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China's Urban GHG Inventory and Emissions

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Abstract

China is now experiencing dramatic urbanization, the environmental impact of which is a global concern. This paper focuses on city-level GHG (Greenhouse Gas) inventory and emission in the metropolitan areas. Firstly, the paper introduces various inventory methods especially three key models that have been used to develop a GHG inventory: the emission-oriented IPCC and WRI/WBCSD GHG emission model, the demand-oriented mixed lifecycle method, and the ICLEI GHG inventory method. Secondly, the paper introduces the progress of the national and provincial GHG inventory and provides an overview of key research results related to development of individual city's inventories in China. Thirdly, in order to examine the progress of the urban GHG inventory in China, the paper takes Beijing as an example to review the relevant research. Beijing's GHG studies are mainly focused on CO_2 emissions, without considering other GHGs required by the IPCC reporting. According to current publications, most research on Chinese urban GHG inventory fails to meet the method of IPCC. It is difficult for Chinese researchers to achieve statistical requirements of the ICLEI protocol on two levels and three scopes or the Global Protocol. Therefore, it is very important that cities in China establish a GHG inventory framework and methodology system that effectively addresses climate change and permits international comparisons as well.

Keywords: Urban GHG Inventory; CO_2 Emissions; China; Beijing

Introduction

By 2010, urban areas contained more than 50% of the world's population, consumed 75% of the world's energy resources, and took up 80% of greenhouse gas (GHG) emissions from global human activities [1]. As population increases and the urbanization process speeds up, the issue of global GHG emissions will become more and more severe. GHG emissions have been both the focus of global attention and a hot spot of research. China, as the most populated country in the world, is accelerating its urbanization process. In 2013, the Chinese urbanization level reached 53.73% with a population of 20 million added into cities each year. China is also undertaking an important international obligation and plays an increasingly essential role in addressing global climate change and reducing GHG emissions. This paper analyzes the progress of the urban GHG inventory and emissions in China, with particular reference to Beijing.

Urban GHG Inventory Methods

There are many calculation methods of greenhouse gas (GHG) [2] emissions based on nations, cities, buildings, corporations, products and production processes, and so on. We can divide these methods into two categories. The first has geographic boundaries, such as IPCC Guidelines for National GHG Inventories (IPCC, 1996), ICLEL local GHG Inventories (ICLEL, 2009b) and GRIP regional GHG inventory Protocol [3]. China's Guidelines for provincial-level GHG Protocol [4] belongs to this category. The second is concerned with the organization's operational boundaries, such as The GHG Protocol: A Corporate Accounting and Reporting Standard [5], Series of ISO 14064 standards [6] Guide PAS2050 and standard PAS2060 (Table 1). We also can divide the GHG inventory into two kinds of scopes: production and consumption (Table 1). The production pattern calculates the total GHG emissions due to goods and service productions within a geographical boundary, regardless of the location where the goods or service are consumed; the consumption pattern only counts the GHG emissions based on the goods or service that people within a boundary or an organization consume.

There are three key models that may be used to develop an Urban GHG Inventory, as follows:

Emission-oriented IPCC and WRI/WBCSD GHG emission model

Inventory methods at the urban level generally determine the GHG emission model based on the International Climate Framework Convention of Nations [7] and Enterprises (WRI/WBCSD 2009).

Demand-oriented mixed lifecycle method

Ramaswami et al. [8] and Kennedy et al. [9] developed an urban-scale GHG inventory oriented in demand and based on mixed lifecycle: (1) the amount of emissions of surface space of metropolis region and air travels between peer cities; (2) Lifecycle Assessment, the amount of emissions of urban main quantifiable substantial supply - food, water, fuel, energy and concrete.

Methods	Purpose	Preparation	Type of boundaries	Scope	Agency
IPCC Guidelines for National GHG Inventories	GHG inventories in different countries and regions to provide accounting framework and approach	Countries and regions	Geographical boundaries	Production	IPCC
ICLEL City GHG Inventories	To find major sources of GHG emissions in urban areas	Cities	Geographical boundaries	Production + consumption	ICLEL
GHG Regional Inventory Protocol, (GRIP)	Statistical monitoring of GHG emissions in order to compare to the potential emissions reductions between the cities	Cities	Geographical boundaries	Production + consumption	University of Manchester
China Provincial GHG Inventory Protocol	To find out the status of provincial GHG emissions in order to implement long-term plan to control GHG emissions	Provinces	Geographical boundaries	Production	China's NDRC
The GHG Protocol: A Corporate Accounting and Reporting Standard	Accounting corporate GHG emissions and GHG action plan on the basis of business enterprises, trade	Enterprises	Organizations operating boundaries	Production + consumption	WRI/WBCSD
Series of ISO 14064 standards	To emphasize on ISO standards	Corporate, business projects,	Organizations operating boundaries	Production + consumption	ISO standards
Guide PAS2050	Accounting of full life cycle of a product or service consumer	Products, services	Organizations operating boundaries	Production + consumption	British Standards Institute
Standard PAS2060	Reducing compensation to implement a carbon neutral	Countries, communities, companies, individ	Organizations operating boundaries	Production + consumption	British Standards Institute

Table 1: Types of GHG inventory methods.

This mixed method will separately report the GHG emitted directly from terminal use of energy (comprising Environmental Protection Agency (EPA) methods and IPCC methods), and the extra cross-border effects such as emission amount from air travel and main substantial production in the city (Scope 3 suggested by the World Resource Institute). The mixed method has been applied to Denver, State of Colorado, and generated a more comprehensive GHG inventory which is identical to the result of GHG trace calculation.

ICLEI GHG inventory method

The International Council for Local Environmental Initiatives [10] classifies GHG inventory into two levels: government and community. The degree of complexity with respect to emissions calculations depends on many factors, including scale, a function of the number of actors and geographies involved, as well as data availability and accuracy; and scope of the estimate: Scope I for direct emissions; II, which includes indirect emissions from purchased electricity; and III, that includes emissions associated with the production of purchased materials, product use, outsourced activities, contractor owned vehicles, waste disposal, and employee business travel among others.

Therefore, by viewing the GHG emissions of a city, we can view the city as a demand center of energy and material rather than being concerned only with how much has been emitted within the city. The GHG inventory at the urban level includes direct and indirect emission inventory separately. The demand-oriented mixed life-cycle GHG inventory methods mainly include three classifications: (1) direct energy consumption in buildings and facilities (terminal use), including housing, commercial, industrial and governmental buildings and facilities; (2) transportation-related direct (tailpipe) emissions associated with transportation, including surface and air travel, with a unique spatial allocation procedure applied to allocate such travel within and across city boundaries (3) indirect emission involving embodied energy of the city's main substantial energy and household waste (e.g. landfills). According to the basic functions of the city, the main substances of the city include food, water, fuels and concrete (dominating building materials). Demand-oriented mixed life-cycle method is oriented by demand, which includes a mixed GHG inventory method of urban direct GHG emissions related to terminal energy use and indirect GHG emission amount related to main substances that supported the city. The emissions inventory of direct terminal use complies with the IPCC. ICLEI's revised inventory protocol closely follows WRI/WBCSD's method, but does not explicitly define the relevant Scope 3 activities. More recently, the ICLEI has become one of the three partners in the emergence of the Global Protocol, along with the C40 Cities Climate Change Leadership Group and the World Resource Institute [10] and is expected to be the international standard, but for China in general, and Beijing in particular, this approach is still in its infancy.

Urban GHG inventory in China

China has 30 provinces as its second level administrative boundaries, while cities are the sub-regions of the province. Development of urban GHG inventories may directly be influenced by the provincial or national inventory. Some research results of four Municipalities directly under the central government, namely Beijing, Shanghai, Tianjin and Chongqin, are related to development of the individual city's inventory.

China's national and provincial GHG inventory

According to the requirements of the United Nations Framework Convention on Climate Change (UNFCCC), all countries will submit national information notification, including an Emissions Inventory. China is one of the first contracting parties of the UNFCCC. As a developing country, China belongs to non-Annex I parties which do not have to undertake the obligation of emission reduction, but have to submit national information notification. The core element of national information notification is the national inventory of source and sink of three GHGs: CO_2, CH_4 and N_2O, and the measures taken or to be taken to honor the agreement. Lin [11] was among the earliest publications about preparation of China's GHG inventory.

In 2004, China published the National Information Notification, in which China preliminarily calculated the amount of CO_2 emission of China in 1994. Actually, until recently, although analysts have been discussing the GHG emissions, China lacks exact CO_2 statistical data. China national level GHG inventory had been completed according to the IPCC Guidelines for National GHG Inventories in 1994 and 2005.

In 2010, China launched the Second National Information Notification, including an emissions inventory. According to the requirements in the UNFCCC, China's second National Information Notification will not only calculate carbon dioxide (CO_2), nitrous oxide (N_2O) and methane, but also three other GHGs: hydrofluoric acid (HFC), PFC and SF_6. And it will cover Hong Kong and Macau for the first time. It is predicted to be finished in 2013.

In March 2010, "China's Preparation for Second National Information Notification Construction" program put forward five sub-programs Preparation of GHG Inventory from Energy Activities, Preparation of GHG Inventory from Farmland, Preparation of GHG Inventory from Land Use Change and Forestry, Building China's GHG Emissions inventory Database and China's GHG Emission Forecast Methods. The Department of Climate of the State Development and Reform Commission held a discussion forum about "China's GHG Emission Forecast Methods" program progress in June 2010, and also a "Preparation of GHG Inventory from Energy Activities" discussion forum in August and a "Preparation of GHG Emissions inventory from Industrial Production Process" in September.

Geng et al. [12] estimates CO_2 emission inventories from energy consumption and carbon intensities of provinces and municipalities in Mainland China in 1990, 1995, 2000, and 2005–2008 using the IPCC mass balance approach. In 2012, China stated that its energy consumption was 2735.3 Mt and carbon emissions have reached 9208.1 Mt CO_2, accounting for 21.9% and 26.7% respectively of the world total [13] and reached 6.82 tons of carbon emissions per capita CO_2/person, more than the world average of 4.89 t CO_2/person (Table 2).

At the provincial level, China also made every effort in this work. In 2005, The Provincial Level GHG Inventory Preparation Guidelines (Trial), which were based on IPCC Guidelines for National GHG Inventories and were combined with the experience of the work on the national GHG inventory, issued for guiding the preparation of low-carbon [14] pilot provinces GHG inventories.

Country/Regions	Carbon emissions (Mt CO_2)	energy consumption (Mtoe)	Per capita carbon emissions (T CO_2/ person)	Carbon productivity ($/ton CO_2)	energy carbon emission factor (t CO_2/toe)
China	9208.1	2735.2	6.82	893.46	3.367
U.S.A.	5786.1	2208.8	18.43	2710.77	2.620
Japan	1409	478.2	11.05	4229.75	2.946
EU	3977.5	1673.4	7.88	4187.01	2.377
India	1823.2	563.5	1.47	1010.16	3.235
World	34466.1	12476.6	4.89	2079.33	2.762

Table 2: Global energy consumption and carbon emission in 2010

In 2008, the State Development and Reform Commission started China's provincial climate change project, whose basic task is to require every province (autonomous regions, municipalities) to calculate GHG emissions. For this task China lunched the Provincial GHG Inventory Protocol. However, this has occurred without any city-level GHG inventories in China, except provincial level municipalities such as Beijing, Shanghai, Tianjin and Chongqin up until now.

Carbon emissions related with urbanization in China

Global CO_2 emissions from the energy sector using data sets of power plants and motor vehicles, as well as estimates of fossil fuel emissions produced directly by industry, households, businesses, and other forms of transport [15]. In China, economy from 10.9655 trillion RMB Yuan soared to 56.8845 trillion RMB Yuan, the level of urbanization from 37.7% to 52.3% between 2001-2013. Infrastructure inertia is greatest in China, where rapid economic development and industrialization in the past decade have led to a prodigious expansion of energy Infrastructure. Nearly 1/4 of electrical generating capacity commissioned worldwide since 2000 is in coal-burning plants in China (322.3GW) [15]. Expansion of fossil infrastructure commonly project cumulative emissions from China's primary energy sector. China's primary energy consumption accounted for 11.0% of the world in 2001 to 21.3% in 2011 [13]. China alone accounts for roughly 27% of the global CO_2 emissions.

Some of them such as industrial, residential and commercial infrastructure that burns fossil fuels represent a considerable commitment to future emissions. Non-energy emissions, of those

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unrelated to the combustion of fossil fuels, occur as the result of industrial processes such as the manufacture of cements and steel, where the chemical transformation of feedstock's releases CO_2. China's industrial energy consumption has been from 1.595 billion tons of standard coal in 2005 to 2.4 billion in 2010, which accounted for about 73% of the China energy consumption. Six large high energy consumption industries such as iron and steel, nonferrous metals, building materials, petrochemical, chemical and power accounted for the proportion of total industrial energy consumption from 71.3% to about 77%. Currently per capita living area of urban residents is 32.7M^2, about half of the United States. Quick urbanization will use more steel and cements because the construction of one million M2 building of urban areas need to consume about 8.1 million tons of steel, 22 million tons of cement and 2.4 million M3 timber. China's road density is only 0.4km/km^2, per capita road length of road also is less than 3 m, about 40% and 50% in developed countries. China's per capita railway is only 0.06 m, less than 6.9 m of the United States and 1.6 m of Japan. Chinese cities will increase energy demand of 2.8 billion tons of standard coal in 2010 to 3.6-4.0 billion tons in 2020, urban per capita energy consumption will be from 4.1 tons of standard coal in 2010 to 4.3-4.8 tons in 2020. Chinese steel, cement, glass, ammonia and other major energy-intensive products will reach a peak in 2020-30.

The global transport sector also represents the next largest share of annual CO_2 emissions (22.9% in 2007) [16], of the total transport-related emissions, nearly two-thirds is from road transport (74 Gt CO_2) [15]. The proportion of China's oil consumption from transportation, storage and postal industry is about 34% (Table 3). According to the Release of People's Republic of China on Climate Change second national communications (2004), CO_2 emissions from transport energy activities (only mobile sources) was about 415.74 million tons, accounting for 7.5% of the total emissions. 2010 China accounted for energy and transport sectors account for carbon emissions such as Table 3. Surging vehicles sales in China 1990-2007 reflect growth of private vehicles ownership at a rate of 20% per year [17]. Chinese family car had an average capacity of 18.58 every 100 urban households, the lowest income households accounting for 10% of the total number of cities and towns was only 1.96 in 2011. It is clear that the oil consumption from transportation will be rise quickly in the near future.

	Energy%	carbon emissions%
Highway	59	49.0
Railway	7	4.0
Waterway	24	35.0
Civil Aviation	10	12.0

Table 3: China transport energy consumption and carbon emissions (2010)

No doubt, Chinese cities have been and will be the main resources of the GHG emissions. China's huge scale of urbanization means that more GHG emissions in the future world. For this reason, research on methods, emission factors and characteristics of GHG emissions in urban China will help the government set reduction goals, draw up and carry out action plans, put forward practical and effective GHG emission reduction measures and lay a solid scientific foundation for cities for negotiation and communication on climate change and GHG problems internationally.

Urban GHG Inventory and methods in China

Research on urban GHG emission in China has only just begun. From the existing literature, China's national level inventory is too rough to use CO_2 emission on the city level, and even where some cities have published results, the specific methods have not been described much. Xing [18] based his analysis on statistical data, according to the IPCC guideline method for estimating Beijing final energy carbon emissions between 1995-2005. In 2009, Zhu published "Research on Current Situations of Beijing's GHG Emissions and Emission Reduction Countermeasures" in China Soft Science [19]. Chen et al. [20] reviewed the research of urban greenhouse gas emission inventories.

Zhang and Yang [21] also estimated Shanghai 2008 CO_2 emissions inventory using the IPCC guideline method, of which coal accounted for 54% of CO2 emissions and petroleum use 32% of CO_2 emissions. Zhao [22] show more than 90% energy activities in GHG emissions in Shanghai from 1996 to 2008 based on the IPCC method. Geng [23] portrayed four megacities of Beijing, Shanghai, Tianjin, Chongqing as the major source of CO_2 emissions with one billion tons of carbon emissions, accounting for 10.8% coal-based energy consumption by IPCC methods in 1990, 1995 and 2004-2007. Wang et al. [1] estimated Wuxi City GHG emissions into the industrial, transportation, living, commercial, industrial processes and waste treatment by ICLEI method, and displayed the largest proportion of GHG from industry, energy, industrial processes and transport. Xu [24] shows that Nanjing's GHG emissions generated by energy consumption accounts for 69% of all emissions by the same methodology. Li et al. [25] reported their preliminary research on industrial carbon emissions in Kunming City.

Yang et al. [26] made a carbon emissions inventory by the energy, industry, waste treatment, agribusiness and animal husbandry, wetlands and forestry carbon sequestration process. Gu et al. [27] researched on carbon emissions from industry, transport, construction, agriculture of the four areas which refer to methods from the IPCC GHG inventory and the ICLEI urban inventory, and found that the industry is the largest source of carbon emissions in Harbin, with 76% of the total emissions from manufacturing and construction industry, energy, waste treatment. Ranked second were those from non-industrial emissions of carbon, including commercial buildings and residential buildings, about 14% of total emissions. Traffic carbon was listed as the third source of emissions, accounting for 9%. Carbon emissions from agriculture were extremely weak, accounting for only 1% (Table 4).

Authors	City	Year	Accounting gas	Division
Xing, et al. [18]	Beijing	1995-2005	carbon emissions from final energy	Agriculture, secondary industry, tertiary consumer life
Zhu [19]	Beijing	2001-2007	CO_2	agriculture, industry, buildings, transportation, commercial, residential area and living, electricity and heating
Zhang and Yang [21]	Shanghai	2008	CO_2 from energy activities	Thermal power plants, industry, agriculture, commerce, transport, living
Guo et al. [28]	Shanghai	2001-2006	carbon emissions a final energy	Primary industry, secondary industry and tertiary
Cao et al. [2]	Xiamen	2007	CO_2 from energy activities	Industries, family, traffic, commerce
Wang, et al. [1]	Wuxi	2004	$CO_2CH_4N_2O$	industries, transportation, living, commercial, industrial processes and waste disposal
Yang, et al. [26]	Chongqing	1997-2003	$CO_2CH_4N_2O$	energy activities, industry, waste disposal, agriculture, animal husbandry, wetlands and forestry carbon sequestration process
Guo, et al. [29]	Beidaihe New District	2011	CO_2	industries (tourism, services, industry, energy, agriculture)
GU, et al. [27]	Harbin	2011	CO_2	industries, energy, living, transport, aviation, coal development, industrial processes, agriculture, waste treatment, land use/land use change and forestry
Hu and Song [30]	Liu Zhou	2013	CO_2	energy, industries
Jiang, et al. [35]	Beijing	2011	CO_2 from land use	public facilities, residential areas, industrial sites, warehouse space, airports, towns, railroads, long-distance passenger transport, garden and woodland, farmland, grassland farming land and fish ponds, etc.

Table 4: Studies on urban GHG inventory in China.

GHG Inventory and CO_2 Emission in Beijing

Because Beijing is the capital city, where more data is available and more policy-makers and researchers are located, not surprisingly there have been comparatively more reports about its CO_2 emission and GHG inventory.

Early studies on Beijing's CO_2 Emissions

According to Cai et al. [31], from the 1980s, China has cooperated with Canada to start "Beijing's GHG Emissions Inventory Research". The preparation of the inventory mainly includes the estimation of the emission amount of three GHGs: CO_2, CH_4 and N_2O from energy, industrial production, agricultural activity, land-use change and forestry, urban waste disposal. City-level GHG emission calculation is strictly prepared according to a series of principles and guidance widely accepted. Zhu [19] first calculated Beijing's carbon emissions. The thesis uses data from 2005 to analyze and finds that Beijing's GHG emissions mainly come from energy, industrial production, agriculture, land use change and forestry as well as urban waste disposal. CO_2 is the most influential GHG which takes up 76.7% of the total amount. According to Zhu's research, during 1970-2007, 93.78% of Beijing's GHG emissions originated from energy activities, among which the greatest rise came from power generation and urban heating, industry and transportation. These three industries emitted 80% of the total.

GHG Inventory in Beijing

Chinese cities exhibit many differences from western cities. Firstly, the Chinese city is an administrative body instead of an autonomous one like the Western city; the municipal government has the right of financial revenue and expenditure, while urban districts and sub-districts do not have the right. Secondly, the Chinese city is an administrative area, including urban and suburban areas. A municipality is similar to a province, consisting of urban areas, suburban areas and counties. A prefecture-level city consists of urban areas and counties, while a county-level city consists of urban areas and villages and towns, not as clearly demarcated as Western cities. Thirdly, the statistical data of the Chinese city are scattered, thus, it is difficult to count and calculate GHG emissions inventories as in Western developed countries. Some research works in 1980-90 did not use Western methodologies and therefore they are difficult to use to make international comparisons.

Gu and Yuan [32] present the flow chart of Chinese city-level GHG inventory and GHG emissions preparation to explain the gap between China and overseas. By the use of ICLEI2009 GHG inventory protocol, Beijing GHG inventory and data sources were consolidated (Table 5), and found that Beijing GHG inventory can only meet the comparability requirements and categories in the aggregate due to statistical differences [33]. It is difficult to achieve statistical requirements of the ICLEI protocol on two levels and three-ranges.

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UNFCCC Department		**Emission by Category**	**Data Selection**	**Data of Beijing in 2007**	**Data Format**	**Data Source**	**Assessment**
Energy	Static Emission Source	Fuel consumption of public facility	Fuel consumption of tertiary industry	Total energy consumption by industry and the consumption of primary energy species	Standard quantity of different energy types	Statistical Yearbook of Beijing in 2010	Power and heat need to be subtracted and calculated in energy industry
		Primary industry, manufacturing and building industry and residents' living	Fuel consumption of primary and secondary industry (not including energy)	Total energy consumption by industry and the consumption of primary energy species	Standard quantity of different energy types	Statistical Yearbook of Beijing in 2010	Data needs to be converted into physical quantity
		Consumption of energy industry (power and heat supply)	Energy consumption of power and heat supply	Energy balance sheet (physical quantity)	Physical quantity of energy types	Statistical Yearbook of Beijing in 2010	In terms of the electricity, double counting should be avoided
	Transportation	Highway transportation	Transportation, storage and mail business	Total energy consumption by industry and the consumption of primary energy species	Physical quantity of energy types	Statistical Yearbook of Beijing in 2010	Since it includes storage and mail business, the index only acts as a calibration one
			Vehicle type and amount	Amount of civil vehicles	Amount of vehicles	Statistical Yearbook of Beijing in 2010	It needs to calculate combined with energy statistics
			Amount of public tram/bus and taxis	Public transportation and passenger transport taxis	Amount of vehicles	Statistical Yearbook of Beijing in 1949 to 2010	still needs data such as mileage and oil consumption
		Track traffic (metro)	Mileage of track traffic	Public transportation and passenger transport taxis	Kilometrage	Statistical Yearbook of Beijing in 1949 to 2010	still needs mileage per day and energy consumption per mileage unit
		Railway transportation	Local Distance	Transportation line	Kilometrage	Statistical Yearbook of Beijing in 1949 to 2010	It is not available because there is only distance without total mileage
		Air transportation					No Data
		Waterway transportation	-	-	-	-	Beijing does not contain waterway transportation
	Fugitive Emission	Coal mining process and post-mine activities	transportation and distribution loss	Energy balance sheet (physical quantity)	Crude oil, natural gas	Statistical Yearbook of Beijing in 2010	Beijing lacks coal and natural gas mining data, use loss data to replace it
		Petrol and natural gas mining and post-mine activities					
Industrial Production Process		Building material, chemical, metal, electronic industry, ODS products etc.					Need the detailed data related to the process of each industry
Agriculture		stockbreeding	Amount of livestock	Livestock breeding and production	heads	Statistical Yearbook of Beijing in 2010	Mainly calculate methane emission of animal intestinal fermentation

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	Crop production	Agricultural land and arable land are	Land area and its use	Square kilometers	Statistical Yearbook of Beijing in 2010	Within the city boundary
		Crops area	Crops sowing area and forestation area	Square kilometers	Statistical Yearbook of Beijing in 2010	Need the detailed data of crop varieties
Land use, land use change and forestry	Land use change	Agricultural land, building land, unused land change	Land area and use2006, 2007	Square kilometers	Statistical Yearbook of Beijing in 2010	Not identical to international standards, lacking in grassland and wetland
	Forestry carbon sequestration	Forest area, forestation area of this year	gardening, greening and forest status	hectare	Statistical Yearbook of Beijing in 1949 to 2010	Need to use the data of different years
Waste	Waste landfill	Trash amount, feces amount, disposal rate	Environmental health	10 thousand tons	Statistical Yearbook of Beijing in 2010	Amount of burning and landfill
	Waste burning					Need to get the data from municipal sector
	Living sewage, industrial sewage and silt disposal	Annual amount and rate of sewage disposal	Water disposal and saving	10 thousand cubic meters	Statistical Yearbook of Beijing in 2010	Combine the two data to obtain living sewage
		Industrial sewage	Environmental protection	10 thousand tons	Statistical Yearbook of Beijing in 2010	

Table 5: Beijing GHG Inventory Data and Assessment

CO_2 emission in Beijing

According to the data of the China Energy Statistical Yearbook, based on the calculation method of IPCC, fuel net carbon values provided by IPCC and China's energy heat values were used for statistics on Beijing carbon emissions (methane and nitrous oxide equivalent values were excluded in carbon emissions). The results show that Beijing CO_2 emission was about 173.0 million tons in 2011, an increase of 38.27 million tons over 2005 (Table 6).

Year	CO_2 emission (Million tons)
2005	134.73
2007	153.39
2008	151.39
2009	158.00
2011	173.00

Table 6: Beijing CO_2 emission

Beijing carbon emissions are mainly sourced from three major sectors, i.e., industry, construction and transport. On the basis of urban energy consumption survey and analysis, the calculation method of IPCC was used for statistics on Beijing urban carbon emissions [34].

Industry: The CO_2 emission of the manufacturing sector accounted for 83% of the industrial total, those of power, gas, water production and supply sector accounted for 16%, and that of the mining industry accounted for 1%. As viewed from internal manufacturing industry, the carbon dioxide emission of three traditional manufacturing sectors accounted for 64%, while that of modern manufacturing industry accounted for 14%, and that of urban industry accounted for 10%.

Construction: Beijing carbon emission of the construction sector was 60.533 million tons in 2009, accounting for 40% of Beijing total carbon emission, of which the residential carbon emission was 27.195 million tons, accounting for 45%, and that of public buildings accounted for 55%. Among various energy consumption and carbon emissions of the construction sector, the carbon emission of power was the maximum at 33.53 million tons, accounting for 55%; followed by that of coal, heat and natural gas. The carbon emissions of these four energy consumptions accounted for 98% of total carbon emission in the construction sector. The total carbon emission of residential buildings was 27.195 million tons in 2009, of which that of urban and rural residential buildings accounted for 75% and 25% respectively.

Transportation: In 2009, the energy consumption of the transportation sector was 14.88 million tons of standard coal, and the CO_2 emission was 31.22 million tons, of which the carbon dioxide

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emission of rail transit was 530,000 million tons, that caused by air energy consumption was 10.62 million tons, that of the rail sector was totaled at 3.72 million tons, and that of the road sector was approximately 3.98 million tons. Beijing per-capita motor vehicle occupation reached 0.18 automobiles/person with an annual growth rate of 0.2 automobiles/person. The passenger volume of ground bus transit was 5.17 billion in 2009.

Based on the Beijing Statistical Yearbook 2011 of the energy, Jiang et al. [35] calculated Beijing 2011 final energy consumption as 66,950,000 tce (tons of standard coal), CO_2 emissions related was 173 million tons, per unit of GDP emission intensity 1.06t CO_2 /10 thousand Yuan GDP, per-capita carbon emission intensity 8.56t CO_2 / person. The Beijing GHG emissions inventory included production, construction and transportation, and the three sectors accounted for 34%, 44% and 22% respectively. Urban land use divided into public facilities, residential areas, industrial sites, warehouse space, airports, towns, railroads, long-distance passenger transport, garden and woodland, arable land, pasture land and aquaculture ponds, etc.. All types of land use emissions of CO_2 were estimated as shown in Table 7.

	Energy consumption		**CO2 emissions**		**CO2 emissions from various types of land**		
	10,000 tons	%	10,000tons	%	land type	10,000tons	%
Building	2762	41	7548	44			
					Public facilities	4367	30.26
					Urban residential areas and villages	3181	22.04
Production	2194	33	5928	34			
					Industrial land	4084	28.30
					Warehouse space	1077	7.47
Transportation	1739	26	3801	22			
					Airports, railways, long-distance passenger	1455	10.08
Other					cultivated garden and woodland, grassland farming land and fish ponds, etc.	266	1.85
Subtotal	6695		17277			14430	
Redeployment of electricity and heating	5997	39.31	15476	39.39			
Intercity passenger and freight	2533	16.64	6535	16.63			
Total	15225		39288				

Table 7: Types of land use and CO_2 emissions in Beijing (2011)

Beijing CO_2 Emission in 2020

In order to explore urban energy and carbon emissions under different development scenarios, China launched a low-carbon road map. The Beijing Institute of Urban Planning also gave scenarios of Beijing urban development based on the survey and analysis of Beijing carbon emission intensity, including: (1) Basic scenario - climate change countermeasures are not carried out in the premise of economic development as the major driving factor. (2) Low-carbon scenario - achieved through national policies in the premise of national energy security, domestic environment and low carbon roadmap [34].

Based on energy consumption intensity and expected energy-saving level of various industrial sectors in 2000-2010, combined with future economic growth expectation and considerations on economic growth, total population, urban scale and energy-saving potential, the energy data in 2011 - 2020 were forecasted, and scenario analysis was carried out on the energy data for 2020. According to current energy-use data and level, CO_2 emission will reach 257 million tons in 2020.

Discussion and Conclusion

The preparation of China's GHG inventory [36] needs the support of a large amount of accurate data. But now, due to the difference in statistical scope between domestic and international emissions inventory, the current research can only satisfy the comparability in the total amount and main categories, and fails to meet the statistics of two levels and three scopes in ICLEI or the Global Protocol. As introduced above, Beijing's GHG studies are mainly focused on CO_2 emissions, without considering other GHGs required by the IPCC reporting. In addition, the categorization of emission sources is unique and not internationally compatible. Table 5 consolidates Beijing's data sources with IPCC and ICLEI2009 GHG inventory protocol, but the static emission in energy departments can basically meet the classification demand, and transportation data lacks the correspondence of vehicle type and fuel amount. As for the industrial production process sector, data about annual production of products such as cement or steel need to be obtained from industry associations. The data of agricultural department and land, land use change and forestry department is basically available, but classification of land use is not identical to that of LULUCF (land-use, land use change and forestry), lacking in grassland and wetland. Data of waste amount and sewage amount of waste department are available, but still lack the waste amount data disposed by different methods. In short, China's urban GHG inventory can only meet the comparability requirements and categories in the aggregate due to statistical differences, but it is difficult to achieve statistical requirements of the ICLEI protocol on two levels and three scopes. However, it is also very important that urban China establish a unique GHG inventory framework and methodology system that effectively addresses climate change and permits international comparisons.

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