PROBLEMY EKOROZWOJU – PROBLEMS OF SUSTAINABLE DEVELOPMENT
2012, vol. 7, no 2, 33-41

Low Carbon Development of China's Yangtze River Delta Region

Gospodarka niskowęglowa w delcie rzeki Jangcy w Chinach

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Abstract
Low carbon development is a development pattern to enable social and economic progress along the path of sustainable development. This paper analyzes the low carbon development situation and trend in the China's Yangtze River Delta region, one of the most important industrial and economic centers of China. The results indicate low carbon development in this region continues to move forward. However, many barriers, such as unbalanced energy consumption structure and limited research and development capability still exist. Some solutions to overcoming the barriers are proposed in the paper, covering policy, strategic, technological, educational measures.
Key words: sustainable development; low carbon development, Yangtze River Delta region of China, barriers, solution

Streszczenie
Gospodarka niskowęglowa sprzyja zarówno rozwojowi społecznemu, jak ekonomicznemu i jest zgodna z koncepcją rozwoju zrównoważonego. Ten artykuł analizuje uwarunkowania wprowadzania gospodarki niskowęglowej w delcie rzeki Jangcy w Chinach, będącej jednym z najważniejszych przemysłowych i ekonomicznych obszarów w tym kraju. Otrzymane rezultaty wskazują na pozytywny rozwój gospodarki niskowęglowej na tym obszarze. Jednakże nadal występuje wiele barier, takich jak niezrównoważona struktura konsumpcja energii i ograniczone możliwości badawcze i rozwojowe. W artykule zawarto propozycje pokonania tych barier, uwzględniające wskaźniki polityczne, strategiczne, techniczne i edukacyjne,

Słowa kluczowe: rozwój zrównoważony, gospodarka niskowęglowa, Delta rzeki Jangcy w Chinach, bariery, rozwiązania

1. Introduction

Fossil energy use and its adverse impacts on environment have become a major issue in the last few decades. World primary energy consumption grew by 5.6% in 2010, the largest increase since 1973 (BP, 2011). Of all greenhouse gases carbon dioxide (CO_2) is the most important one. The rising concentration of atmospheric CO_2 results in rising temperature of the earth during the past several decades. According to the World Meteorological Organization (WMO, 2010), over the ten years from 2001 to 2010, global temperature grows averaged 0.46 °C above the 1961-1990 mean, and are the highest ever recorded for a 10-year period based on instrumental climate records.

Most countries, especially the European Union Community, take great effort to decrease greenhouse gases emissions. Although CO_2 accounts for 77% of anthropogenic greenhouse gas emissions and burning of fossil fuels stands for 57% (IPCC, 2007), there are other important greenhouse gases like methane emitted mostly from agriculture activity (51%) and landfills (12%) (EPA, 2006).

In the case of landfills a great effort has been made to control methane emissions, mostly biogas recovery for use as energy resources. However, when methane content in landfill biogas is below 30% it cannot be used as energy carrier. Therefore there are a lot of efforts to control methane emission from landfills. The most important effort, but not applied yet on industrial scale is enrichment of biogas in methane by carbon dioxide removal (Pawłowska at al., 2008a, 2008b, 2008d). Much wider biochemical oxidation of methane emitted from landfills is used (Stępniewski at al., 1995, 1996, 1997, 2008a, 2008b; Pawłowska at al., 2005, 2006a, 2006b, 2006c, 2006d, 2008c, 2010, 2011a, 2011b).

During last a few decades most countries in the world have taken attempts to make development more sustainable. The concept of sustainable development was introduced by famous Brundtland Report (WCED, 1987) and it says: *Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.* Pawłowski (2006) reviewing development of sustainability over last century showed that nowadays idea of sustainable development has multidimensional nature (Pawłowski, 2008, 2011a) and touches so many aspects of our civilization that Pawłowski (2003a, 2003b, 2009a, 2010a, 2011b) named nowadays period as a sustainable development revolution.

Recently, much attention has been given to philosophical aspects of sustainable development (Gawor, 2010; Udo at al., 2010; Keitsch, 2011; Krajewski, 2012; Rodojicic at al., 2012), social (Venkatesh, 2010; Krasm, 2011; Pawłowski, 2010a, 2010b; Bernat, 2012; Golušin at al., 2012) and economical (Tuziak, 2010; Hoedl 2011, Hueting, 2011; Gurtowski, 2011).

Although most researchers insist on to decrease greenhouse gases emissions which may slow down economic development, some known scholars (Lindzen, 2010) argue that threat created by emissions of greenhouse gases is not so great as described in most publications and primary energy supply is the most important to assure introduction of sustainable development (Pawłowski, 2009b, 2010b, 2011c; Pieńkowski 2012).

As the biggest developing country China has been experiencing a rapid economic growth with GDP increasing from 364.5 billion RMB in 1978 to 40120.2 billion RMB in 2010 (National Bureau of Statistics, 2011a). The rapid economic growth is accompanied with increasing energy demand and increasing greenhouse gas emissions. China's total energy consumption reached 3.25 billion tonnes of coal equivalent (tce) in 2010 and has become the world's second largest energy consuming country (National Bureau of Statistics, 2011b). Faced with the grim situation, Chinese government has initiatively taken concrete actions to develop low carbon economy. China has pledged to cut 40-50% of CO_2 emissions per unit of GDP by 2020 on the 2005 basis. According to China's 12th Five-Year Plan (2011), during the next five years China will raise the share of non-fossil energy in primary energy consumption to 11.4%, and reduce energy consumption and CO_2 emission per unit of GDP by 16% and 17%, respectively.

The Yangtze River Delta region of China encompasses Shanghai Municipality, Jiangsu and Zhejiang provinces with total area of about 210,700 square kilometers. The region is one of the most important industrial and economic centers of China, responsible for 21.5% of China's GDP and 36.6% of China's imports and exports in 2010 (National Bureau of Statistics, 2011a). However, this region is being faced with many problems during its industrialization and urbanization. For example, energy efficiency is low and energy consumption is too much, energy supplies and natural resources are scarce, carbon emissions gradually increase and ecological environment has been deteriorating. So it is necessary for this region to realize sustainable development and change the economic growth mode to low carbon economy.

2. Current Situation of Low Carbon Development

2.1. Energy Consumption

Since China's reform and opening up, the Yangtze River Delta region has maintained a high economic growth rate. Its nominal GDP rose from 310.3 billion RMB in 1990 to 8631.4 billion RMB in 2010 (Shanghai Municipal Bureau of Statistics, 2011; Jiangsu Bureau of Statistics, 2011; Zhejiang Bureau of Statistics, 2011). Meanwhile, its energy consumption rose from 112.6 million tce in 1990 to 538.4 tce in 2010 (National Bureau of Statistics of China, 2011). Its share in the country's total energy consumption increased gradually from 11.4% in 1990 to 16.6% in 2010. This increase is largely attributed to the contribution of Jiangsu and Zhejiang provinces.

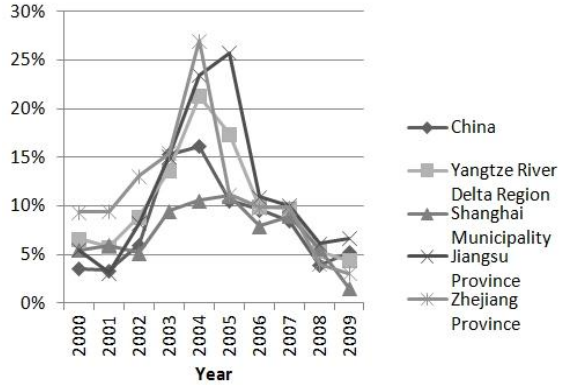

Figure 1. Growth Rate of Energy Consumption for China and the Yangtze River Delta Region (National Bureau of Statistics of China 1997-1999, 2004, 2007, 2010).

To further see the change trend in energy consumption, we analyze the energy consumption growth rate (percentage change on previous year) in this region. As shown in Figure 1, the growth rate in each year is positive, meaning that the energy consumption has been increasing over the ten years (2000-2009). Besides, the growth rate in this region is also too high when compared with the whole country. The average annual growth rate in this region reached 10.6% in the ten years, greater than the country average growth rate (8.6%). Such a high growth rate is mainly contributed by the rapid energy consumption growth in Jiangsu and Zhejiang, especially Jiangsu. Increasing energy consumption is a great challenge to low carbon development and sustainable development for the Yangtze River Delta region. Facing such a situation, the region has made great effort to improve it. As we can see from Figure 1, the energy consumption growth rate of this region began to decline sharply from 2004.

2.2. Energy intensity

Energy intensity is a measure of the energy efficiency relative to a nation's economy. It is calculated as units of energy consumption per unit of GDP. Figure 2 shows the energy intensity in Yangtze River Delta Region. It indicates that energy intensity of this region is much lower than the whole country in the past decade from 2000 to 2009, and shows an overall downward trend, dropped from 0.89 tce per ten thousand Yuan of GDP in 2000 to 0.75 in 2009. The overall downward trend of energy intensity in this region means the improving energy efficiency, which is good for low carbon development. Specially, energy intensity of this region declined from 2000 to 2003 at first, then increased till 2005, and declined again till 2009. Variation of energy intensity in Jiangsu and Zhejiang is consistent with the whole region. However, energy intensity of Shanghai has been continuing to decline from 2000 to 2009 without any fluctuation.

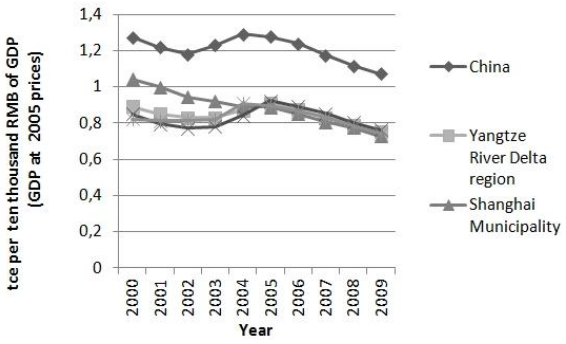

Figure 2. Energy Intensity of China and the Yangtze River Delta Region (Shanghai Municipal Bureau of Statistics, 2010; Jiangsu Bureau of Statistics, 2010; Zhejiang Bureau of Statistics, 2010, and National Bureau of Statistics of China, 2004, 2007 and 2010).

2.3. CO_2 emission

The energy-related CO_2 emissions in the Yangtze River Delta region were analyzed using the first method in IPCC Guidelines for National Greenhouse Gas Inventories (2006). A total of 11 kinds of fuels were included. The calculation was conducted using the following equation:

$$G = \sum G_i = \sum E_i \times EC_i$$

where G is the total CO_2 emissions, G_i is the CO_2 emissions by fuel type i, E_i is the consumption of fuel type i and EC_i is the CO_2 emission factor of fuel type i.

Table 1 shows the CO_2 emission factors and conversion factors from physical units to coal equivalent of 11 kinds of fuels[1].

Table 1 CO_2 emission factors and conversion factors of 11 kinds of fuels (Zhao at al., 2009; Rao, 2011 and Jiang, 2011).

Fuel	CO_2 Emission Factor	Conversion Factor
Raw Coal	2.7716 t/tce	0.7143 kgce/kg
Cleaned Coal	2.7716 t/tce	0.9000 kgce/kg
Coke	3.135t/tce	0.9714 kgce/kg
Crude Oil	2.1482 t/tce	1.4286 kgce/kg
Gasoline	2.0306 t/tce	1.4714 kgce/kg
Kerosene	2.0955 t/tce	1.4714 kgce/kg
Diesel Oil	2.171 t/tce	1.4571 kgce/kg
Fuel Oil	2.2678 t/tce	1.4286 kgce/kg
LPG	1.8421 t/tce	1.7143 kgce/kg
Refinery Gas	1.6874 t/tce	1.5714 kgce/kg
Natural Gas	1.6438 t/tce	1.330 kgce/cu.m

Figure 3 illustrates that CO_2 emissions in this region have been continually increasing from 622.3 million tonnes in 2000 to 1344.9 million tonnes in 2009. The average annual growth rate of CO_2 emissions is 8.9%, less than national average 9.8%[2]. For Shanghai, the average annual growth rate of CO_2 emissions is only 3.9%, far below national average and CO_2 emissions dropped from 268.0 million tonnes in 2008 to 267.0 million tonnes in 2009. The dropping is mainly due to the consumption decline of the fuels which has greater CO_2 emission factor such as raw coal, cleaned coal, coke and crude oil. However, for Jiangsu and Zhejiang the average annual growth rate of CO_2 emissions is 10.5% and 10.9% respectively, much higher than the national average.

[1] CO_2 emission factors in this paper are based on IPCC default CO_2 emission factors. The unit of original data in IPCC is converted from t/TJ to t/tce based on GB/T 2589-2008 (1tce = 293 TJ). In China Energy Statistical Yearbook, the unit of energy consumption for each fuel is physical unit, so we need to convert physical unit to coal equivalent for calculation.

[2] National average is calculated by using the same method and the same 11 kinds of fuels.

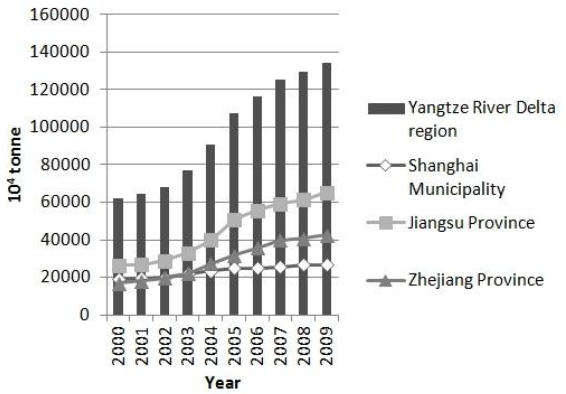

Figure 3. CO_2 emissions of the Yangtze River Delta region 2000-2009 (National Bureau of Statistics of China 2004, 2007 and 2010).

2.4. Carbon intensity

To analyze the impact of this region's economic growth on CO_2 emissions, carbon intensity (CO_2 emissions per unit of GDP) is calculated and shown in Table 2. As we see, declining trend occurred in carbon intensity of this region, which means the same units of GDP can be produced with less and less CO_2 emissions. Shanghai, Jiangsu and Zhejiang all show the declining trend and carbon intensity declined fastest in Shanghai. In 2000 Shanghai's carbon intensity is 3.6, the highest in this region. However, in 2009 Shanghai's carbon intensity is only 1.87, the lowest in this region. Better industry structure and energy consumption structure contribute to this (Zhu, 2011).

Table 2. Carbon Intensity in the Yangtze River Delta Region 2000-2009, unit: tonne/10^4 RMB, GDP at 2005 prices (Shanghai Municipal Bureau of Statistics 2010, Jiangsu Bureau of Statistics 2010, Zhejiang Bureau of Statistics 2010, and National Bureau of Statistics of China 2004, 2007 and 2010)

Year	Yangtze River Delta	Shanghai	Jiangsu	Zhejiang
2000	2.75	3.60	2.61	2.31
2001	2.57	3.36	2.40	2.24
2002	2.44	3.09	2.31	2.15
2003	2.42	3.04	2.33	2.11
2004	2.49	2.82	2.46	2.29
2005	2.61	2.69	2.74	2.37
2006	2.47	2.39	2.60	2.35
2007	2.31	2.13	2.42	2.28
2008	2.15	2.03	2.22	2.12
2009	2.03	1.87	2.09	2.03

2.5 Development of new and renewable energy

New and renewable energy, such as solar, wind, ocean and biomass, generally has the characteristics of large reserves and less pollution, which is very important to solve the world's serious environmental pollution problems and resources (especially fossil energy) depletion (He and Shan, 2009). As the world's major carbon emitter, China, in addition to a need to limit greenhouse emissions in the long run, need to seek a new engine to lead the long-term economic growth, and the new energy industry is undoubtedly the logical choice. In the State Council's Decision on the Accelerating the Fostering and Development of New Strategic Emerging Industries (State Council of China, 2010), the important role of new energy industry has been further clarified and the new energy industry has been recognized as one of China's leading industries.

The Yangtze River Delta region is one of the most important regions for new energy industry development in China. This region mainly undertakes new energy industrial R&D and high-end manufacturing functions and has concentrated 60% of China's photovoltaic enterprises, over 20% of wind power equipment manufacturing enterprises, 53.5% of installed capacity of nuclear power plants and nearly 40% of biomass power generation capacity (CCID, 2011).

Shanghai has developed its strategic layout planning of new energy industry, and will build Nanhui Industrial Park into the dominant solar photovoltaic industry base, Pudong District and Minhang District into the dominant nuclear power industry bases, Jiading District into the center of new energy vehicles and key parts industry base, and Lingang District into the dominant wind power industry base. Jiangsu has issued a proposal for developing into the country's new energy equipment manufacturing industry bases. New materials industry will be mainly in Lianyungang City, wind power equipment industry mainly in Yancheng City, renewable energy industry mainly in Kunshan City, and photovoltaic industry mainly in Xuzhou City. Zhejiang has proposed to build low carbon industry agglomeration districts with high competitiveness. Photovoltaic industry cluster will be mainly in Quzhou City, Hangzhou City, Jiaxing City and Shaoxing City, wind energy equipment industry cluster mainly in Hangzhou City and Wenzhou City, solar thermal industry cluster mainly in Haining City, and hydropower and tidal energy industry cluster mainly in Tonglu County.

3. Challenges and Barriers to Low Carbon Development

3.1. Population

The Yangtze River Delta region is a very densely populated area. The population density of Shanghai, Jiangsu and Zhejiang, has reached 3654, 767 and 535 people per square km respectively, greater than national average level (140). The excessive increase of population has brought greater pressure on ecol-

ogy, environment, resources, and transportation. For example, Shanghai's residential energy consumption reached 10.1 million tce in 2010, which has increased by 56.3% during the 11th Five-Year Plan period (2006-2010). Of all residential petroleum products, gasoline consumption has greatest increase, from 30800 tonnes in 1995 to 1036800 tonnes in 2009 (National Bureau of Statistics of China, 2010).

3.2. Low Energy self-sufficiency rate

China has been the largest energy production country in the world for five consecutive years and energy self-sufficiency rate is over 90%. However the Yangtze River Delta region's energy self-sufficiency is very low. Most consumption of raw coal, crude oil and natural gas is from other provinces and foreign imports. In 2009, self-sufficiency rate of raw coal is nearly zero in Shanghai, 11.2% in Jiangsu and 0.1% in Zhejiang. Self-sufficiency rate of crude oil is 0.5% in Shanghai, 6.9% in Jiangsu and 0% in Zhejiang. Self-sufficiency rate of natural gas is 12% in Shanghai, 0.9% in Jiangsu and 0% in Zhejiang. Such a low rate of primary energy self-sufficiency requires the Yangtze River Delta region must turn to the road of sustainable development and reduce energy consumption.

3.3. Limited deployment of low carbon technologies

Development and diffusion of low carbon technologies is very important to solve the challenges of climate change and energy security. According to *China Human Development Report* 2009/10 (UNDP, 2011), China's innovation capability in the field of low carbon technologies is weak. Currently, China only masters 19 kinds of low carbon technologies of 62 kinds of key support technologies. As to the other 43 kinds of low carbon technologies, China has not mastered the core. Low carbon technology development in the Yangtze River Delta region faces many obstacles. For example, the world's largest carbon capture project launched by a coal-fired power plant broke ground in July, 2009 in Shanghai. It's the second program developed by Huaneng Power International Inc. However, due to technical, financial and project implementation reasons, the current development of this project is still relatively slow. Limited R&D capability, imperfect laws and regulations, insufficient investment and diffusion difficulty of new technologies all hampered the development of low carbon technologies in this region (Wang, 2010).

3.4. Unbalanced energy consumption structure

According to *BP Statistical Review of World Energy* (2011), coal accounted for only 29.6% of global primary energy consumption in 2010. However, China's proportion was as high as 70.2%. In the Yangtze River Delta region, energy consumption also mainly relies on coal. Proportion of oil and natural gas consumption, especially natural gas consumption is very low. In 2007 coal accounted for 60.1% of this region's consumption. Natural gas only accounted for 0.2%. Energy consumption structure of Shanghai is a little better than Jiangsu and Zhejiang, but still unbalanced. Because the CO_2 emission factor of coal is the highest in the main fossil fuels, a coal-dominant energy endowment and consumption structure must be changed in the long run in order to further promote low carbon development.

4. The Way to Low Carbon Economy

4.1. Integration and coordination

As the Yangtze River Delta region is in a shift to market economy, many obstacles including limited integration and coordination of policies among local government and sectors still exist during the process of low carbon development. Fragmentation among authorities, particularly in different sectors, often leads to bias in and sometimes contradictions between the policies of different government departments. The limited integration and coordination among Shanghai, Jiangsu and Zhejiang has weakened the effectiveness of many laws, polices and other measures. So regional cooperation, regional division and joint development in this region is the inevitable choice. A linkage mechanism for low carbon development among Shanghai, Jiangsu and Zhejiang should be established from the perspectives of joint planning and decision-making, cooperation in environmental protection, industrial reconstruction, and free movement of production factors. The linkage mechanism should cover decision-making, implementation, monitoring and advisory systems.

4.2. Diversity of energy supply

Because energy consumption structure is a coal-dominated one in the Yangtze River Delta region and cannot be changed in the short term, we should focus on the development of clean coal technology to reduce CO_2 emission in the short term. Measures should be taken to save energy and reduce emissions in the energy-intensive industries such as power, iron, steel, building materials, and aluminum electrolysis industry. The region especially Jiangsu and Zhejiang should continue to phase out obsolete production capacities. In the long run the region should change the coal-dominated energy consumption and gradually increase the consumption proportion of natural gas. The Yangtze River Delta region should take advantage of its technological advantage and opening up to actively develop new energy industry; increase the consumption proportion of renewable resources such as hydropower, nuclear, solar, and biomass (Shan at al., 2008).

4.3. Technology support

International technology transfer lies at the core of mitigation to tackle climate change challenges (Dasgupta and Taneja, 2011). Moving to a low carbon growth path poses immense technological challenges for China. The Yangtze River Delta region should take advantage of its opening up to accelerate the introduction, digestion and absorption of advanced and applicable low carbon technologies from other developed countries. Meanwhile this region should attract creative talent, increase innovation fund investment, and improve the government's incentive policies to form the technological support system of low carbon economy.

The Yangtze River Delta region should operate pilots and demonstration projects in different types of cities, communities and sectors based on the *point-line-surface* promotion model. This region should initiate appropriate support policies and evaluation indicators including energy intensity and carbon intensity indicators to stress the quality of GDP. Each pilot's emission reduction rate should be clear through the detailed decomposition of evaluation indicators. Through exploring replicable models, each city in this region will achieve low carbon development ultimately.

4.4. Education and promotion

Residential energy consumption has been continuously increasing in the Yangtze River Delta region and this region is becoming a major luxury goods market in China recently. More generally, consumption patterns are influenced by larger socio-economic changes and increased consumption levels are induced by economic growth (Kronenberg and Iida, 2011). So it is necessary and urgent to raise public awareness and reduce residential energy consumption in the context of economic development. A robust public awareness-building mechanism should be established. Encourage the media (i.e., TV, radio, press and the Internet) to fully play their roles in public education through institutional arrangements. Educate the public to reverse the ideas of luxury spending and foster the public awareness of low carbon and energy-efficient products so that the public can form environmentally friendly consumption and lifestyles.

5. Conclusion

The concept of low carbon has received more and more attention around the world. The Yangtze River Delta region, one of the most developed regions in China, has large numbers of energy intensive industries and businesses. Energy shortage and environmental deterioration require this region to move to the path of low carbon and sustainable development. This paper aims to comprehensively analyze low carbon development in this region and provide a useful reference for relevant government departments for policy-making. The analysis shows that the situation of low carbon development in this region gets improved, but it is not enough. The situation in Shanghai is the best compared with Jiangsu and Zhejiang. This is largely due to its best industry structure. Many barriers still exist in this region and some cannot be overcome in the short run. Labor intensive and carbon intensive industries are still one of the important driving forces of economic growth in this region. Energy security is a serious problem for the region because of its low energy self-sufficiency rate. Limited R&D capability and imperfect diffusion mechanism hamper a further development of low carbon technologies. In order to achieve sustainable development, this paper proposes some measures such as establishment of integration and coordination mechanism, diversity of energy supply, technology innovation, and raising public awareness.

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