Carbon Emission of Guangxi's Major Industries and Measures for Low-carbon Economic Development

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Abstract Guangxi's economic development mainly relies on major industries such as electric power, steel, cement, nonferrous metallurgy, papermaking, sugar, starch, and glass industry. With continuous development of the economy, the situation of carbon emission reduction of these industries is not optimistic. In this paper, carbon emission of Guangxi's major industries in 2012 was calculated using Oak Ridge National Laboratory (ORNL) and Intergovernmental Panel on Climate Change (IPCC) method, and then, the situation of carbon emissions was analyzed. The results showed that carbon emission of Guangxi's major industries mainly came from energy consumption, but carbon emissions in the technological process also should not be ignored; carbon emissions were mainly from industries such as steel, cement, thermal power, and nonferrous metallurgical and chemical industry where energy consumption is high and energy efficiency is low. The key factors that influence carbon emissions of these industries included irrational energy consumption structure and energy processing, the overall low utilization efficiency, and the increasing demand with the rapid economic growth. In order to realize a low-carbon economy and sustainable development in these major industries, the following measures were proposed such as formulation of low-carbon development planning and regulatory standards in these industries, management strengthening of the energy consumption in existing enterprises, optimization of the industrial and energy structure, and actively carrying out industrial upgrade, vigorous promotion of the use of new energy, establishment of the financing and policy guaranteeing system, and improvement of the processing and utilization of energy resources.

Keywords Carbon emission · Low-carbon economy · Guangxi · Measures

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1 Introduction

The global warming caused by greenhouse gas emissions is a major environmental problem facing the present humanity. In general, the greenhouse gases associated with climate change are mainly referred to six gases which are identified by the Kyoto protocol, including carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, fluorinated carbon, and sulfur hexafluoride. Among these, carbon dioxide has attracted the most attention due to the longest survival time and the largest stock in the atmosphere. The Intergovernmental Panel on Climate Change (IPCC) points out that in all kinds of greenhouse gases blamed for climate change, carbon dioxide accounted for more than 50 and 70 % carbon dioxide of human activities is from fossil fuel combustion (IPCC 2006). Therefore, reduced carbon emissions have become the key measure in response to global climate warming (Schimel 1995). At present, China's economic development is faster, but it is the extensive economic growth mode which is based on a large number of resource consumption. According to the statistics, China is one of the world's largest carbon emitters; China's annual greenhouse emission is by nearly half of all the emissions in developing countries and is close to 15 % of the world's total emissions (Energy research institute national development and reform commission 2003); and high CO_2 emission to make carbon reduction in China is facing greater pressure (Zhu et al. 2010; Zhu and Qiu 2010; Zhao et al. 2009; Li and Xian 2014; Tang et al. 2010).

Guangxi is located in the fringe of the southern and the southwestern, it is the important gateway for the association of Southeast Asian nations and frontal zone of China, and it is also the most convenient sea channel in southwest of China, especially the Beibu Gulf Economic Zone will become new growth pole of coastal economic development in China. In recent years, the key industries of Guangxi such as electric power, steel, cement, chemical industry, nonferrous metallurgical, papermaking, sugar, starch, lime, and glass developed rapidly; in the meanwhile, the energy consumption is also increasing, and the reduce situation of carbon emissions is not optimistic. Therefore, to calculate the carbon emissions in Guangxi key industries, analysis of carbon emission characteristics of the present situation and key factors that influence the carbon emissions have been made, and based on this, measures to develop low-carbon economy and sustainable development in the key industry of Guangxi, have been put forward, which has an important practical significance on the carbon emission reduction work and healthy development of the social economy in Guangxi.

2 Carbon Emission of Guangxi's Major Industries

2.1 Calculation Method of Carbon Emissions

Carbon emissions of the key industries in Guangxi were mainly from energy consumption and technological process.

Due to the energy consumption of clean energy such as water and electricity, nuclear power, wind power, solar, and biomass energy does not produce carbon dioxide, carbon emissions of energy consumption mainly consider the burning of fossil fuels. The carbon emissions of the energy consumption were calculated using the Oak Ridge National Laboratory (ORNL) (1990), and its general formula is as follows:

$$C = Ekn \tag{1}$$

where C is carbon emissions, E is energy consumption, k is effective oxidation scores, and n is carbon content of every tons standard coal.

The carbon emissions of the technological process were calculated using the carbon emissions calculation method proposed by 2006 IPCC guidelines for national greenhouse gas inventories (IPCC 2006).

Therefore, the total amount of carbon emissions of the key industries in Guangxi were added carbon emissions from technological process and energy consumption, whose main calculation formula is shown in Table 1.

All kinds of fossil fuels are converted to standard coal coefficient by using numerical reference in Chinese Energy Statistics Yearbook 2013 (Table 2). The energy consumption, industrial production, product type, product yield, and electric power consumption data of the key industries were from the Guangxi statistical yearbook 2013.

2.2 Status Quo of Carbon Emissions

1. Carbon emissions of the energy consumption in the key industries
   The usage of fossil fuels in the key industries of Guangxi in 2012 was shown in Table 3. The main fossil fuel in Guangxi is coal, of which the usage of the raw coal is 47.7453 million tons, washed coal is 7.8523 million tons, and coke is 6.8943 million tons. As for the usage of fuel oil, the usage of diesel is 0.0869 million tons and gasoline is 0.0085 million tons. The usage of fuel gas in the major industries in Guangxi was almost zero. The energy consumption and carbon emissions of the key industries are shown in Fig. 1. As can be seen from the figure, energy consumption of the thermal power industry was the largest (17.166 million tons), followed by steel industry (6.8527 million tons), cement industry (6.3784 million tons), nonferrous metallurgical industry (3.5728 million tons),

Table 1 Calculation formula of the key industries

Industry	Carbon source		Total carbon emissions
	Energy consumption	Technological process	
Power	1. Coal: $M_1 = C \times 0.982 \times 0.73257 \times 44/12$ 2. fuel: $M_2 = C \times 0.982 \times 0.73257 \times 0.813 \times 44/12$ 3. fuel gas: $M_3 = C \times 0.982 \times 0.73257 \times 0.561 \times 44/12$ $M_{energy} = M_1 + M_2 + M_3$ Where C is standard coal equivalent; 0.982 is effective oxidation scores; 0.73257 is carbon content of every tons standard coal; 44/12 is conversion ratio of C and CO_2.	/	M_{energy}
Steel		[a]E_{CO_2} = Production × Emission factor	$M_{energy} + E_{CO_2}$
Cement		E_{CO_2} = Cement clinker × 0.52	$M_{energy} + E_{CO_2}$
Chemical		E_{CO_2} = Synthetic ammonia production × 2.1-urea production × 12/60	$M_{energy} + E_{CO_2}$
Glass		E_{CO_2} = Glass production × 0.17	$M_{energy} + E_{CO_2}$
Lime		E_{CO_2} = Lime production × 0.75	$M_{energy} + E_{CO_2}$
Nonferrous metallurgical		/	M_{energy}
Sugar		/	M_{energy}
Papermaking		/	M_{energy}
Starch		/	M_{energy}

Note [a]E_{CO_2} = (BOF × 1.46 + EAF × 0.08 + OHF × 1.72) + (Pig iron production × 1.35) + (Direct reduced iron production × 0.70) + (Slag production × 0.20) + (Pellet production × 0.03), where BOF is the steel production of the alkaline oxidation of converter, EAF is the steel production of the electric arc furnace, and OHF is the steel production of the open hearth

Table 2 The fold of standard coal reference coefficient between different fossil fuels and standard coal

Name	The fold of standard coal reference coefficient (tons/standard coal)	Name	The fold of standard coal reference coefficient (tons/standard coal)
Raw coal (tons)	0.7143	Oil field gas (million cu. m)	13.300
Cleaned coal (tons)	0.9000	Crude oil (tons)	1.4286
Other cleaned coal (tons)	0.3571	Gasoline (tons)	1.4714
Briquette coal (tons)	0.6000	Kerosene (tons)	1.4714
Coke (tons)	0.9714	Diesel (tons)	1.4571
Other coke (tons)	1.3000	Fuel oil (tons)	1.4286
Coke oven gas (million cu.m)	6.143	Liquefied petroleum gas (tons)	1.7143
Blast furnace gas (million cu.m)	1.286	Refinery dry gas (tons)	1.5714
Other gas (million cu. m)	3.570	Other petroleum products (tons)	1.2000

chemical industry (2.5882 million tons), and papermaking industry (2.2341 million tons). The energy consumption of the six industries accounted for 95.96 % of the major industries' overall energy consumption. These results show that steel industry, cement industry, nonferrous metallurgical industry, chemical industry, and papermaking industry were the main energy consumption industries in Guangxi. As for carbon emission, the more the energy consumption, the more the carbon emission, and the main energy consumption industry is also the major carbon industry. Carbon emission of the thermal power industry is 45.2794 million tons, followed by steel industry (18.0757 million tons), cement industry (16.8245 million tons), nonferrous metallurgical industry (9.4238 million tons), chemical industry (6.8375 million tons), papermaking industry (5.893 million tons), glass industry (1.6774 million tons), sugar industry (1.4149 million tons), lime industry (0.9111 million tons), and starch industry (0.3039 million tons).

2. Carbon emissions of the technological process in the key industries
   As for carbon sources, in addition to energy consumption, the technological process also produces CO_2. Carbon emissions of the technological process in the

Table 3 The usage of fossil fuel in the major industries of Guangxi in 2012 (million tons)

	Steel	Thermal power	Nonferrous metallurgical	Cement	Chemical	Sugar	Papermaking	Lime	Glass	Total
Washed coal	7.5765	–	0.1209	3.83×10^{-2}	8.14×10^{-2}	–	–	0.038	–	7.8523
Coke	6.7555	–	0.1118	3.7×10^{-3}	1.12×10^{-2}	1.21×10^{-2}	–	–	–	6.8943
Raw coal	2.5987	25.3409	3.0988	7.9387	3.4702	0.7294	3.8352	0.4054	0.328	47.7453
Gasoline	9.2×10^{-5}	9.4×10^{-5}	0.7×10^{-3}	6.7×10^{-5}	0.1×10^{-3}	0.5×10^{-3}	0.1×10^{-3}	6.7×10^{-3}	0.1×10^{-3}	8.5×10^{-3}
Diesel	2.9×10^{-3}	2.17×10^{-2}	9.8×10^{-3}	2.96×10^{-2}	5.3×10^{-3}	0.2×10^{-2}	2.8×10^{-3}	1.21×10^{-2}	0.7×10^{-3}	8.69×10^{-2}

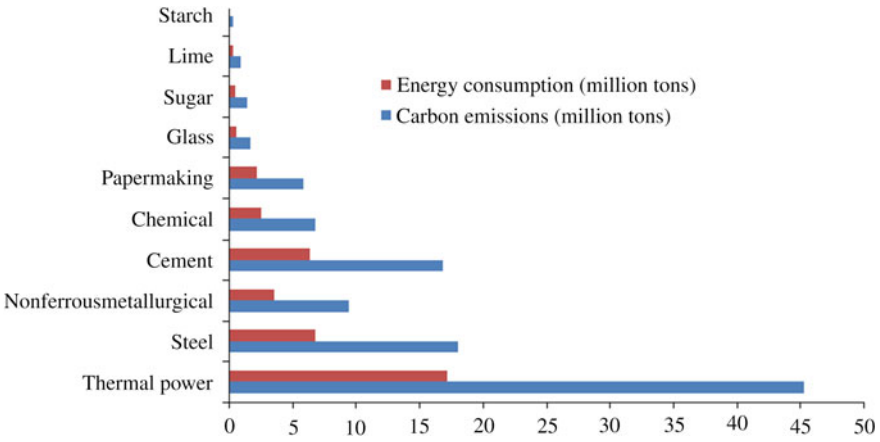

Fig. 1 Energy consumption and carbon emission of energy consumption in key industries in Guangxi in 2012

key industries in Guangxi were calculated according to Table 1, and the results are shown in Fig. 2. As shown in Fig. 2, the total carbon emission of the technological process in Guangxi was 94.6372 million tons in 2012. Among them, carbon emission of the technological process in the steel industry was the largest (60.5344 million tons), which accounts for 63.96 % of the overall technological process carbon emissions, followed by the cement industry (29.2159 million tons), which accounts for 30.87 % of the overall technological process carbon emissions, synthetic ammonia industry (2.2127 million tons), lime industry (1.6413 million tons), and glass industry (1.0329 million tons), and carbon emissions of the technological process in the synthetic ammonia industry, lime industry, and glass industry only account for 5.17 % of the overall technological process carbon emissions. These results show that carbon emission of the technological process was mainly from steel industry and cement industry.

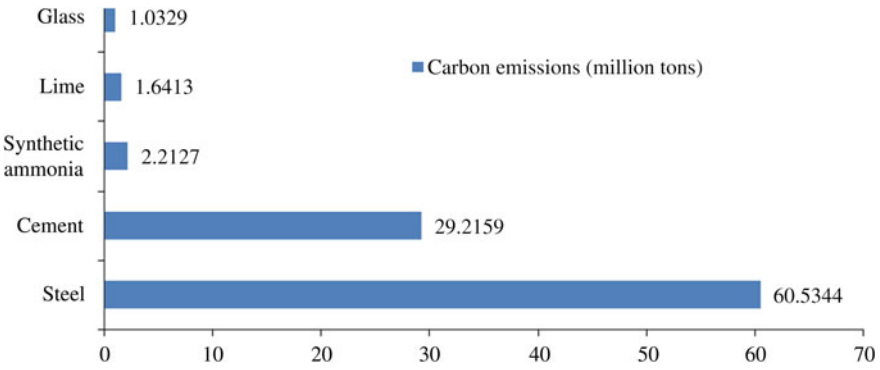

Fig. 2 Carbon emissions of the technological process in the key industries of Guangxi in 2012

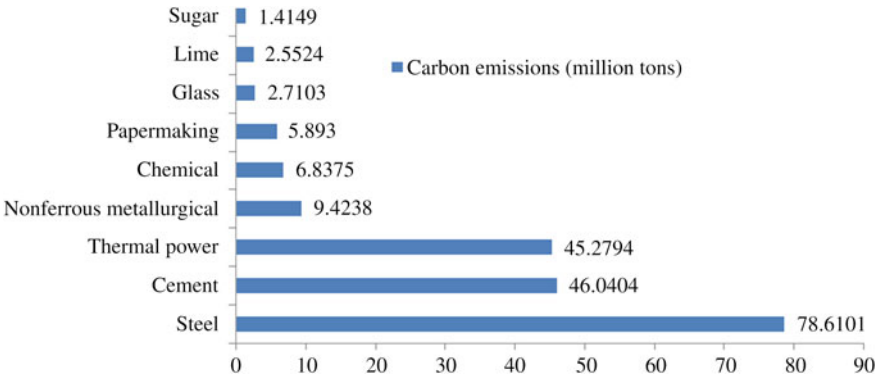

Fig. 3 Overall carbon emissions of the key industries in Guangxi in 2012

3. Overall carbon emissions of the key industries in Guangxi
   The overall carbon emissions of the key industries were calculated based on the carbon emissions from the energy consumption and technological process in the key industries in Guangxi in 2012. Carbon emissions of the steel industry were the largest (78.6101 million tons), which accounts for 37.38 % of the overall carbon emissions of the key industries in Guangxi. The second is the cement industry and thermal power industry, carbon emissions by 46.0404 million tons and 45.2794 million tons account for 21.90 and 21.53 %, respectively, followed by other key industries such as nonferrous metallurgical industry (9.4238 million tons), chemical industry (6.8375 million tons), and papermaking industry (5.893 million tons). The six industries are the most important carbon emissions industry, and carbon emissions of the six industries accounted for 96.64 % of the overall carbon emissions of the key industries in Guangxi (Fig. 3).

3 Analysis of Influence Factors for Carbon Emissions of the Key Industries in Guangxi

3.1 Energy Consumption Structure

According to the energy consumption of the key industries in Guangxi, the energy consumption structure of the key industries of Guangxi was based on coal consumption; raw coal consumption accounted for 76.3 % of fossil fuel consumption in 2012. Coal is the main source of carbon emissions, and carbon emissions of the energy consumption in Guangxi were mainly from the key industries such as thermal power, steel, cement, nonferrous metallurgical, chemical, and papermaking industry. Therefore, Guangxi's economic growth is based on huge coal consumption and is highly dependent on coal resources, but Guangxi is not a major

coal production area of coal resources; coal resources are mainly transferred from other provinces. Therefore, improving the clean energy utilization and optimizing the energy structure will become the key to reducing carbon emissions in Guangxi.

3.2 Energy Efficiency

The key industries such as steel, nonferrous metallurgical, papermaking, cement, chemical, and thermal power industry of Guangxi all belong to high energy consumption industries. According to statistics, the GDP of the key industries in Guangxi was 439.645 billion yuan and total energy consumption of the key industries was 420.381 million tons, and per 10,000 yuan GDP energy consumption is 0.96 tons which is significantly higher than the national average (0.7 tons). This result has shown that the key industries in Guangxi still belong to the extensive economic growth mode. Economic growth mainly depends on the large consumption of energy, but the efficiency of energy processing and utilization is low; most of the energy resources are lost and wasted in the resource exploitation, processing, conversion and utilization process, which leads to large carbon emissions.

3.3 Economic Development

In the "twelfth five-year" period, with the "several opinions on further promote economic and social development in Guangxi," "development planning of Guangxi beibu gulf economic zone," "development planning of Pearl River-Xijiang River economic zone," and other policy documents to implement, the key industries of Guangxi faced with an excellent opportunity for development, the GDP of Guangxi has grown significantly, however, the energy consumption demand of Guangxi is also increasing; energy consumption growth will remain at about 11 %, while the absolute increment will continue to increase (Su and Wu 2008). It can be foreseen that in the quite a long period of time, carbon emissions of the key industries in Guangxi will increase with the development of economy, and the reduction in carbon emissions is not optimistic.

4 Measures to Develop a Low-carbon Economy and Sustainable Development in Guangxi

4.1 Optimize the Industrial Structure, Actively Carry Out Industrial Upgrading

The key industries in Guangxi are mainly high energy consumption industries, and the new low-power industrial proportion is low. To achieve a low-carbon economy, on the one hand, it need to optimize the internal structure of the industries, reduce the proportion of high energy consumption industries, and foster emerging low-carbon industry, especially to speed up the development of the emerging strategic industries such as new energy, energy conservation and environmental protection, new materials, and information industry; on the other hand, to the existing traditional high energy consumption, key industries such as steel, electric power, and nonferrous metallurgical industry can, through the enterprise implementation of technological transformation and clean production, improve the efficiency of the processing and utilization of energy resources and take a new road to industrialization.

4.2 Optimize the Energy Structure; Vigorously Promote the Use of New Energy

The energy consumption structure of the key industries in Guangxi is based on fuel coal; the proportion of using natural gas and other clean energy is less. This energy consumption structure objectively causes lower energy efficiency, serious environmental pollution, and higher carbon emissions in Guangxi. Therefore, it should step up the development and use of clean energy, and strive to reduce the proportion of coal in the energy consumption structure, and accelerate energy consumption structure mainly from fuel coal change to oil and natural gas. In the meanwhile, new energy is the direction of the future energy development and also the only way for developing low-carbon economy, and Guangxi is one of the largest sugar cane and cassava production bases in China. It should actively implement the key technology of new energy in the biological chemical and biomass gasification fuel industry and speed up the industrialization of biomass energy development. At the same time, it should, according to the geographical position advantage of Guangxi, promote new energy such as solar energy, oceanic energy, and wind energy development and utilization.

4.3 Strengthen the Energy Consumption Management of Existing Key Industrial Enterprise, Full Implementation the Energy Assessment of the Key Industries

Formulating of energy consumption management measures of key enterprises in Guangxi as soon as possible, establish energy consumption management database of the key enterprises, key industries enterprise should execute mandatory energy evaluation, and be assessed by the government regularly. Strict implementation of national industry access system, control unreasonable growth of energy consumption timely, improve energy assessment based on results of shutting down the exit mechanism for elimination, close or move high energy consumption and high pollution enterprises step-by-step, eliminate inefficient equipment and backward production capacity.

4.4 Formulate the Low-carbon Development Planning and Regulations Standard of the Key Industries and Improve the Fund and Policy Security System

According to the economic development of the key industries in Guangxi, and the status quo of the energy consumption and demand, combined with the concept of low-carbon economy development, formulate the low-carbon economy development plan of the key industries in Guangxi, establish reasonable low-carbon development goals and tasks of the key industries in Guangxi, determine the key areas of conserving energy and emission reduction, propose the key projects and implementation plan of carbon reduction, and issue the standard system, technical specification and other policy documents, promoting the low-carbon development of the key industries as soon as possible.

Increase the funding support for the low-carbon development of key industries, improve the financial input and subsidy policy of low-carbon development. Through the economic means, give financial support and preferential tax policy incentives to the enterprise which get obvious effect of energy saving and emission reduction by implementing clean production and circular economy, give moderate fiscal subsidies to the enterprise which implements low-carbon key technology research and development and promote achievement, provide strong policy and financial security for the key industries to achieve low-carbon development.

5 Conclusions

Guangxi is located in the fringe of the southern and the southwestern of China. It is a gateway to Southeast Asian nations and frontal zone of China and also the most convenient sea channel in southwest of China, especially the Beibu Gulf Economic Zone will become new growth pole of coastal economic development in China. In this paper, based on the analysis on the status quo of carbons emissions in the key industries such as power, steel, cement, chemical, nonferrous metallurgical, papermaking, sugar, starch, lime, and glass industry, it points out the key factors that influence the carbon emissions of the key industrial, and put forward measures to realize the low-carbon economy and sustainable development.

The results showed that the carbon emission of major industry in Guangxi was mainly from energy use, but carbon emissions of the technological process also cannot be ignored; the economic development of Guangxi was mainly rely on the steel industry, cement industry, and so on, and these industries were high energy consumption industries, and mainly, energy was coal-fired, energy efficiency was low, and carbon emissions were large. Quite a long period of time in the future, economy of the key industries in Guangxi will grow rapidly and seriously in the form of carbon emissions reduction, and to realize the low-carbon economy and sustainable development of the key industries, the following measures must be taken: formulation of low-carbon development planning and regulatory standards in these industries, management strengthening of the energy consumption in existing enterprises, optimization of the industrial and energy structure, actively carrying out industrial upgrade, vigorous promotion of the use of new energy, establishment of the financing and policy guaranteeing system, and improvement of the processing and utilization of energy resources.

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