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Article

Study on the Decomposition of Factors Affecting Energy-Related Carbon Emissions in Guangdong Province, China

Wenxiu Wang [1,2,3], Yaoqiu Kuang [1,2,*] and Ningsheng Huang [1]

1 Sustainable Development Research Center, Guangzhou Institute of Geochemistry, Chinese Academy of Sciences, Guangzhou, Guangdong 510640, China; E-Mails: wenxiu5759859@163.com (W.W.); nshuang@gzb.ac.cn (N.H.)

2 Key Laboratory of Marginal Sea Geology, Chinese Academy of Sciences, Guangdong 510640, China

3 Graduate University of Chinese Academy of Sciences, Beijing 100049, China

* Author to whom correspondence should be addressed; E-Mail: yaoqiuk@gig.ac.cn; Tel.: +86-020-85290476; Fax: +86-020-85290476.

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Abstract: Guangdong is China's largest province in terms of energy consumption. The energy-related carbon emissions in Guangdong province are calculated, and two extended and improved decomposition models for energy-related carbon emissions are established with the Logarithmic Mean Divisia Index method based on the basic principle of Kaya identity. Main results are as follows: (1) the energy-related carbon emissions from the three strata of industry, except the primary industry, and household energy consumption in Guangdong province show increasing trend from 1995 to 2009; (2) the main driving and inhibiting factors which influence energy-related carbon emissions are economic output and energy intensity, respectively, while the contributions of energy mix, industrial structures, population size and living standards are not significant during the period of interest. It is concluded that optimizing the energy mix by exploiting new energy sources and cutting down energy intensity by developing low-carbon technologies are the two most effective approaches to reduce carbon emissions for Guangdong province in the future. The results and proposals in this paper provided reference for relevant administrative departments in the Government of Guangdong province to develop policies for energy conservation and emission reduction as well as to promote development of low-carbon economy.

Keywords: energy consumption; carbon emission; factor decomposition; Logarithmic Mean Divisia Index (LMDI)

1. Introduction

As stated in the IPCC Fourth Assessment Report (AR4), energy-related greenhouse gas emissions, mainly from fossil fuel combustion for heat supply, electricity generation and transport, account for around 70% of total emissions including carbon dioxide, methane and some traces of nitrous oxide [1]. Energy-related carbon emissions in China occupy a considerable share of the World's total emissions. The International Energy Agency listed the statistical data (IEA, 2010) of energy-related carbon emissions of countries around the world during the period 1971–2008 [2], which shows that energy-related CO_2 emissions were 6.044 billion tons in China and 5.85 billion tons in the United States in 2007, when China surpassed the United States for the first time and became the world's top country of energy-related carbon emissions. Since then, China has played an outstanding role in the issue of World carbon emissions and is facing growing international pressure to reduce emissions. The Chinese government has made a solemn promise to the World in the United Nations Conference on Climate Change held in Copenhagen in late 2009 to cut down the CO_2 emissions per unit GDP in 2020 by 40%–45% compared to that in 2005, which had been already incorporated into the medium and long-term planning program of national economic and social development as a binding indicator. China's energy-related carbon emissions have became hot research topics for domestic and foreign scholars since then [3–11]. Researches on energy-related carbon emissions and analysis on their factors in Provinces and Cities of China have also become issues of interest recently [12–23].

Guangdong, located in the subtropical part of southern China mainland (Figure 1), between latitude 20°13'–25°31'N and longitude 109°39'–117°19'E, is one of the regions which have the most abundant light, heat and water resources in China. Guangdong's economy has achieved rapid development since reform and opening up in 1978. Guangdong's Gross Domestic Product (GDP), urbanization rate and permanent population reached 3948.26 billion Yuan (constant price), 63.4% and 101.3 million persons in 2009, respectively. This indicates that Guangdong has become the biggest province in population and economy in China. There are nine major industries, including three fresh industries (electronic and information technology, electric equipment and special-purpose machinery, petroleum and chemistry), three traditional industries (textile and garments, food and beverage, building materials) and three potential industries (logging and papermaking, medicine, motor vehicle). Energy is the main driving force of economic development, for the rapid economic development must bring about huge amount of energy consumption, so Guangdong has inevitably become China's largest province in terms of energy consumption and carbon emissions, and is facing greater pressure to reduce emissions.

On July 19, 2010, the National Development and Reform Commission of China issued *the notice of conducting national pilot work of low-carbon provinces and low-carbon cities*, in which five Provinces, including Guangdong, and eight Cities were selected as the pilot districts for the national pilot program for low-carbon development, so the pressure on carbon reduction become more urgent for Guangdong.

Figure 1. Geographic location of Guangdong province in China.

However, the literature search results show that there are indeed some studies on energy consumption, but few on energy-related carbon emissions in Guangdong province [24–27]. Only related researches from Xiao *et al.* [28], Liu *et al.* [29], Kuang *et al.* [30] and Chen [31] have appeared up to now. Therefore, we here calculated the energy-related carbon emissions in Guangdong province and established two decomposition models with the Logarithmic Mean Divisia Index (LMDI) method based on the extended Kaya identity, and discussed the contribution of the major factors to the energy-related carbon emissions and quantified their contribution as well. We also try to provide some proposals and suggestions for carbon reduction, and expect that the results and proposals in this paper can be of reference value for administrative departments in the Government of Guangdong province to develop policies for energy conservation and emission reduction and promote development of a low-carbon economy.

2. Methods and Data Sources

2.1. Calculation of Energy-Related Carbon Emissions

In this article we divide the energy consumption into two sectors: termed Productive and Household (Figure 2). Productive energy consumption refers to energy consumption by the three strata of industry. Farming, forestry, animal husbandry, fishery and water conservancy belong to the primary industry. Industry and Construction belong to the secondary industry. Transport, storage, postal and telecommunication services, wholesale and retail trade and catering services, and others, belong to the tertiary industry. Among them, energy consumption by the industry sector includes the End-use energy consumption by industry sectors and energy consumption of thermal power and heat power production. There are 17 types of energy, including coal, crude oil, natural gas and other fossil fuels and their products, according to *Energy Balance Sheet of Guangdong Province* in *China Energy Statistical Yearbook*. Energy-related carbon emissions are calculated as follows:

$$C = \sum_i \sum_j C_{ij} = \sum_i \sum_j E_{ij} \times f_j \quad (1)$$

where C is carbon emissions from energy consumption, i is the type of industry, j is the type of energy, C_{ij} represents carbon emissions of energy j in industry i, E_{ij} represents consumption of energy j in industry i, and f_j is carbon emission coefficient of energy j. Carbon emission coefficients of different kinds of energy can be seen from Table 1.

Figure 2. The division of energy consumption sectors. Note: As the electricity and heat consumption do not produce carbon emissions directly, their carbon emissions are produced indirectly from fossil fuels combustion in the production process. In addition, hydropower, nuclear power and wind power almost do not produce carbon emissions. Therefore, carbon emissions of power generation calculated in this paper only include carbon emissions of electricity generated by thermal power plants. To avoid double counting, indirect carbon emissions of thermal power and heat in End-use part no longer included in the total carbon emissions.

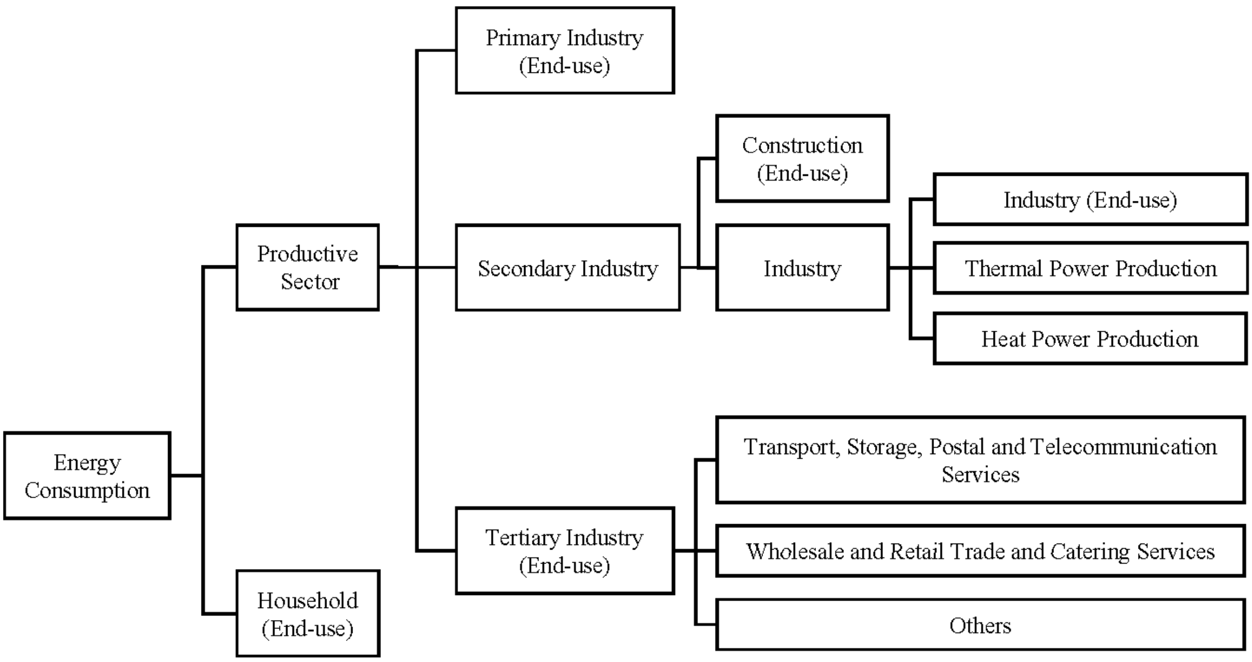


Table 1. Carbon emission coefficients of different kinds of energy.

Energy Type	Net Calorific Value ($TJ/10^3$ t)	Carbon Content (t/TJ)	Carbon Emission Coefficients (tC/t)	Energy Type	Net Calorific Value ($TJ/10^3$ t)	Carbon Content (t/TJ)	Carbon Emission Coefficients (tC/t)
Raw Coal	20.7	26.6	0.551	Crude Oil	42.3	20.0	0.846
Washed Clean Coal	28.2	25.8	0.728	Gasoline	44.3	18.9	0.837
Other Washed Coal	28.2	25.8	0.728	Kerosene	43.8	19.6	0.858
Briquettes	20.7	26.6	0.551	Diesel Oil	43.0	20.2	0.869
Coke	28.2	29.2	0.823	Fuel Oil	40.4	21.1	0.852
Coke-oven Gas			0.197	Liquefied Petroleum Gas	47.3	17.2	0.814
Other Gas			0.197	Refinery Gas	49.5	15.7	0.777
Other Coking Products	28.2		0.823	Other Petroleum Products	40.2	20.0	0.804
Natural Gas			0.444				

Notes: 1. The unit of carbon emission coefficient of "Coke-oven Gas", "Other Gas" and "Natural Gas" is "ton Carbon/ton standard coal equivalent" or "tC/tSCE". Carbon emission coefficient of Natural Gas comes from reference [32], carbon emission coefficients of "Coke-oven Gas" and "Other Gas" are calculated according to the relationship between their calorific value and natural gas'; 2. The unit of other energy's carbon emission coefficient is "ton C/ ton"or "tC/t", it represents carbon emission from one tone physical quantity energy. Carbon emission coefficient = net calorific value × carbon content, net calorific value and carbon content come from *2006 IPCC Guidelines for National Greenhouse Gas Inventories* [33]. Carbon content per unit coal is higher than oil, but its net calorific value is lower than that of oil, resulting in the carbon emission coefficient of coal being lower than for oil. We reference here the article [16].

2.2. Decomposition of Factors Affecting Energy-Related Carbon Emissions

Models used for decomposition of factors affecting energy-related carbon emissions by scholars from China and abroad varies in form due to the different focus in their research [34–41]. The LMDI (Logarithmic Mean Divisia Index) method is widely used in decomposition of factors affecting energy-related carbon emission for that it can satisfy the requirement of factor reversible and the residual item eliminated, which makes the model more convincing [42].

Nevertheless, most researches use the LMDI technique based on time series analysis. We divide the energy consumption into two sectors in this article, and thereupon, we establish extended models for the Productive and Household sectors respectively, based on the basic principle of Kaya identity [43] and LMDI decomposition method. For giving detailed statement to the decomposition results, we use both period-wise analysis [37] and time series analysis. Total energy-related carbon emission C is the sum of energy-related carbon emissions from productive sector C_1, and that from household sector C_2:

$$C = C_1 + C_2 \quad (2)$$

(1) Model for Decomposition of Factors Affecting Energy-Related Carbon Emissions from Productive Sector

The population size in China was twice as large as in the USA, but the carbon emissions in the Productive sectors was much less than that in USA 20 years ago. Hence, it is the economic output rather than the population size that contributed most to the carbon emission in Productive sectors. This article highlights the influence of total economic output (GDP) on carbon emission from Productive sectors, economic development level (*per capita* GDP) and population size do not appear in the model. Therefore, we extended the Kaya identityand established a decomposition model for Productive sector as follows:

$$C_1 = \sum_i \sum_j \left(\frac{C_{ij}}{PE_{ij}} \cdot \frac{PE_{ij}}{PE_i} \cdot \frac{PE_i}{GDP_i} \cdot \frac{GDP_i}{GDP} \cdot GDP\right) \quad (3)$$

where GDP represents Gross Domestic Product, *i* is the type of industry, *j* is the type of energy, C_{ij} represents carbon emissions of energy *j* in industry *i*, PE_{ij} represents consumption of energy *j* in industry *i*, PE_i represents energy consumption of industry *i*, GDP_i is the value contribution of the industry *i* to GDP.

Let $f_{ij} = \frac{C_{ij}}{PE_{ij}}$, $m_{1_{ij}} = \frac{PE_{ij}}{PE_i}$, $d_i = \frac{PE_i}{GDP_i}$, $s_i = \frac{GDP_i}{GDP}$, $g = GDP$,

Equation (3) can be rewritten as:

$$C_1 = \sum_i \sum_j (f_{ij} \cdot m_{1_{ij}} \cdot d_i \cdot s_i \cdot g) \quad (4)$$

where f_{ij} is the carbon emission coefficients of different kinds of energy, m_{1ij} is the share of energy *j* in energy consumption of industry *i*, d_i is the energy consumption per unit GDP in the industry *i*, s_i is the share of gross domestic product of the industry *i*, *g* is GDP.

Setting carbon emissions as C_0 for the baseline year and C_T for the year *T*, with the subscript *tot* represents the total change, there is:

$$\Delta C_{tot} = C_T - C_0 \quad (5)$$

The expression for the contribution of the decomposed factors to the energy-related carbon emissions from the Productive sector are as follows:

$$\Delta C_{f_{ij}} = \sum_i \sum_j \alpha \ln \frac{F^T{}_{ij}}{F^0{}_{ij}} \quad (6)$$

$$\Delta C_{m_{1ij}} = \sum_i \sum_j \alpha \ln \frac{M^T{}_{ij}}{M^0{}_{ij}} \quad (7)$$

$$\Delta C_{d_i} = \sum_i \sum_j \alpha \ln \frac{D^T{}_i}{D^0{}_i} \quad (8)$$

$$\Delta C_{s_i} = \sum_i \sum_j \alpha \ln \frac{S^T{}_i}{S^0{}_i} \tag{9}$$

$$\Delta C_g = \sum_i \sum_j \alpha \ln \frac{G^T}{G^0} \tag{10}$$

where $\alpha = \dfrac{C^T{}_{ij} - C^0{}_{ij}}{\ln C^T{}_{ij} - \ln C^0{}_{ij}}$, $\Delta C_{f_{ij}}$, $\Delta C_{m_{1ij}}$, ΔC_{d_i}, ΔC_{s_i} and ΔC_g represent carbon emission coefficient effect, energy mix effect, energy intensity effect, industrial structure effect, and economic output effect respectively.

The total effect of energy-related carbon emission from productive sector is as follows:

$$\Delta C_{1_{tot}} = \Delta C_{f_{ij}} + \Delta C_{m_{1ij}} + \Delta C_{t_i} + \Delta C_{s_i} + \Delta C_g \tag{11}$$

(2) Model for Decomposition of Factors Affecting Household Energy-Related Carbon Emissions

Household energy-related carbon emissions are not only related to the types and consumption structures of energy, but also related to population size. The factor decomposition model for household energy-related carbon emissions is as follows:

$$C_2 = \sum_j \left(\frac{C_j}{E_j} \cdot \frac{E_j}{E} \frac{E}{P} \cdot P\right) \tag{12}$$

where E is the household energy consumption, E_j is the household consumption of energy j, C_j is carbon emissions from energy j, P is the size of population.

Let $f_j = \dfrac{C_j}{E_j}$, $m_{2_j} = \dfrac{E_j}{E}$, $l = \dfrac{E}{P}$, $p = P$, Equation (12) can be rewritten as:

$$C_2 = \sum_j (f_j \cdot m_{2_j} \cdot l \cdot p) \tag{13}$$

where f_j has the same mean with f_{ij} in Equation (4), m_{2_j} is the share of energy j in household energy consumption, l is the energy consumption per capita and p is population size. The expression for the contribution of the decomposed factors to the energy-related carbon emissions from Household sector are:

$$\Delta C_{f_j} = \sum_j \beta \ln \frac{F^T{}_j}{F^0{}_j} \tag{14}$$

$$\Delta C_{m_{2j}} = \sum_j \beta \ln \frac{M^T{}_j}{M^0{}_j} \tag{15}$$

$$\Delta C_l = \sum_j \beta \ln \frac{L^T}{L^0} \tag{16}$$

$$\Delta C_p = \sum_j \beta \ln \frac{P^T}{P^0} \tag{17}$$

where $\beta = \frac{C_j^T - C_j^0}{\ln C_j^T - \ln C_j^0}$, ΔC_{f_j}, $\Delta C_{m_{2j}}$, ΔC_l, and ΔC_p represent carbon emission coefficient effect, energy mix effect, living standard effect and population size effect, respectively.

The total effect of household energy-related carbon emissions is as follows:

$$\Delta C_{2_{tot}} = \Delta C_{f_j} + \Delta C_{m_{2j}} + \Delta C_l + \Delta C_p \tag{18}$$

A comprehensive model for decomposition of factors affecting energy-related carbon emissions is obtained by combining the above-established decomposition model Equation (11) and Equation (18) as follows:

$$\Delta C_{tot} = \Delta C_{1_{tot}} + \Delta C_{2_{tot}} = \Delta C_f + \Delta C_m + \Delta C_{t_i} + \Delta C_{s_i} + \Delta C_g + \Delta C_p + \Delta C_l \tag{19}$$

where $\Delta C_m = \Delta C_{m_{1ij}} + \Delta C_{m_{2j}}$. Carbon emission coefficient of different kinds of energy is generally treated as constant in the actual application. Therefore, in the comprehensive decomposition model, $\Delta C_f = \Delta C_{f_{ij}} = \Delta C_{f_j} = 0$. Equation (19) can be simplified as:

$$\Delta C_{tot} = \Delta C_m + \Delta C_{t_i} + \Delta C_{s_i} + \Delta C_g + \Delta C_p + \Delta C_l \tag{20}$$

where ΔC_m, ΔC_{t_i}, ΔC_{s_i}, ΔC_g, ΔC_p and ΔC_l represent energy mix effect, energy intensity effect, industrial structure effect, economic output effect, population size effect and living standard effect, respectively.

2.3. Data Sources and Processing

The energy data used in this paper are listed in Table A1 and A2, data quoted from *Energy Balance Sheet of Guangdong Province* in the *China Energy Statistical Yearbook* (1996–2010). Other data used in this article come from the *Statistical Yearbook of Guangdong Province* (1996–2010) of the corresponding year. To eliminate the effect of price changes, we converted the GDP at current price to the GDP at constant price in the year 2000 by using Indices of GDP (IGDP, preceding year = 100). The way of this transformation is shown in Figure 3. GDP is a magnitude of value index, its value influenced by the change of price and volume. GDP at constant prices is the GDP at a price for a fixed period (baseline period) converted from the GDP at current price, so that it can eliminate the effect of price change, reflect changes in volume and reflect actual results of production activity when the values of two different periods are compared. GDP at constant price by sectors are listed in Table A3. The year 1995 is set as baseline year in LMDI factor decomposition.

Figure 3. The way to convert the GDP at current price to the GDP at constant price in the year 2000. Notes: IGDP represent Indices of GDP (taking the Indices of GDP for the preceding year = 100), which can be obtained from the official statistical yearbooks directly.

$$GDP_{(2000-j)}\text{ (constant price)} = GDP_0 \cdot 10^{2j}/(IGDP_{(2000)} \cdot IGDP_{(2000-1)} \cdot IGDP_{(2000-2)} \cdot \ldots \cdot IGDP_{(2000-j+1)})$$

$$\ldots$$

$$GDP_{(2000-1)}\text{ (constant price)} = GDP_{1999} = GDP_0 \cdot 10^2/IGDP_{(2000)}$$

Let, $\mathbf{GDP_0 = GDP_{2000}}$ **(constant price)** $\mathbf{= GDP_{2000}}$ **(current price)**

$$GDP_{(2000+1)}\text{ (constant price)} = GDP_{2001} = GDP_0 \cdot IGDP_{(2000+1)}/10^2$$

$$\ldots$$

$$GDP_{(2000+i)}\text{ (constant price)} = GDP_0 \cdot IGDP_{(2000+1)} \cdot IGDP_{(2000+2)} \cdot \ldots \cdot IGDP_{(2000+i)}/10^{2i}$$

where, $j = 1,2,3,\ldots,5$; $i = 1,2,3,\ldots,9$.

3. Results and Discussion

3.1. Discussion on the Estimates of Energy-Related Carbon Emissions

The estimated results of energy-related carbon emissions (Table 2) show that the total energy-related carbon emissions in Guangdong province increased from 4452.44 × 10^4 tC (ton of Carbon) in 1995 to 13007.02 × 10^4 tC in 2009, and the average annual growth rate is 7.96%.For the energy-related carbon emissions from the three strata of industry and household sectors, only energy-related carbon emissions from the primary industry showed decreasing trend, which fluctuate in a narrow range, decreasing from 145.60 × 10^4 tC in 1995 to 120.86 × 10^4 tC in 2009, and the average annual decline rate is 1.32%. The energy-related carbon emissions from the secondary industry, tertiary industry and household show increasing trends, from 3580.04 × 10^4 tC, 403.25 × 10^4 tC and 323.55 × 10^4 tC in 1995 to 10611.96 × 10^4 tC, 1628.49 × 10^4 tC and 645.72 × 10^4 tC in 2009, respectively, and the average annual growth rate are 8.07%, 10.48% and 5.06%, respectively. It is obvious that the secondary industry is the largest source of carbon emissions, which accounts for more than 80% of the total energy-related carbon emissions. End-use in industry and thermal power plants are the two major contributors to carbon emissions in the secondary industry. They acted alternatively as the largest source of carbon emissions. The largest contributor to carbon emissions in tertiary industry is the sector of transport, storage, postal and telecommunication services. Therefore, in the process of carbon emission reduction in Guangdong province, the secondary industry, especially the industrial sector, is undoubtedly the focus of emission reduction. Moreover, carbon emission reduction in tertiary industry, especial in the sector of transport, storage, postal and telecommunication services, cannot be ignored.

Growth rates of economic development and carbon emission during the period 1995–2009 can be seen from Figure 4. During the period of *9th Five-Year Plan* (1996–2000), short for China's *9th Five-Year Plan for National Economic and Social Development* (1996–2000), the Asian Financial Crisis (1997) originated in Thailand made China's foreign trade export growth rate decreased from 20% in 1996 to 0.5% in 1997, it is undoubtedly was a fatal blow to Guangdong where economic development mainly relies on exports. Meanwhile, some deep-seated contradictions formed in the rapid development of Guangdong since reform and opening up began to surface gradually during this period. Both reasons lead to economic growth rate of Guangdong declining year to year. Until 2000, it began to rise again.

The growth rate of energy-related carbon emissions increased year by year after a sharp drop in 1997. During the execution period of the *10th Five-Year Plan* (2001–2005), Guangdong's economy achieved rapid development by seizing the opportunities of economic globalization; China formally joined the WTO and the international industrial transfer system. The growth rate of the economy reached its highest point (14.84%) in 2003. Driven by the rapid development of the economy, growth rates of energy consumption and carbon emissions increased year by year. At the same time, Guangdong was facing a gradually intensifying situation of domestic and international energy supply and energy price fluctuations, energy development and conservation policy was involved, and the growth rate of energy-related carbon emissions began to decline in the late *10th Five-Year Plan Period.* Guangdong's economy maintained a steady and rapid growth rate in the first two years of the *11th Five-Year Plan Period* (2006–2010). The Global Financial Crisis in 2008 once again frustrated the development of Guangdong's economy, and its economic growth rate dropped significantly compared to 2007. With the implementation of industry and labor "double transfer" policy in 2008, Guangdong's economic growth rate declined in 2008 and 2009 during the process of industrial restructuring. Guangdong made greater energy conservation efforts to achieve the target to drop the energy consumption per unit GDP by 16% in 2010 compared to that in 2005, resulting in a declining growth rate of carbon emissions, especially in 2008, growth rate of carbon emissions has declined abruptly as compared to 2007.

Figure 4. Growth rate of GDP and total carbon emissions.

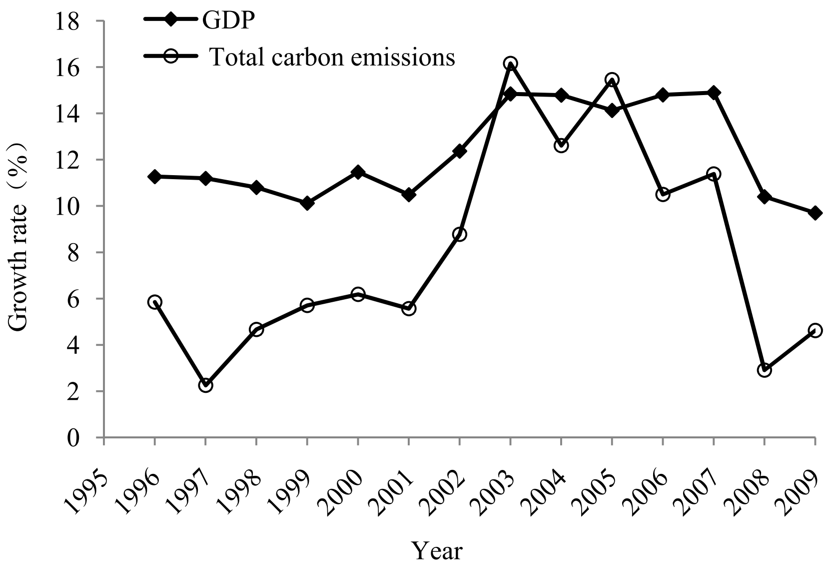


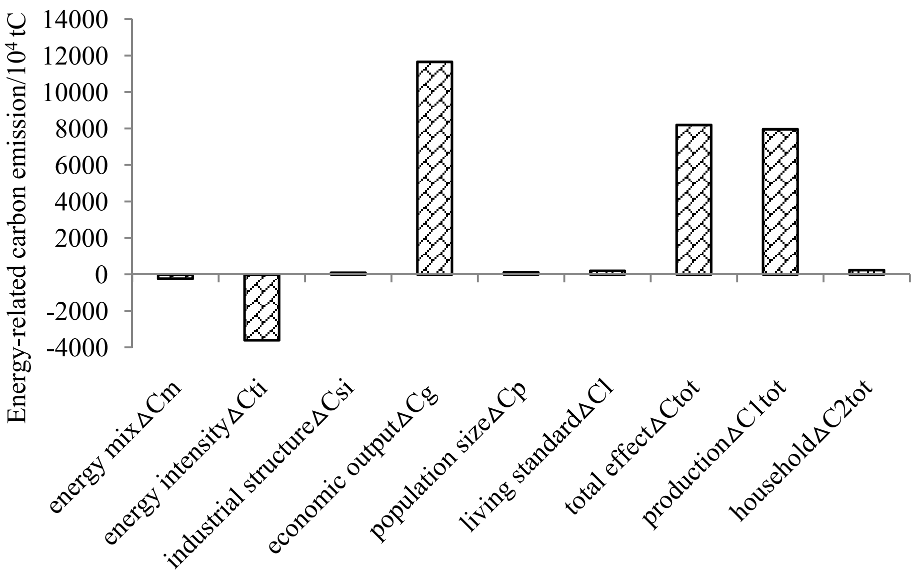
Table 2. Estimation results of energy-related carbon emissions in Guangdong province.

Year	Carbon Emission by Sectors (10^4 tC)											Total Carbon Emissions
	Primary Industry	Secondary Industry					Tertiary Industry				Household	
		Total	Industry (End-use)	Power	Heat	Construction	Total	Transport *etc.*	Wholesale *etc.*	Others		
1995	145.60	3580.04	1857.16	1587.75	102.26	32.86	403.25	313.20	61.53	28.52	323.55	**4452.44**
1996	146.46	3811.26	1906.58	1789.55	101.90	13.22	406.08	331.42	58.51	16.15	348.90	**4712.71**
1997	118.31	3987.11	2090.25	1784.80	100.56	11.48	375.21	310.54	53.17	11.50	338.10	**4818.73**
1998	145.88	4134.78	2112.48	1883.16	126.66	12.48	447.13	382.81	51.95	12.37	315.70	**5043.49**
1999	119.62	4374.68	2096.12	2142.26	122.99	13.32	516.93	457.81	56.60	2.52	319.94	**5331.18**
2000	141.29	4610.83	1989.96	2488.75	117.03	15.09	600.66	526.44	58.70	15.52	307.99	**5660.77**
2001	155.74	4839.78	2086.73	2604.54	132.52	15.99	649.20	569.95	62.64	16.60	330.93	**5975.65**
2002	120.44	5337.76	2206.13	2944.46	170.46	16.71	709.80	615.01	75.91	18.89	331.89	**6499.89**
2003	119.42	6276.97	3018.44	3054.65	182.87	21.00	781.08	689.44	70.71	20.93	372.54	**7550.01**
2004	130.82	7080.51	2742.14	4194.61	118.60	25.17	898.44	793.25	81.28	23.90	392.16	**8501.93**
2005	150.88	7919.22	3265.99	4496.74	116.07	40.42	1242.15	1058.53	142.28	41.34	504.07	**9816.32**
2006	131.67	8905.41	3958.83	4754.06	149.00	43.52	1288.03	1088.22	158.36	41.45	521.77	**10846.87**
2007	116.67	9948.80	4414.36	5289.46	197.15	47.83	1427.78	1199.50	181.27	47.01	588.13	**12081.38**
2008	120.43	10188.72	4882.21	5093.83	168.74	43.95	1507.96	1293.05	171.96	42.95	615.57	**12432.68**
2009	120.86	10611.96	5354.80	4980.43	226.14	50.58	1628.49	1355.13	227.53	45.83	645.72	**13007.02**

3.2. Discussion on the Factor Decomposition Results of Energy-Related Carbon Emissions

Results of period-wise analysis (Figure 5) show that the decomposed factors have an overall increase effect on carbon emissions, of which, the economic output gives the largest contribution to the increase in energy-related carbon emissions during the period 1996–2009. This indicates that the increase of carbon emissions is mainly caused by the increase of total economic output. Energy intensity has a significant reduction effect on energy-related carbon emissions, it is the main inhibitory factor. Other factors show weak effects on carbon emission temporarily during the period of interest in this article, e.g., energy mix show weak reduction effect, while population size, industrial structure and living standard show weak increase effect. As the sectors of energy consumption is concerned, the productive sector accounts for more than 94% of the total increased energy-related carbon emissions, much larger than that from household sector.

Figure 5. The contribution of each decomposition factors.

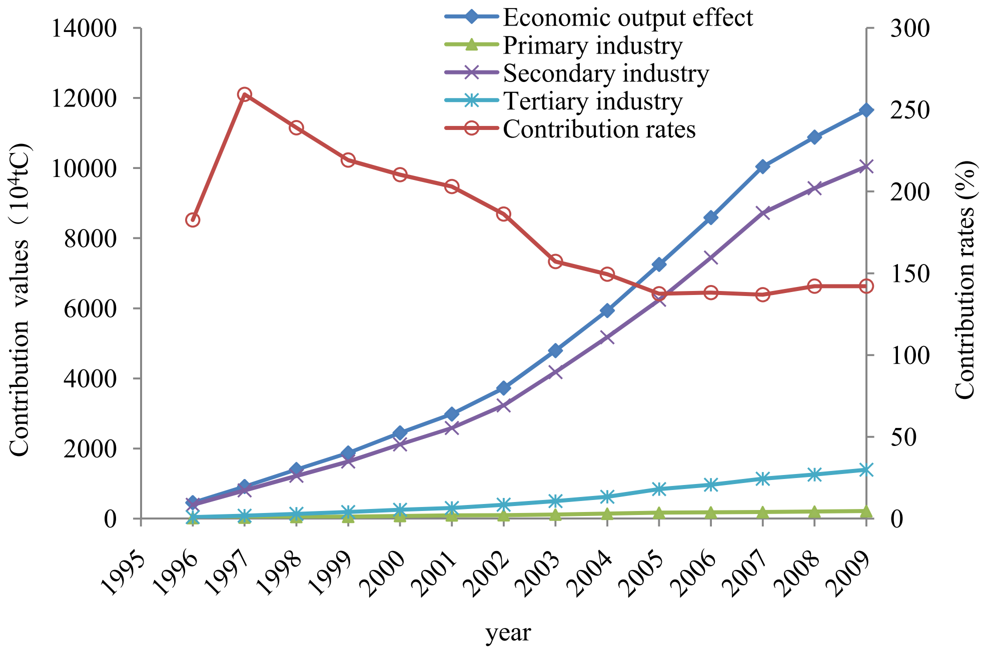


Results of LMDI factor decomposition listed in detail in Table A4 and Table A5. Total contribution values of the six factors on the carbon emissions increased from 248.18 × 10^4 tC in 1996 to 8199.54 × 10^4 tC in 2009. Detailed description of contribution of the six factors on carbon emissions will be given by time series analysis.

(1) Economic Output Effect

Guangdong's economy grows rapidly and GDP increased from 638.3 billion Yuan (Renminbi) in 1995 to 3204 billion Yuan in 2009, with an average annual growth rate as high as 12.22%. From Figure 6, the contribution of economic output to carbon emissions increased from 453.15 × 10^4 tC in1996 to 11653.35 × 10^4 tC in 2009. The secondary industry produced the largest contribution to carbon emissions, which increased from 394.59 × 10^4 tC in 1996 to 10046.13 × 10^4 tC in 2009, and accounts for more than 86% of the total contribution from economic output effect. Second to that is the tertiary industry, and contribution of the primary industry is the least. The contribution rate of economic output to carbon emissiond declined markedly since its peak level (259.34%) in 1997, but began to rise again slightly since 2008. It shows that increase effect of economic output on energy-related carbon emissions was becoming gradually weaker from 1997 to 2007, but an increasing trend occurred again since 2008.Further study is needed to find out if this increasing trend would last to the *12th Five-Year Plan Period* (2011–2015) or even later. The contribution rate of economic output to carbon emission is more than 100% all over the period of interest, indicating that all the reduction effects are offset by the increasing effect of the economic output. The fact that economic growth has a growing influence on energy-related carbon emissions give us a warning that it is still crucial to coordinate the relationship between economic development and energy consumption properly.

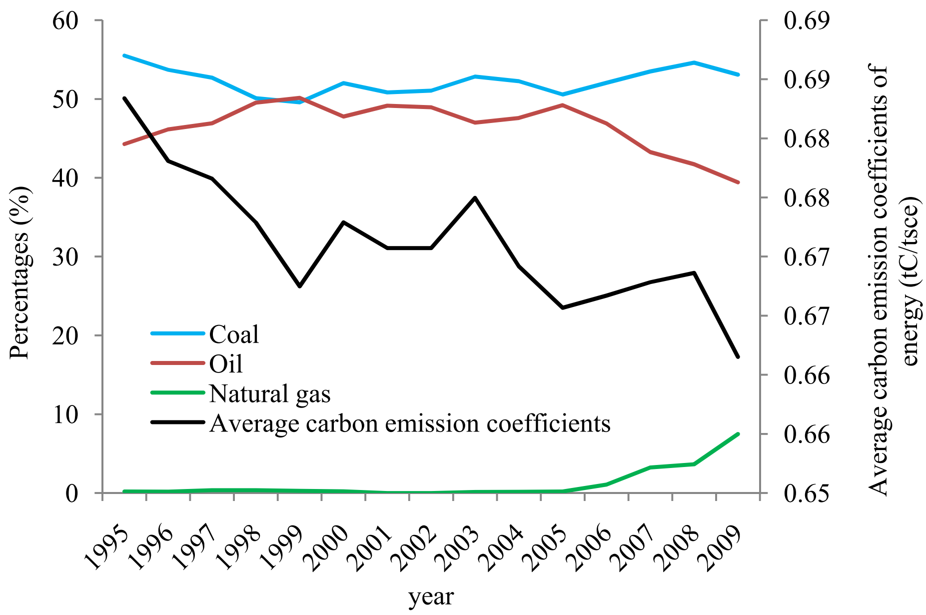
Figure 6. The contribution of economic output effect from 1996 to 2009.



(2) Energy Mix Effect

The energy mix in Guangdong improved a little during the period of interest. This small improvement can be seen from the contributions of coal, oil and natural gas to total energy consumption, it also can be seen from the change trend of the average carbon emissions coefficient of energy, which is the ratio of total carbon emissions to total energy consumption. From Figure 7, the proportion of coal was essentially unchanged, the proportion of oil had a slight decline and natural gas has risen during the *11th Five-Year Period*, while the average carbon emissions coefficient showed only a small reduction. Overall, the energy mix based on coal, oil and other carbon-rich energy in Guangdong province had not changed much yet. Results of LMDI factor decomposition indicate that the effect of energy mix on carbon emissions is not significant during this period. The contribution of energy mix to carbon emission reduction increased from 50.86×10^4 tC in1996 to 238.40×10^4 tC in 2009 (Table A4), while its contribution rate decreased from 20.50% to 2.91% (Table A5). With the nuclear power, wind power, solar power, natural gas and other clean energy sources flowing into consumption field in recent years, the proportion of coal in terminal energy consumption is decreasing, while that of high-quality clean energy is increasing year by year. However, the advantage of resource endowment to develop new energy sources in Guangdong province has not been fully utilized, and the strategic effect of its substitution is still not significant. Yet, with the gradual increase of the capacity of the hydro, nuclear and wind power plants, coupled with the active promotion of the pilot projects on the utilization of solar energy and biomass energy in Guangdong province, development and utilization of renewable energy sources promise good prospects in the future. There is great potential to optimize the energy mix and it will be one of the most effective approaches for Guangdong to meet carbon abatement targets in the future.

Figure 7. Energy mix and average carbon emission coefficients of energy.

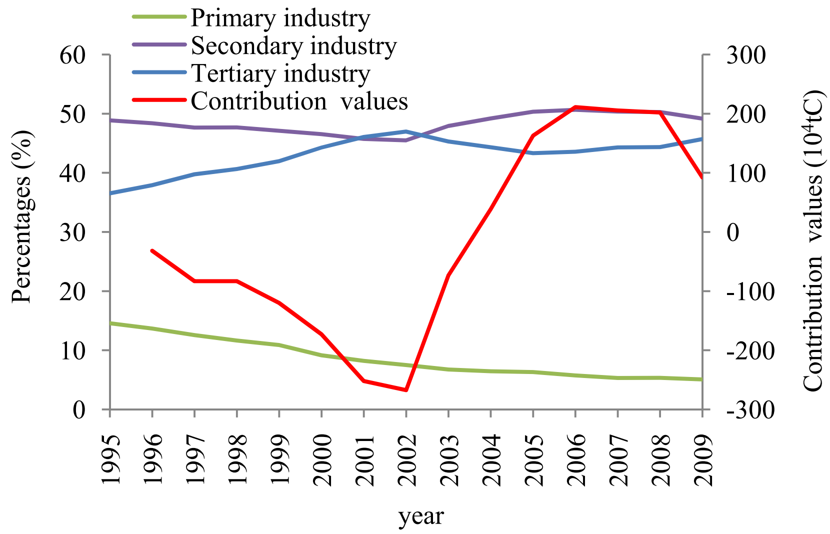


(3) Industrial Structure Effect

Much attention has been paid to the adjustment of the industrial structure in Guangdong province. However, industrial restructuring is more difficult in Guangdong than in other provinces. Because Guangdong's economic and social development mainly relies on exports, its industry support is relatively weak. During the period of interest, the effect of the industrial structure adjustment is not obvious. Figure 8 shows that the industrial structure was optimized during 1995–2002, the proportion of second industry declined while the proportion of tertiary industry increased almost linearly, and the industrial structure showed a reduction effect on energy-related carbon emissions in this stage.

The proportion of second industry increased while the proportion of tertiary industry declined during 2003–2006, so the industrial structure showed overall increase effect on energy-related carbon emissions in this period. The proportion of second industry declined again during 2007–2009, the increase effect weakened and shows a tendency to a reduction effect. This indicates that the bottleneck constraining the industrial restructuring in Guangdong province had been broken through by then. Especially during the *11th Five-Year Plan* (2006–2010) period, great efforts were made to adjust the industrial structure in Guangdong, when industrial structure optimization began to take effect on the mitigation of carbon emissions.

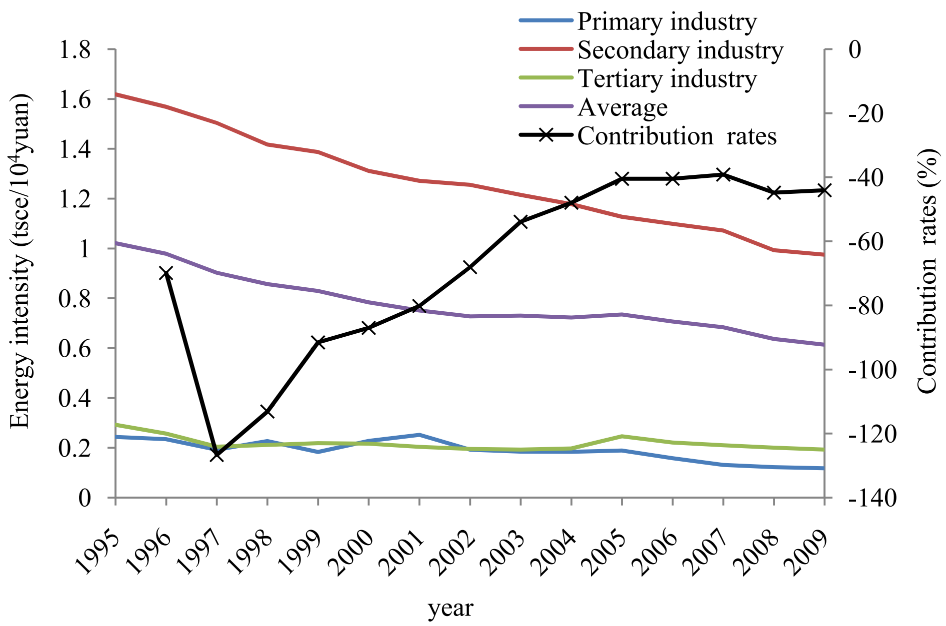
Figure 8. Change of industrial structures and contribution of industrial structure effect.



(4) Energy Intensity Effect

Energy intensity has a significant constraining effect on the increase of carbon emissions. Figure 9 shows that energy intensity of the three strata of industry and average energy intensity declined year by year.

Figure 9. Changes of energy intensity and contribution rates of energy intensity effect.



Average energy intensity decreased from 1.02 tsce (tons of standard coal equivalent) per ten thousand Yuan GDP in1995 to 0.61 tsce per ten thousand Yuan GDP in 2009, with a yearly declining rate of 3.61%. The carbon emissions decline due to energy intensity decline increased from 173.49×10^4 tC in 1996 to 3612.81×10^4 tC in 2009. The contribution rates of the energy intensity to total carbon emissions have increased year by year since its lowest level (−126.73%) in 1997, but has began to rise again slightly since 2008. This shows that the reduction effect of energy intensity on carbon emissions is gradually becoming weaker from 1997 to 2007, but it shows a slowly increasing trend since 2008. That contribution rates of the energy intensity to total carbon emissions have declined since 1997 can be explained from the aspect of economics. Improving energy efficiency and reducing energy intensity is relatively easy at the beginning, but it will become more difficult later according to the laws of economic development. In the *11th Five-Year Period* (2006–2010), Guangdong has put much effort and paid a high price such as eliminating backward productive capacity and shutting down many small scale thermal power plants and cement factories to achieve the target to drop the energy consumption per unit GDP by 16% in 2010 compared to that in 2005. The potential to lower the energy intensity by eliminating backward productive capacity and shutting down small scale power plants and cement factories is very limited. It means that it will become increasingly difficult in the future to achieve emission reductions through shutting down power plants and cement factories. Guangdong needs other ways to reduce energy intensity and improve energy efficiency.

(5) Population Size and Standard of Living Effects

Guangdong's rapid economic and social development and labor-intensive industries require a lot of labor. This attracts many outsiders seeking to find a job or a chance for doing business in Guangdong. As a result, the permanent population increased every year. Carbon emissions from households increased from 323.55×10^4 tC in 1995 to 645.72×10^4 tC in 2009, per capita carbon emissions of household increased from 0.044 tC in 1995 to 0.067 tC in 2009. The contribution of population size to carbon emissions increased from 7.87×10^4 tC in 1996 to 106.97×10^4 tC in 2009 (Table A4), while its contribution rate decreased from 3.17% to 1.3% Table A5). This indicates that the increase effect of population size on carbon emissions is weakening. The standard of living is the dominant factor affecting household energy-related carbon emissions, however, its contribution to total energy-related carbon emissions is neither significant nor stable, and its contribution rates remain at the range of −5% to 5% (Table A5). Population and energy consumption and carbon emissions *per capita* are listed in Table A6.

Overall, total energy-related carbon emissions in Guangdong province increased year by year from 1995 to 2009 because the emission reduction effects are not strong enough to offset the emission increase effects of economic output, and this upward trend will be difficult to reverse in the forthcoming *12th Five-Year Period* (2011–2015).

4. Conclusions and Suggestions

4.1. Conclusions

In this paper, we have analyzed the variation trends of energy-related carbon emissions from the Productive and Household sectors in Guangdong province, China, during the period 1995–2009 based on the estimated results. We also discussed the influence of energy mix, energy intensity, industrial structure, economic output, population size and living standard on the energy-related carbon emissions in Guangdong province in detail by both period-wise analysis and time series analysis.

The energy-related carbon emissions from the three strata of industry, except the primary industry, and household energy consumption in Guangdong province show an increasing trend from 1995 to 2009. The main driving and inhibiting factors which influence energy-related carbon emissions are economic output and energy intensity, respectively, while the contributions of energy mix, industrial structures, population size and living standard are not significant during the period of interest.

Recently, two kinds of decomposition methods have been used for energy-related carbon emissions, decomposition on energy-related carbon emissions *per capita* and decomposition on total energy-related carbon emissions. We adopt here decomposition on total energy-related carbon emissions, where economic factor is referred to as total economic output. In other studies which adopt decomposition on energy-related carbon emissions *per capita* method, economic factor is referred to as economic level (economic output *per capita*).

Same conclusions in our study and other similar studies at China and abroad are: the main driving factor and inhibiting factor affecting energy-related carbon emissions are economic output (or level) and energy intensity, respectively. Optimization of energy mix and industrial structure can help reduce carbon emissions. There are three major differences in our study: (1) this article highlights the influence of total economic output (GDP) on carbon emission of the Productive sectors, and therefore, population size does not appear in the model. That is to say, the influence of population size on energy-related carbon emissions of Productive sectors is not considered. That's why the contribution of population size to carbon emissions is not significant in this article, but significant in other similar studies at China and abroad; (2) our results show that the contribution rates of economic output to carbon emissions declined markedly since its peak level (259.34%) in 1997, but began to rise again slightly since 2008. But in other similar studies at China and abroad, the contribution rate of economic factor has almost always kept growing, and in some studies even exponential growth occurred during the period of interest; (3) We found a very interesting phenomenon (Figure 6 and Figure 9), namely that the contribution rate of economic output and energy intensity have exactly the same change route during the period studied. The increase effect of economic output and reduction effect of energy intensity were enhanced at the same time and also weakened at the same time.

4.2. Suggestions on Carbon Emission Reduction

The authors hold that there are two most effective approaches to reduce carbon emissions in the future for Guangdong province according to the analysis results in Section 3 and the current situation that Guangdong is facing:

(1) Optimizing energy mix by exploiting new energy sources. The irrational energy structure based on coal, oil and other carbon-rich energy in Guangdong province had not improved too much yet, so the potential to improve the energy mix in the future is great. Optimization of the energy mix can be realized mainly by means of making great efforts to exploit new energy sources. Its subtropical maritime climate characteristics make Guangdong rich in solar energy, wind energy, biomass energy, oceanic energy and other new energy resources, and it is endowed with a broad space and potential to develop and utilize low carbon energy sources. As the biggest province in the economy of China, Guangdong has a strong economic basis to develop new energy sources. Guangdong should take full use of its economic advantage to invest in the exploitation of clean energy sources, especially solar energy, wind energy and oceanic energy.

(2) Cutting down energy intensity by developing low-carbon technologies. The potential to lower the energy intensity through eliminating backward productive capacity and shutting down small scale

power plants and cement factories is very limited. Guangdong needs other ways to reduce energy intensity and improve energy efficiency in the future. Energy intensity is closely related with energy mix, industrial structure and technological progress. Cutting down energy intensity to achieve carbon emissions reduction by optimizing energy mix and industrial structure are mainly from the perspective of controlling carbon sources. It is incomplete because economic development is inseparable from the energy consumption, so carbon emissions are inevitable. It is necessary to use advanced technology to reduce carbon emissions or CO_2 should be used as a useful resource to achieve real carbon emission reduction in the future. As the biggest province in economy of China, Guangdong should make full use of its economic advantages to invest in developing low-carbon technologies or introducing advanced foreign technology, such as in the industry sector, conversion of energy into power, industrial processing capacity and heat by widely adopt symbiotic production technology. In the power production sector, by adopting advanced Natural Gas Combustion Combined Cycle Power Generation technology or cogeneration technology. In the sector of transportation, by developing technology for improving power and energy efficiency. Paying attention to research and development of CCS technology is also very important, for it will be the main technique used for future carbon reductions.

Acknowledgements

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Appendix

Table A1. Energy consumption by types (10^4 ton standard coal equivalent).

Year	Raw Coal	Washed Clean Coal	Other Washed Coal	Briquettes	Coke	Coke-oven Gas	Other Gas	Other Coking Products	Crude Oil	Gasoline
1995	3453.4	3.0	0.0	0.0	128.1	12.9	19.0	0.0	27.7	413.8
1996	3542.8	0.5	0.0	21.8	135.1	9.3	18.9	2.9	39.7	387.3
1997	3539.6	1.3	0.0	25.5	154.4	12.5	19.0	1.4	29.4	386.3
1998	3541.8	9.2	0.7	22.2	154.3	8.8	16.8	1.2	46.6	414.6
1999	3683.4	6.2	0.1	21.1	159.3	9.6	87.1	1.4	51.1	423.6
2000	4137.0	5.1	0.0	17.1	140.9	9.9	63.1	1.6	49.3	441.8
2001	4255.6	5.7	0.0	17.9	168.0	10.4	70.0	1.8	29.6	476.8
2002	4652.2	9.9	0.0	18.5	171.7	9.7	72.6	0.5	24.2	505.7
2003	5552.3	23.6	0.3	18.9	221.3	10.2	84.5	0.5	36.9	550.4
2004	6093.0	13.6	5.5	22.3	267.8	33.5	199.4	2.6	32.4	656.7
2005	6864.5	17.8	3.5	24.5	290.3	26.8	227.6	3.0	24.9	1039.1
2006	7682.5	15.2	3.9	143.9	286.7	25.1	306.4	3.3	141.3	1135.0
2007	8602.1	17.7	4.4	289.1	430.7	19.6	312.2	2.3	30.0	1232.6
2008	9028.0	18.0	4.7	322.9	424.8	23.5	327.8	6.4	28.3	1305.0
2009	8912.6	378.2	5.3	337.9	441.3	24.1	328.6	9.5	28.5	1408.4

Table A1. *Cont.*

Year	Kerosene	Diesel Oil	Fuel Oil	Liquefied Petroleum Gas	Refinery Gas	Other Petroleum Products	Natural Gas	Total
1995	82.4	869.9	911.7	319.8	56.4	203.7	13.6	**6515.3**
1996	82.5	872.6	1032.3	498.4	69.9	223.8	12.1	**6950.0**
1997	95.3	796.4	1023.4	501.8	78.6	430.9	26.4	**7122.1**
1998	96.6	941.0	1182.8	521.3	75.9	434.6	26.7	**7495.4**
1999	98.5	1110.9	1243.5	536.4	82.9	467.3	22.7	**8005.1**
2000	131.3	1114.7	1334.9	545.6	104.4	297.0	19.0	**8412.5**
2001	140.7	1187.3	1473.4	614.9	111.0	346.2	0.0	**8909.4**
2002	151.2	1233.9	1640.9	666.5	115.0	392.8	0.0	**9665.4**
2003	175.3	1361.3	1764.6	767.6	113.0	488.2	16.8	**11185.8**
2004	191.9	1489.3	2177.2	865.7	105.0	527.5	21.5	**12705.2**
2005	226.2	1903.9	2275.4	1043.5	105.9	638.7	31.0	**14746.7**
2006	231.6	1992.7	2242.9	923.2	131.4	830.4	174.2	**16269.7**
2007	251.8	2095.6	1880.7	1038.4	134.9	1160.7	587.5	**18090.4**
2008	269.4	2213.2	1538.6	1092.4	127.5	1184.0	680.2	**18594.6**
2009	282.7	2284.6	1278.6	1119.0	126.7	1223.2	1473.5	**19662.6**

Table A2. Energy consumption by sectors (10^4 ton standard coal equivalent).

Sector		1995	1996	1997	1998	1999	2000	2001	2002
Primary Industry		226.2	227.7	190.6	230.9	192.0	223.9	245.1	192.4
Secondary Industry	Industry(End-use)	2614.0	2698.2	2987.4	3051.4	3090.1	2903.9	3064.0	3258.9
	Thermal Power production	2227.5	2519.8	2507.6	2654.0	3004.1	3450.7	3612.8	4080.8
	Heat Power production	152.9	149.5	143.1	184.3	180.1	173.5	194.0	248.8
	Construction(End-use)	54.7	21.7	19.4	21.1	22.5	25.5	26.9	28.2
	Total	5049.1	5389.2	5657.5	5910.8	6296.8	6553.6	6897.7	7616.7
Tertiary Industry (End-use)	Transport, Storage, Postal and Telecommunication Services	532.9	564.2	530.2	641.4	778.4	895.8	970.8	1053.1
	Wholesale and Retail Trade and Catering Services	100.9	100.1	91.1	88.6	98.7	105.6	113.1	135.2
	Others	147.4	189.1	185.0	166.4	169.6	157.9	172.8	165.2
Household (End-use)		559.0	641.5	632.8	601.9	616.9	606.7	653.8	660.6
Total		**6515.3**	**6950.0**	**7122.1**	**7495.4**	**8005.1**	**8412.5**	**8909.4**	**9665.4**

Sector		2003	2004	2005	2006	2007	2008	2009
Primary Industry		190.6	208.5	239.7	209.1	184.8	190.5	191.3
Secondary Industry	Industry(End-use)	4421.1	4183.3	4994.8	6081.7	6706.9	7343.1	8177.9
	Thermal Power production	4189.5	5782.6	6146.3	6445.6	7204.0	6928.1	6794.8
	Heat Power production	266.7	172.5	172.3	218.0	289.0	233.7	306.2
	Construction(End-use)	35.4	42.5	69.1	74.5	81.8	75.2	86.5
	Total	8912.7	10180.9	11382.5	12819.8	14281.7	14580.1	15365.4
Tertiary Industry （End-use）	Transport, Storage, Postal and Telecommunication Services	1175.4	1352.0	1815.4	1867.8	2059.2	2219.4	2325.9
	Wholesale and Retail Trade and Catering Services	125.5	144.4	248.9	277.1	316.5	300.9	415.2
	Others	198.2	200.4	278.9	263.4	284.9	325.8	349.2
Household (End-use)		745.1	777.8	987.4	1023.0	1166.1	1228.3	1284.3
Total		**11185.8**	**12705.2**	**14746.7**	**16269.7**	**18090.4**	**18594.6**	**19662.6**

Table A3. GDP by sectors.

Year	GDP (100 Million Yuan)				Percentages of the Three Strata of Industry (%) (Industrial Structure)			
	GDP	Primary Industry	Secondary Industry	Tertiary Industry	GDP	Primary Industry	Secondary Industry	Tertiary Industry
1995	6382.98	930.05	3120.15	2332.78	100	14.6	48.9	36.5
1996	7102.29	971.82	3436.87	2693.60	100	13.7	48.4	37.9
1997	7897.22	993.76	3762.85	3140.60	100	12.6	47.6	39.8
1998	8750.32	1020.13	4171.74	3558.45	100	11.7	47.7	40.7
1999	9636.19	1051.06	4540.66	4044.47	100	10.9	47.1	42.0
2000	10741.25	986.32	4999.51	4755.42	100	9.2	46.5	44.3
2001	11867.90	974.76	5427.70	5465.44	100	8.2	45.7	46.1
2002	13336.33	1002.60	6067.83	6265.90	100	7.5	45.5	47.0
2003	15316.08	1037.12	7339.50	6939.46	100	6.8	47.9	45.3
2004	17581.18	1136.85	8649.32	7795.01	100	6.5	49.2	44.3
2005	20065.41	1270.49	10102.01	8692.91	100	6.3	50.3	43.3
2006	23035.09	1327.44	11669.93	10037.71	100	5.8	50.7	43.6
2007	26467.31	1412.25	13330.36	11724.70	100	5.3	50.4	44.3
2008	29219.91	1566.78	14692.42	12960.71	100	5.4	50.3	44.4
2009	32040.01	1631.33	15759.04	14649.64	100	5.1	49.2	45.7

Table A4. Contribution of each decomposed factor to energy-related carbon emissions in Guangdong province.

Year	Contribution of Carbon Emission by Factors (10^4 tC)						Total Effect ΔC_{tot}	Carbon Emissions (10^4 tC)	
	Energy Mix ΔC_m	Energy Intensity ΔC_{ti}	Industrial Structure ΔC_{si}	Economic Output ΔC_g	Population Size ΔC_p	Living Standard ΔC_l		Productive ΔC_{1tot}	Household ΔC_{2tot}
1996	−50.86	−173.49	−31.61	453.15	7.87	43.12	**248.18**	228.94	19.24
1997	−79.06	−446.82	−83.17	914.38	16.35	30.90	**352.58**	348.99	3.60
1998	−102.38	−663.18	−82.98	1400.43	23.64	10.48	**586.01**	597.55	−11.55
1999	−160.97	−781.81	−119.96	1871.29	32.45	12.71	**853.71**	856.67	−2.96
2000	−103.18	−1012.08	−172.89	2443.93	46.27	−39.52	**1162.53**	1208.29	−45.76
2001	−108.48	−1177.30	−251.93	2980.41	50.76	−25.51	**1467.95**	1496.07	−28.12
2002	−122.89	−1361.25	−267.28	3722.03	54.89	−26.22	**1999.27**	2019.85	−20.57
2003	−93.94	−1643.76	−73.46	4791.55	61.02	6.69	**3048.11**	3035.86	12.25
2004	−182.29	−1904.11	38.91	5933.78	68.45	15.57	**3970.30**	3938.81	31.49
2005	−187.59	−2135.41	162.83	7249.04	81.02	102.68	**5272.56**	5134.71	137.86
2006	−262.25	−2516.38	211.16	8586.38	85.01	110.84	**6214.75**	6068.28	146.47
2007	−294.80	−2873.23	205.56	10039.41	94.88	160.47	**7332.28**	7147.06	185.23
2008	−277.72	−3432.30	202.08	10881.05	101.07	180.83	**7655.02**	7445.33	209.69
2009	−238.40	−3612.81	92.15	11653.35	106.97	198.29	**8199.54**	7959.39	240.15

Table A5. Contribution rate of each decomposed factor to energy-related carbon emission (%).

Year	Energy Mix	Energy Intensity	Industrial Structure	Economic Output	Population Size	Living Standard	Productive	Household
	$\Delta C_m/\Delta C_{tot}$	$\Delta C_{ti}/\Delta C_{tot}$	$\Delta C_{si}/\Delta C_{tot}$	$\Delta C_g/\Delta C_{tot}$	$\Delta C_p/\Delta C_{tot}$	$\Delta C_l/\Delta C_{tot}$	$\Delta C_{1tot}/\Delta C_{tot}$	$\Delta C_{2tot}/\Delta C_{tot}$
1996	−20.50	−69.90	−12.74	182.59	3.17	17.37	92.25	7.75
1997	−22.42	−126.73	−23.59	259.34	4.64	8.76	98.98	1.02
1998	−17.47	−113.17	−14.16	238.98	4.03	1.79	101.97	−1.97
1999	−18.86	−91.58	−14.05	219.20	3.80	1.49	100.35	−0.35
2000	−8.88	−87.06	−14.87	210.23	3.98	−3.40	103.94	−3.94
2001	−7.39	−80.20	−17.16	203.03	3.46	−1.74	101.92	−1.92
2002	−6.15	−68.09	−13.37	186.17	2.75	−1.31	101.03	−1.03
2003	−3.08	−53.93	−2.41	157.20	2.00	0.22	99.60	0.40
2004	−4.59	−47.96	0.98	149.45	1.72	0.39	99.21	0.79
2005	−3.56	−40.50	3.09	137.49	1.54	1.95	97.39	2.61
2006	−4.22	−40.49	3.40	138.16	1.37	1.78	97.64	2.36
2007	−4.02	−39.19	2.80	136.92	1.29	2.19	97.47	2.53
2008	−3.63	−44.84	2.64	142.14	1.32	2.36	97.26	2.74
2009	−2.91	−44.06	1.12	142.12	1.30	2.42	97.07	2.93

Table A6. Energy consumption and carbon emissions per capita.

Year	Population (10^4 Persons)	Energy Consumption per Capita (tsce)	Per Capita Energy Consumption of Household (tsce)	Carbon Emissions per Capita (tC)	Per capita Carbon Emissions of Household (tC)
1995	7387.50	0.882	0.081	0.603	0.044
1996	7569.78	0.918	0.093	0.623	0.046
1997	7779.69	0.915	0.090	0.619	0.043
1998	7990.03	0.938	0.084	0.631	0.040
1999	8217.91	0.972	0.085	0.649	0.039
2000	8650.03	0.973	0.071	0.654	0.036
2001	8733.18	1.020	0.075	0.684	0.038
2002	8842.08	1.096	0.075	0.735	0.038
2003	8962.69	1.248	0.083	0.842	0.042
2004	9110.66	1.395	0.085	0.933	0.043
2005	9194	1.604	0.107	1.068	0.055
2006	9304	1.749	0.110	1.166	0.056
2007	9449	1.915	0.123	1.279	0.062
2008	9544	1.948	0.129	1.303	0.064
2009	9638	2.040	0.133	1.350	0.067

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