Guangdong's Energy Outlook in China's Context

June 2013

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ENERGY MIX

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About Civic Exchange

Civic Exchange is a Hong Kong-based non-profit public policy think tank that was established in October 2000. It is an independent organisation that has access to policy-makers, officials, businesses, media and NGOs – reaching across sectors and borders. Civic Exchange has solid research experience in areas such as air quality, energy, urban planning, climate change, conservation, water, governance, political development, equal opportunities, poverty and gender. For more information about Civic Exchange, visit http://www.civic-exchange.org.

About the authors

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Preface and acknowledgements

Civic Exchange has a long-standing interest in energy-related issues. Since 2006, we have organised seminars and published reports on energy-related topics to inform and stimulate community discussion. In early 2012, Civic Exchange embarked on another two year energy mix research project, in an attempt to further advance relevant policy deliberation. Civic Exchange will release a series of papers on various topics in 2013, such as Guangdong's energy outlook, Hong Kong people's attitudes towards Hong Kong's energy mix, as well as nuclear energy. A number public forums will also be organised to stimulate discussion and engage the community in constructive dialogues in shaping Hong Kong's energy policy.

With its growing energy demand and heavy reliance on energy imports, Hong Kong needs to carefully consider its long-term energy mix options. On the one hand, Hong Kong needs to work even harder on demand-side management, i.e. energy efficiency and conservation. On the other, we also need to give the supply side further thought. What will our future energy mix look like if Hong Kong aims to provide reliable, safe and affordable energy with better environmental performance? What should the mix among coal, natural gas, nuclear and renewables be?

This report looks at Guangdong's energy outlook and its implications for Hong Kong. While Hong Kong is charting its energy policy, we hope that this paper will add value to the relevant policy deliberation. We thank Dr. Chi-Jen Yang and Dr. Yuan Xu, authors of this report, for their efforts in articulating Guangdong's energy outlook. We also benefited from the insights contributed by the following individuals: Dr. Peter Lam, Dr. Didier Kechemair, Andrew Lawson, participants in the discussion group and the report reviewer. We are grateful to CLP Power Hong Kong Limited for supporting this research project.

We must thank our colleagues Simon Ng and Su Liu for shepherding this research project, Bill Leverett for editing the English version of this report, DESIGNORM for designing the report cover and Rae Leung for laying out the report.

Yan-yan Yip
Chief Executive Officer
11 June 2013

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1 Overarching Goals of China's Energy Policy

1.1 From the 10th Five-year Plan to the 12th Five-year Plan

China included attainment targets in its 11th Five-year Plan

The Five-year Plans for National Economic and Social Development of the People's Republic of China (The Five-year Plans) are the guiding blueprints of China's national development strategy. Chinese national policy makers have increasingly emphasised energy efficiency and environmental goals since the 10th Five-year Plan (2001-2005). Although the 10th Five-year Plan set many quantitative targets for energy and environment, many of them were not met.[1] Starting in the 11th Five-year Plan (2006-2010), the Chinese government decided to include the attainment of energy and environmental targets in local officials' performance evaluations to strengthen the implementation.[2]

China met some important energy and environmental targets in the 11th Five-year Plan

As a result of strengthened incentives and the central government's promotion, target attainments in energy and environment improved significantly compared to those in the previous (9th and 10th) Five-year Plans. In the 11th Five-year Plan, the two most important energy and environmental targets were: (1) 20% reduction in energy intensity, i.e. energy consumption per Gross Domestic Product (GDP); (2) 10% reduction of major pollutants: sulphur dioxide (SO_2) and chemical oxygen demand (COD). At the end of the 11th Five-year Plan, China managed to reduce both pollutants by over 10%, and lowered energy intensity by 19.1%.

The 12th Five-year Plan continues the emphasis on energy efficiency and pollution reduction. For its first time, China included CO_2 targets in the Plan

The target-setting and implementation reveal that Chinese energy policy makers consider energy efficiency and pollution reduction as their top priorities, in addition to sufficient supplies of energy. The 12th Five-year Plan continues the emphasis on energy efficiency and pollution reduction. Major energy-related targets include: 8% reduction of SO_2; 10% reduction of nitrogen oxides (NO_x); 16% reduction of energy intensity; and for the first time in history, the Chinese government includes carbon dioxides (CO_2) intensity (CO_2 emissions per GDP) (17% reduction) as a major target. The inclusion of a CO_2 target indicates that the Chinese government is considering global warming as a serious issue.

Guangdong is charged with higher standards than the national average in terms of pollution reduction

Guangdong, being the most developed province in China, is charged with higher standards than the national average. In the 12th Five-year Plan, Guangdong is required to reduce SO_2 by 14.8%, nitrogen oxides (NO_x) by 16.9%, and to lower energy intensity by 18% and CO_2 intensity by 19.5%.[3,4]

1.2 Energy consumption and economic development

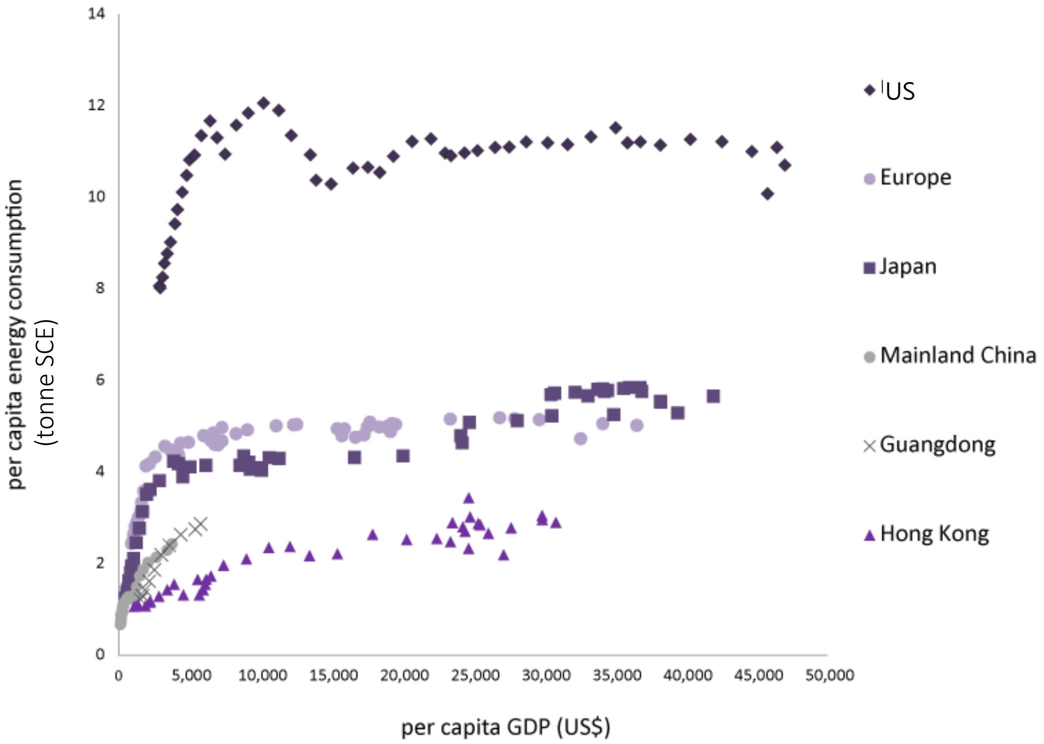
Energy supply is a pivotal issue in national development and the welfare of the people. Energy infrastructure requires huge capital investment and typically has a service life of many decades. The nature of energy policy requires very long-term planning. Changes in energy structure can only be achieved gradually and incrementally.

A general trend: Per capita energy consumption increases with economic development in the early stages, but will slow down or decline as the economy matures

The developmental paths of countries all over the world clearly show that per capita energy consumption increases with economic development. Due to differences in natural resource endowments, infrastructure, lifestyles, and government policies, each country's developmental path may differ.

Figure 1 shows the correlation between per capita energy consumption and per capita GDP in major countries and regions.[5,6] We can clearly see that the growth of per capita GDP invariably accompanies increasing per capita energy consumption in the early stages of economic development. Energy consumption tends to grow more slowly, or even decline, after the economy reaches a certain level of maturity. The figure also shows that China is still in an early stage of economic development. It is expected that China's per capita energy consumption will continue its growth for many years to come.

Figure 1: Per capita energy consumption vs. per capita GDP in major countries and regions (1960-2009)



Sources:
1. World Databank, World Development Indicators (WDI) & Global Development Finance (GDF), World Bank, Washington DC.
2. National Bureau of Statistics (2011), *Guangdong Statistical Yearbook 2011*.

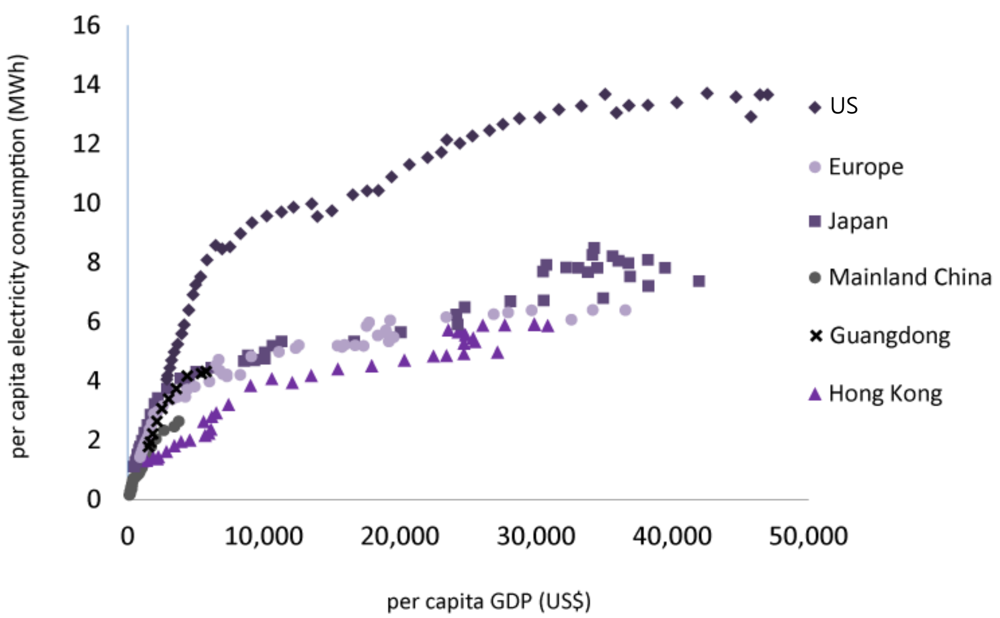
Hong Kong's per capita energy consumption is comparatively low

The economy of Hong Kong is highly specialised in the service sector, which is low in energy use. As a result of the specialisation in service, Hong Kong has unusually low per capita energy consumption as compared to the other economies in Figure 1. Guangdong is a relatively developed province in China. Both Guangdong's per capita GDP and per capita energy consumption are above China's national average. The historical path of Guangdong's energy intensity is largely consistent with China's national average. (The GDP values in this paper are all in current prices.)

Another general trend: The more developed an economy, the higher the reliance on electricity in energy use, the higher its electricity consumption per capita

In less developed rural areas, people often cook and heat their houses with locally available fuels such as crop residues, wood, and coal. Burning solid fuels indoors creates serious indoor air pollution and has very harmful health effects. In addition to the pollution, stoves for solid fuels are generally not as convenient as gas or electric stoves. As the economy develops, most households are likely to switch from solid fuels to gas or electricity. As they get richer, people also tend to use more electrical household appliances (television, refrigerator, air-conditioner, etc.). A general trend in economic histories all over the world is: the more developed an economy, the higher its reliance on electricity in energy use, and the higher its per capita electricity consumption. Figure 2 shows the correlation between per capita electricity consumption and per capita GDP in major countries and regions.[7]

Figure 2: Per capita electricity consumption vs. per capita GDP in major countries and regions (1960-2009)



Sources:

1. World Databank, World Development Indicators (WDI) & Global Development Finance (GDF), World Bank, Washington DC.
2. National Bureau of Statistics (2011), *Guangdong Statistical Yearbook 2011.*

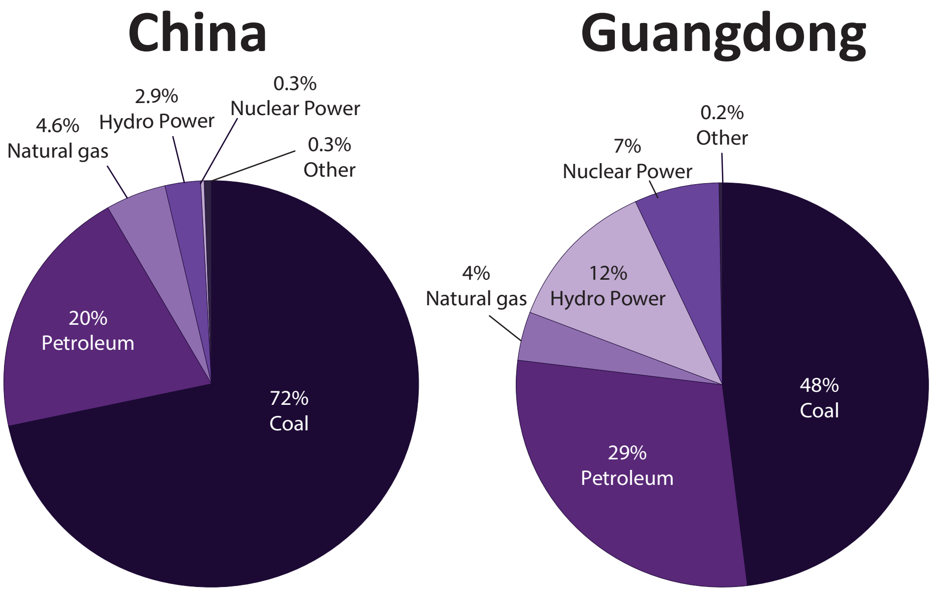
1.3 Reliance on energy imports

Guangdong relies on imports for more than 70% of its total energy demand

China's energy system is highly dependent on coal. In 2010, coal constituted 72% of China's energy consumption, and 48% of Guangdong's. Figure 3 compares the energy mix of China and Guangdong Province. Guangdong stopped coal extraction in 2006. All the coal consumed in Guangdong is imported either from other provinces or from abroad. More than 70% of Guangdong's oil is also imported. Overall, Guangdong relies on imports for more than 70% of its total energy demand. Compared to the national average, Guangdong is more dependent on foreign imports for coal and natural gas, but slightly less dependent on foreign imports for oil.

In 2010, China imported 144 million tonnes of coal, accounting for 4.5% of its consumption. Guangdong imported 4.78 million tonnes of coal from outside, accounting for 29.9% of its consumption. The percentages of import in total consumption for natural gas in China and Guangdong are 49.5% and 75.1% respectively; and 57.4% and 29.0% for oil.[8] Guangdong does not produce nuclear fuel either. However, because nuclear fuels are very compact, a nuclear power plant can easily store years of fuel supplies. For the sake of energy security, nuclear power is typically considered as domestic energy. According to Organisation for Economic Co-operation and Development (OECD)/ International Atomic Energy Agency (IAEA) 2011 estimates, global proven uranium reserves amount to 5.33 million tonnes and the production in 2011 was 55 thousand tonnes (reserve/production ratio: 97 years). China has a proven reserve of 1,660 thousand tonnes, and produced 1,500 tonnes in 2011 (reserve/production ratio: 110 years).[9] With its rapidly increasing nuclear power capacity, China's demand for uranium will increase accordingly. In the future, China will likely become increasingly dependent on imported uranium resources.

Figure 3: The energy mix of China and Guangdong in 2010



Source: National Bureau of Statistics (2011), *China Energy Statistical Yearbook 2011*.

1.4 Energy mix

Despite the many problems associated with using coal...

Hydropower and nuclear power are the major sources of Guangdong's domestic energy. The shares of wind and photovoltaic power in Guangdong's energy supply are very small. Hydropower is not as stable as nuclear power because its output varies with river flows. From an environmental perspective, coal-fired power is the most polluting among major power generating technologies. A coal-fired power plant not only emits sulphur oxides, nitrogen oxides, and particulates, but also a huge amount of carbon dioxide, contributing to global warming. In addition to its air emissions, a coal-fired power plant creates large volume of ashes as solid waste. Reducing the coal-fired power in the electricity mix is therefore an effective way of improving environmental quality.

...it is likely to remain the major source of energy in China

Guangdong Province, and indeed China as a whole, is still a developing economy, which requires a sufficient and stably increasing supply of energy to ensure its development. Coal is likely to remain the major source of energy in China, while petroleum is likely to continue to be essential in transportation. Significant growth in natural gas, hydropower, and nuclear power is expected, but these are likely to play only secondary roles in China's energy mix. Wind and photovoltaic power are likely to grow rapidly, but will still account for minimal shares in the overall energy system.

The three binding targets in the 12th Five-year Plan on energy were not affected by the Fukushima accident

In China's 12th Five-year Plan, there are three binding targets on energy: (1) the share of non-fossil energy in China's primary energy consumption should increase from 8.3% in 2010 to 11.4% in 2015; (2) energy intensity should be reduced by 16%; (3) CO_2 intensity should be reduced by 17%. These three binding targets were unaffected by the Fukushima accident.

1.4.1 Coal

Coal production in China is market-driven and is projected to increase to 3.9 billion tonnes in 2015

According to the 12th Five-year Plan for Energy, China's coal production is projected to increase from 3.24 billion tonnes in 2010 to 3.9 in 2015. Notably, the second figure is just a projection and is not a binding target. The production of coal in China is largely market-driven, where the output is determined by the market demand rather than government plans.

1.4.2 Petroleum

Over 50% of its petroleum is imported

China's petroleum supply is also market-driven. In recent years, China has been relying on imports for more than half of its petroleum. Although the Chinese government technically exercises price controls on gasoline and diesel, it adjusts the controlled prices frequently to largely match international market prices.

1.4.3 Natural gas

Natural gas consumption in 2015 is projected to reach 230 billion cubic meter

China has maintained price controls on natural gas. At the end of 2011, the Chinese central government announced a pilot natural gas pricing reform in Guangdong and Guangxi. The reform is expected to decontrol the natural gas price in these two provinces and significantly boost supply. According to the 12th Five-year Plan for Natural Gas, the natural gas consumption in 2015 is projected (not a binding target) to reach 230 billion cubic meter. The share of natural gas in China's primary energy consumption is expected to increase from 4% in 2010 to 6.5% in 2015.[10]

1.4.4 Renewable energy

Total renewable energy output in 2015 is projected at 478 million tonnes SCE...

China's total renewable energy output in 2015 is projected at 478 million tonnes standard coal equivalent (SCE). Table 1 shows the major targets in the 12th Five-year Plan for Renewable Energies. According to a news report, after Fukushima, the Chinese government raised the 2015 photovoltaic installation target from 5 GW to 10 GW.[11] This target was later revised upward again to 21 GW when the 12th Five-year Plan for Renewable Energies was officially announced. The total upward revision after Fukushima is over fourfold. As shown in Table 1, the revised target for photovoltaic power is expected to generate 8.1 million tonnes SCE of energy in 2015, accounting for 0.2% of China's primary energy consumption.

...accounting for 10.5% of primary energy consumption, leading to a 0.9% gap with the non-fossil energy binding target. Nuclear energy is supposed to fill the gap...

China's total primary energy consumption is projected to increase from 3.25 billion tonnes SCE in 2010 to 4.0 billion in 2015. Renewable energy outputs are expected to account for 10.5% of primary energy consumption, leaving a 0.9% gap with the binding target of 11.4% non-fossil energy. Nuclear power is supposed to fill this gap. In 2010, nuclear power accounted for roughly 0.3% of China's primary energy consumption. To increase nuclear power output to meet 0.9% of China's primary energy consumption, the nuclear power production must increase roughly 3.7 times by 2015.

Table 1: Major targets in China's 12th Five-Year Plan for Renewable Energies

	Installation		Annual Output		1,000 SCE
	Target	**Unit**	**Target**	**Unit**	**tonnes/Year**
Electricity	394,000	MW	1,203,000	GWh	390,000
Hydropower	260,000		910,000		295,800
Wind power	100,000		190,000		61,800
Solar power	21,000		25,000		8,100
Biomass power	13,000		78,000		24,300
Gas			22,000	million m^3	17,500
Biogas (residential)	50,000,000	households	21,500		17,000
Industrial biogas	1,000	system	500		500
Heating and Cooling					60,500
Solar water heater	400,000,000	m^2			45,500
Solar stove	2,000,000	units			
Geothermal					15,000
Heating and Cooling	580,000,000	m^2			
Water heater	1,200,000	households			
Fuel					10,000
Biomass pellets	10,000,000	tonnes			5,000
Bio-ethanol	40,000,000	tonnes			3,500
Bio diesel	10,000,000	tonnes			1,500
Total					**478,000**

Source: State Council (2012), *12th Five-year Plan for Renewable Energy.*

2 International Responses to the Fukushima Accident

2.1 The 'nuclear renaissance'

The Fukushima accident was a severe blow to the so-called 'nuclear renaissance'

The Fukushima nuclear reactor meltdown on 11 March 2011 was a tremendous shock to the whole world. Almost every country with nuclear power immediately started to reexamine its nuclear energy policy after this event.[12] The Fukushima accident was a severe blow to the so-called 'nuclear renaissance'. The United States (US) nuclear power construction industry had been in a long-term hiatus since the late 1970s. In the early 2000s, many power companies started to consider building new nuclear power plants. This phenomenon was touted as a nuclear renaissance. The nuclear renaissance appeared not only in the US, but also in Europe.

2.2 Responses from European countries

Germany, Italy and Belgium phased out nuclear power while some other European countries contiued their commitments to deploying nuclear power

Before the accident, Germany planned to extend the operation of seven existing nuclear power plants beyond their original design lives. After Fukushima, on 15 March, the German prime minister quickly abandoned the plan for life extension and shut down these seven outdated plants immediately. Germany is also planning to shut down its remaining nine nuclear power stations by 2022. It is not yet clear what will be Germany's alternative power sources to replace those nuclear stations and whether Germany will greatly increase CO_2 emissions. Italy used to have nuclear power plants, but has shut down all of them after the Chernobyl accident in 1986. In 2009, Italy planned to build nuclear power plants again. After Fukushima, the plan was vetoed in referendum in June 2011. Italy currently imports nuclear electricity from France. It is not yet clear whether Italy will increase its import of nuclear electricity from France due to the decision of not building nuclear power plants within its borders. In October 2011, Belgium decided to gradually phase out nuclear power after 2015.[13,14] Other European countries, such as the United Kingdom (UK), France, the Netherlands, Finland, the Czech Republic, Hungary, Slovakia and Romania, have reasserted the importance of safety while remaining committed to deploying nuclear power.

2.3 Responses from the United States

US nuclear policy remains unchanged

The US nuclear policy remains largely unchanged after Fukushima, but nuclear power plants in the US are mostly privately owned. The so-called nuclear renaissance largely exists only on paper. So far there are two new nuclear power plants which have started construction in 2012, and these are the only two new plants since the late 1970s. The Fukushima event has probably discouraged many private power companies from building new nuclear power plants. However, the life extension of existing nuclear power plants, due to its profitability, will likely continue as planned (i.e. most old nuclear power plants will apply for life extensions).[15] The US Nuclear Regulatory Commission has approved 20-year life extensions for 71 reactors.

2.4 Responses from Asian countries

2.4.1 Japan and other Asian countries

Japan made no immediate plan to abandon nuclear energy, but the prospect of nuclear power in Japan is highly uncertain

The Fukushima accident was a huge shock to Japan's nuclear power development plans. However, Japan's policy response is not yet clear. Before the accident, Japan relied on nuclear power for 30% of its electricity and was planning to build more nuclear plants. The original plan was to increase its reliance on nuclear power to 50%. After the accident, Japan made no immediate plans to abandon nuclear energy. Faced with strong antinuclear pressure, the Japanese government was forced to shut down some nuclear power plants for safety inspections. After the inspections, however, local opposition often delayed the restart of the plants. From 5 May to 1 July 2012, Japan was temporarily without any nuclear power.[16] It was once reported that the Japanese government was considering a plan to totally phase out nuclear power by 2040, but faced strong opposition from the industries, who are worried about higher electricity prices if nuclear power is phased out. The prospect of nuclear power in Japan remains highly uncertain.[17] Most other Asian countries, such as Korea and India, remain committed to developing nuclear power.

2.4.2 China

China ordered a comprehensive safety inspection of all nuclear facilities after the Fukushima accident

After the Fukushima accident, China suspended the approval of new nuclear projects, and ordered a comprehensive safety inspection of all nuclear facilities. According to their report, no serious safety issues were discovered in the inspection. Immediate safety improvements are mainly engineering measures, which include: waterproofing and embankments; adding mobile and emergency power supplies and mobile pumps; increasing facilities' earthquake resistance, etc. The mid- to long-term measures include: improving flood-resisting structures; further assessing earthquake and tsunami risks in potential sites; improving accident prevention and mitigation measures; enhancing information transparency; and conducting safety analyses of external impacts, etc.[18]

China also published on a report stipulating the overarching principles for future nuclear projects

In addition to the safety inspection, the Chinese government also published a report on *The 12th Five-year Plan on Nuclear Safety and Radioactive Contamination Prevention and Treatment and the 2020 Vision*. This report not only discusses engineering and management measures for safety, but also stipulates the overarching principle for future nuclear power projects as 'adopting more mature and advanced reactor types, increasing inherent safety' and 'reasonably control the speed and scale of deployment before the technology with the most advanced safety standards has been fully tested.'

Most mature (CPR1000) and most advacned (AP1000) nuclear reactors

Among the major nuclear reactor types in China's existing and planned stations, the most mature is the CPR1000, while the most advanced are the third-generation designs AP1000 and Evolutionary Pressurized Reactor (EPR).[19] After Fukushima, some have called for abandoning all new CPR1000 projects and replacing them with the more advanced third-generation designs.[20] The maturity and advancement of a design are indeed conflicting features. The most mature design is usually not the most advanced. The most advanced design is typically not the most mature.

China developed its own brand CPR1000, which is used in Lingao #2

The meltdown reactors at Fukushima Daiichi Nuclear Plant are boiling water reactors (BWR), a second-generation design originally developed by General Electric in the 1950s. BWR is the second most popular design among existing nuclear power plants in the world. Mainland China, however, does not have any BWR reactors. The most popular reactor type in China is pressurised water reactor (PWR) (also of second generation), which was originally developed by Westinghouse. In the 1970s, when France decided to deploy nuclear power on a large scale, the French government went through a series of debates and eventually decided to license the Westinghouse PWR design and made it the standard design for French nuclear power stations. After the Three Mile Island and Chernobyl accidents, countries all over the world have implemented various retrofits to enhance nuclear power safety. Although the main reactor structure remains unchanged, various auxiliary safety systems were added. The Daya Bay and the Lingao #1 nuclear stations adopted the improved French PWR design. Since the introduction of the French PWR design, the China Guangdong Nuclear Power Group has indigenised and improved upon the French design and developed its own brand CPR1000, which is used in Lingao #2.

AP1000 theoretically being the most advanced, but it has not been tested in real world.

Learning the lessons from Three Mile Island and Chernobyl, as well as the operational experience in existing second-generation stations, Westinghouse fundamentally redesigned the nuclear reactor with greatly improved safety standards, at least in theory. The new (third-generation) design is AP1000. Although AP1000 is commonly acknowledged as the most advanced, it suffers a major shortfall: lack of maturity. The world's first AP1000 reactor is still under construction in Sanmen, Zhejiang, with expected completion in 2015. Although theoretically being the most advanced, the AP1000 design has not been tested in real-world operation.

There has been a debate over 'one-step' or 'two-step' strategy in terms of near-term nuclear power deployment

Between 2003 and 2005, the Chinese policy makers went through a series of studies and debates on nuclear power strategy, and eventually chose AP1000 as the future standard design for China. Regarding the near-term deployment of nuclear power, there has been a debate over 'one-step' or 'two-step' strategy.[21] 'One-step' strategy is to suspend construction of second-generation reactors and wait until the AP1000 demonstration is completed, and then deploy AP1000 on a large scale. The advantage of the 'one-step' strategy is standardisation around the most advanced design, which in theory is much safer. The disadvantage is that it requires a long suspension of nuclear power deployment until the AP1000 demonstration becomes successful. The 'one-step' strategy is likely to postpone the deployment schedule significantly.

The 'two-step' strategy is to continue with the deployment of second-generation reactors while conducting the AP1000 demonstration. The advantage is no delay in nuclear power deployment. The disadvantage is a more complex nuclear system with various designs. In addition, the older reactors may occupy many good sites and limit the room for deploying the more advanced reactors. Before the Fukushima accident, China was following the 'two-step' strategy. After Fukushima, many have called for a return to the 'one-step' strategy, which the Chinese policy makers eventually adopted.

The 'two-step' approach was eventually abandoned

In October 2012, China's State Council approved the revised *Nuclear Power Mid- to Long-term Plan (2011–2020)*, and resumed nuclear power plant construction. The revised plan announced that China would not build any inland nuclear project before 2015. All new nuclear power projects must meet third-generation safety standards. The original 2015 nuclear installation target (40GW) remained the same. The 2020 target was recently revised to 58 GW installed and 30 GW in construction (the 2020 target set under the original plan in 2007 was 40GW).[22] The 'two-step' approach was abandoned.[23]

China's overaching energy policy goals remain unchanged after Fukushima

After Fukushima, the approval of new nuclear projects during the 12th Five-year Plan is likely to be slightly lower than pre-Fukushima estimates, while the long-term targets will remain largely the same. China's overarching energy policy goals, i.e. energy saving and emissions reduction, also remain unchanged after Fukushima.

3 Guangdong's Energy Development Plan

3.1 Guangdong's development path and energy demand

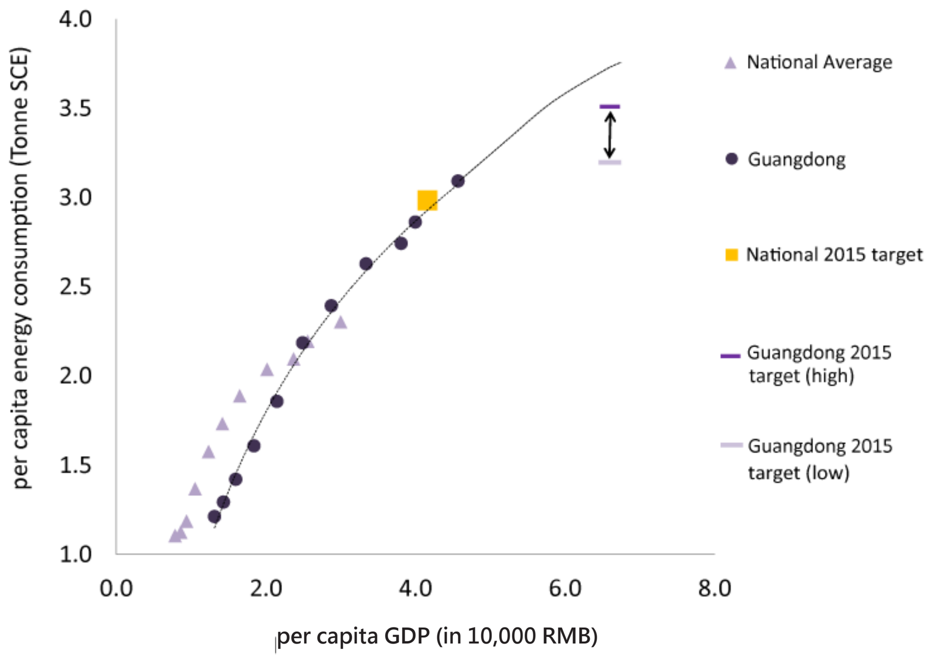
Guangdong's reliance on manufacturing makes it hard to meet its energy and environmental goals

Figure 4 compares the historical path of per capita energy consumption versus per capita GDP in Guangdong with China's national average.[24,25] The targets of national and Guangdong provincial 12th Five-year Plans are also indicated in Figure 4. The national target is largely an extrapolation of the historical path, while Guangdong's target slightly deviates from its historical path, revealing the policy makers' intention to lower energy intensity. Guangdong is the largest economy among all Chinese provinces. It is also one of the fastest growing provinces. The economic structure of Guangdong is very similar to China's national average, with a slightly lower proportion of primary sector industry (agriculture, forestry, fishery, and animal husbandry), and slightly higher share of secondary sector industries (manufacturing, construction and mining) (Figure 5).[26] For comparison, the economy of Hong Kong is highly concentrated in the service sector, with a small secondary sector and negligible primary sector. Generally speaking, a more developed economy tends to have a higher proportion of the tertiary (service) sector. The secondary sector is typically more energy intensive than the service and primary sectors. Guangdong's reliance on manufacturing industries makes its energy and environmental goals rather challenging.

Economic activities in Guangdong are highly concentrated in the PRD

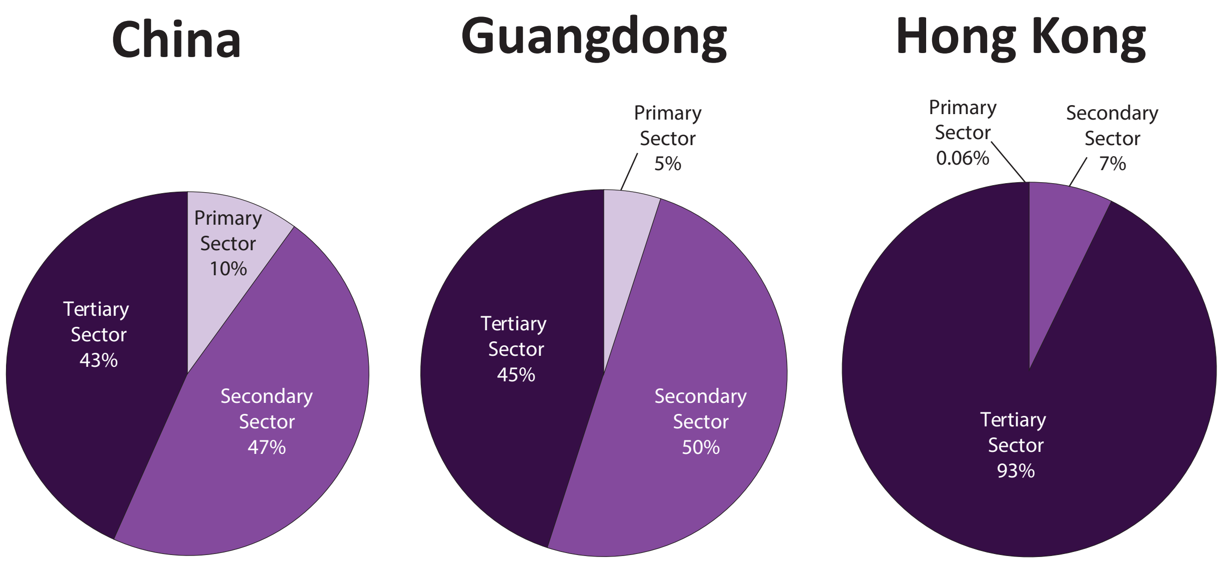
Guangdong Province is traditionally divided into 4 regions: the Pearl River Delta (PRD) (comprising the following cities: Guangzhou, Shenzhen, Foshan, Dongguan, Zhuhai, Zhongshan, Huizhou, Jiangmen, Zhaoqing); the eastern region (Shantou, Shanwei, Jieyang, Chaozhou); the western region (Yangjiang, Maoming, Zhanjiang); and the mountainous region (Meizhou, Heyuan, Shaoguan, Qingyuan, Yunfu). Guangdong's economic activities are highly concentrated in the PRD. The other regions are much less developed. Figure 6 shows the 2010 per capita GDP in each and every city in Guangdong.[27]

Figure 4: National and Guangdong's paths of per capita GDP vs. per capita energy use (2000-2010), and their 12th Five-year Plan targets



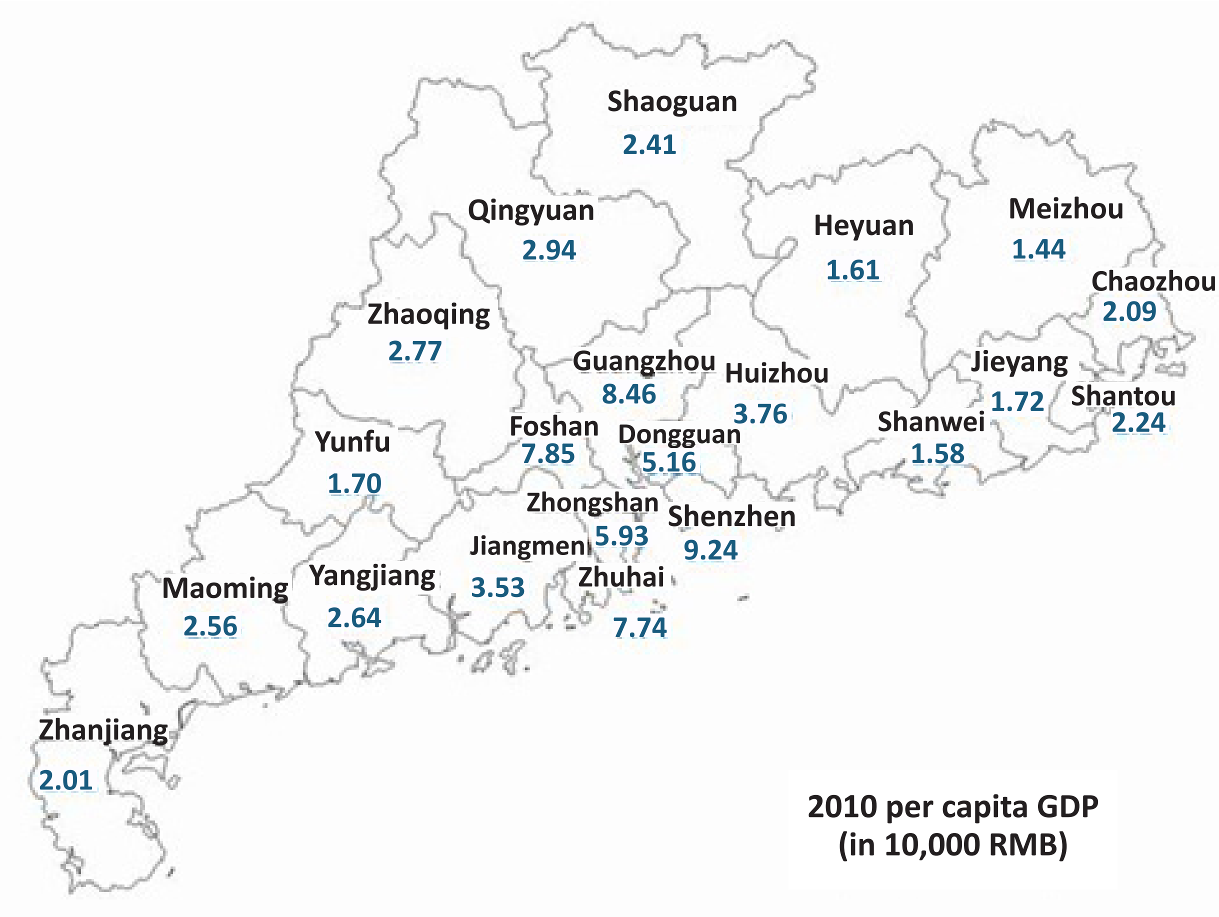
Sources:
1. State Council, *The Outline of the 12th Five-year Plan for National Economic and Social Development of the People's Republic of China*, Beijing.
2. Guangdong People's Government, *The 12th Five-year Plan for Energy Development of Guangdong*, Guangzhou.
3. National Bureau of Statistics (2011), *Guangdong Statistical Yearbook 2011*.

Figure 5: Industrial structure in Mainland China, Guangdong, and Hong Kong



Sources:
1. National Bureau of Statistics (2011), *China Statistical Yearbook 2011*.
2. National Bureau of Statistics (2011), *Guangdong Statistical Yearbook 2011*.

Figure 6: Per capita GDP in Guangdong cities

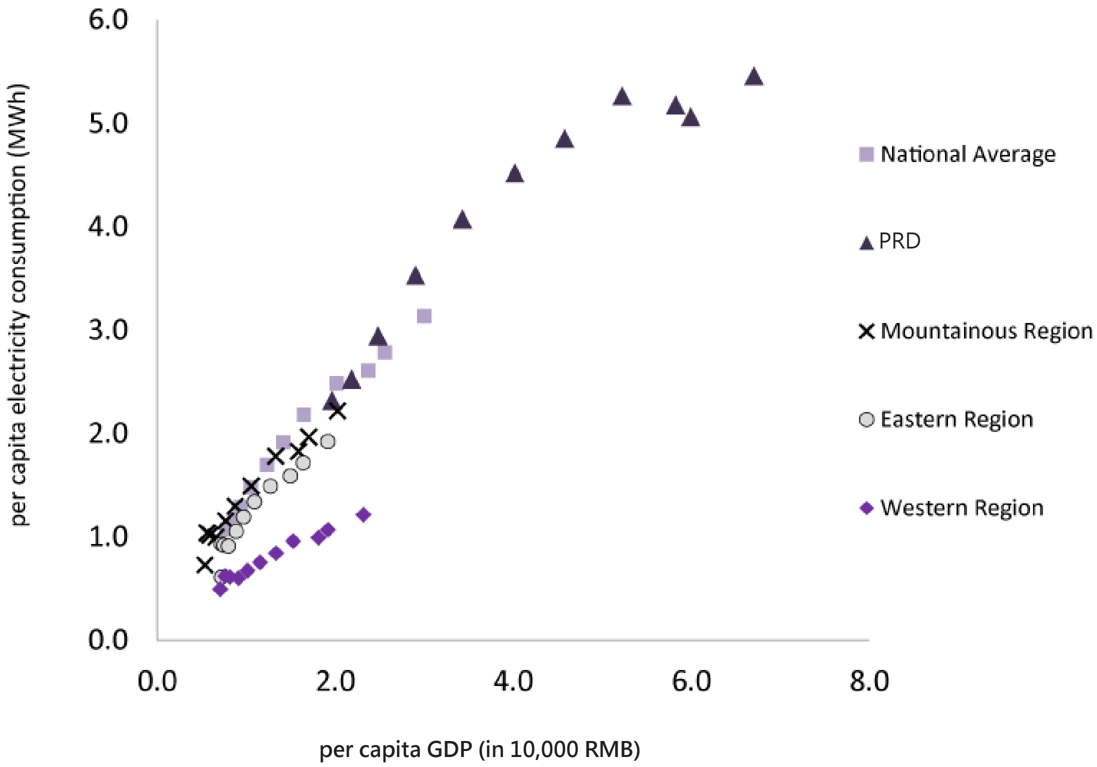


Source: National Bureau of Statistics (2011), *Guangdong Statistical Yearbook 2011.*

The more developed regions need more electric power. The Western region will likely consume more energy as more energy-intensive industries are moving from the PRD to the region

The lifestyles and patterns of energy consumption in each region are directly related to the levels of economic development. The more developed regions demand more electric power. Figure 7 shows the historical paths of per capita electricity consumption versus per capita GDP in the four regions in Guangdong. The PRD, the eastern, and the mountainous regions, although with differing levels of economic development, are all largely following the same path of development. This path is also consistent with the national average. The western region appears to move on a path of significantly lower electricity consumption. In recent years, many energy-intensive industries have relocated from the PRD to the western and northern regions. The western region may not be able to remain on its low-electricity path in the future.

Figure 7: Paths of per capita electricity consumption vs. per capita GDP in Guangdong's four regions (2000-2010)



Source: National Bureau of Statistics (2011), *Guangdong Statistical Yearbook 2011*.

3.2 The South China power grid

Guangdong is a net importer of electricity, with roughly one-fifth coming from Yunnan and Guizhou...

Guangdong is the demand centre of the South China power grid, which covers five provinces: Guangdong, Guangxi, Yunnan, Guizhou and Hainan. Table 2 is the electricity balance table of the five provinces in 2010.[28] According to the electricity balance, Guangxi and Hainan are largely self-sufficient in electricity. Guangdong is a net importer on the grid, while Yunnan and Guizhou are net exporters of electricity. Roughly one-fifth of Guangdong's electricity is transmitted from the western provinces (Yunnan and Guizhou).

... and Yunnan and Guizhou mainly rely on hydropower and thermal power respectively

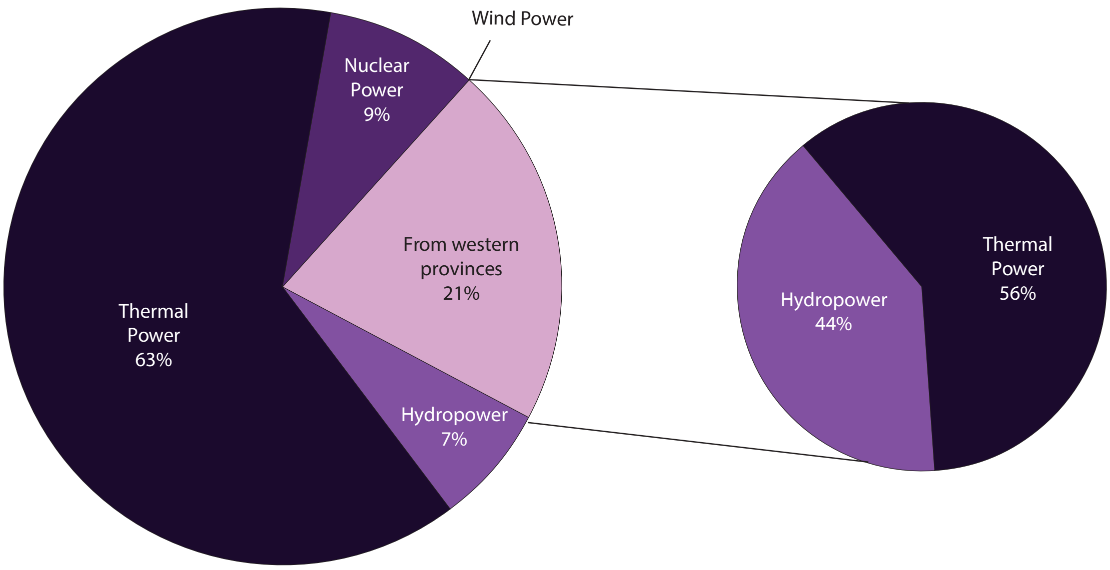
According to 2010 statistics, fossil-fired thermal power contributes the largest share in Guangdong's electricity supply, followed by nuclear power and hydropower. As mentioned previously, Guangdong's electricity imports mainly come from Yunnan and Guizhou. Both Yunnan and Guizhou rely on two main power sources: thermal power (predominantly coal-fired power) and hydropower. Yunnan has more hydropower than thermal power, while Guizhou has more thermal power than hydropower. Thermal power's share is slightly higher than hydropower when the power outputs in Yunnan and Guizhou are summed up. Figure 8 shows Guangdong's electricity by source.[29]

Table 2: Electricity balance table of the South China Grid (Hong Kong not included)

Unit: 10^8 kWh	Guangdong	Guangxi	Guizhou	Yunnan	Hainan
Non-fossil power	613.4	475.3	416.6	818.4	21.7
Fossil-fired power	2,589.9	556.9	969.1	546.5	136.2
From other provinces	856.8	46.0	0.3	4.0	0.1
From other countries				17.2	
To other provinces (-)		85.0	550.4	325.7	2.1
To other countries (-)				56.3	
Loss (-)	217.1	61.5	60.9	71.8	10.0
Final consumption	**3,843.1**	**931.7**	**774.6**	**932.2**	**148.2**

Source: National Bureau of Statistics (2011), *China Energy Statistical Yearbook 2011.*

Figure 8: Sources of electricity consumed in Guangdong in 2010



Source: China Electricity Council (2010), Electric Power Industry Statistical Compilation, Beijing.

4 Guangdong's Energy Strategy under the Constraints of Emission and Energy Saving Targets

4.1 Two-pronged approach to reduce energy consumption and pollution

Both demand- and supply-side measures are used to reduce energy consumption and pollution in Guangdong

Policy measures for saving energy and reducing pollution can be classified into two main categories: demand-side and supply-side. Examples of demand-side measures include energy efficiency standards for household appliances and subsidies for retiring outdated/inefficient appliances. China has made significant improvements in the past few years,[30] and Guangdong Province is no exception. The purpose of these measures is to reduce energy consumption and lower pollution through improving energy efficiencies. Demand-side management aims to change consumers' behaviour, which is rather challenging.

Demand-side management is challenging while regulating the supply-side is relatively straight forward in China

Regulating the supply side of energy is relatively straightforward, particularly in China, where the electric power sector is largely state owned. The Chinese government can directly mandate targets for energy saving and emissions reduction in the electric power sector's development plans. Table 3 lists Guangdong's 2010 statistics and 2015 targets for consumption of each primary energy resource and electric power generation capacities.[31] In the foreseeable future, coal will remain the largest source of energy in Guangdong.

Table 3: Guangdong's primary energy sources and electric power capacities

	2010	2015 target	Unit
Primary energy			
Coal cosumption	10,524	16,600 - 17,730	10,000 tonne SCE
Petroleum consumption	5,560	5,600 - 5,730	10,000 tonne
Gases	2,350	4,280 - 6,130	10,000 tonne SCE
Include: Natural gas	95	300 - 430	10^8 cubic meter
LPG	560	250 - 350	10,000 tonne
Electricity			
Total electricity consumption	406,012.0	630,000.0	GWh
Thermal power capacity	52.9	70.0	GW
Include: Coal-fired	48.3	55.0	GW
Gas-fired	4.7	15.0	GW
Nuclear power capacity	5.0	13.8	GW
Hydropower capacity	12.2	15.4	GW
Dedicated capacity in western provinces	23.0	36.0	GW
Wind power capacity	0.8	3.8	GW
Photovoltaic power capacity	0	0.1	GW

Sources:
1. National Bureau of Statistics (2011), *Guangdong Statistical Yearbook 2011*.
2. Guangdong People's Government, *The 12th Five-year Plan for Energy Development of Guangdong*,Guangzhou.
3. China Electricity Council (2010), Electric Power Industry Statistical Compilation, Beijing.

4.2 The availability of energy

4.2.1 Coal

Coal will remain the largest source of energy in Guangdong in the foreseeable future

During the 11th Five-year Plan (2006-2010), China retired 73.8 GW of small and outdated coal-fired power plants. Among them, 9.64 GW of the retirement occurred in Guangdong, the highest amount of any province. In 2010, the average efficiency of Guangdong's coal-fired power plants was 325 grams (SCE) per kWh, putting Guangdong in seventh place among the provinces.

4.2.2 Wind and photovoltaic power

Wind power and photovoltaic power are expected to increase, but will remain insignificant in Guangdong's total energy shares

In Guangdong's 12th Five-year Plan for Energy, the largest absolute increases in power generating capacities are in natural gas-fired power, followed by nuclear power. Although wind power and photovoltaic power are expected to increase several-folds, their total shares in the electricity mix will remain small.

4.2.3 Natural gas and liquefied natural gas

Natural gas supply will increase (replacing LPG) and there will likely be a dramatic increase in natural gas consumption

In the coming years in Guangdong, the biggest change in the energy economy is likely to be the dramatic increase of natural gas consumption. The Shenzhen Dapeng Liquefied Natural Gas (LNG) terminal in Guangdong (completed in 2006) is the first LNG terminal in Mainland China. Additional LNG terminals in Zhuhai and Jieyang will be completed in the coming years, which will greatly increase natural gas supply to Guangdong during the 12th Five-year Plan period (2011-2015). Some of the increased natural gas supply will be used for power generation, while the rest will mainly be used as residential cooking fuel. Many cities in Guangdong are currently converting their Liquefied Petroleum Gas (LPG) pipelines to deliver natural gas. The relatively more expensive LPG will be gradually replaced by natural gas, leading to a decline in the consumption of LPG in Guangdong in the coming years.

4.2.4 Nuclear power

a) Nuclear power's niche

Nuclear power offers advantages in siting and security of supply. It occupies a niche in Guangdong's low carbon strategy

Among the major energy sources with low air emissions, nuclear power offers several advantages in siting and security of supply. The siting of hydropower projects are constrained by the hydrology, geology and topography. The remaining available sites for hydropower in Guangdong are limited. The output of a hydropower plant is also limited by the seasonally varied river flow and would be severely constrained by a drought. Wind power and photovoltaic power are still relatively more expensive and their outputs vary with weather. Guangdong relies primarily on seaborne LNG import for its natural gas supply. The LNG prices in East Asia are relatively expensive and pegged to the volatile oil prices. Compared to its alternatives, nuclear power offers a relatively affordable and stable (with no impact from weather and seasonality) electricity supply. Although the siting of a nuclear power plant is subject to stringent requirements on geological stability and available cooling water resources, the constraints in siting are compensated by the enormous capacity of each site. Because of its unique advantages, nuclear power occupies a special niche in Guangdong's low carbon strategy.

b) Existing and planned nuclear power stations in Guangdong

Two nuclear power plants currently in operation in Guangdong: Daya Bay and Lingao

Guangdong Province has one of the first nuclear power stations in Mainland China. The Daya Bay Nuclear Power Station was brought on line in 1994, with 70% of its output exported to Hong Kong. Lingao Nuclear Power Station is only 1 km away from the Daya Bay station. The two reactors of Lingao #1 started operation in 2002 and 2003. The two reactors of Lingao #2 started in 2010 and 2011. Daya Bay and Lingao are currently the only two operating nuclear power stations in Guangdong, with a combined installed capacity of 6.1 GW.

Two more under construction: Taishan and Yangjiang

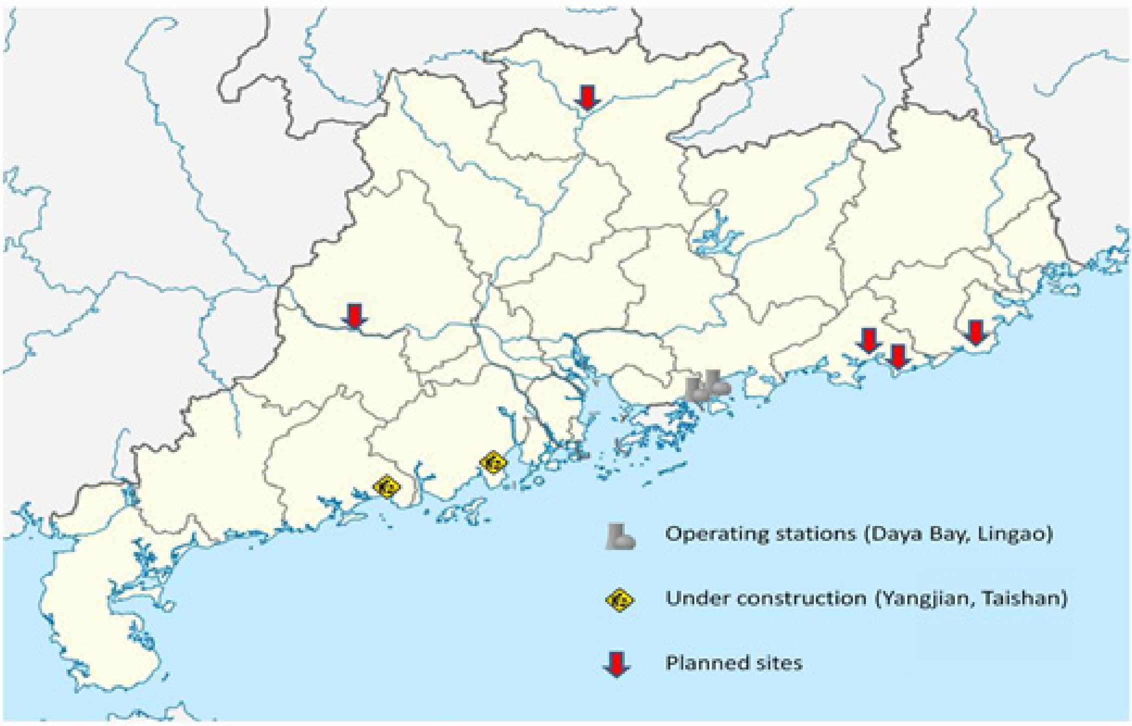
Two nuclear power plants (Taishan and Yangjiang) are currently under construction in Guangdong (Table 4 and Figure 9). The construction of Taishan commenced in 2009, with two reactors expected to be completed in 2013 and 2014. The construction of the first three reactors in Yangjiang started between 2008 and 2010. The first two reactors are expected to be completed in 2013, and the third in 2015. The construction of the fourth reactor in Yangjiang was originally scheduled to begin in 2011, but was postponed to November 2012 because of the Fukushima accident. Another two reactors in Yangjiang Phase 2, which were originally scheduled to start construction during this period, were also postponed. The originally scheduled completion in 2017 is likely to be delayed.

Table 4: Nuclear power stations in Guangdong

	No. of Reactors	Total Capacity (MW)	Reactor Type	Operation Date
Operating				
Daya Bay	2	1,968	PWR (French M310)	1994
Lingao #1	2	1,980	PWR (French M310)	2002, 2003
Lingao #2	2	2,000	CPR-1000	2010, 2011
Under Construction				
Yangjiang #1	4	4,320	CPR-1000	2013, 2015, ?(#4)
Taishan #1	2	3,500	EPR	2013, 2014
Planned				
Yangjiang #2	2	2,160	~~CPR-1000~~ AP1000?	2017 (?)
Shaoguan	4	5,000	AP1000	?
Lufeng #1	2	2,160	~~CPR-1000~~ AP1000?	?
Taishan #2	2	3,500	EPR	?
Lufeng #2	4	4,320	~~CPR-1000~~ AP1000?	?
Haifeng	2			?
Jieyang	4	5,000	AP1000	?
Zhaoqing				?

Source: China Nuclear Power Information Network, http://www.heneng.net.cn/index.php?mod=npp

Figure 9: Locations of nuclear power stations in Guangdong



Source: China Nuclear Power Information Network, http://www.heneng.net.cn/index.php?mod=npp

5 Carbon Leakage in Guangdong-Hong Kong Nuclear Power Cooperation

Legally binding CO_2 intensity target was stipulated in the 12th Five-year Plan

In 2010, the Environment Bureau of the Hong Kong Special Administrative Region government proposed *Hong Kong's Climate Change Strategy and Action Agenda*, which specifies Hong Kong's CO_2 reduction target. The 2020 target is to reduce CO_2 intensity (CO_2 emissions divided by GDP) by 50-60% from its 2005 level. A key strategy to achieve this target is to increase the use of nuclear power from 23% in 2009 to 50% in 2020, while reducing coal-fired thermal power from 54% to less than 10%.[32] China's national 12th Five-year Plan stipulates a legally binding CO_2 intensity target, which is to reduce 17% in 2015 from the 2010 level, and Guangdong's 2015 target is a 19.5% reduction, which is the highest among all provinces.[33] Nuclear power also plays a pivotal role in the national and Guangdong CO_2 strategies.

How Hong Kong and Guangdong may collaborate in their CO_2 reduction strategy remains unclear

How Hong Kong and Guangdong may collaborate in their CO_2 reduction strategy is still unclear. There is a potential for double counting in Hong Kong's plan to increase the import of nuclear power as a means to reduce carbon emissions. What we mean by 'double counting' is that both Hong Kong and Guangdong may count the same reduction from nuclear power as their own contribution. The nuclear power consumption in Hong Kong comes from Daya Bay in Guangdong. Whether Hong Kong's low-carbon electricity from Daya Bay should be Hong Kong's or Guangdong's contribution is arguable. There will be double counting if both sides counted the same reduction as their own. Furthermore, from Guangdong's perspective, exporting nuclear power reduces its available low-carbon energy resources. In order to meet the increasing demand for electricity, Guangdong must acquire additional energy resources, most likely coal. To meet its own CO_2 reduction target, Guangdong will need additional efforts if it is going to increase nuclear power sales to Hong Kong.

Increased import of nuclear power to Hong Kong may mean moving Hong Kong's emissions to Guangdong

Currently, most of the nuclear electricity imported to Hong Kong is consumed in Kowloon and the New Territories, which are served by the CLP Group. Increased nuclear power imports are likely to replace the output from the four 677 MW coal-fired generators at the Castle Peak Power Station. According to this scenario, although the increased import of nuclear electricity will reduce the CO_2 emissions from Hong Kong, it is likely to increase those in Guangdong, or at least make it more difficult to meet its target. The average thermal efficiency in Guangdong's coal-fired power plants is largely at the same level as the Castle Peak power station. Hong Kong's CO_2 reduction through importing more nuclear power is equivalent to moving Hong Kong's emissions to Guangdong. If we combine the CO_2 emissions from Hong Kong and Guangdong, the total benefit of increasing Hong Kong's nuclear power import to the two parties may be very little or non-existent.

Whether or not Hong Kong increases its nuclear power import, China and Guangdong are likely to continue with their deployment schedules

The question of whether Hong Kong should increase its use of nuclear power is the subject of many debates. The discussions in Hong Kong are in fact mostly about whether to import more nuclear electricity from Guangdong. Hong Kong's nuclear power policy is obviously different from countries who are deciding whether to build nuclear power plants on their own territories. Because China and Guangdong are faced with rapid growth in electricity demand and pressure to lower emissions, their nuclear power deployment schedules are likely to continue with or without the additional sales to Hong Kong. Nevertheless, due to Hong Kong's special political status, China's central government may pay more attention to public opinion in Hong Kong in its nuclear siting decisions. The discussions in Hong Kong tend to have great influence on public opinion in the Mainland, and particularly in Guangdong. Mass protests over environmental issues in the Mainland have become more frequent in recent years. Public opinion is increasingly influencing policy making. For example, in 2007, local opposition caused the suspension of the Rushan nuclear power project in Shandong. So far there has been no such protest against nuclear power in Guangdong.

Straightly speaking, Hong Kong could be self-sufficient in electricity, but electricity supply reliability will not be assured

The CLP Group owns 25% of the Daya Bay Nuclear Power Station and imports 70% of its generated power (among its total 1,968 MW installed capacity, 1,378 MW is designated for Hong Kong).[34] Meanwhile, Guangdong also imports electricity from Hong Kong, particularly to meet peak summer demand. For example, in 2005, Hong Kong provided 1,500 MW of peaking capacity to Guangdong.[35] From a strict capacity perspective, Hong Kong does not need to import electricity from Daya Bay. In 2011, Hong Kong's peak demand was 10,296 MW, while its installed capacity (excluding Daya Bay) were 11,246 MW. Hong Kong could be self-sufficient in electricity with a 9.2% reserve margin,[36] though at this percentage electricity supply reliability in Hong Kong will not be well assured. However, almost all the power generators in Hong Kong are powered with fossil fuels (6,608 MW coal-fired; 3,750 MW gas-fired; 300 MW diesel-fired; 1.35 MW wind and solar power; 600 MW pumped hydro in Guangzhou). Importing nuclear electricity is the easiest way to reduce fossil fuel consumption and lower air emissions.

From a life cycle perspective, different energy sources lead to very different emissions in CO_2, SO_2, NO_x, and particulate matter. On average, coal, natural gas, and nuclear power emit in the ratio of 1 kg, 0.4 kg, and 0.01 kg of CO_2 respectively.[37] Natural gas and nuclear power are much cleaner than coal-fired power on most pollutants. The most significant pollutant from natural gas is NO_x, and it emits about one-third as much as coal. Hong

Kong's two coal-fired power stations (Castle Peak and Lamma) have undergone significant improvements in pollution controls. Four of the eight generators in Castle Peak and six of the eight in Lamma have been equipped with flue gas desulphurisation facilities. These facilities have lowered the SO_2 emissions in Hong Kong. The generators without desulphurisation are primarily reserved for peaking capacity. If Hong Kong reduces its imports of nuclear electricity, these dirtier facilities are likely to be operated more frequently.

6 Conclusion

China's long-term national energy policy should remain unchanged

China has made no significant change in its national energy policy targets after the Fukushima nuclear accident. China's major policy response to Fukushima is to strengthen nuclear safety, in particular, abandoning the second-generation nuclear reactor design. In the near-term, China may slow down its nuclear construction schedule, while the long-term targets should remain largely the same.

Guangdong must take up more responsibility in saving energy and reducing emissions...

Guangdong, being one of the most developed provinces in China, must shoulder a greater responsibility than many other provinces in saving energy and reducing emissions. In order to achieve its targets, Guangdong is expected to expand natural gas-fired and nuclear power generation, as well as purchase more electricity from its western neighbour provinces. Although wind power and photovoltaic electricity are expected to increase rapidly, their shares in the overall energy mix will remain small, playing only supplemental roles in Guangdong's emissions reduction plan.

...Hong Kong's emission reduction target must be considered in the context of Guangdong's system

Hong Kong's emission reduction target must be considered in the context of Guangdong's energy system. If Hong Kong relies on buying more nuclear power from Guangdong to reduce its carbon emissions, it is likely only transferring Hong Kong's emissions to Guangdong, with little or no contribution to fighting global warming.

Endnotes

1. Anon., "「十五」兩大指標「落空」，考驗政府執行力", China.com.cn, 10 March 2006, http://big5.china.com.cn/chinese/news/1149707.htm, accessed 26 April 2013. (Chinese only)

2. Liu, Jianguo and Diamond, J. (2008), "Revolutionizing China's Environmental Protection", *Science*, Vol.319, No. 5859, pp. 37-38.

3. State Council of PRC (2011), "Notice on the 12th Five-year Plan for Energy Saving and Emission Reduction", 31 August 2011, http://big5.gov.cn/gate/big5/www.gov.cn/zwgk/2011-09/07/content_1941731.htm, accessed 26 April 2013. (Chinese only)

4. State Council of PRC (2012), "Notice on the 12th Five-year Plan for Greenhouse Gas Control", 31 January 2012, http://big5.xinhuanet.com/gate/big5/news.xinhuanet.com/2012-01/13/c_111436437.htm, accessed 26 April 2013. (Chinese only)

5. World Databank of the World Bank, "World Development Indicators (WDI)" and "Global Development Finance (GDF)".

6. National Bureau of Statistics of PRC (2011), "Guangdong Statistical Yearbook 2011", http://www.gdstats.gov.cn/tjnj/2011/ml_e.htm, accessed 9 May 2013.

7. See notes 5 and 6.

8. National Bureau of Statistics of PRC (2011), *China Energy Statistical Yearbook 2011*.

9. OECD/IAEA (2012), "Uranium 2011: Resources, Production and Demand", http://wwweth.cern.ch/~dittmar/thoiry/U2011.pdf, accessed 9 May 2013.

10. State Council of PRC (2012), "12th Five-year Plan for Natural Gas", http://zfxxgk.ndrc.gov.cn/Attachment/%E5%A4%A9%E7%84%B6%E6%B0%94%E5%8F%91%E5%B1%95%E2%80%9C%E5%8D%81%E4%BA%8C%E4%BA%94%E2%80%9D%E8%A7%84%E5%88%92.pdf, accessed 26 April 2013. (Chinese only)

11. Li (2011), "「十二五」光伏發電裝機目標量上調至10吉瓦", Finance Channel of MSN China, 3 June 2011, http://msn.finance.sina.com.cn/cjyw/20110603/0940107325.html, accessed 26 April 2013. (Chinese only)

12. Schneider, M., Froggatt, A. and Thomas, S. (2011), *Nuclear Power in a Post-Fukushima World - 25 Years after the Chernobyl Accident*, Worldwatch Institute.

13. European Commission Joint Research Centre, "Post-Fukushima Policy", http://ehron.jrc.ec.europa.eu/post-fukushima-policy, accessed 26 April 2013.

14. Clerici, A., et al. (2011), *World Energy Perspective: Nuclear Energy One Year after Fukushima*, World Energy Council.

15. Joskow, P.L., and Parsons, J.E. (2012), *The Future of Nuclear Power after Fukushima*, MIT Center for Energy and Environmental Policy Research.

16. US Energy Information Administration (2012), "Japan's use of thermal generation is up since March 2011 due to nuclear plant outages", http://www.eia.gov/today-inenergy/detail.cfm?id=6470, accessed 26 April 2013.

17. Tabuchi, H. (2012), "Japan, Under Pressure, Backs Off Goal to Phase Out Nuclear Power by 2040", *New York Times*, 19 September 2012.

18. Ministry of Environmental Protection, National Energy Administration, China Earthquake Administration of PRC (2012), "Report on Comprehensive Safety Inspection of Civilian Nuclear Facilities", http://big5.mep.gov.cn/gate/big5/www.mep.gov.cn/ztbd/rdzl/zqyj/gbdbg/201206/P020120618354487241607.pdf, accessed 26 April 2013. (Chinese only)

19. Zhang (2012), "Before resuming nuclear power", Oriental Outlook, 2012, Vol. 13, http://www.lwdf.cn/wwwroot/dfzk/bwdfzk/201043/bmbd/254831.shtml, accessed 26 April 2013. (Chinese only)

20. Ye (2012), "China's nuclear power development after Fukushima nuclear power plant accident", *Proceedings of the CSEE*, Vol. 32, No. 11, pp.1-8. (Chinese only)

21. Wen (2007), "Insisting on 'two-step' principle, steadily developing nuclear power", *China Nuclear Industry*, Vol. 79, No. 3, pp.20-25.

22. National Development and Reform Commission of PRC (2007), "Nuclear Power Mid-to-long-term Development Plan (2005–2020)", October 2007. (Chinese only)

23. Central People's Government of PRC (2012), "溫家寶主持召開國務院常務會議討論通過《能源發展「十二五」規劃》，再次討論並通過《核電安全規劃(2011—2020年)》和《核電中長期發展規劃(2011—2020年)》", http://www.gov.cn/ldhd/2012-10/24/content_2250357.htm, accessed 26 April 2013. (Chinese only)

24. See notes 6 and 8. State Council of PRC (2011), *The Outline of the 12th Five-year Plan for National Economic and Social Development of the People's Republic of China*.

25. The People's Government of Guangdong Province of PRC, "The 12th Five-year Plan for Energy Development of Guangdong", http://www.stats.gov.cn/tjsj/ndsj/2011/indexch.htm, accessed 9 May 2013. (Chinese only)

26. See note 6. National Bureau of Statistics of PRD (2011), *China Statistical Yearbook 2011*.

27. See note 6.

28. See note 8.

29. China Electricity Council (2010), "Electric Power Industry Statistical Quick Report".

30. Zhou N., et al. (2012), *International Comparative Analysis of Appliance Efficiency Standards & Labeling Programs: Implications for China*, Ernest Orlando Lawrence Berkeley National Laboratory, June 2012.

31. See notes 6, 25 and 29.

32. Environment Bureau of HKSAR Government (2010), *Hong Kong's Climate Change Strategy and Action Agenda*.

33. See note 4.

34. China Light & Power (CLP) Hong Kong, http://www.clp.com.hk.

35. Liu and Zhang (2005), "廣東：錯峰用電企業輪休，向香港購電", XINHUANET.com, 20 June 2005, http://news.xinhuanet.com/fortune/2005-06/20/content_3109590.htm, accessed 26 April 2013. (Chinese only)

36. Census and Statistics Department of HKSAR Government (2012), *Hong Kong Energy Statistics Annual Report 2011*, http://www.censtatd.gov.hk/fd.jsp?file=B11000022011AN11B0100.pdf&product_id=B1100002&lang=1, accessed 9 May 2013.

37. OECD (2008), *Nuclear Energy Outlook 2008*.

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