 = WX\_TFC21 - WX\_ITHP21 - WX\_PESIP21 \quad (15)$$

Assumptions for the forecast of primary energy supply and CO_2-emissions.

The forecast of primary energy supply and CO_2-emissions in Wuxi is based on assumptions on the development of

- Population;
- Gross Value Added;
- CO_2-intensity of Gross Value Added and;
- Output of major industrial products in Wuxi.

The development of permanent population in Wuxi

until 2050 is based on the estimated annual growth rates for Jiangsu Province by Wu [22]: 2011-2020: 0.1278%; 2021-2030: −0.3326%; 2031-2040: −0.5279% and 2041-2050: −0.9795%.

Between 2010 and 2050, population in Wuxi is expected to decrease by 12.2% down to 5.597 Mill. urban population, however, is still growing by 33.8% to 4.421 mill following the prevailing urbanization trend in Wuxi. Against this background, rural population will decrease by 61.7% down to 1.175 Mill. inhabitants in 2050 (**Table 7**).

The speed of sectoral Gross Value Added growth is estimated with the growth rates in Wuxi between 2005 and 2009. As for selected sectors (paper industry, chemical industry, cement industry, iron and steel and aluminium industry as well as the primary, secondary and tertiary sector, output value growth is estimated with the respective GDP growth rates given in a study of the Energy Research Institute on China of NDRC on China's Energy Demand and Greenhouse Gas Emission Scenarios in 2050 [23]. To reach the output values in the three sectors of the economy, the growth of Gross Value Added on the single branches are calibrated with correction factors. **Table 8** shows the assumed development of Gross Value Added in Wuxi (2010 is observed data).

Figure 1 shows the assumed sectoral development in Wuxi between 2010 and 2050 and reveals a trend of tertiarization especially after 2030. By 2050, the agricultural sector almost diminished. In addition, within the industrial sector, production of energy intensive goods is decreasing sharply, as indicated in Jiang *et al.* (2008) [23] especially of products in paper industry, chemical industry, cement industry, iron and steel and aluminium industry.

The reduction of CO_2-intensity of Gross Value Added is the most prominent goal in China to achieve a low carbon economy. The national goal for 2020 is a reduction of 40% - 45% against 2005. Wuxi City government is heading for an even higher goal: 50% in 2020. For the time after 2020, it is assumed to be gradually reduced further (65% by 2030, 70% by 2040, and 75% by 2050).

The output of major industrial products is one of the most important factors for the energy demand in Wuxi and reflects the development mentioned above. Its development in the main sectors again is estimated with data on China until 2050 (**Table 9**) from Jiang *et al.* [23].

As for Wuxi, the growth rate of physical output of the main products is estimated with the assumed national

Table 7. Development of population and age structure in Wuxi (2010-2050, in 1000).

Year	2010	2020	2030	2040	2050
Total	6376	6620	6422	6120	5597
Wuxi urban	3304	4170	4496	4529	4421
Wuxi rural	3072	2449	1927	1591	1175

Source: [13]. 2010 is observed data.

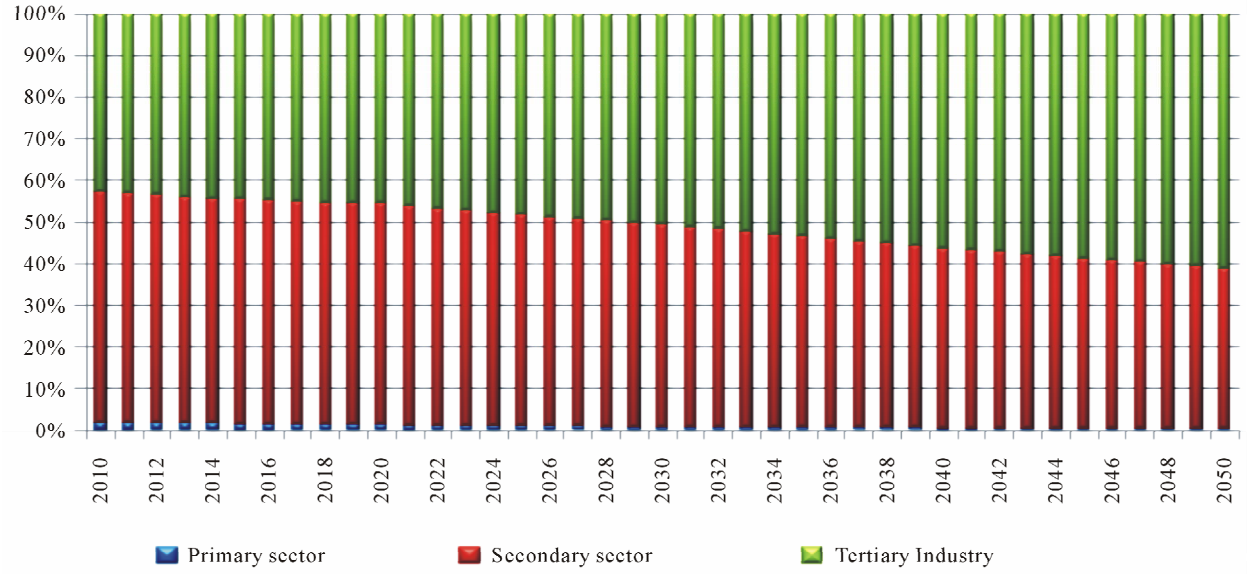

Figure 1. Sectoral development in Wuxi (2010-2050 in percent of total Gross Value Added). Source: [13,23], own calculations. 2010 is observed data.

Table 8. Development of gross value added in Wuxi (2010-2050, in bn. RMB and prices of 2005).

	2010	2020	2030	2040	2050
Total	**485294**	**1107680**	**2232189**	**3650525**	**5214014**
Primary Sector	**9348**	**14146**	**17880**	**21080**	**23657**
Secondary Sector	**268740**	**588487**	**1085757**	**1573432**	**2004811**
Industry	250468	548040	1010641	1464357	1865733
Agriculture and Non-Staple Food Processing	342	253	208	189	178
Food Production	949	1089	1191	1247	1282
Beverage Production	281	595	977	1261	1471
Textile Industry	13990	10464	8669	7878	7441
Clothes, Shoes and Hats Products	8888	24590	48277	68507	84578
Leather, Fur, Down and Related Products	259	248	242	238	237
Timber Processing, Bamboo, Cane, Palm	357	541	711	818	889
Fiber and Straw Products	113	244	407	530	621
Papermaking and Paper Products	1602	2214	2285	2345	2345
Printing and Record Medium Reproduction	1174	2361	3742	4746	5474
Stationery , Educational and Sports Goods Products	257	335	397	434	457
Petroleum, Coking and Nuclear Fuel Processing	1291	2100	2891	3407	3761
Raw Chemical Materials and Chemical Products	17425	22410	22655	22162	20958
Medical and Pharmaceutical Products	2572	4392	6245	7485	8345
Chemical Fiber Manufacturing	9428	10684	11593	12087	12393
Rubber Products	1498	2713	4012	4908	5539
Plastic Products	3906	3973	4018	4041	4054
Non-Metallic Mineral Products	4430	5589	5589	4692	3993
Smelting and Pressing of Ferrous Metals	35178	47762	45511	38880	34731
Smelting and Pressing of Nonferrous Metals	13315	31258	32559	32559	31000
Metal Products	10745	15460	19625	22181	23871
General Purpose Equipment Manufacturing	14796	33369	57107	75395	89103
Special Purpose Equipment Manufacturing	10221	19267	29252	36278	41284
Transportation Equipment Manufacturing	24350	105618	281412	469635	639921
Electric Equipment and Machinery Manufacturing	30817	81754	156028	218134	266886
Telecommunications, Computers and Other	32714	74981	129716	172230	204243
Electronic Equipments Products	3793	23179	78173	148087	218049
Instruments, Meters, Culture and Office Machinery Manufacturing	367	436	488	517	535
Handicraft Articles and Others Manufacturing	78	393	1160	2045	2882
Recycling and Disposal of Waste	4437	13309	27593	40298	50627
Electricity and Heating Power Production and Supply	685	6225	27663	60888	98322

Continued

Gas Production and Supply	210	232	247	256	261
Water Production and Supply	18272	40446	75116	109075	139078
Construction	207206	505047	1128552	2056013	3185546
Tertiary Industry	**11131**	**15819**	**21363**	**26490**	**30858**
Transportation, Storage and Post	7728	15348	27627	42153	56942
Information Transmission, Computer and Software Services	72278	156881	304869	491747	691249
Wholesale and Retail	12160	34691	85363	163527	260123
Catering Trade	28455	78044	185613	346836	541914
Real Estate	12360	29231	61166	104111	152108
Hiring and Commercial Services	1971	919	482	305	221
Commurity Services and Others	4767	9765	18053	28085	38469
Health Care, Social Ensure and Social Welfare	2127	4383	8144	12715	17461
Culture, Sports and Entertainment	35790	119182	335316	708564	1209805
Others	18439	40784	80557	131481	186396
Other Tertiary	485294	1107680	2232189	3650525	5214014

Source: [13,23], own calculations.

Table 9. Products output in major sectors in China (2005-2050, in physical units).

Product	Unit	2005	2020	2030	2040	2050
Steel	Million ton	355	610	570	440	360
Cement	Million ton	1060	1600	1600	1200	900
Glass	Million cases	399	650	690	670	580
Copper	Million ton	2.6	7	7	6.5	4.6
Ammonia	Million ton	8.51	16	16	15	12
Ethylene	Million ton	5.1	7.2	7	6.5	5.5
Soda Ash	Million ton	14.67	23	24.5	23.5	22
Caustic Soda	Million ton	12.64	24	25	25	24
Paper	Million ton	62.05	110	115	120	120
Fertilizer	Million ton	52.2	61	61	61	61
Aluminum	Million ton	7.56	34	36	36	33
Paper Board	Million ton	46.3	50	50	50	45
Calcium Carbide	Million ton	8.5	10	8	7	4

Source: [23].

development (**Table 10**).

Table 11 shows the output of major industrial products in Wuxi and reveals the trend of a decrease of energy intensive heavy industry products (steel, cement, copper, chemical products) in favor of less energy intensive light industrial products such as household washers or refrigerators.

Based on the assumptions of the Energy Research Center of the National Development and Reform Commission [23] on the growth of Gross Value Added in the key sectors in China are as shown in **Table 11** presenting a mixed picture. Generally, there will be a structural

Table 10. Growth rates of physical product output in major sectors in China (2011-2050, in percent p.a.).

	2011-2020	2021-2030	2031-2040	2041-2050
Steel	3.67	−0.68	−2.56	−1.99
Cement	2.78	0.00	−2.84	−2.84
Glass	3.31	0.60	−0.29	−1.43
Copper	6.83	0.00	−0.74	−3.40
Ammonia	4.30	0.00	−0.64	−2.21
Ethylene	2.33	−0.28	−0.74	−1.66
Soda Ash	3.04	0.63	−0.42	−0.66
Caustic Soda	4.37	0.41	0.00	−0.41
Paper	3.89	0.45	0.43	0.00
Fertilizer	1.04	0.00	0.00	0.00
Aluminum	10.54	0.57	0.00	−0.87
Paper Board	0.51	0.00	0.00	−1.05
Calcium Carbide	1.09	−2.21	−1.33	−5.44

Source: [23].

Table 11. Output of major industrial products in Wuxi (2005-2050, in physical units).

		2020	2030	2040	2050	2005-2020 (%)	2005-2050 (%)
				Ferrous and Non-Ferrous Metal			
Coke	(Mill. tons)	0.456	0.434	0.371	0.331	41.2	2.7
Steel	(Mill. tons)	16	15	13	11	162.3	90.7
Steel Material	(Mill. tons)	32	40	45	49	114.6	231.3
Copper Material	(Mill. tons)	1.925	2.005	2.005	1.909	379.9	376.0
Aluminium Material	(Mill. tons)	1.341	1.397	1.397	1.330	484.2	479.4
				Building Material and Forestry Products			
Cement	(Mill. tons)	21	21	18	15	83.9	31.4
Granite Board Material	(Mill. sq·m)	0.568	0.568	0.477	0.405	94.6	39.0
Fire-Resistant Material Products	(Mill. tons)	0.730	0.730	0.613	0.522	106.4	47.4
				Light Industry and Grain Products			
Wheat Powder	(Mill. tons)	0.075	0.062	0.056	0.052	0.4	−29.5
Edible Vegetable Oil	(Mill. tons)	0.016	0.013	0.012	0.011	−82.7	−87.9
Milk	(ton)	15285	12572	11384	10730	−70.3	−79.1
Beverage Wine	(Mill. litres)	876	720	652	615	−17.0	−41.7
Leather Shoes	(Mill. pairs)	0.290	0.282	0.279	0.276	−54.1	−56.3
Machine-Made Paper Board	(Mill. tons)	1.180	1.218	1.250	1.250	90.1	101.4
Paper-Made Products	(Mill. tons)	0.270	0.279	0.286	0.286	209.8	228.2
Man-Made Board	(Mill. cu.m)	0.063	0.065	0.066	0.066	58.3	67.7
Compound Floor	(Mill. sq.m)	0.096	0.178	0.258	0.328	−41.2	100.0
Plastic Products	(Mill. tons)	1.515	1.532	1.541	1.546	64.7	68.1

Continued

Plastic Film	(Mill. tons)	0.349	0.353	0.355	0.356	29.1	31.8
Motorcycle	(Mill. units)	2.183	5.817	9.708	13.229	351.8	2637.2
Bicycle	(Mill. units)	0.501	1.335	2.229	3.037	14.8	595.7
Household Washer	(Mill. units)	8.821	16.834	23.535	28.795	376.6	1455.7
Household Refrigerator	(Mill. units)	2.326	4.438	6.205	7.592	570.2	2087.8
Electric Shower-Bath Device	(Mill. units)	4.883	9.319	13.029	15.941	293.1	1183.2
Lamp	(Mill. units)	1.901	3.627	5.071	6.205	–	–
				Textile			
Yarn	(Mill. tons)	0.463	0.384	0.349	0.329	−3.8	−31.6
Cloth	(Mill. m)	374	310	282	266	−55.7	−68.5
Cotton Cloth	(Mill. m)	205	170	154	146	−53.4	−66.9
Blend Fabrics	(Mill. m)	132	109	99	94	−60.3	−71.8
Pure Chemical-Fibre Cloth	(Mill. m)	37	31	28	26	−48.0	−63.0
Printing and Dyeing Cloth	(Mill. m)	670	555	504	476	−45.5	−61.3
Curtain Cloth	(Mill. tons)	0.016	0.013	0.012	0.011	82.7	29.9
Knitting Wool	(Mill. tons)	0.020	0.016	0.015	0.014	−6.1	−33.2
Wool Fabrics	(Mill. m)	90	75	68	64	26.6	−10.0
Silk	(ton)	618	512	465	439	−65.9	−75.8
Silk Fabrics	(Mill. m)	3	2	2	2	−89.8	−92.8
Clothing	(Mill. units)	439	363	330	312	−9.2	−35.4
Shuttle-Woven Clothing	(Mill. units)	151	125	113	107	−34.7	−53.5
Knitted Clothing	(Mill. units)	288	239	217	205	14.1	−18.8
Chemical Fibre	(Mill. tons)	3	4	4	4	76.8	105.1
Synthetic Fibre	(Mill. tons)	3	4	4	4	74.8	102.8
				Petro-Chemical and Pharmaceuticals Products			
Crude Oil Processing	(Mill. tons)	0.651	0.897	1.057	1.167	283.2	586.4
Petroleum	(Mill. tons)	0.104	0.144	0.169	0.187	28.0	129.3
Diesel Oil	(Mill. tons)	0.072	0.098	0.116	0.128	120.0	294.1
Lubricating Oil	(Mill. tons)	0.631	0.869	1.025	1.131	267.3	557.9
Fuel Oil	(Mill. tons)	0.272	0.374	0.441	0.486	546.7	1058.3
Liquefied Petroleum Gas	(Mill. tons)	0.026	0.036	0.042	0.046	14.8	105.6
Sulphuric Acid	(Mill. tons)	0.179	0.181	0.177	0.167	−32.9	−37.3
Salt Acid	(Mill. tons)	0.072	0.073	0.072	0.068	148.7	132.6
Caustic Soda	(Mill. tons)	0.155	0.157	0.154	0.145	0.6	−5.9
Synthetic Ammonia	(Mill. tons)	0.480	0.485	0.474	0.449	67.3	56.5
Chemical Fertilizer	(Mill. tons)	0.431	0.436	0.426	0.403	107.9	94.4
Urea	(Mill. tons)	0.337	0.341	0.333	0.315	64.2	53.5
Chemical Pesticide	(Mill. tons)	0.023	0.023	0.023	0.022	32.5	23.9
Pesticides	(tons)	866.7	876.2	857.1	810.6	131.1	116.1

Continued

Dye	(Mill. tons)	0.026	0.026	0.025	0.024	−14.3	−19.9
Primary-Form Plastic	(Mill. tons)	1.215	1.229	1.202	1.137	200.9	181.4
Synthetic Fiber Polymers	(Mill. tons)	2.438	2.465	2.411	2.280	143.2	127.5
Medicinal Chemicals	(ton)	4967	7063	8466	9438	377.3	806.9
		Machinery Products					
Industrial-Boiler	(evaporative capacity: ton)	31479	53873	71126	84058	157.2	586.9
Power-Station Boiler	(evaporative capacity: ton)	49517	84741	111880	132222	88.3	402.9
Engine	(Mill. kilowatt)	116	198	261	309	722.4	2095.9
Metal-Cutting Machine Tool	(unit)	12098	20704	27334	32304	264.8	874.2
Metal Forming Machine	(unit)	2029	3472	4584	5418	−25.7	98.4
Pump	(Mill. units)	0	0	0	0	131.4	518.0
Gas-Pressing Machine	(unit)	97275	166473	219786	259748	834.9	2396.4
Power-Driven Portable Tool	(Mill. units)	0.285	0.488	0.644	0.761	−	−
Kolling Bearing	(Mill. sets)	369.2	631.9	834.3	985.9	99.0	431.4
Liquid-Pressed Part	(Mill. units)	0.138	0.236	0.311	0.368	−64.1	−4.2
Pneumatic Part	(Mill. units)	0.442	0.757	0.999	1.180	204.2	712.4
Harvester	(unit)	12634	21621	28545	33735	524.5	1567.6
A.C. Machine	(Mill. kw)	20	37	52	64	285.4	1158.1
Transformer	(Mill. kv·a)	4	7	10	13	67.4	446.6
Electric Cable	(Mill. km)	3	7	9	11	384.4	1481.3
Telecommunications Cable	(Mill. km)	3	6	8	10	2.0	232.9
Oil Pump	(Mill. yuan)	7960	12085	14988	17057	436.7	1050.0
		Communications, Electronics and Transportation Product					
Telephone	(Mill. units)	4.959	8.580	11.392	13.509	123.7	509.3
Display Machine	(Mill. units)	2.125	3.677	4.882	5.789	−42.2	57.4
Notebook Computer	(Mill. units)	0.575	0.994	1.320	1.566	459.6	1424.4
Semiconduction Separating Part	(Mill. units)	57581	99614	132262	156846	327.9	1065.5
IC	(Mill. pieces)	20955	36251	48132	57079	351.9	1130.9
Numerical Camera	(Mill. units)	21	36	48	56	−99.8	−99.6
Electronic Instrument and Meter	(Mill. units)	2	4	6	7	595.4	1794.1
Hard Disk Storage Device	(Mill. units)	169	293	388	461	242.4	832.7
Reinstalled Automobile	(Mill. unit)	0.053	0.140	0.234	0.319	591.8	4091.7
Civil Steel Ship	(Mill. complex ton)	2.717	7.239	12.081	16.461	1806.4	11450.4
		Products of Electric Power, Tap Water and Gas					
Electricity Generation Volume	(Mill. kw·h)	12.303	25.507	37.252	46.801	411.4	1845.3
Heat Supply	(bn·kJ)	193797	401788	586792	737210	804.5	3340.9
Gas Production	(Mill. m3)	330	1468	3231	5217	227.3	5069.2
Tap Water Production	(Mill. m3)	723	771	797	813	45.6	63.8

Source: [13], own calculations.

change away from energy intensive heavy (iron and steel, chemical industry etc.) to light industry. Textile industry output will decrease by 60% - 70% by 2050. However, other light industry machinery and electronic products will increase in output such as computers (1400%), electronic instruments and meters (1800%) or engines (2000%).

3. Development until 2050 without Implementation of the Low Carbon City Plan

3.1. Overview

For modeling the scenario without the implementation of a Low Carbon City plan un Wuxi, the variable $CO2INT_{j,t}$ is kept constant for the single sectors (j) after 2010.

Based on the assumptions of the model, total primary energy in Wuxi will increase by 93.7% in 2020 and by 244.7% in 2050 against the 2005 values (**Table 12**). Access demand for electricity and all other primary energy in Wuxi is imported. Primary energy imports increase by 76.7% in 2020 and 210.1% in 2050.

In 2010, 80.8% of primary energy was coal, 9.3% coke, 3.2% oil, 3.1% gas, 3.0% electricity imports and 0.7% recovery of heat energy through co-generation. By 2020, this fuel mix will already change considerably as electricity imports will grow to 156 PJ in 2020 and 665 PJ in 2050 (**Table 13**). In 2020, electricity imports will already have a 14.0% share of total primary energy supply. By 2050, the share of electricity will more than double to 33.6%. As co-generation and gas consumption will increase, in 2050 coal share will drop to 49.9%. To contribute to the overall reduction of CO_2-intensity, by 2020, there will be renewable power generation of 0.084 PJ.

Table 14 shows the Wuxi CO_2-balance until 2050. Until 2020, CO_2-emissions increase by 103.1% to 121 Mt, until 2050 by 301.2% to 238 Mt. In the following sections, the development of the sectoral CO_2-emissions are described in detail.

Most of the CO_2-emissions are due to coal combustion and imported electricity (**Table 15**). In 2005, CO_2-emissions per capita were 10.3 tons. By 2020, per capita emissions will reach 18.2 t, by 2050 42.6 t. Compared to the current consumption in 2010 [24] in the US (19.1 t), Germany (10.1 t) or the current Chinese average (6.4 t), this is very high. In a post Kyoto regime, the determination of per capita emissions may be important for the allocation of emission rights [25].

According to the Kaya Identity [26], CO_2-emissions can be expressed as an ex-post identity of the following factors: population, Gross Value Added per capita, energy intensity of Gross Value Added and CO_2-intensity of energy consumption. Here, we define it as:

$$CO_2 = CO_2/PES * PES/GVA * GVA/POP * POP \quad (15)$$

with

CO_2 = CO_2-emissions (Mt);
PES = Primary Energy Supply (PJ);
GVA = Gross Value Added (Mill. RMB);
POP = Population (Mill.).

Figure 2 shows the development of the factors in the Kaya Identity in Wuxi. Clearly, it can be seen that the energy intensity of Gross Value Added decreases over time according to the Low Carbon City plan in Wuxi. The same is for population and CO_2-intensity of Primary Energy Supply. Per capita income, however increases considerably.

To show the impact of the different factors, the development is shown relative to the year 2005 (**Figure 3**). Kaya Identity factor decomposition shows that the increase of per capita income has the largest impact on the growth of CO_2-emissions and the decrease of energy

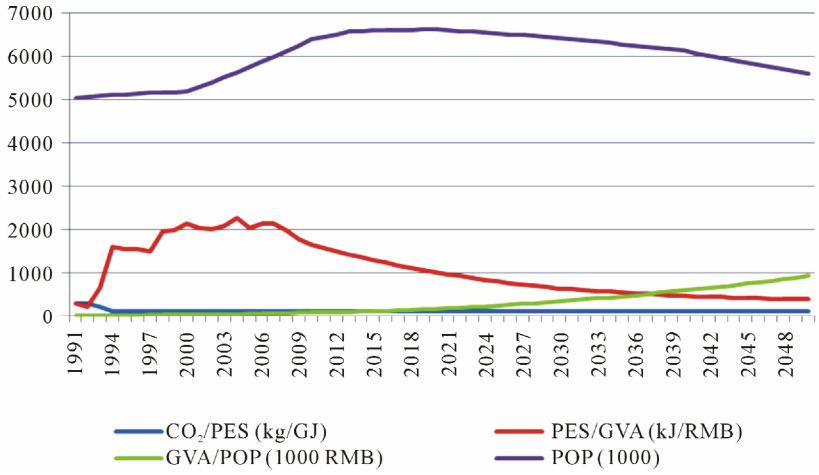

Figure 2. Development of macro-economic variables in Wuxi without implementation of the Low Carbon City Plan (1991-2050, in specific values). Source: Own calculation.

Table 12. Wuxi energy balance without implementation of the Low Carbon City Plan (2005-2050, in PJ).

	2005	2020	2030	2040	2050
Total Primary Energy Supply	573.669	1110.994	1414.434	1693.976	1977.234
Indigenous Production	0.000	0.084	0.056	0.045	0.038
Indigenous Production—Hydro Power	0.000	0.000	0.000	0.000	0.000
Indigenous Production—Nuclear Power	0.000	0.000	0.000	0.000	0.000
Indigenous Production—Renewable Energy	0.000	0.084	0.056	0.045	0.038
Recovery of Energy	0.000	40.400	66.195	84.760	98.278
Interprovincial Imports (+)	605.891	1070.509	1348.182	1609.171	1878.918
Import (+)	0.000	0.000	0.000	0.000	0.000
Chinese Vessels Refueling Abroad (+)	0.000	0.000	0.000	0.000	0.000
Interprovincial Exports (−)	−3.502	0.000	0.000	0.000	0.000
Export (−)	−1.195	0.000	0.000	0.000	0.000
Foreign Vessels Refueling in China (−)	0.000	0.000	0.000	0.000	0.000
Stock Change (increase: −; decrease: +)	−27.525	0.000	0.000	0.000	0.000
Total Transformation (input: −; output: +)	−135.404	−253.798	−286.359	−322.640	−365.723
Thermal Power	−125.139	−237.487	−274.908	−317.854	−367.047
Heating Supply	−5.794	−11.786	−9.711	−7.798	−6.036
Coal Washing	0.000	0.000	0.000	0.000	0.000
Coking	−1.099	−1.155	−1.150	−1.136	−1.127
Petroleum Refineries	−3.372	−11.604	−12.980	−12.275	−11.354
Gas Works	0.000	8.235	12.390	16.422	19.841
Gas Works—Coke Input	0.000	0.000	0.000	0.000	0.000
Briquettes	0.000	0.000	0.000	0.000	0.000
Losses in Transformation	0.000	0.000	0.000	0.000	0.000
Total Final Consumption	438.264	857.196	1128.075	1371.336	1611.512
Agriculture	0.623	1.567	2.329	3.050	3.714
Secondary Industry	416.285	766.303	949.683	1077.416	1182.241
Industry	415.575	764.175	945.692	1071.599	1174.812
Coal Mining	0.000	0.000	0.000	0.000	0.000
Non-Metal Mining and Processing	0.122	0.000	0.000	0.000	0.000
Agriculture and Non-Staple Food Processing	0.577	0.517	0.495	0.439	0.404
Food Production	3.759	2.426	2.762	2.932	3.035
Beverage Production	0.272	0.522	0.519	0.518	0.518
Textile Industry	58.583	34.989	29.749	27.464	26.229
Clothes, Shoes and Hats Products	9.921	16.589	20.063	23.012	25.620
Leather, Fur, Down and Related Products	0.217	0.253	0.244	0.239	0.236
Timber Processing, Bamboo, Cane, Palm	0.165	0.252	0.323	0.353	0.351
Furniture Manufacturing	0.010	0.150	0.428	0.793	1.218
Papermaking and Paper Products	7.126	11.636	12.009	12.325	12.325
Printing and Record Medium Reproduction	0.420	0.250	1.950	2.535	2.974
Stationery, Educational and Sports Goods Products	0.368	0.105	0.375	0.422	0.454

Continued

Petroleum, Coking and Nuclear Fuel Processing	1.217	0.550	1.448	1.737	1.932
Raw Chemical Materials and Chemical Products	66.392	39.300	110.565	108.118	102.147
Medical and Pharmaceutical Products	2.017	3.206	2.161	2.161	2.161
Chemical Fiber Manufacturing	23.803	9.680	30.725	31.655	32.090
Rubber Products	3.217	0.981	3.584	4.305	5.096
Plastic Products	5.465	2.475	6.774	6.976	7.184
Non-Metallic Mineral Products	33.771	25.793	59.987	50.375	42.877
Smelting and Pressing of Ferrous Metals	134.912	31.427	223.740	200.421	185.921
Smelting and Pressing of Nonferrous Metals	7.146	3.668	33.665	33.703	32.191
Metal Products	10.297	4.738	21.544	24.340	26.429
General Purpose Equipment Manufacturing	9.082	5.470	53.151	70.029	82.801
Special Purpose Equipment Manufacturing	1.798	1.941	19.396	25.544	30.152
Transportation Equipment Manufacturing	3.255	1.003	73.972	123.518	168.812
Electric Equipment and Machinery Manufacturing	7.264	2.079	97.004	128.615	152.544
Telecommunications, Computers and Other Electronic Equipments Products	7.088	1.471	70.953	93.021	109.637
Instruments, Meters, Culture and Office Machinery Manufacturing	0.317	0.196	2.448	3.320	4.062
Handicraft Articles and Others Manufacturing	0.928	0.290	1.770	1.950	2.063
Recycling and Disposal of Waste	0.000	0.000	1.244	2.189	3.082
Electricity and Heating Power Production and Supply	12.218	3.915	61.969	87.735	109.167
Gas Production and Supply	0.011	0.004	0.338	0.590	0.869
Water Production and Supply	0.502	0.334	0.335	0.266	0.231
Construction	0.710	0.236	3.991	5.817	7.429
Tertiary Sector	7.950	3.661	69.434	113.752	162.074
Transportation, Telecommunications, Postal	0.494	0.262	6.012	10.912	16.880
Commerce, Hotel and Catering Service	3.084	1.137	16.752	25.955	35.726
Other	4.372	2.262	46.670	76.885	109.468
Residential Consumption	13.406	9.178	106.629	177.118	263.482
Residential Consumption—Rural	9.407	6.550	56.743	86.643	126.169
Residential Consumption—Urban	3.935	2.505	49.886	90.476	137.313
Statistical Difference	0.000	0.000	0.000	0.000	0.000

Source: Own calculations.

Table 13. Primary energy mix Wuxi without implementation of the Low Carbon City Plan (2005-2050, in PJ).

	2005	2010	2020	2030	2040	2050	2005-2020 (%)	2005-2050 (%)
Total	574	798	1111	1414	1694	1977	93.7	244.7
Coal	442	645	750	827	898	988	69.5	123.2
Coke	54	74	73	71	65	60	35.8	12.6
Oil	35	25	42	49	54	57	20.3	65.6
Gas	8	24	50	70	88	109	533.3	1262.5
Electricity	39	24	156	331	505	665	304.3	1627.2
Heat	−4	5	40	66	85	98	−1253.5	−2906.0

Source: Own calculations.

Table 14. Wuxi CO_2-balance (2005-2050, in Mt).

	2005	2020	2030	2040	2050
Total Primary Energy Supply	59.438	120.692	165.232	203.858	238.494
Indigenous Production	0.000	0.000	0.000	0.000	0.000
Indigenous Production—Hydro Power	0.000	0.000	0.000	0.000	0.000
Indigenous Production—Nuclear Power	0.000	0.000	0.000	0.000	0.000
Indigenous Production—Renewable Energy	0.000	0.000	0.000	0.000	0.000
Recovery of Energy	0.000	4.751	7.554	9.388	10.564
Interprovincial Imports (+)	61.946	115.941	157.678	194.470	227.931
Import (+)	0.000	0.000	0.000	0.000	0.000
Chinese Vessels Refueling Abroad (+)	0.000	0.000	0.000	0.000	0.000
Interprovincial Exports (−)	−0.421	0.000	0.000	0.000	0.000
Export (−)	−0.083	0.000	0.000	0.000	0.000
Foreign Vessels Refueling in China (−)	0.000	0.000	0.000	0.000	0.000
Stock Change (increase: −; decrease: +)	−2.526	0.000	0.000	0.000	0.000
Total Transformation (input: −; output: +)	−0.445	−0.638	−0.557	−0.323	−0.101
Thermal Power	0.000	0.000	0.000	0.000	0.000
Heating Supply	0.000	0.000	0.000	0.000	0.000
Coal Washing	0.000	0.000	0.000	0.000	0.000
Coking	−0.180	−0.129	−0.128	−0.127	−0.126
Petroleum Refineries	−0.265	−0.875	−0.978	−0.925	−0.856
Gas Works	0.000	0.365	0.550	0.729	0.880
Gas Works—Coke input	0.000	0.000	0.000	0.000	0.000
Briquettes	0.000	0.000	0.000	0.000	0.000
Losses in Transformation	0.000	0.000	0.000	0.000	0.000
Total Final Consumption	57.555	117.168	160.422	197.537	230.180
Agriculture	0.144	0.325	0.459	0.571	0.662
Secondary Industry	52.600	100.152	128.121	146.565	159.260
Industry	52.436	99.711	127.334	145.476	157.936
Coal Mining	0.000	0.000	0.000	0.000	0.000
Non-Metal Mining and Processing	0.009	0.000	0.000	0.000	0.000
Agriculture and Non-Staple Food Processing	0.072	0.063	0.059	0.051	0.045
Food Production	0.458	0.324	0.353	0.364	0.366
Beverage Production	0.034	0.060	0.057	0.056	0.054
Textile Industry	7.847	4.597	3.750	3.343	3.093
Clothes, Shoes and Hats Products	0.987	2.076	2.520	2.874	3.167
Leather, Fur, Down and Related Products	0.030	0.034	0.032	0.030	0.029

Continued

Timber Processing, Bamboo, Cane, Palm	0.024	0.038	0.043	0.044	0.043
Furniture Manufacturing	0.002	0.030	0.083	0.145	0.212
Papermaking and Paper Products	0.973	1.463	1.471	1.472	1.437
Printing and Record Medium Reproduction	0.073	0.201	0.310	0.385	0.433
Stationery, Educational and Sports Goods Products	0.046	0.041	0.049	0.053	0.055
Petroleum, Coking and Nuclear Fuel Processing	0.136	0.130	0.189	0.226	0.247
Raw Chemical Materials and Chemical Products	6.832	11.936	11.842	11.357	10.513
Medical and Pharmaceutical Products	0.291	0.297	0.287	0.277	0.269
Chemical Fiber Manufacturing	2.985	3.674	3.845	3.869	3.829
Rubber Products	0.403	0.399	0.425	0.459	0.498
Plastic Products	0.861	1.009	0.988	0.967	0.948
Non-Metallic Mineral Products	3.905	6.659	6.549	5.409	4.530
Smelting and Pressing of Ferrous Metals	15.122	26.066	25.700	23.123	21.335
Smelting and Pressing of Nonferrous Metals	0.989	4.046	4.205	4.083	3.787
Metal Products	1.843	2.337	3.008	3.381	3.632
General Purpose Equipment Manufacturing	1.301	4.582	7.453	9.444	10.756
Special Purpose Equipment Manufacturing	0.311	1.916	3.171	4.026	4.569
Transportation Equipment Manufacturing	0.521	5.328	13.747	21.953	28.591
Electric Equipment and Machinery Manufacturing	1.171	7.408	12.360	15.899	18.298
Telecommunications, Computers and Other Electronic Equipments Products	1.382	7.767	12.371	15.486	17.432
Instruments, Meters, Culture and Office Machinery Manufacturing	0.050	0.258	0.417	0.531	0.611
Handicraft Articles and Others Manufacturing	0.164	0.256	0.301	0.317	0.321
Recycling and Disposal of Waste	0.000	0.087	0.244	0.409	0.548
Electricity and Heating Power Production and Supply	2.726	6.507	11.382	15.296	18.116
Gas Production and Supply	0.001	0.028	0.059	0.095	0.133
Water Production and Supply	0.115	0.097	0.065	0.049	0.040
Construction	0.164	0.442	0.787	1.090	1.323
Tertiary Sector	1.836	7.300	13.684	21.307	28.868
Transportation, Telecommunications, Postal	0.114	0.564	1.185	2.044	3.007
Commerce, Hotel and Catering Service	0.712	1.947	3.302	4.862	6.363
Other	1.010	4.789	9.198	14.402	19.498
Residential Consumption	2.975	9.390	18.158	29.093	41.391
Residential Consumption—Rural	2.087	6.115	9.479	13.791	19.164
Residential Consumption—Urban	0.883	3.275	8.679	15.301	22.227
Statistical Difference	0.000	0.000	0.000	0.000	0.000

Source: Own calculations.

Table 15. CO_2-mix in Wuxi without implementation of the Low Carbon City Plan (2005-2050, in PJ).

	2005	2020	2030	2040	2050	2005-2020 (%)	2005-2050 (%)
Total CO_2 (Mt)	59	121	165	204	238	103.1	301.2
Coal	42	71	78	85	93	69.5	123.2
Coke	5	7	7	6	6	35.8	12.6
Oil	3	3	3	4	4	6.5	50.9
Gas	0	3	4	6	7	586.5	1376.9
Electricity	10	32	65	94	118	226.9	1102.2
Heat	0	5	8	9	11	−1228.6	−2609.6
Total CO_2 (%)	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Coal	70.4	58.8	47.4	41.7	39.2		
Coke	8.6	5.8	4.1	3.0	2.4		
Oil	4.3	2.3	2.0	1.8	1.6		
Gas	0.8	2.6	2.7	2.7	2.9		
Electricity	16.5	26.6	39.3	46.2	49.5		
Heat	-0.7	3.9	4.6	4.6	4.4		
Population (1000)	5747	6620	6422	6120	5597		
CO_2-Emissions per Capita (t)	10.3	18.2	25.7	33.3	42.6		

Source: Own calculation.

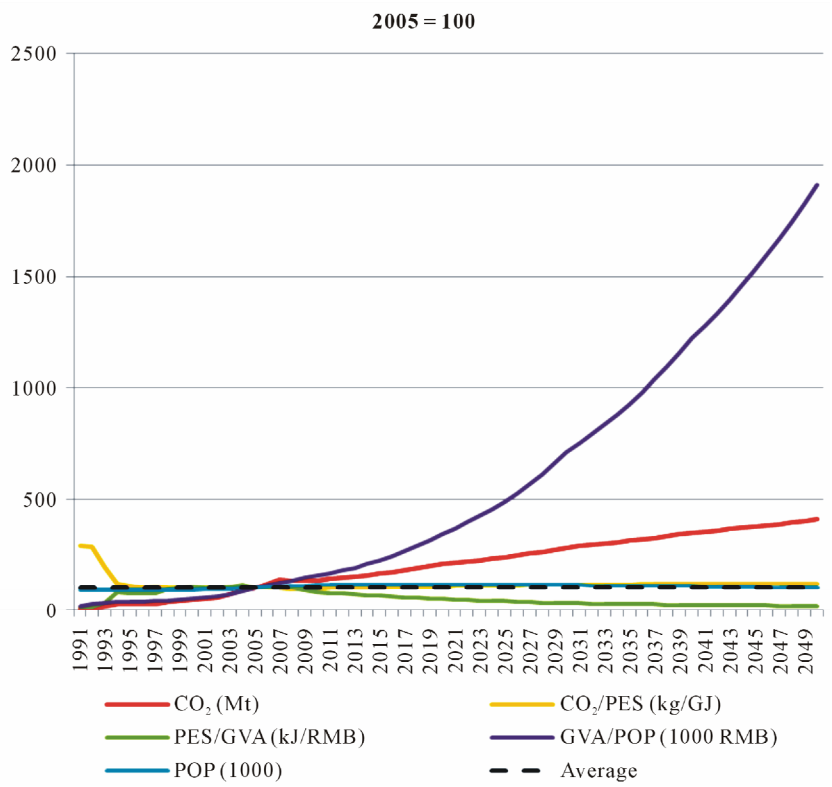

Figure 3. Development of macro-economic variables in Wuxi without implementation of the Low Carbon City Plan (2005 = 100). Source: Own calculation.

intensity of Gross Value Added the largest impact on the reduction of CO_2-emissions in Wuxi. A decrease of population and CO_2-intensity of Primary energy supply are only average.

Total Final Energy consumption in Wuxi will increase by 95.6% in 2020 and 271.3% in 2050. The average final energy consumption of all economic sectors also shows the shift away from coal to electricity and gas (**Table 16**). Related CO_2-emissions will grow by 103.9% to 117 Mill. tons in 2020 and by 300.4% to 230 Mill. tons in 2050.

3.2. Electricity and Heat Generation

In Wuxi electricity is generated through coal combustion, and this will not change in the future, in 2005, 99.5% is coal, only a very small fraction diesel or fuel oil. According to the low carbon city plans, natural gas will increasingly used for power generation. In 2050, the share of natural gas will increase to 1.7% (**Table 17**). Between 2005 and 2020, CO_2-emissions from power generation will increase by 90.0%, by 2050 even by 214.6% against 2005. Only 0.084 PJ will be generated with renewable energies in 2020 and 0.038 PJ in 2050.

Efficiency of thermal power generation will increase from 40.9% in 2005 to 41.4% in 2020 and 45.3% in 2050. Efficiency may relatively high on the average, if flue gas desulphurisation is not done.

Heat generation in Wuxi is 100% coal. As Wuxi is south of the Yangtse River, there is no central heating in Wuxi. Hence, the heat generated is entirely process heat. Residential heat demand in winter time is mostly generated with electricity or liquefied gas. According to the assumptions of the model until 2020, energy efficiency of heat generation will grow by 2.2% in 2020 and 11.8% by 2050 against 2005. Most importantly, an increasing share of heat is generated in combined heat and power plants. In 2020, 40PJ heat will be from CHP, in 2050 CHP will generate 98PJ of process heat (**Table 18**). The Wuxi energy balance, however, does not show how much electricity is generated in the CHP plants. It is assumed to be included in the total electricity output.

3.3. Agriculture

In the past, agriculture production developed stably in the last years. Wuxi City Government intends to push forward

Table 16. Energy- and CO_2-mix and related intensities of total final energy consumption in Wuxi without implementation of the Low Carbon City Plan (2005-2050).

	2005	2020	2030	2040	2050	2005-2020 (%)	2005-2050 (%)
Total Final Consumption (PJ)	438	857	1128	1371	1612	95.6	267.7
Coal	193	280	288	276	267	45.5	38.5
Coke	63	82	81	74	69	30.5	10.4
Oil	29	29	34	40	45	−0.1	54.8
Gas	11	53	75	96	118	393.6	995.7
Electricity	125	324	536	754	970	158.7	674.8
Heat	18	89	113	130	143	396.0	695.6
Total CO_2 (Mt)	58	117	160	198	230	103.6	299.9
Coal	18	27	27	26	25	45.5	38.5
Coke	6	8	8	7	7	30.5	10.4
Oil	2	2	2	3	3	10.2	81.2
Gas	1	3	5	6	7	445.2	1095.8
Electricity	29	67	106	141	173	132.5	497.5
Heat	2	10	13	14	15	385.3	611.6
Gross Value Added (bn. RMB)	280.4	1107.7	2232.2	3650.5	5214.0	295.1	1759.6
Population (1000)	5747	6620	6422	6120	5597	15.2	−2.6
Energy Intensity of GVA (MJ/RMB)	1.563	0.774	0.505	0.376	0.309	−50.5	−80.2
CO_2-INtensity of GVA (kg/RMB)	0.205	0.106	0.072	0.054	0.044	−48.5	−78.5

Source: Own calculations.

Table 17. Mix of energy and CO_2 in power generation in Wuxi without implementation of the Low Carbon City Plan (2005-2050).

	2005	2020	2030	2040	2050	2005-2020 (%)	2005-2050 (%)
Renewable Electricity Generation (PJ)	0.000	0.084	0.056	0.045	0.038	-	-
Output Electricity (PJ)	87	168	205	250	304	94.0	251.4
Input Coal	−210	−398	−471	−558	−660	89.3	213.4
Input Oil	−1.3	−0.2	−0.2	−0.2	−0.3	−87.1	−78.6
Input Gas	0.0	−7.0	−8.2	−9.7	−11.5	-	-
Total CO_2 (Mt)	20	38	45	53	63	90.0	214.6
Input Coal	−20	−38	−45	−53	−62	89.3	213.4
Input Oil	−0.1	0.0	0.0	0.0	0.0	−87.1	−78.6
Input Gas	0.0	−0.3	−0.4	−0.4	−0.5	-	-
CO_2-Intensity of Power Generation (kg/MJ)	0.231	0.226	0.220	0.213	0.207	−2.1	−10.5
Efficiency (%)	40.9	41.4	42.7	44.0	45.3	1.3	10.8

Source: Own calculations.

Table 18. Mix of energy and CO_2-emissions in heat generation in Wuxi without implementation of the Low Carbon City Plan (2005-2050).

	2005	2020	2030	2040	2050	2005-2020 (%)	2005-2050 (%)
Recovery of Heat (PJ)	0	40	66	85	98	-	-
Output Fossil Fuelled Electricity (PJ)	21	48	47	46	44	126.3	106.8
Input Coal	−27	−60	−57	−53	−50	121.5	85.0
Input Oil	0.0	0.0	0.0	0.0	0.0	-	-
Input Gas	0.0	0.0	0.0	0.0	0.0	-	-
Total CO_2 (Mt)	0.0	5.7	5.4	5.1	4.8	121.5	85.0
Input Coal	−2.6	−5.7	−5.4	−5.1	−4.8	121.5	85.0
Input Oil	0.0	0.0	0.0	0.0	0.0	-	-
Input Gas	0.0	0.0	0.0	0.0	0.0	-	-
Efficiency (%)	78.7	80.4	82.9	85.4	88.0	2.2	11.8

Source: Own calculations.

the adjustment of agriculture structure energetically, optimize the supply structure of agriculture products and satisfy the market demands efficiently. The annual yield of crops was 805,100 tons, which was 0.7% up over last year. Main agricultural products in 2009 are: grain (0.81 Mill. tons), oil-seeds (18,426 tons), silkworms (130 tons), tea (6866 tons), fruits (137,960 tons), pork (64,837 tons), aquatic products (121,690 tons). The average distance from agricultural production in Wuxi rural areas to Wuxi urban area are about 20 - 30 km. The 2009, gross output of oil plants rose by 8.5% with 18,400 tons and the yield of rapeseeds was 17,100 tons, up by 7.2% compared to the previous year. The amount of cocoon production was 130 tons, indicating a decrease by nearly 45%. Throughput of tea and fruits in-creased by 1% and 6.7% respectively up to 6866 tons and 137,960 tons [11].

According to the model assumptions, final energy consumption (which is only electricity in the available energy balance data) in the agricultural sector will grow by about 151.5 in 2020 and 496.2% in 2050 compared to 2005 (**Table 19**).

Due to the reduction of CO_2-intensity of electricity

Table 19. Final energy consumption, CO_2-emissions and related intensities in the agricultural sector in Wuxi without implementation of the Low Carbon City Plan (2005-2050).

	2005	2020	2030	2040	2050	2005-2020 (%)	2005-2050 (%)
Final Energy Consumption (PJ)	0.623	1.567	2.329	3.050	3.714	151.5	496.2
CO_2-Emissions (Mt)	0.176	0.325	0.459	0.571	0.662	126.0	359.7
Gross Value Added (bn. RMB)	5212	14146	17880	21080	23657	171.4	353.9
Energy Intensity of GVA (MJ/RMB)	0.120	0.111	0.130	0.145	0.157	−7.3	31.3
CO_2-Intensity of GVA (kg/RMB)	0.034	0.023	0.026	0.027	0.028	−16.7	1.3
CO_2-Intensity of Final Energy Consumption (kg/MJ)	0.283	0.208	0.197	0.187	0.178	−10.1	−22.9

Source: Own calculations.

generation in 2020 by 10.1%, CO_2-emissions per Gross Value Added decreased by 16.7% in 2020 and will increase by 1.3% in 2050 compared to 2005.

3.4. Industry

Currently Wuxi has two large industrial parks devoted to new industries. While being the current manufacturing centers on textiles, there are projects to move to electric motor manufacturing and software development. Wuxi is the solar technology hub in China with two major photovoltaic companies (Suntech Power and Jetion Holdings Ltd) based in the city and listed on overseas stock exchanges. Currently, industry Gross Value added in Wuxi is dominated by Smelting and Pressing of Ferrous Metals (13.8%), Electric Equipment and Machinery Manufacturing (12.8%) and Telecommunications, Computers and Other Electronic Equipments Products (12.8%), Raw Chemical Materials and Chemical Products (6.8%) and Textiles (5.5%). Wuxi is one of the top business cities in China. According to Forbes ranking, Wuxi is in the third position for best business cities in Mainland China in 2008.

In Wuxi, industrial production increased steadily. Industrial enterprises above designated size created a value added of 239.1 billion RMB including 59.4 billion RMB in the light industry sector and 179.7 billion RMB in the heavy industry sector in 2009, totally increasing 11.3%. In 2010, Gross Added Value in the industrial sector grew by 9.5% against 2009. For the 12th Five-Year Plan (2011-2015), Wuxi strives to keep a stable and fast economic development and improve the influence and competitiveness in regional development and in comparison to other cities in China, as well as build an innovation-oriented city. Its per capita GDP is expected to see an annual growth by 10% in the coming years and local budgetary revenue is projected to grow by 12% annually. The expenditure on social research and development as percentage of the local GDP will be raised to above 3%. The contribution rate of science and technology will be over 65%. Employment and re-employment in Wuxi is also advancing steadily. In 2009, the net increase of employment was 85,000. The registered overall unemployment rate in Wuxi was 2.8% in 2009 [11].

In the future, final consumption and CO_2-emissions in Wuxi are following the development of industrial output and the other exogenous variables in the model. Until 2020, total industrial energy consumption is increasing by 83.9% against 2005, until 2050 by 182.7% compared to 2005 (**Table 20**).

As for the energy mix, there will be a shift away from carbon-intensive coal to electricity with co-generation, heat and low carbon natural gas. CO_2-intensity of energy consumption will decrease by 3.4% in 2020 and 6.5% in 2050 (**Table 18**). Based on the assumptions of the model, there will be a structural shift of energy consumption away from energy intensive sectors such as iron and steel or the chemical industry to light industry sectors such as electronics. In addition, tertiarisation of Gross Value Added shifts energy consumption to the less energy intensive service sector.

3.5. Construction and Service Sector

In Chinese statistics, construction belongs to Secondary Industry. In Wuxi, construction contributed 3.7% of total Gross Value Added in this aggregate in 2010. Until 2020 and beyond, it is assumed as one of the fastest growing sectors in Wuxi (**Table 21**). With increasing income, the demand for modern accommodation in Wuxi is growing. And as currently, the life cycle of new buildings is only around 20 years, construction demand will continue to be high.

Between 2005 and 2020, final energy consumption in the construction sector (which in the available energy balance is only electricity) is expected to grow by 200%, until 2050 even by 946%. Despite a reduction of CO_2-intensity of final energy consumption of 10.1% in 2020,

Table 20. Final consumption, CO_2-emissions and related intensities in the industrial sector in Wuxi without implementation of the Low Carbon City Plan (2005-2050).

	2005	2020	2030	2040	2050	2005-2020 (%)	2005-2050 (%)
Final Consumption (PJ)	416	764	946	1072	1175	83.9	182.7
Coal	193	280	288	276	267	45.5	38.5
Coke	63	82	81	74	69	30.5	10.4
Oil	29	29	34	40	45	−0.1	54.8
Gas	10	41	54	63	70	302.0	597.3
Electricity	103	244	375	488	581	136.1	463.2
Heat	18	89	113	130	143	396.0	695.6
CO_2 (Mt)	52	100	127	145	158	90.2	201.2
Coal	18	27	27	26	25	45.5	38.5
Coke	6	8	8	7	7	30.5	10.4
Oil	2	2	2	3	3	10.2	81.2
Gas	1	3	3	4	4	346.3	655.5
Electricity	24	51	74	91	103	112.1	334.3
Heat	2	10	13	14	15	385.3	611.6
Gross Value Added (tn. RMB)	158.8	548.0	1010.6	1464.4	1865.7	245.2	1075.1
Energy Intensity of GVA (MJ/RMB)	2.617	1.394	0.936	0.732	0.630	−46.7	−75.9
CO_2-Intensity of GVA (kg/RMB)	0.330	0.182	0.126	0.099	0.085	−44.9	−74.4
CO_2-Intensity of Final Energy Consumption (kg/MJ)	0.126	0.130	0.135	0.136	0.134	3.4	6.5

Source: Own calculations.

Table 21. Final consumption, CO_2-emissions and related intensities in the construction sector in Wuxi without implementation of the Low Carbon City Plan (2005-2050).

Construction	2005	2020	2030	2040	2050	2005-2020 (%)	2005-2050 (%)
Final Energy Consumption (PJ)	0.71	2.13	3.99	5.82	7.43	199.6	946.4
CO_2-Emissions (Mt)	0.16	0.44	0.79	1.09	1.32	169.3	706.9
Gross Value Added (bn. RMB)	10.8	40.4	75.1	109.1	139.1	273.7	1185.1
Energy Intensity of GVA (PJ/1000 RMB)	0.07	0.05	0.05	0.05	0.05	−19.8	−18.6
CO_2-Intensity of GVA (kg/RMB)	0.02	0.01	0.01	0.01	0.01	−28.0	−37.2
CO_2-Intensity of Final Energy Consumption (kg/MJ)	0.23	0.21	0.20	0.19	0.18	−10.1	−22.9

Source: Own calculations.

the growth rates of CO_2-emissions per Gross Value Added of this sector in Wuxi are slightly below average (**Table 21**).

In 2010, the tertiary sector counts for 42.8% of total Gross Value Added in Wuxi, most of it is Wholesale and Retail (14.6%) and Real Estate (6.3%) and are one of the fastest growing aggregate in Wuxi (**Table 22**). This leads to a considerable growth of energy demand and CO_2-emissions in the city, by 2050 energy consumption will twentyfold, due to a reduction of the CO_2-intensity of

Table 22. Energy and CO_2-intensities of gross value added in the service sector in Wuxi without implementation of the Low Carbon City Plan (2005-2050).

	2005	2020	2030	2040	2050	2005-2020 (%)	2005-2050 (%)
Final Energy Consumption (PJ)	8.0	35.2	69.4	113.8	162.1	342.3	1938.7
CO_2-Emissions (Mt)	1.8	7.3	13.7	21.3	28.9	297.5	1472.0
Gross Value Added (bn. RMB)	105.6	505.0	1128.6	2056.0	3185.5	378.4	2917.4
Energy Intensity of GVA (MJ/RMB)	0.08	0.07	0.06	0.06	0.05	−7.5	−32.4
CO_2-Intensity of GVA (kg/RMB)	0.02	0.01	0.01	0.01	0.01	−16.9	−47.9
CO_2-Intensity of Final Energy Consumption (kg/MJ)	0.231	0.208	0.197	0.187	0.178	−10.1	−22.9

Source: Own calculations.

energy consumption of 10.1%, the CO_2-emissions will almost fifteenfold.

3.6. Residential Sector

In 2010, the residential sector was responsible for 3.4% of total final energy consumption in Wuxi, 2.4% in rural areas and 1.0% in urban areas. Hence, currently, the residential sector is only a minor source of CO_2-emissions in the city. Due to the large share of CO_2-intensive electricity, the total residential share of CO_2-emissions is slightly higher (5.6%). Between 1991 and 2010, per capita real Gross Value Added ninefolded from about 8600 RMB to 77500 RMB [13].

Until 2020, per capita income is assumed to grow by 246% against the 2005 values, in 2050 by 1812% to a value of 993000 RMB. Against this background, the contribution of the residential sector to final energy demand and CO_2-emissions are expected to almost nineteenfold (energy) and elevenfold (CO_2) (**Table 23**). By 2020, the residential share of total energy demand will grow to 4.9% (2010: 2.4%), by 2050 even to 13.3%, CO_2-emissions will cover 7.8% resp. 17.4% in 2050. This is a large increase. By 2050, per capita emissions in Wuxi will only reach 7.4 tons (16.3 tons in rural areas and 5.0 tons in urban areas).

According to the Wuxi City Statistical Bureau, most of the energy is electricity (2005: 95%), a minor fraction is gas (LPG and natural gas). Energy for private transport (mainly gasoline) is not explicitly included in the Wuxi energy balance. It can be assumed that it is part of the industrial gasoline consumption as, at least in the past, a large fraction of the cars had been owned by the companies. However, here, the city statistics have to improve in the future.

By 2020, the share of gas will increase (23.7%), but drop back to 18.6% in 2050 because of the increase of electricity utilization due to a larger use of electricity for cooling purposes and other electrical household appliances (**Table 24**).

4. Expected Development until 2050 under the Low Carbon City Plan

4.1. Overview

Through the implementation of the Low Carbon City plan, Primary Energy Supply in Wuxi will reach about 990 PJ in 2020 and about 1800 PJ in 2050 (**Table 25**). In 2020, Primary Energy Supply will decrease by 10.8% in 2020 and by 9.1% by 2050 against the business as usual development following the national trend.

Especially, coke imports and coke consumption will decrease through the shift of steel production away from the traditional blast furnace technology based on the reduction of iron ore with coke to the utilization of electric furnace steel process. By 2020, coke consumption will decrease by 32.8% in 2020 and 55.1% in 2050 against the Business as Usual scenario. Against 2005, coal consumption in Wuxi will increase vs. 2005 (53.7% in 2020 and 99.2% in 2050), but much slower than without the implementation of the Low Carbon City plan. Compared to this, coal consumption will drop by 9.3% in 2020 and 10.7% in 2050.

CO_2-emissions in Wuxi from Primary Energy Supply will grow by 83% in 2020 and by 273% in 2050 vs. 2005 (**Table 26**), but will decrease by 11.4% in 2020 and by 8.5% in 2050 against the BAU-scenario.

Implementing the Wuxi Low Carbon City plan, in absolute terms, Total Final Energy Consumption will grow by 73.4% in 2020 and by 234.6% in 2050 (**Table 27**), but will decrease by 11.3% and 9.0% in 2050 against the BAU-scenario.

CO_2-emissions from Final Energy Consumption will decrease by 10.2% in 2020 and by 7.4% in 2050 against the BAU-scenario. These additional emission reductions accrue from the reduction on coke (−29.2% in 2020 and 48.0% in 2050) against the trend without specific low carbon policies in Wuxi. Energy intensity of Gross Value

Table 23. Energy and CO_2-intensities of gross value added in the residential sector in Wuxi without implementation of the Low Carbon City Plan (2005-2050).

	2005	2020	2030	2040	2050	2005-2020 (%)	2005-2050 (%)
Residential Sector (total)							
Final Energy Consumption (PJ)	13	2020	2030	2040	2050	2005-2020 (%)	2005-2050 (%)
CO_2-Emissions (Mt)	3						
Population (1000)	5747	54	107	177	263	304.0	1865.3
Final Energy Consumption per Capita (GJ)	2333	9	18	29	41	215.6	1291.4
CO_2-Emissions per Capita (t)	0.5	6620	6422	6120	5597	15.2	−2.6
		8182	16603	28939	47079	250.7	1918.1
Residential Sector (rural)		1.4	2.8	4.8	7.4	174.0	1328.7
Final Energy Consumption (PJ)	9						
CO_2-Emissions (Mt)	2						
Population (1000)	2847	35	57	87	126	269.7	1241.3
Final Energy Consumption per Capita (MJ)	3304	6	9	14	19	193.0	818.1
C02-Emissions per Capita (t)	0.7	2449	1927	1591	1175	-14.0	-58.7
		14197	29452	54447	107352	329.7	3149.2
Residential Sector (urban)		2.5	4.9	8.7	16.3	240.6	2124.2
Final Energy Consumption (PJ)	4						
CO_2-Emissions (Mt)	1						
Population (1000)	2900	19	50	90	137	392.7	3389.3
Final Energy Consumption per Capita (MJ)	1357	3	9	15	22	270.7	2415.8
CO_2-Emissions per Capita (t)	0.3	4170	4496	4529	4421	43.8	52.5

Source: Own calculations.

Table 24. Mix of energy and CO_2 in the residential sector in Wuxi without implementation of the Low Carbon City Plan (2005-2050).

	2005	2020	2030	2040	2050	2005-2020 (%)	2005-2050 (%)
Final Consumption Residential (PJ)	13	54	107	177	263	304.0	1865.3
Gas	1	13	21	33	48	1666.6	6532.5
Electricity	13	41	85	144	215	226.0	1598.2
CO_2 Residential (Mt)	4	9	18	29	41	215.6	1291.4
Gas	0	1	1	2	3	1666.6	6532.6
Electricity	4	9	17	27	38	193.0	1209.5

Source: Own calculations.

added will decrease by 11.4% in 2020 and by 9.1% in 2050 compared to the BAU-scenario.

In absolute terms, CO_2-emissions from total final energy consumption per unit of Gross Value Added will decrease by 53.7% in 2020 and by 80.1% in 2050 compared to 2005. Until 2020, this well represents reaching the quantitative goal of a 50% reduction of the CO_2-intensity of Gross Value Added as stipulated in Wuxi's Low Carbon City plan.

The sectoral structure of final energy consumption in Wuxi will shift from industry to the other sectors, mainly the residential and service sector, and so does its average

Table 25. Primary energy mix Wuxi under the Low Carbon City Plan (2005-2050, in PJ).

	2005	2020	2030	2040	2050	2005-2020 (%)	2005-2050 (%)
Total	574	991	1262	1528	1797	72.8	213.2
Coal	442	680	740	802	882	53.7	99.2
Coke	54	49	42	33	27	−8.8	−49.5
Oil	35	38	43	48	51	9.0	47.2
Gas	8	51	70	89	109	539.8	1273.6
Electricity	39	134	302	473	631	249.1	1538.4
Heat	−4	39	65	83	97	−1216.8	−2861.7

Source: Own calculations.

Table 26. CO_2-emission mix in Wuxi under the Low Carbon City Plan (2005-2050, in PJ).

	2005	2020	2030	2040	2050	2005-2020 (%)	2005-2050 (%)
Total	58	107	148	185	218	82.8	273.4
Coal	42	64	70	76	83	53.7	99.2
Coke	5	5	4	3	3	−8.8	−49.5
Oil	3	3	3	3	4	0.8	41.2
Gas	0	3	4	6	7	593.5	1389.0
Electricity	9	28	59	88	112	212.9	1164.5
Heat	0	4	7	9	10	−1138.1	−2446.4

Source: Own calculations.

sectoral CO_2-intensity. In 2005, about 95% of final energy consumption was in the industrial sector (**Table 28**). In 2020, the share of industry will drop down to 88.8% and to 71.2% in 2050. In 2050, the residential energy demand will count for 17.5% of total final energy consumption (2005: 3.1%) and the service sector for 10.6% (2005: 1.8%). As the CO_2-intensity of energy consumption in the non industry sectors is much higher than in industry (in the available data for agriculture, construction and services, it is only electricity), CO_2-intensity of Total Final Energy Consumption will increase by 5.5% in 2020 and by 10.7% in 2050 against 2005.

However, as at the same time, the sectoral structure changes lead to a shift from the energy intensive industry to energy extensive service sectors and the residential sector, the average CO_2-intensity of Gross Value Added will decrease as described in **Table 29**.

4.2. Electricity and Heat Generation

According to the Wuxi Low Carbon City Plan, main measures in electricity and heat generation are:

- energy efficiency improvements,
- promotion of power generation from gas and renewable energies, and
- fostering the utilization of combined heat and power generation [11].

Even in the Low Carbon City scenario, electricity is generated through coal combustion. According to the low carbon city plans, natural gas will increasingly used for power generation. In 2050, the share of natural gas will increase to 1.7% (**Table 30**). Between 2005 and 2020, CO_2-emissions from power generation will increase by 80.5%, in 2050 even by 198.8% against 2005.

Compared to the BAU-scenario, additional CO_2-emissions are realized through the increase of energy efficiency in power generation. It will increase from 40.9% in 2005 to 43.6% in 2020 (BAU: 41.1%) and 47.7% (BAU: 45.3) in 2050 (**Table 30**). This leads to a 5% reduction of primary energy input in power generation.

In addition to the energy efficiency gains, 0.139 PJ will be generated with renewable energies in 2020.

Due to the Low Carbon City plan, energy efficiency in heat generation shall increase. By 2020, energy efficiency of heat generation will grow by 7.6% in 2020 and 17.7% by 2050 against 2005 (**Table 31**). Compared to the BAU-scenario, energy efficiency will increase by 4.2 percentage points in 2020 and 4.6 percentage points in 2050 and reduce CO_2-emissions from heat generation by

Table 27. Final energy consumption and CO_2-emission mix in Wuxi under the Low Carbon City Plan (2005-2050, in PJ).

	2005	2020	2030	2040	2050	2005-2020 (%)	2005-2050 (%)
Total Final Consumption (PJ)	438	760	1002	1236	1466	73.4	234.6
Coal	193	233	227	211	196	21.1	1.9
Coke	63	58	51	42	36	−7.5	−42.6
Oil	29	25	29	35	39	−13.4	34.5
Gas	11	54	76	97	119	395.7	1000.0
Electricity	125	302	507	723	935	141.7	647.5
Heat	18	88	112	129	141	388.8	686.9
Total CO_2 (Mt)	58	105	145	181	213	82.9	270.3
Coal	18	22	22	20	19	21.1	1.9
Coke	6	6	5	4	3	−7.5	−42.6
Oil	2	2	2	2	3	1.7	68.1
Gas	1	3	5	6	7	448.5	1101.8
Electricity	29	63	100	135	167	117.4	476.5
Heat	2	10	12	14	14	354.4	568.6
Gross Value Added (bn. RMB)	280.4	1107.7	2232.2	3650.5	5214.0	295.1	1759.6
Population (1000)	5747	6620	6422	6120	5597	15.2	−2.6
Energy Intensity of GVA (MJ/RMB)	1.563	0.686	0.449	0.339	0.281	−56.1	−82.0
CO_2-Intensity of GVA (kg/RMB)	0.205	0.095	0.065	0.050	0.041	−53.7	−80.1
CO_2-Intensity of Final Energy Consumption (kg/MJ)	438	760	1002	1236	1466	73.4	234.6
CO_2-Emissions per Capita (t)	193	233	227	211	196	21.1	1.9

Source: Own calculations.

Table 28. Development of sectoral total final energy consumption and its CO_2-intensities in Wuxi (2005-2050, in % and kg CO_2/MJ).

LCE (TFC, %)	2005	2020	2030	2040	2050	2005-2020 (%)	2005-2050 (%)
Total	100.0	100.0	100.0	100.0	100.0	0.0	0.0
Agriculture	0.1	0.2	0.2	0.2	0.2	45.9	70.2
Industry	94.8	88.8	83.0	76.8	71.2	−6.4	−24.9
Construction	0.2	0.3	0.4	0.5	0.5	62.9	201.7
Service	1.8	4.1	6.4	8.7	10.6	123.9	483.9
Residential	3.1	6.7	10.1	13.8	17.5	118.8	471.5
LCE (CO_2-Intensity TFC)	2005	2020	2030	2040	2050	2005-2020 (%)	2005-2050 (%)
Total	0.131	0.138	0.145	0.147	0.145	5.5	10.7
Agriculture	0.231	0.208	0.197	0.187	0.178	−10.1	−22.9
Industry	0.126	0.132	0.138	0.139	0.137	5.0	8.9
Construction	0.231	0.208	0.197	0.187	0.178	−10.1	−22.9
Service	0.231	0.208	0.197	0.187	0.178	−10.1	−22.9
Residential	0.222	0.171	0.169	0.164	0.157	−22.7	−29.4

Source: Own calculations.

Table 29. Develoment of sectoral CO_2-intensity of gross value added in Wuxi (2005-2050, in kg CO_2/RMB).

	2005	2020	2030	2040	2050	2005-2020 (%)	2005-2050 (%)
Total	0.205	0.095	0.065	0.050	0.041	−53.7	−80.1
Agriculture	0.028	0.023	0.025	0.026	0.027	−16.1	−3.2
Industry	0.330	0.163	0.113	0.090	0.077	−50.6	−76.7
Construction	0.015	0.010	0.010	0.010	0.009	−32.0	−39.4
Service	0.017	0.013	0.011	0.010	0.009	−27.0	−50.1

Source: Own calculations.

Table 30. Mix of energy and CO_2 in power generation in Wuxi under the Low Carbon Plan (2005-2050).

	2005	2020	2030	2040	2050	2005-2020 (%)	2005-2050 (%)
Renewable Electricity Generation (PJ)	0.000	0.139	0.101	0.081	0.071	-	-
Output Electricity (PJ)	87	168	205	250	304	94.0	251.4
Input Coal	−210	−378	−448	−530	−627	79.8	197.7
Input Oil	−1.3	−0.2	−0.2	−0.2	−0.3	−87.7	−79.7
Input Gas	0.0	−6.6	−7.8	−9.2	−11	-	-
Total CO_2 (Mt)	20.0	36.1	42.7	50.5	60	80.5	198.8
Input Coal	−19.9	−35.8	−42.4	−50.1	−59	79.8	197.7
Input Oil	−0.1	0.0	0.0	0.0	0	−87.7	−79.7
Input Gas	0.0	−0.3	−0.3	−0.4	−0.5	-	-
CO_2-Intensity of Power generation (kg/MJ)	0.231	0.215	0.209	0.202	0.196	−7.0	−15.0
Efficiency (%)	40.9	43.6	44.9	46.3	47.7	6.6	16.7

Source: Own calculations.

Table 31. Mix of energy and CO_2 in heat generation in Wuxi under the Low Carbon Plan (2005-2050).

	2005	2020	2030	2040	2050	2005-2020 (%)	2005-2050 (%)
Recovery of Heat (PJ)	0	39	65	83	97	-	-
Output Fossil Fuelled Electricity (PJ)	21	48	47	46	44	126.3	106.8
Input Coal	−27	−57	−54	−51	−48	110.4	75.7
Input Oil	0.0	0.0	0.0	0.0	0	-	-
Input Gas	0.0	0.0	0.0	0.0	0	-	-
Total CO_2 (Mt)	0.0	0.0	0.0	0.0	0	-	-
Input Coal	−2.6	−5.4	−5.1	−4.8	−5	110.4	75.7
Input Oil	0.0	0.0	0.0	0.0	0	-	-
Input Gas	0.0	0.0	0.0	0.0	0.0	-	-
Efficiency (%)	78.7	84.7	87.3	89.9	92.6	7.6	17.7

Source: Own calculations.

0.3 Mt in 2020 and 0.2 Mt in 2050.

4.3. Agriculture

As for the agricultural sector, the Wuxi Low Carbon strategy includes the following targets:

- To develop a low-carbon agriculture;
- To strengthen ecological management and increase carbon sequestration. By 2015, the urban green space rate is envisaged to reach 41% of Wuxi urban area. The green coverage rate of total Wuxi area will reach 46%, the per capita green area will reach 15 m^2, 33.15 km^2 of wetland will be restored [12].

According to the model assumptions, final energy consumption in the agricultural sector will grow by about 153% in 2020 and 470% in 2050 compared to 2005 (**Table 32**). In 2050, final energy consumption is decreasing by 4.5% against the Business as Usual scenario without Low Carbon City plan.

Due to the reduction of CO_2-intensity of electricity generation in 2020 by 10.1%, CO_2-emissions per Gross Value Added decreased by 16.1% in 2020 and 3.2% in 2050 compared to 2005. With 16.1 the agricultural sector does not reach the target of a 50% reduction of CO_2-intensity of GVA by 2020 compared to 2005. However, with 1.9% in 2010 and only 0.7% in 2050, the contribution of the agricultural sector to total Gross Value Added is very small.

4.4. Industry

According to the Wuxi City Low Carbon Plans, the industrial sector shall be made climate-friendly by taking the following steps for a low carbon development:

- To adjust the structure of the industrial sector;
- To adjust the political framework for industry;
- To adjust production technologies of industry;
- To achieve a more sustainable production in industry [12].

Final consumption and CO_2-emissions in Wuxi are following the development of industrial output and the other exogenous variables in the model. Until 2020, total industrial energy consumption is increasing by 62.4% against 2005, until 2050 by 151.2% compared to 2005 (**Table 33**). Implementing the Low Carbon City plan in Wuxi, Final Energy consumption in the industrial sector decreases by 11.7% in 2020 and 11.1% in 2050 against the BAU-scenario. In the same period of time, industrial CO_2-emissions decrease by 10.4% in 2020 and 9.2% in 2050.

As for the energy mix, there will be a shift away from carbon-intensive coal to electricity with co-generation, heat and low carbon natural gas. Based on the assumptions of the model, there will be a structural shift of energy consumption away from energy intensive sectors such as iron and steel or the chemical industry to light industry sectors such as electronics. In addition tertiarisation of Gross Value Added shifts energy consumption to the less energy intensive service sector.

Following the structural effect and the shift to low carbon energy sources, CO_2-intensity of total industrial GVA will decrease by 50.6% in 2020 and 76.7% in 2050 (**Table 33**). Hence, for industry, the 50% reduction goal of CO_2-intensity of GVA in 2020 compared to 2005 will be met.

4.5. Construction and Service Sector

Between 2005 and 2020, final energy consumption in the construction sector (electricity) is expected to grow by 183%, until 2050 even by 910%. With the implementation of the Wuxi Low Carbon City plan, final energy consumption drops by 5.7% in 2020 and by 3.5% in 2050 against the Business as Usual case. With 32.0%, the construction sector will not reach the average target of a 50% reduction of CO_2-intensity of GVA by 2020 compared to 2005 (**Table 34**).

The tertiary sector is one of the fastest growing aggregate in Wuxi and has a considerable growth of energy demand and CO_2-emissions in the city. The promotion of the tertiary sector is also one key to the reduction of the

Table 32. Final energy consumption, CO_2-emissions and related intensities in the agricultural sector in Wuxi under the Low Carbon Plan (2005-2050).

	2005	2020	2030	2040	2050	2005-2020 (%)	2005-2050 (%)
Final Energy Consumption (PJ)	0.623	1.577	2.234	2.919	3.548	153.1	469.5
CO_2-Emissions (Mt)	0.144	0.328	0.440	0.547	0.632	127.6	339.2
Gross Value Added (bn. RMB)	5212	14146	17880	21080	23657	171.4	353.9
Energy Intensity of GVA (MJ/RMB)	0.120	0.111	0.125	0.138	0.150	−6.7	25.5
CO_2-Intensity of GVA (kg/RMB)	0.028	0.023	0.025	0.026	0.027	−16.1	−3.2
CO_2-Intensity of Final Energy Consumption (kg/MJ)	0.231	0.208	0.197	0.187	0.178	−10.1	−22.9

Source: Own calculations.

Table 33. Final consumption, CO_2-emissions and related intensities in the industrial sector in Wuxi under the Low Carbon Plan (2005-2050).

	2005	2020	2030	2040	2050	2005-2020 (%)	2005-2050 (%)
Final Consumption Industry (PJ)	416	675	831	949	1044	62.4	151.2
Coal	193	233	227	211	196	21.1	1.9
Coke	63	58	51	42	36	−7.5	−42.6
Oil	29	25	29	35	39	−13.4	34.5
Gas	10	41	55	64	71	305.1	603.7
Electricity	103	230	357	469	561	122.8	443.7
Heat	18	88	112	129	141	388.8	686.9
CO_2 Industry (Mt)	52	89	114	132	143	70.5	173.5
Coal	18	22	22	20	19	21.1	1.9
Coke	6	6	5	4	3	−7.5	−42.6
Oil	2	2	2	2	3	1.7	68.1
Gas	1	3	3	4	4	350.7	664.0
Electricity	24	48	70	88	100	100.4	319.3
Heat	2	10	12	14	14	354.4	568.6
Gross Value Added (bn. RMB)	158.7	548.0	1010.6	1464.4	1865.7	245.2	1075.1
Energy Intensity of GVA (MJ/RMB)	2.617	1.231	0.823	0.648	0.560	−53.0	−78.6
CO_2-Intensity of GVA (kg/RMB)	0.330	0.163	0.113	0.090	0.077	−50.6	−76.7
CO_2-Intensity of Final Energy Consumption (kg/MJ)	0.126	0.132	0.138	0.139	0.137	5.0	8.9

Source: Own calculations.

Table 34. Final consumption, CO_2-emissions and related intensities in the construction sector in Wuxi under the Low Carbon Plan (2005-2050).

	2005	2020	2030	2040	2050	2005-2020 (%)	2005-2050 (%)
Final Energy Consumption (PJ)	0.71	2.01	3.79	5.58	7.17	182.6	909.6
CO_2-Emissions (Mt)	0.16	0.42	0.75	1.05	1.28	154.1	678.6
Gross Value Added (bn. RMB)	10.8	40.4	75.1	109.1	139.1	273.7	1185.1
Energy Intensity of GVA (PJ/1000 RMB)	0.066	0.050	0.050	0.051	0.052	−24.4	−21.4
CO_2-Intensity of GVA (kg/RMB)	0.015	0.010	0.010	0.010	0.009	−32.0	−39.4
CO_2-Intensity of Final Energy Consumption (kg/MJ)	0.231	0.208	0.197	0.187	0.178	−10.1	−22.9

Source: Own calculations.

overall CO_2-intensity of GVA as its sectoral CO_2-intensity is much smaller than that of the industry (see Section 3.1). Implementing the Low Carbon City plan (**Table 35**), final energy consumption will grow slower than in the BAU-scenario (288.3% in 2020, BAU: 342.3%). CO_2-intensity of final energy consumption also decreases by 10.1% in 2020 and by 22.9% in 2050 compared to BAU.

With 27.0% the tertiary sector, however, will not reach the target of a 50% reduction of CO_2-intensity of GVA by 2020 compared to 2005 (**Table 35**). Based on the assumption of the model, it will take until 2050. On the whole economy, however, until then, this can be counterbalanced by the excess reductions of CO_2-intensity in the industry sector and the structural change towards the less CO_2-intensive tertiary sector (section 3.1 above).

Table 35. Energy and CO_2-intensities of Gross Value Added in the service sector in Wuxi under the Low Carbon Plan (2005-2050).

	2005	2020	2030	2040	2050	2005-2020 (%)	2005-2050 (%)
Final Energy Consumption (PJ)	8.0	30.9	63.7	107.5	155.3	288.3	1853.7
CO_2-Emissions (Mt)	1.8	6.4	12.6	20.1	27.7	249.2	1406.8
Gross Value Added (bn. RMB)	105.5	505.0	1128.6	2056.1	3185.5	378.4	2917.4
Energy Intensity of GVA (MJ/RMB)	0.075	0.061	0.056	0.052	0.049	−18.8	−35.3
CO_2-Intensity of GVA (kg/RMB)	0.017	0.013	0.011	0.010	0.009	−27.0	−50.1
CO_2-Intensity of Final Energy Consumption (kg/MJ)	0.231	0.208	0.197	0.187	0.178	−10.1	−22.9

Source: Own calculations.

In sectoral disaggregation, energy and CO_2-intensity of GVA will decrease in Commerce, Hotel and Catering Service due to the utilization of more energy efficient equipment, e.g. cooling. The same is for the sector Other Tertiary (**Table 36**).

As for the Transportation, Telecommunications, Postal Services, the intensities are likely to increase due to a growth of e-mobility for private and public transport services. Generally, the potential for energy efficiency gains in the tertiary sector is not so high as energy generally is not used intensively. Much is for office equipment and cooling. As for the latter, there is potential for efficiency gains, as for electrical office equipment, this is limited.

4.6. Residential Sector

As to the Wuxi Low Carbon City Plan, main elements of for residential consumption are:

- Establishment of mechanisms for the adjustments of behavioral patterns of the consumers;
- To increase residents' awareness of the need of a low carbon development [12].

Implementing the plan, final energy consumption in Wuxi will increase by 279.4% in 2020 and 1812.4% in 2050 compared to 2005 (**Table 37**). Against the BAU-scenario, energy consumption will decrease by 6.1% in 2020 and 2.7% in 2050. Per capita emissions decrease by 7.1% in 2020 and 3.0% in 2050 compared to the BAU scenario.

In 2020, final energy consumption in the residential sector will increase by 280%, in 2050 by 1812.4% (**Table 38**), but slower than in the BAU-scenario. Here, most of the additional CO_2-emission reductions are from electricity savings (2020: 0.6 Mt; 2050: 1.2 Mt) for cooling and in the use of other electrical appliances.

5. Summary

Urbanisation, and climate change are one of the greatest challenges of the 21st Century. Hence, tackling climate change in urban environments through the implementation of a Low Carbon Economy in cities is the appropriate approach to encounter both issues at the same time. In 2010, the Chinese government introduced a program with 13 pilot regions to establish such a Low Carbon Economy. In addition, many other major cities in China are developing their own Low Carbon City Plan to contribute to the national target to reduce CO_2-intensity of GDP by 40% - 45% in 2020 compared to 2005. One if these cities is Wuxi in Jiangsu Province with a population of 6.4 mill inhabitants and being a major hub for textile, iron and steel and recently also for solar energy industry in China.

In 2010, the City government issued a Low Carbon City Plan to develop Wuxi in agriculture, industry, transport, buildings and residential consumption in a sustainable way by 2020. Goal is to even go beyond the national target and achieve a 50% reduction of the CO_2-intensity of GDP by 2020 vs. 2005.

Based on data from the Wuxi Statistical Yearbook and other sources, in this paper, an econometric energy supply and demand model was developed to estimate and forecast the Wuxi Energy and CO_2-Balance between 2011 and 2050 for the single aggregates of Primary Energy Supply, the transformation sector and Final Energy Consumption for 17 energy sources and 46 economic sectors.

Two scenarios were developed,

1) A Business as Usual Scenario following the sectoral development predicted for China and

2) A Low Carbon Scenario with specific targets for each of the economic sectors to reach the carbon intensity targets of Gross Value Added in 2020 (50% vs. 2005) and beyond (65% by 2030, 70% by 2040, and 75% by 2050).

Decomposing the Kaya-identity for Wuxi, it becomes obvious that the increase of per capita income has the largest impact on the growth of CO_2-emissions and the decrease of energy intensity of Gross Value Added the

Table 36. Energy and CO_2-intensities of Gross Value Added in the branches of the service sector in Wuxi under the Low Carbon Plan (2005-2050).

Energy intensity of GVA (MJ/RMB)	2005	2020	2030	2040	2050	2005-2020 (%)	2005-2050 (%)
Tertiary Sector	0.075	0.061	0.056	0.052	0.049	−18.8	−35.3
Transportation, Telecommunications, Postal	0.057	0.158	0.269	0.402	0.538	174.9	836.5
Commerce, Hotel and Catering Service	0.067	0.047	0.041	0.039	0.037	−30.0	−44.9
Other Tertiary	0.086	0.065	0.058	0.052	0.047	−24.3	−45.4
CO_2-Intensity of GVA (kg/RMB)	2005	2020	2030	2040	2050	2005-2020 (%)	2005-2050 (%)
Tertiary Sector	0.017	0.013	0.011	0.010	0.009	−27.0	−50.1
Transportation, Telecommunications, Postal	0.013	0.033	0.053	0.075	0.096	147.2	622.2
Commerce, Hotel and Catering Service	0.015	0.010	0.008	0.007	0.007	−37.0	−57.5
Other Tertiary	0.020	0.014	0.011	0.010	0.008	−31.9	−57.9

Source: Own calculations.

Table 37. Energy and CO_2-intensities of gross value added in the residential sector in Wuxi under the Low Carbon Plan (2005-2050).

	2005	2020	2030	2040	2050	2005-2020 (%)	2005-2050 (%)
Residential Sector (total)							
Final Energy Consumption (PJ)	13	51	101	171	256	279.4	1812.4
CO_2-Emissions (Mt)	3	9	17	28	40	193.2	1249.8
Population (1000)	5747	6620	6422	6120	5597	15.2	-2.6
Final Energy Consumption per Capita (MJ)	2333	7685	15735	27904	45811	229.4	1863.7
CO_2-Emissions per Capita (t)	0.5	1.3	2.7	4.6	7.2	154.6	1286.0
Residential Sector (rural)							
Final Energy Consumption (PJ)	9	35	56	86	126	267.8	1237.3
CO_2-Emissions (Mt)	2	6	9	14	19	191.8	815.8
Population (1000)	2847	2449	1927	1591	1175	-14.0	-58.7
Final Energy Consumption per Capita (MJ)	3304	14126	29299	54237	107033	327.6	3139.6
CO_2-Emissions per Capita (t)	0.7	2.5	4.9	8.6	16.3	239.2	2118.4
Residential Sector (urban)							
Final Energy Consumption (PJ)	4	16	45	84	131	313.4	3218.5
CO_2-Emissions (Mt)	1	3	8	14	21	198.0	2281.4
Population (1000)	2900	4170	4496	4529	4421	43.8	52.5
Final Energy Consumption per Capita (MJ)	1357	3901	9922	18651	29537	187.5	2076.4
CO_2-Emissions per Capita (t)	0.3	0.6	1.7	3.1	4.8	107.2	1461.8

Source: Own calculations.

Table 38. Mix of energy and CO_2 in the residential sector in Wuxi under the Low Carbon Plan (2005-2050).

	2005	2020	2030	2040	2050	2005-2020 (%)	2005-2050 (%)
Final Consumption Residential (PJ)	13	51	101	171	256	279.4	1812.4
Gas	1	13	21	33	48	1654.9	6507.3
Electricity	13	38	80	138	208	200.7	1543.7
CO_2 Residential (Mt)	4	9	17	28	40	193.2	1249.8
Gas	0	1	1	2	3	1654.9	6507.3
Electricity	4	8	16	26	37	170.4	1167.6

Source: Own calculations.

largest impact on the reduction of CO_2-emissions in Wuxi. A decrease of population and CO_2-intensity of Primary energy supply only have average contributions. The decrease of energy intensity of Gross Value Added is due to energy efficiency gains in the single economic sectors, but to a large extent due to structural changes of the economy away from energy intensive sectors such as iron and steel, chemical industry or cement industry towards the energy extensive service sectors. A growing residential sector also reduces the industrial share of energy demand.

In the model, the specific sectoral CO_2-intensity goals are captured by an exogenous variable ($CO2INT_{j,t}$) which is kept constant in the Business as Usual scenario after 2010 and reduces in the Low Carbon scenario according to the Low Carbon City Plan and the assumptions after 2020. In both scenarios, energy consumption and CO_2-emission in Wuxi will grow in absolute terms. But the specific Low Carbon City measures in Wuxi contribute additionally to the given sectoral structure effect and lead to a total reduction of CO_2-intensity of Gross Value Added of 53.7% in 2020 and by 80.1% in 2050 compared to 2005. The specific Low Carbon City measures increase the speed of macro-economic energy intensity reduction and leads to an emission reduction of 14 Mt CO_2 in 2020 and 20 Mt CO_2 in 2050 compared to the Business as Usual scenario. Only following the national trend (48.5%), the 50% CO_2-emission intensity goal could not be fully reached in Wuxi City. Additional specific Low Carbon City measures, especially the above average reduction of energy intensity of industrial production and the promotion of co-generation of heat and power in Wuxi have to be taken. The promotion of renewable energies only to a minor part contribute to the achievement of the macro-economic CO_2-intensity goal in Wuxi by 2020 and beyond. However, they are absolute essential, if a reduction of absolute CO_2-emissions should be envisaged in Wuxi and beyond.

6. Acknowledgements

The article partly is result of the project "Low Carbon Future Cities—A Sino-German Cooperation on an Integrated Climate and Resource Proof Urban Development" funded by the Mercator Foundation in Germany.

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