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Article

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Journal of Urban Management

Provided in Cooperation with:

Chinese Association of Urban Management (CAUM), Taipei

Suggested Citation: Tsou, Yu-Lin; Edelman, David Joel (2013) : Planning for economic growth with reduced CO2 emissions in Provincial China: The case of Jiangxi, Journal of Urban Management, ISSN 2226-5856, Elsevier, Amsterdam, Vol. 2, Iss. 2, pp. 45-70, [https://doi.org/10.1016/S2226-5856\(18\)30071-2](https://doi.org/10.1016/S2226-5856(18)30071-2)

This Version is available at:

<https://hdl.handle.net/10419/194404>

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Planning for Economic Growth with Reduced CO₂ Emissions in Provincial China: The Case of Jiangxi

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ABSTRACT. Since the Industrial Revolution, the concentration of greenhouse gases (GHG), primarily carbon dioxide (CO₂), has put increasing pressure on the atmosphere's ability to absorb them. China is the fastest growing major economy in the world, and is following a process of rapid industrialization. This process, however, contributes dramatically to global warming through major CO₂ emissions. The widespread provision of electricity through coal-fired power plants is just one contributor, but industrial structures, transportation systems, and the construction of large superblock residential towers also play major roles. The large cities and industrialized provinces of China emit the most CO₂, a fact that requires serious attention. However, stemming this trend elsewhere in China would provide a greater opportunity for success in reducing overall CO₂ emissions in the country. Consequently, the question this paper addresses is what policies can be adopted to reduce CO₂ emissions in provinces in China where development is still in its early stages, while maintaining economic growth. Jiangxi is a province that has historically been a major agricultural area. In recent years, however, because of the economic development policies of the Chinese central government, the province's rich mineral deposits, favorable location, and convenient transportation system are attracting more investments and projects for development (Statistical Bureau of Jiangxi, 2010). Jiangxi, then, provides an excellent case study because the province, although developing quickly, might still produce less CO₂ if proper growth policies and actions are implemented. According to the results of this research, CO₂ emissions would indeed decline in Jiangxi if the province would adopt new technology for electricity generation and increase the GDP role of the service sector.

KEYWORDS. *Provincial Chinese development; economic growth and global warming; CO₂ emissions in China; Chinese industrialization; Chinese power production*

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1. INTRODUCTION

Since the Industrial Revolution, the concentration of greenhouse gases (GHG), primarily carbon dioxide (CO₂), has put increasing pressure on the atmosphere's ability to absorb them. China is the fastest growing major economy in the world, and is following a process of rapid industrialization. This process, however, contributes dramatically to global warming through major CO₂ emissions. The widespread provision of electricity through coal-fired power plants is just one contributor, but industrial structures, transportation systems, and the construction of large superblock residential towers also play major roles. The large cities and industrialized provinces of China emit the most CO₂, a fact that requires serious attention. However, stemming this trend elsewhere in China would provide a greater opportunity for success in reducing overall CO₂ emissions in the country. Consequently, the question this paper addresses is what policies can be adopted to reduce CO₂ emissions in provinces in China where development is still in its early stages, while maintaining economic growth. Jiangxi is a province that has historically been a major agricultural area. In recent years, however, because of the economic development policies of the Chinese central government, the province's rich mineral deposits, favorable location, and convenient transportation system are attracting more investments and projects for development (Statistical Bureau of Jiangxi, 2010). In 2010, the GDP of the province's second ranking economic sector (industrial production) increased by 16.6%, while the province's GDP increased by 14% to rank No.19 in all of China (National Bureau of Statistics of China, 2010). Therefore, Jiangxi is an excellent case for studying the problem of reducing CO₂ emissions while maintaining economic growth because the province, although developing quickly, might still produce less CO₂ if proper growth policies and actions are implemented.

The approach taken here, then, is to focus on this single province, which has been selected because it has the desired features of a province that has increased its CO₂ emissions as a result of the transition from an agricultural to an industrial economy and attained an annual GDP growth rate that is higher than the national average. Under these criteria, the selected province should be less developed than those with major industrial cities, but more so than provinces that have not upgraded their production. Consequently, the final result should be a province that has started to develop industrially but has not reached complete transformation. Determining how to reduce CO₂ emissions in the selected province would, therefore, help China achieve its national goal of CO₂ emissions reduction. Jiangxi was selected because its annual GDP growth rate was higher than China's average over the past five years. In addition, industrialized investment and energy consumption increased during each of those five years, which means that the production of the province is undergoing transition.

First, the context of the study is provided through a background presentation, followed by

sections on China's climate change policy, its recent national development plans, and technical support for energy utilization to reduce CO₂ emissions. The study then proceeds to the case study of Jiangxi Province, with an analysis of its existing conditions. This is followed by sections addressing the research question through 2 measures: (1) transforming the economy by increasing the growth rate of the services sector, and (2) adopting several new energy forms and supplying new technological support to reduce coal consumption. The results of a series of simulations modifying the provincial development policy based on these measures are then described, followed by our conclusions and recommendations.

2. BACKGROUND

Global warming, that is, the rising average temperature of the Earth's atmosphere and oceans, has become a critical issue. Although GHG, a major cause of this phenomenon, are produced from the natural environment, research has demonstrated that most of these gases are produced from human activities (IEA, 2011). Since the Industrial Revolution, the concentration of greenhouse gases, primarily CO₂, has increasingly put pressure on the atmosphere's ability to absorb them. The atmosphere controls the earth's temperature, but it is influenced by the high concentrations of various gases. It retains thermal radiation, and this is why increasing amounts of CO₂ cause the atmosphere to be warmer than before (Gore, 2009). When the atmospheric temperature rises, one of the hazardous consequences is that sea levels will rise as well. Such rising sea levels could have major impacts on many of the world's coastal cities, including New York, New Orleans, Lagos, Rotterdam, and Singapore, among others.

The World Resource Institute summarized emissions by economic sector in 2005. Electricity and heat were the largest emitters, comprising a quarter of all emissions; industry was ranked second, making up 14.7% of the total. Transportation generated 14.3%, ranking number 3, followed by agriculture and land-use changes. These emissions consisted of 77% CO₂, 15% methane (CH₄), 7% nitrous oxide (N₂O), and 1% others. Over 64% of emissions came from energy use. Therefore, most of the emissions were produced from burning coal and other fossil fuels (World Resources Institute, 2008).

According to The World Bank, the largest countries (i.e., the United States, China, and India) produce more GHG emissions than others. As a developed and industrialized country, the United States has experienced an economic growth that is more stable and focused on the service sector. In other words, it is increasingly emerging from high pollution and high labor-intensive and low value-added industries. On the other hand, large developing countries need to attract more investments to increase their competitive advantage and to reduce their capital costs to maintain GDP growth rates. Therefore, developing countries have a faster emission growth than developed

countries. This is especially the case of China, India, Brazil, and Russia.

China, as the fastest growing of these four countries, has had five-year economic plans since the 1980s. By 2002, with the 10th Five Year Plan, CO₂ emissions in China increased faster than in any other country, and this number also reflects its GDP growth. By 2010, China produced approximately 23% of the world's GHG (IEA, 2010). According to the International Energy Agency (IEA), China is now the world's largest carbon producer, and it had the largest emissions growth last year, rising up to 300 million tons, or 3.8% from 2011 (Ritter, 2013). In the 12th Five Year Plan (2011-2015), the goal is a GDP growth of 7% and to maintain development in the middle-western area of the country. This means more high-pollution industries will be initiated there. This area is large, with seven provinces neighboring the already developed coastal ones. Low urbanization and development is significant in these provinces, and the Chinese government believes industrialization is the best path to boost local economic growth and development.

As a result, more investment will flow into these provinces to take advantage of their cheap labor, land, and natural resources. This process would provide more job opportunities and higher income for the residents and exacerbate rural-urban migration. However, most of the investments are intended for labor-intensive, yet highly polluting industries; therefore, how this issue should be dealt with while maintaining economic growth is a serious question for these provinces.

Jiangxi is one of these provinces. Historically, it has been a major agricultural area, but because of the economic development policies of the Chinese central government, mineral deposits, favorable location, and convenient transportation, Jiangxi has been attracting more investment and development recently (Statistical Bureau of Jiangxi, 2010). In 2010, the GDP of the province's second ranking economic sector (industrial production) increased 16.6%, while the province's GDP increased by 14% to rank 19th in all of China (National Bureau of Statistics of China, 2010). This is an excellent place to study reducing CO₂ emissions while maintaining economic growth because the province, although developing quickly, still has time to produce less CO₂ if proper growth policies and actions are implemented.

3. CLIMATE CHANGE POLICY IN CHINA

Under the 12th Five Year Plan (2011-2015), the Chinese government has placed greater emphasis on scientific development and environmental protection and sustainability. This plan relates industrial and energy policies to increased investments in a low-carbon economy to reach its goals. Coal has been a cornerstone of China's economic growth, with over 80% of the global increase in coal demand coming from China over the past decade. Based on preliminary estimates for 2010, China accounted for nearly half of global coal use (Best & Levina, 2011).

Over the past decade, China has pursued industrial and urban development within the powerful

growth of its economy. This has led to an unprecedented demand for energy in concentrated populations and industrial areas. Consequently, China's primary energy demand increased from 1,108 million tons of oil equivalent in 2000 to over 2,271 million tons in 2009 (Ibid.). In 2010, coal comprised nearly 67% of China's total primary energy supply. It was used for power generation and for chemicals and transportation fuels. For power generation, over 78% of China's electricity was produced by coal in 2009. In addition, coal will also be a major energy source in China over the next two or three decades. The demand may remain stable until 2020, when industrial and power sectors will have new energy sources to replace it. However, methods for improving the efficiency of power generation is a major issue in China (Ibid.).

The high demand for energy and the related high CO₂ emissions are a concern of all countries, but China's per-capita energy use is still just one-third of the OECD average. However, if energy demand is projected to follow the existing economic strategy and development policy for the next planning period, China's CO₂ emissions may increase from 7.7 gigatons per year (Gt./yr.) to over 10 Gt./yr. by 2035, an increase of over 35% (Ibid.).

To mitigate the environmental impact of energy use accompanying development, the Auspices of National Development and Reform Commission published China's National Climate Change Program (CNCCP) in 2007. The program states that China will vigorously engage in effective and pragmatic cooperation with the international community as well as individual countries to implement the points in this program (Auspices of National Development and Reform Commission, 2007). According to the report, China's nationwide annual mean air temperature would increase by 1.3-2.1°C in 2020 and 2.3-3.3°C in 2050 from the mean air temperature in 2000 if no action is taken.

Despite the country's steady economic development, the emission intensity, defined as CO₂ emissions per unit of GDP, has been declining generally in China. According to the IEA, China's emission intensity fell to 2.76 kg.CO₂/US\$ (in constant 2000 US\$) in 2004, compared to 5.47 kg.CO₂/US\$ in 1990, which is a 49.5% decrease. For the same period, the average emission intensity of the world dropped by only 12.6% and that of the OECD countries by 16.1% (Ibid.).

However, as noted above, China's primary energy mix is dominated by coal, at 68.9%, whereas the world average is only 27.8%. Compared with oil and natural gas, coal's carbon content per unit of calorific value is 36% and 61%, respectively. Furthermore, China's energy efficiency is approximately 10% lower than that of developed countries, with a per unit energy consumption of energy-intensive products approximately 40% higher than the advanced international level. This leads to the program's 6 principles, which are: 1) to address climate change within the framework of sustainable development; (2) to follow the principle of "common but differentiated responsibilities" of the United Nations Framework Convention on Climate Change; (3) to place equal emphasis on mitigation and adaptation; (4) to integrate climate change

policy with other interrelated policies; (5) to rely on the advancement and innovation of science and technology, and (6) to participate in international cooperation actively and extensively (Ibid.).

4. NATIONAL DEVELOPMENT IN CHINA

The Five Year Plans are a series of social and economic development steps designed to help the government navigate the future, and the three plans that include environmental matters explicitly are reviewed here. These include the 10th (2001-2005), 11th (2006-2010), and 12th (2011-2015) Five Year Plans.

In the 10th Five Year Plan, China focused on a number of special projects, which included urbanization, population, employment, social security, technology, education, high-tech industry, ecological construction, environmental conservation, water conservancy, transportation system, and energy. Regarding environmental conservation, inefficient and highly polluting equipment was replaced by modern facilities in the chemical, spinning, and automobile industries. This policy was part of a major strategy to upgrade industrial production. In addition, the government provided benefits for high-tech industries to attract more investors to set up high-tech factories. Even though CO₂ emissions increased by 34.5%, which is 4 times the GDP growth of 8.6%, the plan did not include significant mitigation. However, this was the first time a Chinese five-year plan took the environment into consideration (Ibid.).

In the 11th Five Year Plan, more environmental policies were developed. First, energy use per unit of GDP over the period 2006-2010 was to be reduced by 19%, compared to the 2001-2005 period. This meant that approximately 1,460 million tons of CO₂ emissions would be saved. Moreover, 3 million tons of coal would be replaced by renewable energy. China has a high potential to develop renewable energy, including water, wind, sun, and biomass energy. Expanding the public transportation system was another strategy to reduce CO₂ emissions. By the end of the plan, CO₂ emissions increased by 24.9%, compared with a GDP increase of 11.2%. Thus, the emissions increased at twice the rate of GDP, which was a significant improvement over the previous plan (Zhi, 2011).

In the current 12th Five Year Plan initiated in 2011, carbon reduction rather than GDP growth is China's major goal. This focus will increase the speed of industrial upgrading, and during this period, the "World Factory" will be transformed into a "World Market." In order to implement this policy, Congress prepared the seven concepts of green industry, including energy saving, new energy, new materials, electric vehicles, new medicine, biotechnology, and the information industry. New energy includes hydropower, nuclear power, wind power, solar power, biogas, geothermal and high-efficiency coal use. China expects to reduce CO₂ emissions by 40% to 50% by 2020, and to replace over 15% of fuel energy with new energy. China had 7,771 million tons

of CO₂ emissions in 2009, which means the number will go down to approximately 5,300 million tons in 2020 (Skypower Ltd., 2011).

In the 10th Five Year Plan, the GDP rate of increase compared to the CO₂ emission growth rate was 1:4. In the 11th Five Year Plan, the rate was down to 1:2. These numbers show that in recent years, China's GHG emissions have been improving relative to economic growth. Upgrading industrial production and focusing on green production are the goals for the current period, and lower emission growth can be expected.

5. EXISTING TECHNICAL SUPPORT FOR ENERGY UTILIZATION THAT REDUCES CO₂ EMISSIONS

China is the largest coal consumer in the world, and most of the coal is used to produce cheap electricity in order to have more competitive industries. However, when China signed the world climate treaty (2009), it obligated itself to reducing carbon dioxide emissions and pursuing renewable energy (Eastman, 2003). Technical and renewable energy options, which are a key strategy in the current five-year plan, are discussed below.

Power plants consume large amounts of coal, and most GHG emissions are produced from these plants. This is one of the reasons why clean coal technologies have become increasingly important around the world. A crucial question, then, is how the equipment to reduce emissions can be upgraded to mitigate CO₂ emissions. The Clean Coal Technology Demonstration Program (CCTDM) was initiated in 1985 to demonstrate a new generation of advanced coal utilization technologies. The Power Plant Improvement Initiative (PPII) and the Clean Coal Power Initiative (CCPI) are two other projects that followed the CCTDM. Over the past 25 years, these projects have successfully demonstrated that technology can increase efficiency and reduce emissions (Miller, 2011).

Bringing new power plants on line to reduce emissions is one thing China can do, and Europe and the United States have begun to cooperate with China on a near-zero emissions coal project. The first clean coal-fired power plant is being built in Tianjin, supported by Integrated Gasification Combined Cycle (IGCC) technology (Wang, 2009). The first carbon capture and storage (CCS) power plant became operational at the end of 2010 (Vazaios, 2010). Although a clean coal power plant is a significant project, people can use other renewable energy forms such as wind and solar power instead, and they are included in China's renewable energy strategy outlined in the 12th Five Year Plan.

Renewable energy provides not only the benefits of energy efficiency to the public but also new economic development opportunities (Nogee, 2000). Wind, solar, hydro, nuclear, biogas and geothermal power are all to be used under the 12th Five Year Plan. Recently, China's wind sector

has received increasing attention. In 2007, over 15% of all global wind investment occurred in China (Xie & Economides, 2009), and by 2010, China was producing over 20 million kilowatts, thereby surpassing Spain as the number 3 wind power user in the world.

Recently, solar power has been used not only in developing nations to provide cheaper electricity, but also in industrialized countries. In Japan, companies have been encouraged to install solar roofing material, and over 70,000 houses have solar installations. Germany is the world leader in solar power. Over 9,785 megawatts were produced in 2010. China produced 305 megawatts in the same year. Even though China is the largest solar panel manufacturer, it has not installed enough of them at home yet (Zachary, 2010). This situation will be improved under the 12th Five Year Plan.

Although nuclear energy can be dangerous, it provides zero emissions and sustainable energy as a way to address the CO₂ problem (Bily, 2006). Nuclear energy is a controversial option, but its benefits, especially in terms of eliminating GHG emissions, cannot be ignored. China started to develop nuclear power plants in the 1970s and began operating them in 1991. Currently, there are six power plants in operation, producing 2.15% of the total electricity, but eleven more will be completed before 2015 (Wang, 2010).

China still has many rural villages inland, which is the best location for developing biogas energy. By 1985, China started to develop biogas resources in rural areas to be used for cooking, heating, and lighting. Under the 11th Five Year Plan, China invested 4 billion dollars to promote this energy. The goal, over the next five years, is to produce 44 billion cubic meters of biogas and apply it to transportation, industries, and cities (Du, 2010).

According to another report, the amount of energy used will increase to 45 million standard tons of coal (Li, 2006). In order to accomplish the goal of a 15% reduction in fossil fuel energy use, hydropower should provide 350 million kilowatts, wind power 150 million kilowatts, solar power 20 million kilowatts, biogas power 30 million kilowatts, and nuclear power 80 million kilowatts in 2020 (Hsu, 2011).

6. CASE STUDY

Having set the context, we now explain why Jiangxi Province has been selected as the case study for analyzing methods of reducing CO₂ emissions while maintaining economic growth in China's provinces. As is well known, most of the urban population growth, economic activities, and development have occurred on China's eastern rim. With the increasing population and investments, CO₂ emissions in this area have also risen. China's government is now trying to balance the nation's growth by developing the interior parts of the country to the west. China has three levels of major cities (Lee, 2009), and these levels are important for understanding

economic development in the country.

First-level cities, such as Beijing and Shanghai, are located predominantly near the coast. Most of these have already passed beyond the initial industrial period. They are changing their economic structures from industry- to service-based, which means the economies of these cities will continue to grow without industrial production, and their CO₂ emissions will probably go down. Beijing is a typical case. After the 2008 Olympic Games, Beijing experienced high population and economic growth for the year. However, the CO₂ emissions did not increase as would have been expected (Zhao, 2011). This situation demonstrates that in the late industrial period, CO₂ emissions are more controllable than before, and it also suggests that other cities will soon undergo the same changes.

The second-level cities are located in the mid-east or are adjacent to the coastal provinces. The characteristics of these cities include a growing population, cheap labor, increasing investments, and a rich natural resource base to support industrial production. In economic structure, agricultural production still plays a critical role in these provinces. However, industrial development is growing because of favorable conditions for investment. An industrial city requires many workers, who come from rural areas, and this provides an opportunity to develop the city's infrastructure to make it more competitive. In addition, more resources are consumed, and CO₂ emissions increase. Of note is the fact that most of the CO₂ emissions of China are produced in the provinces where these second-level cities are located (Auspices of National Development and Reform Commission, 2007). Although China's central government has published the National Climate Change Program, the new five-year economic development strategy should be coordinated more closely with the Climate Change Program. Unfortunately, this is not the case.

The third-level cities are located in the middle and eastern parts of China. Agriculture and livestock are the major production sectors in these areas. These cities have lower GDP and energy consumption, which is why their CO₂ emission growth rates and amounts are lower, compared with those of more industrialized cities (Ibid.).

The approach taken here, then, is to focus on a single province between the second and third levels. The desired features of the province are that it has increased CO₂ emissions due to the transition from an agricultural to an industrial economy, and its annual GDP growth rate is higher than the national average. Under these criteria, the selected province should be less developed than those with major industrial cities but more so than the provinces that have not upgraded their production. Consequently, the final result should be a province that has started to develop industrially but has not reached complete transformation. Determining how to reduce CO₂ emissions in the selected province would, therefore, help China achieve its national goal of CO₂ emissions reduction. Jiangxi was selected because its annual GDP growth rate has been higher

than China's average over the past five years. In addition, industrialized investment and energy consumption increased during each of those five years, which means the production of the province is undergoing transition.

Jiangxi Province borders Zhejiang and Fujian Provinces to the east, Guangdong to the south, Hunan to the west, and Hubei and Anhui to the north. Jiangxi's northern border is the Yangtze River, and it connects to Wuhan upstream and to Nanjing and Shanghai downstream. Both the Beijing-Kowloon and the Zhejiang-Jiangxi railways run through the whole province, which makes it conveniently accessible via transportation (Statistical Data, 2011). The provincial population was 41.68 million in 2000 and 44.62 million in 2010, of which 11.48 million (27% of the total population) were urban dwellers in 2000 and 19.66 million (44% of the total) by 2010. The province's population growth rate was 7% annually from 2000 to 2010. Nanchang, the provincial capital, had over 5 million people in 2010.



Figure 1. Jiangxi Province overview

Data source: Statistical Bureau of Jiangxi, 2010

The 10th Five Year Plan period (2001-2005) was an extraordinary one for Jiangxi Province. The GDP of Jiangxi increased from 200 billion Yuan to 407 billion RMB, equal to an annual

growth rate of 11.6%; the three major sectoral shares were 18.9% for primary industry (agriculture), 47.4% for secondary industry (industry and construction), and 33.7% for tertiary industry (transport, retail, and finance). The industrial sector became a major factor in the province's economic growth, and urbanization was up to 37% by 2005 (China Investment Yearbook Editorial Board, 2007).

During the period of the 11th Five Year Plan (2006-2010), Jiangxi experienced stronger development and higher economic growth, building on the results of the previous period. The new strategies were rural modernization, industrial production upgrade, urbanization increase, economic internationalization, and infrastructure build up. By 2010, the GDP of Jiangxi had increased to 945 billion RMB from 482 billion RMB in 2006, which equals an annual growth rate of 13.2%. The three major sectoral production shares were 12.8% for primary industry, 55% for secondary industry, and 32.2% for tertiary industry. Urbanization was 44.8% by 2010 (Jiangxi Development and Reform Commission, 2011).

In the 12th Five Year Plan, the major economic goals of the province include 1) increasing GDP to 1,800 billion RMB, with an average annual growth rate of no less than 11%, 2) secondary and tertiary industries are to make up 90% of total GDP, and 3) urbanization is to reach 52.8% (Ibid.).

Industrial development is a major factor in supporting Jiangxi's economic growth. However, CO₂ emissions have increased along with economic growth over the past 10 years. Even though China published its Climate Change Program in 2007, CO₂ emissions are still rising with the economic growth of Jiangxi Province. According to the report of Jiangxi Social Sciences, CO₂ emissions increased steadily by 1.9% per year between 1995 and 2000. However, the CO₂ growth rate increased by 16.3% annually between 2002 and 2009. This report illustrates that the CO₂ emissions had developed a stronger relationship with economic growth, especially with industrial production (Fu & Lu, 2011). Therefore, Jiangxi Province is an appropriate case study for understanding how to achieve a balance between CO₂ emissions and economic growth.

7. ANALYSIS OF EXISTING CONDITIONS

In order to determine suitable policies for the provincial government to follow to reduce CO₂ emissions, we first provide a review and analysis of the existing structure of growth and development in the provincial economy. The factors to be considered include existing CO₂ emissions, GDP growth effects in terms of the quantity of emissions produced, the structure of the economy, and the structure of energy use in the province. These are discussed below.

7.1. Emissions produced in the province

The statistics used to present an overview of CO₂ emissions in Jiangxi Province are those from 2005 to 2010, which are the most recent numbers available. During this period, the CO₂ emission growth rate in Jiangxi was 16.3% annually. At the same time, the GDP growth rate of the province was 16.8% annually (Statistical Bureau of Jiangxi, 2011). However, as Figure 2 shows, the provincial GDP growth rate is significantly high and does not seem sustainable (Sun, 2011). As Figure 2 also illustrates, CO₂ emissions have also risen quickly, and they are expected to continue rising, which is unacceptable for China's Climate Change Program, unless policy changes are made. Reducing CO₂ emissions by 25% is a goal of the program (Auspices of National Development and Reform Commission, 2007), but that will not occur in Jiangxi if current trends continue. Therefore, developing an understanding of the economic growth effects on the production of emissions is the first analytical step, which is presented in the following section.

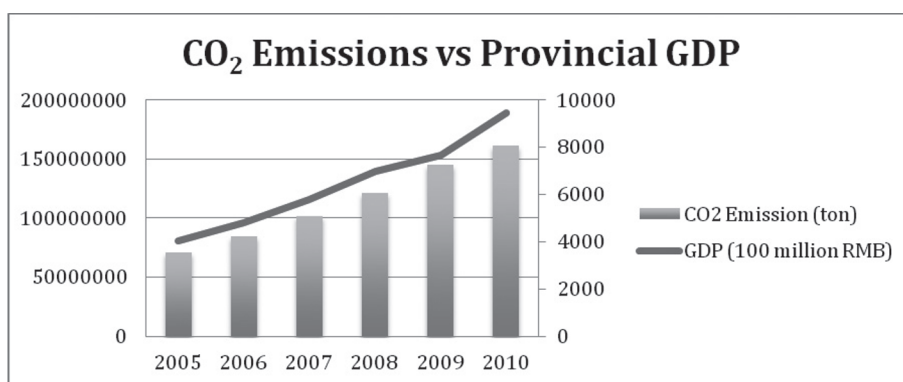


Figure 2. CO₂ emissions produced vs. provincial GDP growth

Data source: Statistical Bureau of Jiangxi, 2011

7.2. Economic growth effects on emissions production

While CO₂ emission growth in parallel with rising GDP has generally been the rule in Jiangxi Province, it is difficult to estimate emission numbers for the future because of factors such as technical improvements, industrial upgrading, and better energy efficiency.

7.3. Structure of economy

The industrial (secondary) sector is a high-density coal consuming sector compared to agricultural (primary) and services (tertiary) sectors (IPCC, 2008). This indicates that CO₂ emissions are collateral with industrial GDP growth. This is the situation that is happening in Jiangxi Province. Industrial development has risen sharply since 2000, and the growth rate of this sector has been higher than those of agriculture and services (See Table 1). The primary sector's growth rate has been at the bottom over the past five years (10.76%), whereas the tertiary sector has been higher at 17.25% and the secondary or industrial sector has been the core of Jiangxi's economic development with a growth rate of 21.91%, twice that of the primary sector. Therefore, if the province continues with the existing growth rates, the curves of GDP and CO₂ emissions would increase significantly, as shown in Figure 3.

Table 1. Jiangxi Province's sectoral growth rates, 2005-2010

Year	Primary	Secondary	Tertiary
2005	727.37	1917.47	1411.92
2006	786.37	2419.74	1614.65
2007	905.77	2975.53	1918.95
2008	1060.38	3554.81	2355.86
2009	1098.66	3919.45	2637.07
2010	1206.98	5122.88	3121.4
2010 Industry Rate	1	4.2443	2.586
Average Growth Rate (2005-2010)	10.76%	21.91%	17.25%

Data source: Statistical Bureau of Jiangxi, 2011

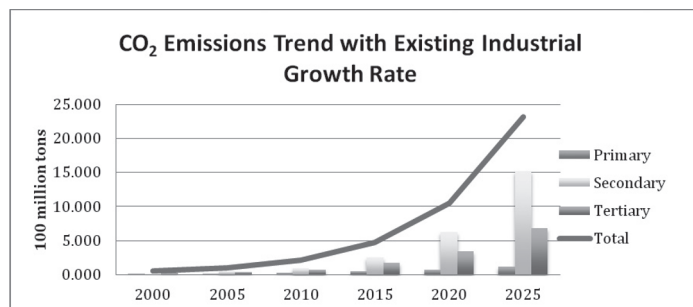


Figure 3. CO₂ emissions trend with existing industrial growth rate

Data source: Calculated by the authors

In order to know how much CO₂ would be emitted by each economic sector, it is necessary to calculate the per capita coal consumption that is required per unit of GDP, which is 0.000002045 for the primary sector, 0.000120806 for the secondary sector, and 0.000000661 for the tertiary sector. Comparing all of these sectors, the ratio is 1 (primary): 59.073 (secondary): 0.3232 (tertiary). From these results, one can see that adjusting the secondary and tertiary industry rates of coal use per unit of GDP is a potential provincial strategy to mitigate the emission growth rate.

8.4. Structure of energy use

Energy use, or more specifically, the combustion of fossil fuels, is closely tied to CO₂ emissions (The World Bank, 2009), and this is the existing situation in Jiangxi Province. That is, fossil fuels are the major fuel sources, and most of this energy is used by power plants and for transportation and domestic heating. The data show that the trend is accelerating. In 2011, over 82% of energy use in the province was from coal and coke (Figure 4). In Figure 5, it can be observed that the consumption of raw coal has increased with GDP growth; however, the amounts of gas, oil, and hydropower consumption remain at steady levels.

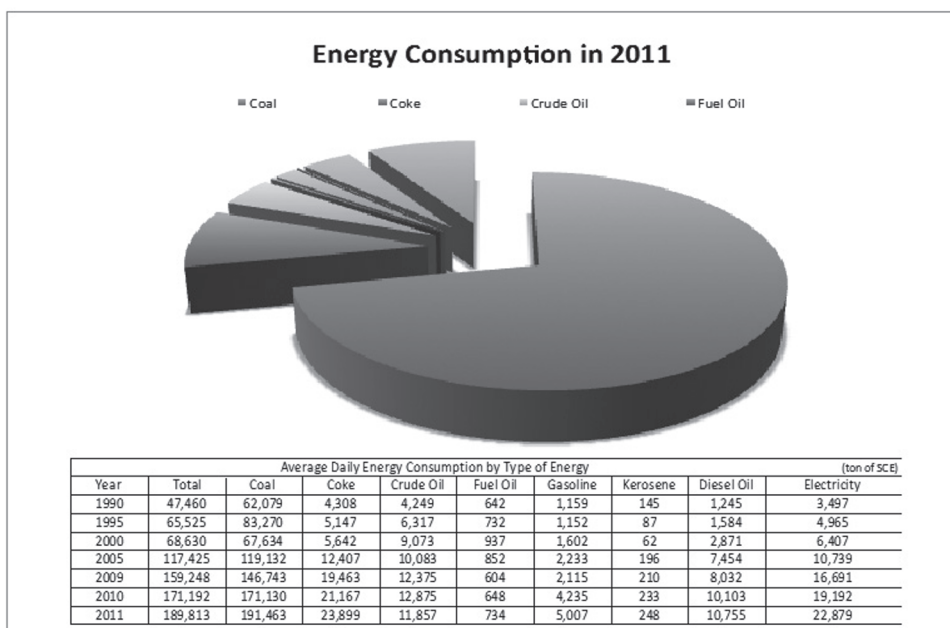


Figure 4. Energy consumption in 2011

Data source: Statistical Bureau of Jiangxi, 2011

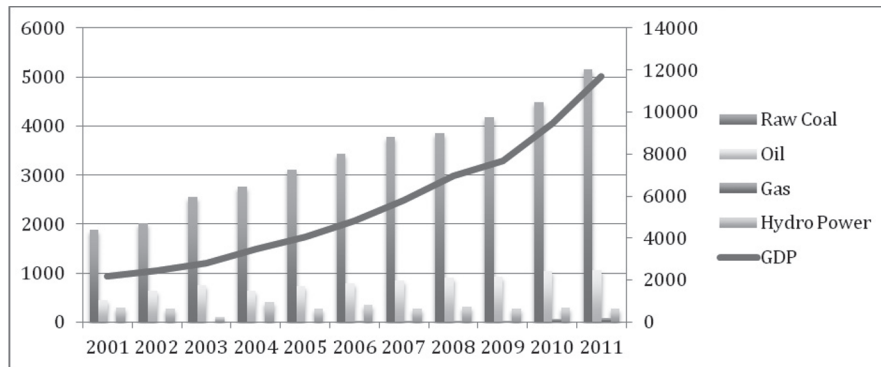


Figure 5. Energy consumption from 2001 – 2011 in Jiangxi Province

Data source: Statistical Bureau of Jiangxi, 2011

Based on the data in Figure 5, it is clear that raw coal consumption is projected to grow at a similar rate to national GDP, whereas oil and hydro energy are not exploited, and gas was used only after 2005. This situation exists despite all the evidence indicating that coal is not only a cornerstone of the economy, but also a major cause of CO₂ emissions. Consequently, if the province does not adopt any policies to address coal demand, which will rise to approximately 240 million tons in 2025 at the existing growth rate, coal use will be almost four times that of 2010 in that year (Figure 6).

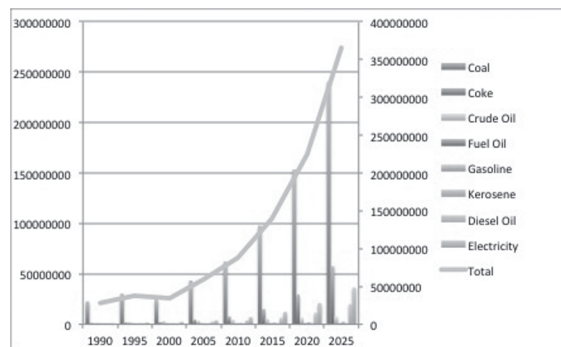


Figure 5. Energy consumption in Jiangxi Province, 1990 – 2025, at current growth rates

Data source: Calculated by the authors

Potential strategies for slowing down CO₂ emission growth include reducing coal consumption and implementing industrial transformation. How these strategies might achieve this goal and what the results might be in Jiangxi Province is discussed in the next section.

8. MODIFIED DEVELOPMENT POLICIES TO REDUCE EMISSIONS

From the economic growth effect analysis, two measures were found to reduce CO₂ emissions. The first is to maintain the GDP growth rate but transform the economy by increasing the rate of growth of the service industry and the second is to adopt several new energy forms and supply new technical support to reduce coal consumption. The following paragraphs modify the provincial development policy to reduce emissions in these two ways.

8.1. Policy 1: Increase the GDP of the service industry

Initially, agriculture was a developing economy's most important sector. However, as income per capita rose, agriculture loses its primacy, giving way first to a rise in the industrial sector, then to a rise in the service sectors. These two consecutive shifts are called industrialization and post-industrialization. All growing economies are likely to go through these stages. (The World Bank, 2007)

This statement can be used to consider if the province is progressing to the stage of post industrialization. When incomes rise, the demand for health, education, entertainment, and other services increases as well. The provision of these items will generate lower CO₂ emissions per unit of output than the production of industrial materials.

In Jiangxi Province, the rate of coal consumption per unit of GDP by economic sector is 1 (primary sector: agriculture) to 59.072 (secondary sector: industry) to 0.3232 (tertiary sector: services), as previously stated. This means that if the province transformed one percent of GDP from industry to services in 2011, the province would have saved approximately 1,312,969 tons of coal consumption, which would account for 1.904% of the year's CO₂ emissions. In this way, the province could maintain its economic growth and reduce CO₂ emissions significantly, while simultaneously increasing provincial employment in services.

Table 2. Reduced coal consumption and CO₂ emissions by different transformation rates

Year	Primary Sector	Secondary Sector	Tertiary Sector	Total	CO ₂ Emissions
2011	324,514.21	68,011,796.23	241,395.01	68,577,705.45	185,159,804.72
-1%	324,514.21	66,698,827.19	248,579.38	67,271,920.79	181,634,186.12
-2%	324,514.21	65,385,858.15	255,763.76	65,966,136.12	178,108,567.53
-3%	324,514.21	64,072,889.11	262,948.14	644,660,351.46	174,582,948.94
-4%	324,514.21	62,759,920.07	270,132.51	63,354,566.79	171,057,330.35
-5%	324,514.21	61,446,951.03	277,316.89	62,048,782.13	167,531,711.75

Data source: Calculated by the authors

Table 2 shows the results of a 15% GDP growth rate in 2011 and transforms 1%-5% of GDP from the secondary sector to the tertiary sector. The results show that the strategy is workable, and approximately 1.9% of total CO₂ emissions would be saved at the same economic growth rate. Therefore, increasing the speed of industrial transformation is an option with a high potential for success.

8.2. Policy 2: Reduce the coal consumption of coal-fired power plants

Approximately 30% of provincial coal use is for electricity generation, so the question arises as to how plants can best be powered in the future to produce more electricity to satisfy the growing demand. This is an issue in any fast growing developing country. Coal-fired power plants were the option chosen by the Chinese government because they are relatively simple technologically, have low maintenance costs, and because the country has a rich supply of this raw material. On the other hand, these plants produce substantial chemical waste and pollution, of which CO₂ is a major emission.

Table 3 shows that over 42% of the coal consumption of Jiangxi Province in 2010 went to providing electricity and heat. At present, 16 coal-fired power plants are running in the province, and if the plants consume an equal amount of coal, that is, 2.63% of coal consumption, almost 1,609,473 tons of coal was used in 2010. According to IEA data, the coal used would produce approximately 2.76 tons of CO₂ emissions per ton of coal consumed by power plants (IEA, 2011). Therefore, the calculations demonstrate that each power plant emitted approximately 2,832,672 tons of CO₂ in 2010.

Table 3. Energy for electricity generation

	Raw Coal	Cleaned Coal	Other Washed Coal	Total (tons)
Total Consumption	51456824	9337790	339509	61134123
For Electricity & Heat	25751572	-	-	25751572
For Gas	-	71143	-	71143
For Water	260	-	-	260
Rate for Electricity	0.500450086	-	-	0.421230742

Data source: Statistical Bureau of Jiangxi, 2011

In addition, electricity shortages are a major problem in the summer and winter in Jiangxi Province. The shortage was 76.04 million kWh in 2011 and is projected to be 155.649 million kWh in 2015. In order to provide more electricity and reduce CO₂ emissions, the provincial

government should focus on building more power plants and adopting cleaner and more efficient power generation through improved technology. Three potential options are discussed below:

Table 4. Fossil fuel emission levels – pounds per billion Btu of energy input

Pollutant	Natural Gas	Oil	Coal
Carbon Dioxide	117,000	164,000	208,000
Carbon Monoxide	40	33	208
Nitrogen Oxides	92	448	457
Sulfur Dioxide	1	1,122	2,591
Particulates	7	84	2,744
Mercury	0.000	0.007	0.016

Data source: EIA – Natural Gas Issues and Trends, 1998

The first technical option is natural gas powered electricity generation. Coal (and nuclear) power plants have been used since 1970 because coal is the most economical energy resource. However, due to economic forces, environmental considerations, and technological change, natural gas has become a very popular fuel for generating electricity. Natural gas is the cleanest of all the fossil fuels, which also include oil and coal. Coal produces nearly twice as much carbon dioxide as natural gas does (Table 4). Consequently, if Jiangxi built natural gas-fired electric power plants to replace the coal-fired power plants, CO₂ emissions would fall by 50%. Near-Zero Emission Power Plants, or plants using what is also called Carbon Dioxide Capture and Storage Technology, comprise a second technical option. The process of electricity generation is similar to that of a conventional plant; however, the emissions are not exhausted via a chimney but instead are stored underground. The technology is not very popular around the world because tests are still being conducted, and the capital costs remain very high. However, it should be considered as firmer data become available.

Renewable energy is the third technical option the province can adopt, especially in the form of wind and solar powered plants. Both forms of energy are used widely across the world; however, they are not suitable for all of Jiangxi Province because of environmental limitations. Wind power plants, for instance, should be located in the monsoon belt to capture enough power to turn their rotors, and solar-power installations should be placed where there would be enough sunlight to provide heat to produce steam for turbines. Since developing a renewable energy industry is one of the major goals of Jiangxi Province, total electricity production from renewable energy is combined with hydropower in the third simulation of the policy simulation section, which follows.

9. POLICY SIMULATIONS

The simulations in this section estimate how much coal consumption could be saved under different strategies and their corresponding CO₂ emissions. Two major policies are used here; the first reduces coal consumption for electricity generation and the second increases the GDP of the tertiary sector (services). In order to provide reasonable projections, it is assumed that the economic growth rate for China will slow down over the next fifteen years, which is already the case in 2013. However, Jiangxi Province is what is called in Chinese terminology a “second-line city,” which means that the secondary economic sector has been forecasted to become a major engine of growth at the same time. Consequently, the overall growth rate in the province is expected be higher than the annual average of China. It is assumed, then, for both sets of simulations, that the provincial GDP growth rate is 15% from 2011 to 2015, 10% from 2016 to 2020, and 8% from 2021 to 2025.

9.1. *Electricity generation simulations*

The first simulation for electricity generation follows the existing growth in demand for electricity to estimate how much would be consumed over the next fifteen years without any policy changes or additional technical support. This will then be followed by four additional simulations that will consider different ways to reduce the shortage in electricity produced and see what the effects are on CO₂ emissions.

The first simulation shows that if electricity shortage is reduced by building coal-fired power plants, the CO₂ emissions would increase to 270,759,870 tons in 2025 for electricity production. However, the second simulation shows that the CO₂ emissions would decline over the next fifteen years if the province adopts hydropower for electricity generation. Before 2010, only 10% of electricity was generated from hydropower, but the percentage would increase to 15% in 2015 and 20% in 2020. In this way, the CO₂ emissions number would decline to 239,481,910 tons.

Let us assume, however, that the shortage is covered by natural gas-fed electricity generation, and that hydropower increases from 2015. In this third simulation, CO₂ emissions would decline to 174,529,361 tons in 2025. The simulation assumes that additional natural gas-fed electricity generation would be substituted for 2% of anticipated coal produced power annually from 2016. The result is that CO₂ emissions would decline to 166,600,352 tons in 2025.

In the fourth simulation, the rate of decrease in coal consumption is 5% instead of 2%. The CO₂ emissions would now decline to 156,894,977 tons.

The fifth simulation in this study combines hydropower technical support, natural gas electricity generation, a 5% reduction in coal consumption, and zero emissions technology. In

other words, if the emissions from coal could be 100% saved by carbon storage technology, the CO₂ emissions would come only from natural gas electricity generation. The CO₂ emissions would then decline to 92,991,586 tons, which is a 66.7% reduction, compared to only building coal-fired power plants.

9.2. Industrial transformation simulations

Five simulations are created and discussed in this section, including 1% to 5% of provincial GDP transformations from a secondary economic sector-based economy (industry) to a tertiary economic sector driven one (services).

The first simulation here shows that with unchanged economic sectoral growth rates, CO₂ emissions in 2025 would quadruple compared to those of 2011 in Jiangxi Province, whereas simulations two through five show emissions savings due to 1%, 2%, 3%, 4%, and 5% transformations, respectively. Through these simulations, it is clear that an economic sector transformation is an effective way to reduce CO₂ emissions. As much as 16.6% of CO₂ emissions could be saved with a 5% transformation of provincial GDP from a secondary economic sector-based economy (industry) to a tertiary economic sector driven one (services).

10. RESULTS OF POLICY MODIFICATION

Through these simulations, the changes that would likely occur under each policy change and the several selected options to reduce CO₂ emissions while maintaining economic growth in Jiangxi Province are apparent. These are summarized below.

Regarding electricity generation, policymakers should change some current strategies to increase electricity supply, while also reducing CO₂ emissions. These changes include: (1) building natural gas electricity generation plants, (2) increasing the electricity supply through renewable energy forms such as solar power, wind power, biogas, and nuclear power, and (3) importing zero emission technology for coal-fired power plants.

In the simulations, one can see that natural gas power generation could reduce the CO₂ emissions of coal-fired power plants by approximately 50%. This is the preferred option before zero emission power plants can be used comprehensively, and it is a popular policy across the world because electricity is produced reliably, consuming factories can operate stably, and the technical level is not very high. This means the province would not have to import the technology from overseas. The provincial authorities could start to estimate how many natural gas-fired electrical generation units they could supply and then build them so that they could begin

operation as early as 2015.

The province should also increase electricity production from renewable energy, which has zero emissions and would be more efficient in the future. This means per capita electricity production would be cheaper than previously. Nuclear energy is a higher risk alternative than the others, which is especially recognized in Asia after the disaster in Fukushima, Japan. As a consequence, the nuclear energy option is not considered.

In addition, the province could cooperate with other countries that have the technology for carbon storage and experience with using that technology. However, the technology does not reduce CO₂ emissions, but rather provides storage underground. Therefore, this option is also not considered further.

Sectoral transformation of the provincial economy, however, is a workable strategy. The province should provide more incentives to attract private and international companies. For example, the government could open provincial-owned land to business investors or provide lower rent for a limited number of company types, while expanding public infrastructure to improve the environment. However, this transformation is not easy. Therefore, the goal of the province could be to implement sectoral transformation at an annual rate of 1% in the first five years, 3% from 2015 to 2020, and 5% from 2020 to 2025. This strategy is feasible because when GDP rises, the demand for services increases as well.

In these ways, the above simulations indicate CO₂ emissions would be reduced by a total of 23,771,064 tons (equal to 2% per year) during the first five years; by a total of 280,954,739 tons (equal to 15.5% per year), which include 5.7% from industry and 9.8% from electricity during the second five-year period; and by a total of 728,169,246 tons (equal to 24.2% per year), which include 9.5% from the industrial upgrade and 14.7% from electricity in the third five-year period.

11. CONCLUSIONS

From the previous sections, it is apparent that CO₂ emissions in China present major issues that need to be addressed. Jiangxi Province is an excellent example of how balancing economic growth and global warming in Chinese provincial development needs to be reformulated. Although this study presents only the energy consumption and economic structure of the province, the case still provides significant insight into the problem of coal consumption. The main topic of interest is to determine how coal consumption can be reduced while simultaneously retaining a high economic growth rate.

However, it is also true that reducing CO₂ emissions in absolute terms is not likely, especially in a developing country. Even though China can be much more efficient in addressing most of the issues involved in CO₂ production, CO₂ emissions will continue to grow in China and Jiangxi

Province along with GDP. While reducing CO₂ emissions in absolute terms is the long-term goal, it is now necessary to focus on how much CO₂ emissions can be reduced per unit of GDP as a first step to moving closer to the goal.

The simulation runs of this study demonstrate that CO₂ emissions would decline if Jiangxi Province adopted new technology for electricity generation and increased the GDP role of the service sector. The CO₂ emissions per unit of GDP would decline from 171 tons/million RMB to 136 tons/million RMB in 2025 without zero emissions technology being adopted. This is almost 21% less than the rate if the province did not take any measures until 2025. If zero emissions technology were to be adopted, however, the CO₂ emissions per unit of GDP would decline from 171 tons/million RMB to 121 tons/million RMB in 2025, a 30% decline in CO₂ emissions.

Based on the energy consumption analysis, over 45% of total coal consumption was used in electricity generation in 2010. In order to reduce this consumption, natural gas-fed electricity generation and hydropower plants (including renewable energy) instead of coal-fired power plants were built into the simulation. The results, then, show that the CO₂ emissions would decline to 156,894,977 tons in 2025, compared to building more coal-fired power plants to increase supply, which would produce 238,027,535 tons. Thus, this policy, if adopted, would reduce CO₂ emissions by 81,132,558 tons, or 34%.

From the industry transformation simulations, it was demonstrated that if 1% of provincial GDP is transformed from industry to services, CO₂ emissions would be reduced by 1.9% in that year; with a 2% transformation, the emissions would decline by 3.9%; with a 3% transformation, CO₂ emissions would be reduced by 5.7%; with a 4% transformation, emissions would decline by 7.6%; and with a 5% transformation,, the reduction would be 9.5% in that year. This means if Jiangxi could implement the transformation of the industrial sector to services by 5%, the provincial CO₂ emissions would decline to 693,378,859 tons in 2025, which would be a savings of about 76,290,132 tons in 2025. Notably, this number is almost equal to the total CO₂ emissions of Jiangxi Province in 2005.

Two conclusions can be drawn from these simulation results. First, the upgrading of electricity generation can reduce CO₂ emissions, especially in coal-dominated China and Jiangxi Province. Second, not only can industry-to-service transformation reduce coal consumption and CO₂ emissions, but it can also maintain the provincial economic growth rate. In China, over 80% of electricity is produced from coal-fired power plants and the total is still increasing. This is one of the reasons why China has surpassed the United States as the country that produces the highest emissions in the world. Although China faces more challenges to reduce its coal consumption because it is a developing country, nevertheless, halting the construction of coal-fired power plants is something China can and should do. Based on the results of these simulations, approximately 30% of emissions of the province can be saved in 2025, which also suggests that

approximately 34% of China's total CO₂ emissions from electricity generation can be saved. Building more natural gas and hydropower/renewable energy electricity generation will not conflict with coal-fired power plants. China has several gas fields located in Changqing and Qinghai that can produce the supply. China also has rich renewable power potential, including hydropower (Yellow River), wind power (Tibetan plateau and coastal areas), and solar power (desert areas and the southern region of China); therefore, it has a high potential for building renewable electricity generation.

Moreover, the simulations show that Jiangxi Province would save approximately 10% of total CO₂ emissions from an industrial transformation policy, which is suitable for second-level Chinese cities. Compared with first level cities such as Beijing, Shanghai, Tianjin, and Xiamen, which have been upgraded to business centers, the industrial GDP of Jiangxi is much higher. Therefore, the policy effects of a transformation policy would not be as significant as in second-level cities. In third level cities, most of the GDP still comes from primary industry (agriculture), which has lower coal consumption, so the policy would not be as effective here as well. Even if the policy were only suitable for second-level cities with high coal consumption, if it is assumed that all second-level cities adopt the policy, there would be a nationwide reduction of approximately 9% of total CO₂ emissions, with a 5% GDP transformation.

From this study, it can be seen that a modified policy of electricity generation and industry upgrading can reduce CO₂ emissions while still maintaining economic growth in China. In addition, if the Chinese government would prepare related policies, such as increasing the rate of public transportation use in coastal cities, improving the specifications of industrial facilities, and retiring facilities in industrial areas that are over 20 years old, these policies would be even more effective. The recommended policy modifications are summarized in Figure 7, below.

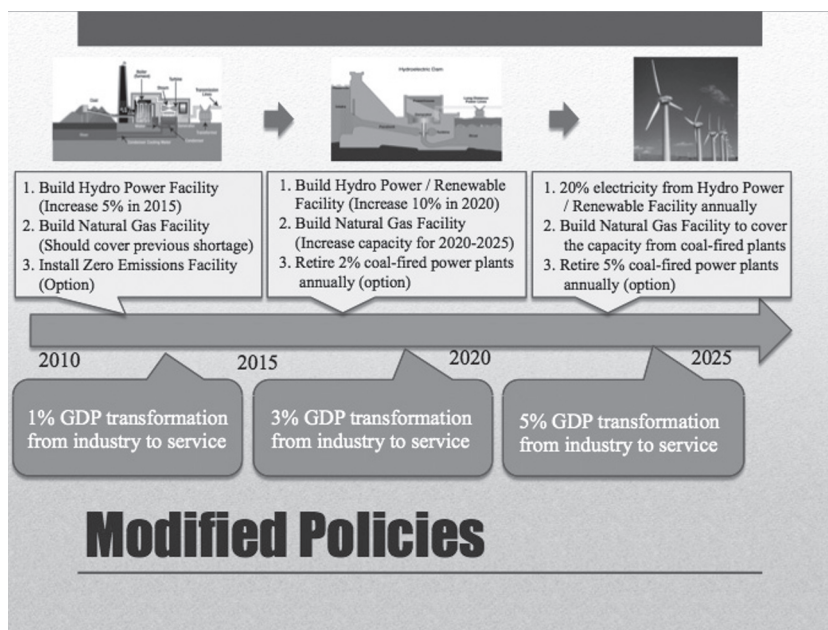


Figure 7. Recommended Modified Policies

Data source: Created by the authors

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