Wuxi – a Chinese City on its Way to a Low Carbon Future

Carmen Dienst*[*1], Chun Xia[1], Clemens Schneider[1], Daniel Vallentin[1], Johannes Venjakob[1], Ren Hongyan[2]
[1]Wuppertal Institute for Climate, Environment and Energy GmbH, Wuppertal, Germany
e-mail: carmen.dienst@wupperinst.org
[2]Jiangnan University, Environment and Civil engineering school, Wuxi Low Carbon Development Research Centre (WLCDC), Wuxi, China

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ABSTRACT

Urbanization and climate change are amongst the greatest challenges of the 21st century. In the "Low Carbon Future Cities" project (LCFC), three important problem dimensions are analysed: current and future GHG emissions and their mitigation (up to 2050), resource use and material flows and vulnerability to climate change. The industrial city of Wuxi has been the Chinese pilot city of the project. To establish the pathway for a low carbon future, it is crucial to understand the current situation and possible future developments. The paper presents the key results of the status quo analysis and the future scenario analysis carried out for Wuxi. Two scenarios are outlined. The Current Policy Scenario (CPS) shows the current most likely development in the area of energy demand and GHG emissions until 2050. Whereas the extra low carbon scenario (ELCS) assumes a significantly more ambitious implementation, it combines a market introduction of best available technologies with substantial behavioural change. All scenarios are composed of sub-scenarios for the selected key sectors. Looking at the per capita emissions in Wuxi, the current levels are already high at around 12 tonnes CO_2 per capita compared to Western European cities. Although Wuxi has developed a low carbon plan, the projected results under current policies (CPS) show that the total emissions would increase to 23.6 tonnes CO_2 per capita by 2050. If the ELCS pathway was to be adopted, these CO_2 emission levels could be reduced to 6.4 tonnes per capita by 2050. However, this is not a problem unique to Wuxi or China. A comprehensive rethink at global level on how to increase energy and resource efficiency and sustainability is required.

KEYWORDS

Low carbon future cities, GHG inventory, Low carbon city strategies, China, Wuxi, Low carbon scenario, Low carbon technologies, Mitigation.

INTRODUCTION

Urbanization and climate change are amongst the greatest challenges of the 21st century and urban areas are key sources of global GHG emissions, with an estimated share of 40 to 78% [1]. Cities are also very likely to face the impacts of climate change and need to learn to adapt. In addition, scarce natural resources further constrain the scope for long-term, sustainable urban development.

The LCFC project

The Low Carbon Future Cities (LCFC) project aims to overcome different challenges in three dimensions - besides GHG emissions and their mitigation, resource use and

[*] Corresponding author

vulnerability to climate change are also analysed. For the pilot city Wuxi (China) project, the research project team has developed an integrated strategy and roadmap for balancing low carbon development, improved resource efficiency and adaptation to climate change [2].

Initially, the project focused on an analysis of the status quo and current policies, as well as extrapolating the most likely resultant development pathway up to 2050 with regard to GHG emissions, energy demand, climate impacts and resource use [3, 4].

During this initial phase it became apparent that in order to effectively tackle all the problem dimensions in the future, further efforts would be required such as the application of a suitable advanced technology portfolio. Moreover, developing a low carbon future strategy for Wuxi calls for integrated tools that can address considerable complexities and uncertainties that are inherent in urban systems and their development. These considerations go beyond the short and medium-term horizon of common urban planning practices.

Therefore, two low carbon scenarios were developed. These scenarios applied the same technologies and policy measures, but with different levels of mitigation ambition, in an attempt to incorporate an understanding of long-term challenges and low carbon solutions [5, 6].

These scenario analyses help to enable policy makers to identify strategic areas for action and provide a basis for decision-making. In contrast to the CPS which reflects the current policies, these two alternative scenarios (LCTS and ELCS) reveal the need for action to achieve certain desirable targets and identify windows of opportunity. Thereby it is crucial to ensure that the scenarios assumptions are adapted to local conditions and the results can effectively contribute to the development of the integrated low carbon strategy. The paper presents the key results of the status quo analysis and the future scenario analysis for the city of Wuxi.

Background to Wuxi

Wuxi is an industrial city with a population of about 6 million, located on the shores of Lake Taihu in the east of China near the megacity of Shanghai. As is the case of many Chinese cities, Wuxi's economy has increased considerably in recent years. The overall GDP in 2010 was about EUR 64.3 billion, which was double that of 2005. This represented an average annual growth rate of 14%. However, this growth has gone hand in hand with a significant increase in negative environmental effects, such as air pollution and GHG emissions. Wuxi is also exposed to climate and weather-related risks, such as extreme temperatures or floods. The city government was already quite aware of these challenges and had developed a low carbon plan. This made Wuxi a good choice for the Chinese pilot city project. The lessons learned from the project study can be used to analyse the situations in other similar Chinese industrial cities. Especially as former studies or low carbon initiatives focus on China's megacities.

METHODOLOGY

The analysis of the status quo and trend assessment, as well as the scenario development for Wuxi, was divided into different working areas, each applying a different type of methodology:

- Emission inventory: status quo and quantification of CO_2 emissions and qualitative analysis of non-CO_2 emissions (Kyoto gases) where possible;
- Key sector identification: mainly based on inventory, future trends and current policies;

- Scenario analysis: including Current Policy Scenario (CPS), Low Carbon Technology Scenario (LCTS) and Extra Low Carbon Scenario (ELCS).

Following a brief description of the methodology used in the GHG inventory and key sector selection, details are given on the scenario analyses and the assumptions applied.

GHG inventory

Over the last decades, much emphasis has been put on the development and implementation of GHG monitoring. However, these methods focused primarily on national inventories, such as in the case of the IPCC guidelines that were applied in this study in a simplified form. Although there is a lot of relevant literature in research, as well as practical handbooks/manuals at city level, there is still lack of standardized and globally applied methods and lack of reliable comparisons of GHG inventories between cities [7].

In China, several cities that are aiming to develop low carbon pathways have applied methods for GHG monitoring and quantified their impacts [7-9], but the comparison of the inventory results is only possible to a very limited extent. This is also due, in part, to the differing scope of emissions (territorial or supply chain and consumption-based approaches) and administrative boundaries considered in the applied methods, which can significantly affect the emission accounting [7]. In contrast to city boundaries in many other countries, the situation in China is different as the administrative city boundaries include not only the city but also non built-up areas such as the surrounding agricultural and forestry land [9].

The GHG emissions in the city of Wuxi are calculated and analysed in a detailed GHG inventory. The inventory has three main objectives:

- To provide a basis for key sector identification;
- To provide a basis for measuring future GHG reductions;
- To identify data gaps and options for developing a comprehensive and regularly updated inventory in the future.

The methodology for national inventories, outlined in the 2006 IPCC guidelines on GHG inventories [10], was followed in a simplified manner. The study focused mainly on CO_2 emissions. Other GHGs were included when data was available. The reporting year for Wuxi's emissions is 2009. For the energy sector, emissions from 2003 to 2009 were calculated.

Four main sectors were considered in accordance with the IPCC guidelines:

- Energy (including all energy-related emissions, also from industry);
- Industrial Processes and Product Use (IPPU) (only process-related emissions);
- Agriculture, Forestry and Other Land Use (AFOLU);
- Waste.

The study focused on CO_2 emissions; other GHGs were considered to a lesser extent depending on available data. According to the IPCC, the so-called "territory principle" was followed, meaning that GHG emissions were allocated to the territory where they were emitted. Life-cycle emissions and material use by specific sectors were not analysed in the inventory, but were included in the work on resource and material use [3, 5].

The inventory is largely based on Wuxi's statistical yearbook [8] and data provided by Chinese project partners, especially by the regional partner institution Wuxi Low Carbon Development and Research Centre (WLCC).

Although the statistical yearbook [11] provides extensive data which is exceptional at city level, there was still a gap between the data available and the data required for the inventory and the projection models. Particularly for the industry sector only statistical data for "above designed size" industries were available, which refers to those with an annual prime operating revenue exceeding CNY 5 million.

In addition to the incompleteness of available data, the available statistical data should be approached with caution. A study that was undertaken by a group of scientists from China, Britain and the United States analysed different sets of Chinese statistical data. The comparison showed that there are significant variances between the data and that these variances could account for a difference of up to 1.4 billion tonnes of CO_2 emissions (for 2010) between the datasets for the same area [12, 13], which is a difference of 18% in estimates of CO_2 emissions from China when using these two different data sets.

Modelling and scenario analysis

Scenario analysis, which has been widely applied in sustainability research over the last decade, is a tool that was used to explore different pathways for future developments in Wuxi and the associated energy demand and CO_2 emissions.

In order to address the local conditions in the scenario assumption and to ensure that the results can contribute to a low carbon strategy of Wuxi, the quantitative scenario modelling was integrated with a qualitative approach.

In this project three scenarios were developed; however for the presentation of results in this particular article, only two have been selected:

- The Current Policy Scenario (CPS) was developed based on the assumption that;
  - No additional policies or targets will be adopted beyond the existing policy framework of Wuxi (i.e. a 50% reduction in CO_2 intensity of GDP by 2020 compared to the 2005 level, in accordance with Wuxi Low Carbon City Development Plan);
  - A reduction in CO_2 intensity of 65%, 70%, and 75% by 2030, 2040 and 2050 respectively, compared to the 2005 level, referring to the baseline scenario in [14].
- The Extra Low Carbon Scenario (ELCS) assumes a significantly more ambitious implementation of low carbon strategies and energy efficient technologies, including "high-hanging fruits" (i.e. those that are more effective but costly).

To create the scenarios a quantitative energy and GHG emission simulation model was used. The modelling approach can be described as a model framework, consisting of one core model and five sub-models. The core model is an energy system simulation model and has been developed by the Wuppertal Institute (WI). The model's database is linked to the sub-models of industry, commerce, households, transport and energy supply. They have been developed as disaggregated technology-based simulation models to account for the use of Low Carbon (LC) technologies. The modelling approach is, therefore, basically bottom-up, without explicit economic optimization. In the CPS, data on industry energy use and economic activity was provided by an econometric projection, whereas the modelling in the ELCS is much more differentiated. Process-sharp modelling of energy-intensive processes allows for the evaluation of individual technologies, which is highly relevant for deriving strategic approaches in the roadmap. The effective production capacity and the age of the manufacturing plants in Wuxi City were evaluated in detail.

The same assumptions about the general socio-economic trends were used for all the scenarios; these assumptions can be characterised by slower yet still significant economic growth and a shift towards more service-oriented products (see Table 1). The specific assumptions were developed based on the China 2050 scenario developed by the Energy Research Institute [14]. In order to adapt the nationwide assumptions to Wuxi's situation, the modeller team consulted local stakeholders and experts about whether certain low carbon technologies were tailored to local conditions and, therefore, applicable in Wuxi.

Table 1. Socio-economic framework

	Unit	2009	2020	2030	2040	2050	2009-2050 [%] growth p.a.
Permanent population	1,000	6,245	6,731	6,598	6,325	5,826	-0.2
GDP	Mill. RMB_{2005}	452,175	1,138,622	2,300,540	3,758,442	5,360,192	6.2
Primary sector	Mill. RMB_{2005}	8,481	14,217	17,970	21,186	23,775	2.5
Secondary sector	Mill. RMB_{2005}	256,933	615,347	1,143,216	1,659,976	2,116,632	5.3
Tertiary sector	Mill. RMB_{2005}	186,761	509,057	1,139,355	2,077,280	3,219,784	7.2
Productivity	1,000 RMB_{2005}/ work-force	99	230	487	913	1,401	6.7

Source: Wuxi Statistical Yearbook, projections derived by China Environmental Research (CER) from Jiang, *et al*. (2008) [11, 14]

The assumed quantity of industrial production emphasizes Wuxi's importance as an industrial centre for energy-intensive products. Whereas Wuxi's share in China's population is only 0.5% today, 1.9% of China's crude steel production is concentrated in the Wuxi region. In the scenarios Wuxi does not lost its role as a centre of energy intensive production. The physical production of energy-intensive products such as steel, cement and fertilizers, as well as paper and caustic soda (or chlorine) remains stable (see Table 2). As the overall levels of steel, cement and fertilizer production in China in 2050 are assumed to be lower than today, Wuxi's share of China's production will increase. The production of paper and caustic soda, however, will increase in China, resulting in a lower share for Wuxi.

Table 2. Wuxi's share of energy-intensive sectors in China (2009 and 2050, in physical units and % in the Current Policy Scenario (CPS) (Variant GDP Medium)

	2009	2050	2009	2050	2009	2050
Output [mln t]	China		Wuxi		Share Wuxi [%]	
Steel	572	360	10.6	11.3	1.9	3.1
Cement	1,644	900	15.5	15.5	0.9	1.7
Caustic soda	18	24	0.1	0.1	0.6	0.5
Paper	90	120	0.8	0.8	0.9	0.7
Fertilizer	64	61	0.3	0.3	0.5	0.5
Population [mln]	1,335	1,460	6.2	5.8	0.5	0.4

Source: Wuxi Statistical Yearbook, CER (Wuxi), Jiang, *et al*. (2008) [11, 14]

Table 3 shows the assumptions about key technologies deployed in the key sectors in the CPS and ELCS. These technologies were identified based on the "Technology Matrix for Germany" developed by the Wuppertal Institute [15, 16] based on literature research and in consultation with local experts from city planning and enterprises in Wuxi taking into account Wuxi's climatic and industrial context.

Table 3. Assumptions for key technologies applied in key sectors in the Current Policy Scenario (CPS) and the Extra Low Carbon Scenario (ELCS)

Key sectors	CPS	ELCS
Industry	Decreasing energy intensity according to global CO_2 intensity targets; very moderate fuel shift	New investments and replacement of old production stock will be equipped with Best Available Technologies (BAT) from 2020 onwards. No substantial energy efficiency improvement will be reached in the short and medium-term in steel and cement industry. Technology improvement of steel production: direct reduction of iron via hydrogen from 2047; Carbon Capture and Storage (CCS) connecting top gas recycling from 2037; smelt reduction process with CCS. Cement industry: cement demand will decline from 2021. Chemical industry: a shift from coal to natural gas in the feedstock; ammonia production will be phased out from 2039.
Power/Heat Generation	Expansion of combined heat and power plants (CHP) as natural gas-fired plants according to industry's thermo power demand. Other new power plants are modelled as conventional coal power plants (ultra-supercritical boilers).	Expansion of combined heat and power plants (CHP) as natural gas-fired plants according to industry's thermo power demand. No further coal-fired power plants will be constructed Increased installation of CHP/CHCP and natural gas power plants. The share of renewable energies will increase (up to 73 GWh in 2050) by: exploiting (limited) local potential: biogas from municipal waste and from agricultural residues, 330 MW wind (installed by 2035), 1,800 MW PV (installed by 2050) and importing renewable energy electricity in addition to local production.
Buildings (residential and commercial)	Heating and cooling appliances are replaced in the old building stock. Refurbishment of the building envelope is not considered. Moderate energy efficiency gains through more efficient household appliances.	Highly energy efficient appliances will be purchased from 2020. Inefficient air conditioners will be replaced. Increasing the share of ultra-low energy and plus energy residential buildings from 2020 (will reach 100% of respective new constructions in 2050).
Transport	Expansion of the subway network according to local plans. Moderate saturation rate of 300 cars per 1000 households is reached in 2025. Rapid growth of freight transport.	Stronger market diffusion of electric vehicles (60% market share of new cars in 2050) compared to CPS. All other assumptions equal to CPS.

Source: Wuppertal Institute based on [15, 16] and expertise of local government and enterprises gained in interviews and online survey.

Table 3 shows from which year on low carbon technologies phase in Wuxi's economy and households in the ELCS. The technology matrix provided information about the availability of technologies on the timeline. Modelling shows necessary new investments in the respective years. So the scope of low carbon technology phase-in can be determined.

Scenario assumptions and results were drafted by the modelling team based on prior work and literature review and discussed with local stakeholders in the context of several expert and stakeholder workshops. The assumptions for key technologies were given to local technology experts who commented on the relevance and applicability of the technologies in Wuxi.

The ELCS can thus be characterized as an explorative scenario rather than a target orientated scenario. It is to show which degree of mitigation can be achieved with technical measures taking into account the socio-economic framework and investment cycles.

GHG INVENTORY RESULTS & KEY SECTORS

GHG inventory results

Of greatest significance for Wuxi are energy-related emissions, which result in the most part from the combustion of raw coal (and only to a limited extend from other fossil fuels, such as diesel). The emissions mainly stem from three different sectors: the energy industry (1A1), the industry sector (1A2) and the transport sector (1A3) (see Figure 1) and are related to the high demand for energy in Wuxi.

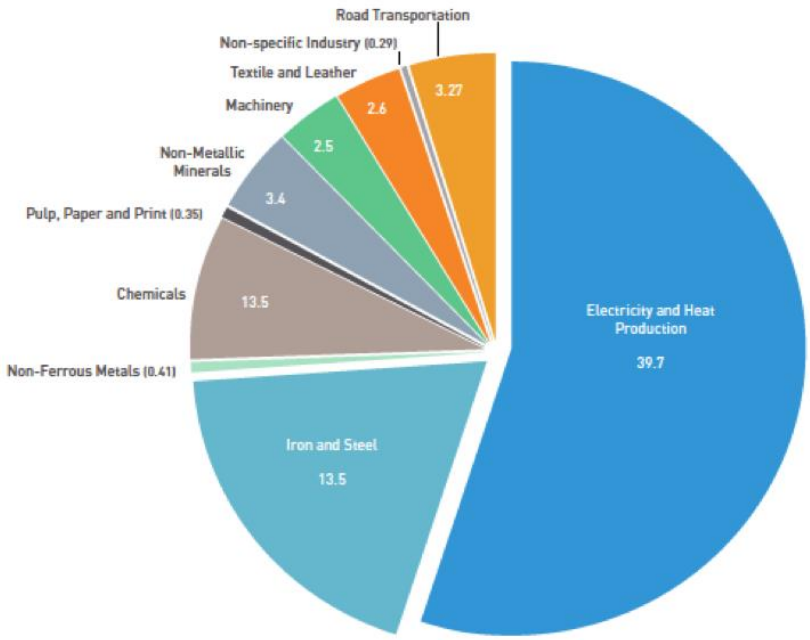

Figure 1. Total CO_2 emissions of Sector 1A, Energy (1A1-1A3), divided into sub-sectors (in mln t CO_2); see also Table 4 for detailed numbers

Electricity and heat production are the main sources of emissions; representing more than half of the current CO_2 emissions at a level of almost 40 million tonnes in 2009 (see Table 4 and Figure 1). In the manufacturing industries, energy-intensive fields such as the iron and steel industry and the chemical industry currently produce a high share of the total CO_2 emissions, but other sectors also produce considerable levels of CO_2.

Wuxi has several industries with potentially high process-related emissions. Although the original intention of the project was to analyse and incorporate all "Kyoto" GHGs, there was insufficient data for these to be calculated comprehensively. Therefore, for non-CO_2 emissions and non-energy related CO_2 emissions, qualitative assumptions or process descriptions have been given. The total emissions as currently reported are higher than the results presented in the inventory [3, 4]. For agriculture, only figures for certain sub-sectors were calculated. Furthermore, it was not possible to produce figures for the waste sector; all of which means that there is the potential for significant improvements to be made in future inventory work.

Table 4. Relevance of proposed key sectors, data availability and improvement potential of calculation methodology, current emissions

			Relevance Key sector	Data	EF & Method	CO_2 emissions	other GHG emissions*
IPCC Sectors				Availability	Improvement potential	[mln t]	[kt CO_2e]
1A1	Energy industry		HIGH	++	+	39.7	
	1A1a	Electricity and heat production	HIGH	++	+	39.7	200.0
	1A1b	Petroleum refining	MIDDLE	(+)	++	NE	NE
1A2	Manufacturing industry		HIGH	+	++	29.0	200.28
	1A2a/2C1	Iron and steel industry	HIGH	+	++	13.5	91.5
	1A2b / 2C3	Non-ferrous metals Aluminium	HIGH / MIDDLE	+ --	++	0.41	2.5
	1A2c / 2B	Chemical industry	HIGH /	+ --	++	5.8	40.5
	1A2f / 2A1	Non-metallic minerals (cement)	HIGH	(+)	+	3.4	23.6
	1A2h/ 2E	Machinery (electronic industry)	MIDDLE	--	+	2.5	17.2
	1A2k	Construction	HIGH	--	++	NE/ND (!)	
	1A2l	Textile and leather	MIDDLE	--	++	2.6	19.4
1A3	Transport		HIGH	(+)	+	3.5	
	1A3b	Road transportation	HIGH	(+)	+	3.27	NE
1A4	Others						
	1A4b	Commercial	HIGH	--	+	IE**	
	1A4b	Residential	HIGH	--	+	IE**	0.58
2	IPPU (other than 1A2)						
	2D	Non-energy from fuels & solvents	MIDDLE	--	++	NE/ND (!)	NE/ND (!)
	2F	Substitute for ozone DS	MIDDLE	--	++	NE/ND (!)	NE/ND (!)
3	AFOLU		MIDDLE	(+)	+		881.2
4	Waste		MIDDLE	--	++	---	NE/ND (!)

Explanation of categories: Relevance: High (key sector); Middle (possible key sector); (++) high potential /sufficient data availability; (+) data available, but not sufficient; (--) no data available; “IE” included elsewhere; “NE” not estimated; “NE/ND (!)” not estimated due to unavailable data/factors; * so far only CH_4 & N_2O; ** calculated for total consumption for information only; included in electricity production; IPPU = Industrial Processes and Product Use ; AFOLU = Agriculture, Forestry and Other Land use

In 2008 the national government had asked provincial governments to urge their cities to develop emission inventories [17, 18]. And in 2011 the Chinese central government issued "Guidelines on Provincial Greenhouse Gas Emission Inventory (Trial)" which now serves as a basis for developing city inventories [19]. These guidelines are based on both the IPCC Guidelines, which were used in this study and on experiences of inventory development in China in 2005 [20]. Approaches to city specific inventory methodologies, also suitable for emerging and developing countries, have recently been developed (e.g. by WRI) [21]. Moreover, the World Resources Institute, together with several other organizations, developed the GHG Accounting Tool for Chinese Cities (pilot 1.0) to explore methods of measuring GHG emissions in Chinese cities. The tool takes the administrative boundary of Chinese cities as the accounting boundary and combines a top-down and bottom-up data collection approach to address the significant data gap [22]. Wuxi is intending to have a regular monitoring system, which is currently being developed.

Key sectors identified

The most relevant key sectors from the perspective of current GHG emissions were identified, taking into account their relevance for regional policies, vulnerability to climate change and (past and) future trends. The relevance of the selected emission sectors, their current CO_2, CH_4 and N_2O emissions, as well as the quality of available data and calculation methodology, are presented in Table 4.

In addition to the dominant power and heat sectors, most of the key sectors are industry sectors such as the iron and steel industry, chemical industry, non-metallic minerals (cement), as well as electrical equipment and machinery manufacturing. In addition, the construction sector is relevant due to its high material/resource use and the increasing demand for electricity for cooling and heating purposes (especially where the design and construction of buildings inhibits the efficient use of energy flows). The latter is also relevant to adaptation needs due to an increase in both temperatures and living standards. Linked to this is the ever-growing requirement for electricity in the residential sector and in the commercial (service) sector, which are also regarded as two relevant key sectors. Road transport is as well considered as key sector due to the remarkable increase in number of vehicles, its related emissions and air pollution, and the future infrastructural challenges.

SCENARIO RESULTS

Energy consumption and total emissions in the Current Policy Scenario (CPS) and the Extra Low Carbon Scenario (ELCS)

Figure 2 illustrates the development of Wuxi's primary energy consumption by energy source in the two scenarios. The most striking feature of the ELCS in comparison to the CPS is the 90% reduction in coal consumption compared to today's level, an 85% reduction is achieved solely in the years after 2040. The most prominent reason is that the existing coal power plants gradually cease production and are not replaced by new coal in the ELCS. The remaining coal use in the industry sector in the ELCS in 2050 is partly due to the production of steel with coal in combination with carbon capture and storage (CCS). The large proportion of natural gas is due to its role as a bridge to renewable electricity production and the local demand of thermo power which cannot be provided by limited biomass resources.

Figure 3 compares the final energy demand in the two scenarios. Thereby the demand for energy of all sectors is illustrated, i.e. direct demand for fossil fuels (e.g. in the heavy industry or transport sector) and the demand for thermo power, hydrogen and electricity. According to the definitions of energy statistics derived energy carriers like hydrogen, thermo power and electricity are not classified as renewable here, although they can be produced from renewable sources. The actual share of renewables can be seen in Figure 2. Final energy demand is projected to increase consistently in both scenarios until 2020. Only from 2030 onwards does the ELCS show a reduction of final energy demand. The ever-growing share of electricity is caused mainly by the rapid growth of the service sector and new industries in Wuxi, such as machinery construction, which consume less heat but are heavily reliant on electricity. Heat demand in industry is, to a large degree, provided by Combined Heat and Power plants (CHP) that are currently fired by coal, but will be replaced in the scenarios by gas-fired units. The use of hydrogen, as a new energy carrier in 2050, is limited to steel production in the ELCS, where it serves as a reducing agent in the direct reduction of iron ore.

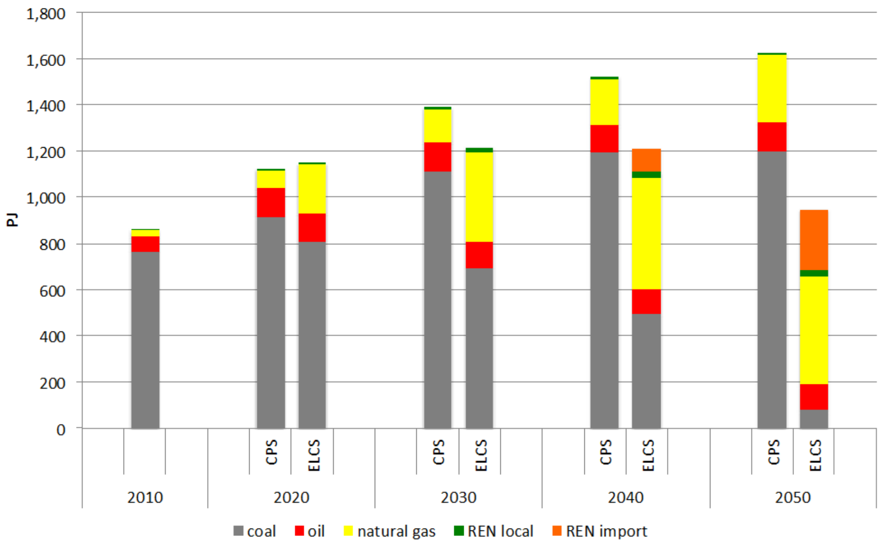

Figure 2. Comparison of primary energy consumption in the Current Policy Scenario (CPS) and the Extra Low Carbon Scenario (ELCS) (2010-2050)

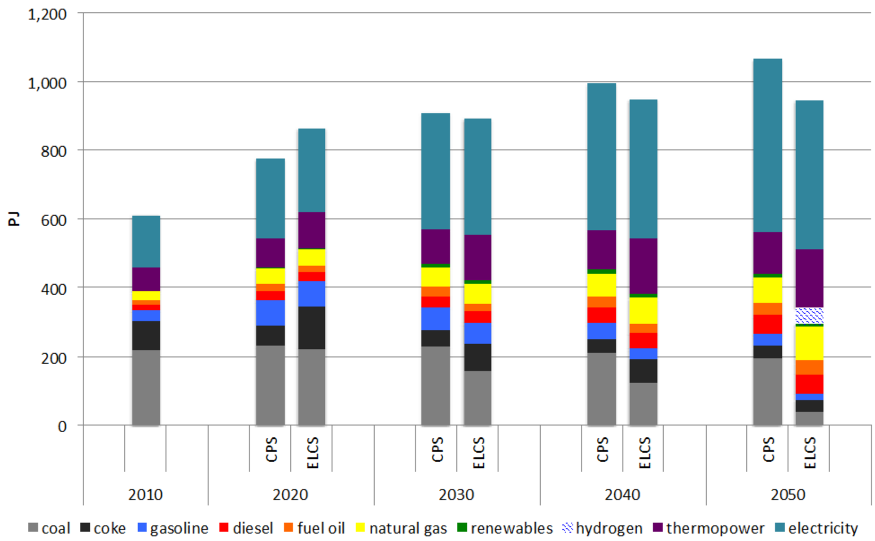

Figure 3. Comparison of final energy use in the Current Policy Scenario (CPS) and the Extra Low Carbon Scenario (ELCS) (2010-2050)

Figure 4 shows CO_2 emission trends (including direct and indirect emissions) in the two scenarios start to deviate considerably after 2020, because the general assumption before 2020 was based on the existing policy framework adopted by Wuxi government. CO_2 emissions in the ELCS will be significantly lower than in the CPS, due to the employment of Best Available Technologies (BAT), a fuel shift towards gas and renewable electricity as well as highly effective mitigation measures in all key sectors. In 2050, CO_2 emissions in the ELCS will be 36 million tonnes, equivalent to a quarter of that in the CPS (140 million tonnes) and a reduction of 56% compared to 2010.

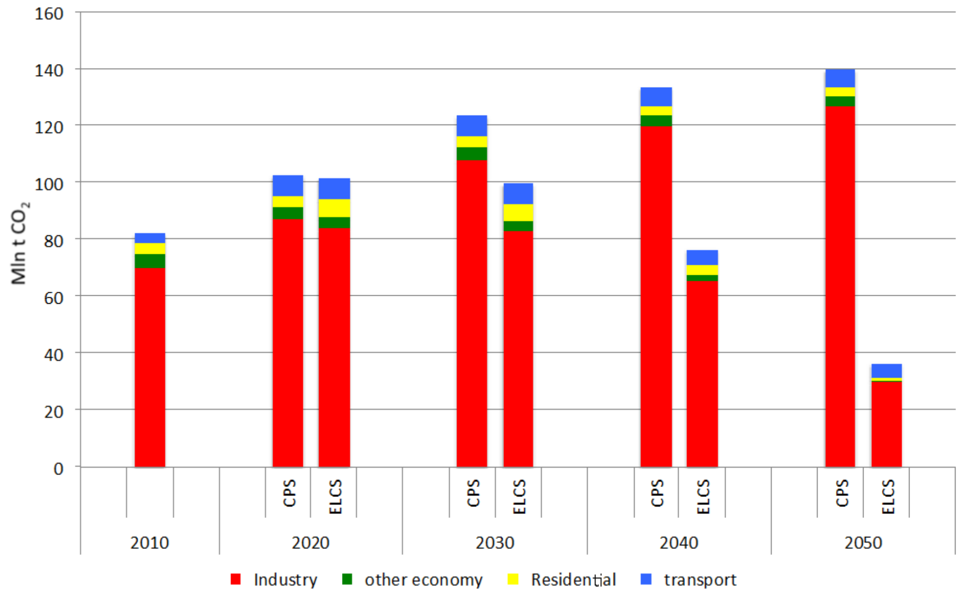

Figure 4. Comparison of direct and indirect CO_2 emissions of sectors (including indirect CO_2 emissions allocated to thermo power, heat and electricity) in the Current Policy Scenario (CPS) and the Extra Low Carbon Scenario (ELCS) (2010-2050)

CONCLUSIONS AND OUTLOOK

In the Low Carbon Future Cities study, important steps were taken to gain reliable information on the current situation and possible future development in Wuxi with regard to its sustainability. The picture gained from the the GHG inventory and scenario analysis is impressive and leads to the conclusion that enormous efforts, on different levels, will be necessary to drive Wuxi towards a low carbon path in the future.

Looking at the per capita emissions in Wuxi, current levels are already high at around 12 tonnes CO_2 per capita (2009, permanent population according to census data) compared to Western European cities (such as Düsseldorf or London) at less than 6 tonnes CO_2 per capita [3]. Although Wuxi has set reduction targets and developed a low carbon plan, the projected results based on the current policies (CPS) show that without more ambitious efforts, the total emissions would increase to 23.6 tonnes CO_2 per capita by 2050. However, if the ELCS pathway was to be adopted, these CO_2 emission levels could be reduced to 6.4 tonnes per capita by 2050 (half of the current levels). This level is, however, still very high despite the already supportive current policies and additional significant technology improvements in the ELCS scenario, even taking into account "high-hanging fruit" technologies (costly and yet to be developed). However, it is worth noting that Wuxi has, and is expected to continue to have, an important role in China's economy, producing a number of energy-intensive goods for the regional, national and international markets.

If we take the ELCS assumptions for Wuxi as a benchmark for China, China will reach an emission level of 2.9 tonnes per capita, which is still above the level necessary to comply with the 2 degree target, following expert analyses. The German Advisory Council on Global Change [23] asserts that industrial and emerging countries should achieve about one tonne of CO_2 per capita by 2050. To reduce CO_2 emissions further, other mitigation measures should be considered; for example, modal shift for freight transport that was not considered in the scenario. Further CO_2 emission reductions will require an overall reduction in resource use, such as steel and cement.

Despite some limitations of the inventory and scenario results presented due to data restrictions, lack of detailed data in certain sectors and uncertainties in the scenario assumptions, the results can be regarded as a good basis for the development of a roadmap towards a low carbon city strategy for Wuxi.

In the analysis of the current and future GHG emissions of Wuxi it became obvious that such information is important to understand the impacts of energy and resource use in different sectors, as well as the underlying and future drivers. However, these types of stand-alone studies and analyses have limitations, are time-consuming and can only be regarded as the first steps. Regular monitoring of current performance is crucial to measure the impacts of the implemented measures and to identify possible new hot spots.

As urban growth is expected to be the highest in “medium-sized” cities and not in the metropolises, which are frequently analysed [15], this study can also serve as an example and basis for discussion for other industrial cities in China of similar size and with similar conditions. As stated in this paper, the implementation of comparative tools at city level and regular accounting are also imperative. In addition to the territorially produced GHG emissions, which are often in the focus of global political discussions, other aspects and impacts are also crucial and need to be considered when aiming for sustainability. This includes not only local activities, but also the external impact of resources used by the city of Wuxi and the city’s vulnerability to climate change. Both these dimensions are considered in the LCFC study and are detailed in the specific background papers [3-5].

Overall, it is clear from the modelling that it would be difficult to initiate and implement a carbon neutral strategy at local level in isolation. Wuxi is an industrial Chinese city that is export oriented and answering the global demand for products. The dominant energy and emission source in China is coal and one city alone cannot easily reduce or even step out of its use. However, this is not a problem unique to Wuxi or China. A comprehensive rethink at global level on how to increase efficiency and sustainability is required. China, and its cities such as Wuxi, have an important role to play and can generate a remarkable impact; however, longstanding industrial countries in Europe and North America need to take the leading role in this global process.

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