POLICY BRIEF

June 2017
Number 40

Carbon Pricing to Accelerate the Diffusion of Low Carbon Technology in China

Xianbing Liu
Senior Policy Researcher, IGES

liu@iges.or.jp

Key messages

- This policy brief suggests that carbon pricing can accelerate the diffusion of low-carbon technology in China, based on the results of empirical studies conducted by Kansai Research Centre of IGES focusing on China's most energy intensive industries.
- Many low-carbon technologies are profitable but require some initial investment. Chinese companies strongly prefer a short payback period for these investments.
- In order to accelerate technology diffusion in its energy intensive industries, China should implement carbon pricing policies to reduce the payback period for these investments and enhance their profitability.
- Even a moderate carbon price could bring about much earlier diffusion of many low-carbon technologies. IGES research found that a moderate carbon price would not significantly reduce the profits of Chinese companies, and it should be acceptable to them.
- To establish moderate and stable carbon prices, the national greenhouse gases emissions trading scheme (GHG ETS) in China should ensure that the emissions allowances of target sectors are in line with the country's emissions peak pledge, allocate the allowances strictly, and strengthen data transparency and accuracy.
- A carbon tax should be also levied in China on the emissions outside of the national GHG ETS to generate a price floor for the carbon market. Even a modest tax rate could generate a large amount of revenue to support further investment in

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climate-friendly technologies and help to strengthen China's competitive advantage in these markets.

- Carbon pricing in China, i.e., the national GHG ETS, should be coordinated with other related policies such as those on energy efficiency. This is because IGES research found that different policy combinations have different effects on the technologies in different sectors and at different diffusion stages. Moreover, the policies themselves are interrelated. For example, a strict energy savings target mandates companies to adopt direct mitigation measures and reduces the demand of emissions credits on the carbon market. Therefore, coordination of different policies in different sectors is necessary in order to effectively accelerate the diffusion of low-carbon technology in China.

I Introduction

To maintain global warming below 2°C across this century from the pre-industrial era requires fundamental changes in economy, technology, society and institutions (IPCC, 2014). However, the world economy continues to grow, and demand of the most carbon-intensive products is not likely to decrease in the medium term due to the economic growth and urbanisation of developing countries. For example, global cement production was estimated to grow by 0.8% to 1.2% annually since 2006, and would reach 3,700 Mt to 4,400 Mt by 2050 (IEA and WBCSD, 2010). Steel production has entered a period of stability, but will undoubtedly pick up again when markets other than China start to drive new demand. Steel use is projected to be 1.5 times higher than the present level by 2050 (WSA, 2015). With the continuously growing economy overall and the slow change in economy structure, the innovation and diffusion of low-carbon technology (LCT) has to play a key role in decoupling GHG emissions from economic growth.

In reality, the diffusion of LCT is determined by many factors, so a package of various countermeasures is necessary to overcome the barriers hindering the diffusion process (Liu et al., 2016). Compared to other instruments, carbon pricing addresses the vast heterogeneity of emitters and minimises the overall cost of carbon mitigation. It should function as a basic element of a policy mix in redirecting technology change toward low-carbon production (Acemoglu et al. 2012).

In China, improvement of energy efficiency in manufacturing has long been a key strategy to address climate change. China's energy saving policies have been quite effective and reduced the country's carbon emissions per unit of gross domestic product (GDP) in 2013 by 28.5% from the 2005 level (Liu et al., 2015). The 12th Five-year Plan (FYP) period (2011-2015) marked a new era in China's climate effort, shifting the country's climate policies from goal setting to an emerging mix of policies to drive emissions reductions in specific sectors (Song et al., 2015). Climate policy progress in China is on the right track, but accelerating climate action requires additional efforts. Therefore, putting a price on carbon is a key policy lever to ensure that emissions peak by 2030 or sooner in China (NCSC et al., 2015). So far, China has largely relied on regulative and administrative approaches, and lacks experience in implementing market mechanisms. The coordination of new carbon pricing policies with existing climate policies is a challenge for China.

The Kansai Research Centre of the Institute for Global Environmental Strategies (IGES) carried out a project between 2013 and 2016 on 'Policies and Business Initiatives toward the Innovation and Diffusion of Low Carbon Technologies in Northeast Asia' ('the PIDT project') in order to clarify the relationship between carbon pricing and technology deployment paths at the level of individual businesses. This research focused on China's cement and iron & steel industries and estimated the changes of diffusion curves of several energy-saving technologies in response to the assumed carbon prices. The potential effect on CO_2 mitigation due to carbon pricing-oriented technology diffusion was estimated for China's cement sector. This policy brief outlines the main policy messages from the PIDT project from a business viewpoint.

2 The need for carbon pricing to accelerate the diffusion of low-carbon technology

There are large differences in how various types of LCT are diffused. Technologies related to energy efficiency may be fully diffused relatively quickly. For example, Pizer et al. (2002) examined the adoption of energy-saving technologies by US manufacturers and found that once a technology is diffused to 10% of the companies, the remaining potential users would adopt it within an average of about 9 years regardless of the sector. The PIDT project found similar results for energy-saving technology diffusion in China. Fitting the data gathered from the companies to an S-shaped technology diffusion model, Liu and Gao (2016) depict the diffusion curves of three energy-saving technologies in China's iron & steel industry, dry top pressure recovery turbines (Dry TRT), sintering waste heat recovery power generation (Sintering WHR) and energy management center (EMC), and found that full diffusion of these energy-saving technologies would take around 10 to 20 years after their introduction (as shown in Figure 1). Another study of China's cement industry by the PIDT project found almost the same result (Liu et al., 2016).

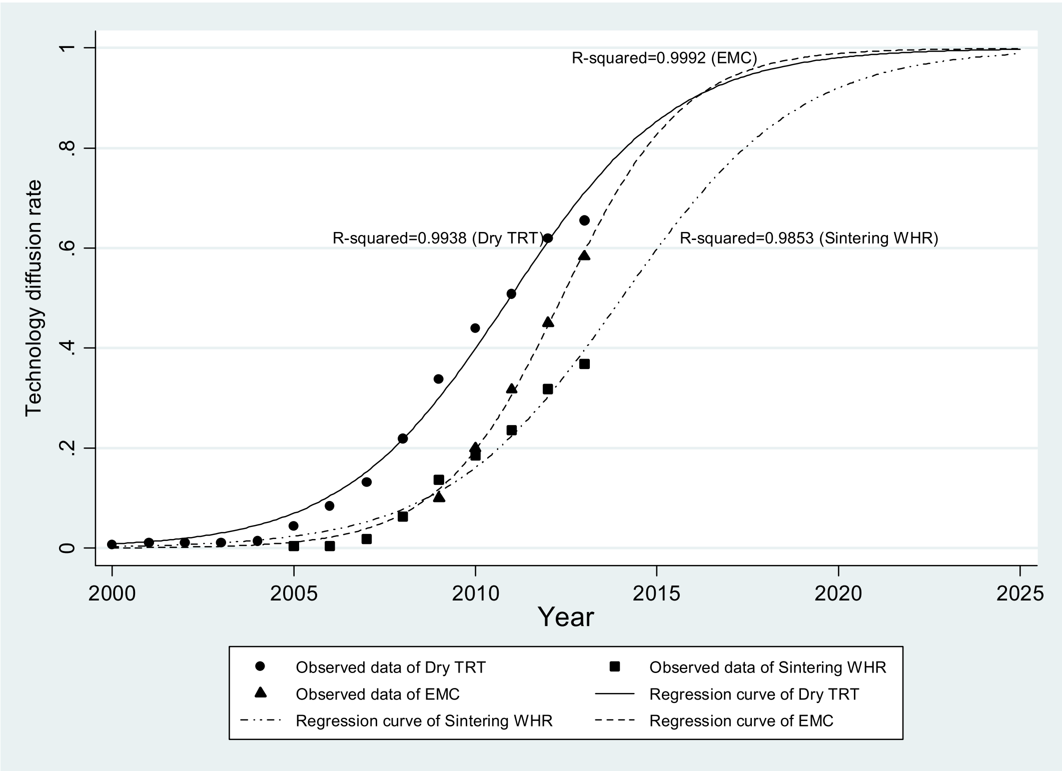

Figure 1: Simulated diffusion curves of three LCT in China's iron & steel industry (N=60[1]).

The diffusion of other energy technologies takes a much longer time. Lund (2006) confirmed that the time needed to move from 1% to 50% diffusion varies from less than 10 up to 70 years for other energy-related technologies, while short diffusion times below 25 years are only associated with energy efficiency technologies.

Practically, businesses are particularly concerned about the economic profitability of low-carbon projects. The PIDT project surveyed a sample of China's cement and iron & steel companies about their willingness to invest in LCT with various payback times. Table 1 shows the percentage of companies in the samples to invest in LCT at various payback time.

[1] The data from iron & steel industry was collected in collaboration with China Metallurgical Industry Planning & Research Institute based in Beijing. Crude steel of the 60 respondents represents around 70% of the country total.

Table 1: Percentage of China's companies to invest in LCT with various payback times (%)

Sector	Payback time of the technology (Years)											
	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	5.0	6.0	8.0	10.0
Cement (N=62[2])	98.1	93.9	84.6	68.8	48.5	28.5	13.6	5.2	0.4	0.0	0.0	0.0
Iron & steel (N=60)	100.0	100.0	100.0	99.9	95.8	67.5	20.6	1.8	0.0	0.0	0.0	0.0

Nearly 70% of the companies surveyed in the two sectors expressed willingness to invest in LCT with a payback time of 2.0 and 3.0 years, respectively. Their willingness to invest declines steeply the longer is the payback period. In order to achieve a 50% adoption rate, the payback time for LCT in China's cement and iron & steel companies to invest ranges from between 2.0-2.5 and 3.0-3.5 years, respectively (Liu et al., 2016; Liu and Gao, 2016). This indicates a great need to provide economic incentives, i.e., by carbon pricing, to encourage LCT investments.

3 The effectiveness of carbon pricing to accelerate low-carbon technology diffusion

One important category of factors determining the investment in LCT is associated with the uncertainty of climate policies, which induces an 'opportunity value' of postponing the technology adoption (Jaffe et al., 2002). Climate sensitivity, international commitments and the stability of carbon prices influence the behaviour of risk-averse and risk-neutral investors. It would be much easier for the business to decide whether or not to invest in LCT if the path of carbon pricing was clear beforehand.

The study by IGES Kansai Research Centre indicates that attaching a carbon price is effective in promoting the diffusion of certain types of LCT. For the technologies that have been widely deployed, like the WHR system in the cement industry and Dry TRT in the iron & steel industry in China, the PIDT project confirmed the very marginal function of carbon pricing in promoting their further diffusion (Liu et al., 2016; Liu and Gao, 2016). However, it also showed that carbon pricing was effective in promoting the diffusion of energy management and optimisation system (EMOS), which is still at an early adoption stage in China's cement industry, as shown in Figure 2.

More specifically, levying a carbon price of CNY20 / t-CO_2 (About USD3.3 /t-CO_2 at the average exchange rate of CNY6.14 /USD in 2014, Scenario 1 in Figure 2) would have generated a 2.6% increase in the rate of technology diffusion from the BAU level in 2015, a 6.3% increase in Scenario 2 (with a price of CNY 60 /t-CO_2) and 9.2% under Scenario 3 (with a price of CNY 100 /t-CO_2) in the same year. By 2020, the increased diffusion rates of this technology would be individually 7.4%, 15.9% and 21.1%. This means that EMOS would be fully adopted around 2030 under the BAU case, and the pricing of carbon emissions could bring about its full diffusion much earlier. Levying a moderate price at CNY 60 /t-CO_2 would generate an effect similar to a price as high as CNY 100 /t-CO_2 for market saturation of EMOS in China's cement industry by around 2025. Therefore, earlier introduction of carbon pricing, with low and affordable initial prices are recommended to redirect business investment towards low-carbon technologies in China.

Moreover, the empirical evidence also shows that even large increases in energy prices, i.e., due to the levying of an upstream carbon tax or GHG ETS focusing on the energy sector, might only lead to

[2] The data from cement industry was collected by the author in collaboration with China Cement Association (CCA). Most samples from this sector may be categorised as small and medium enterprises (SMEs) in China.

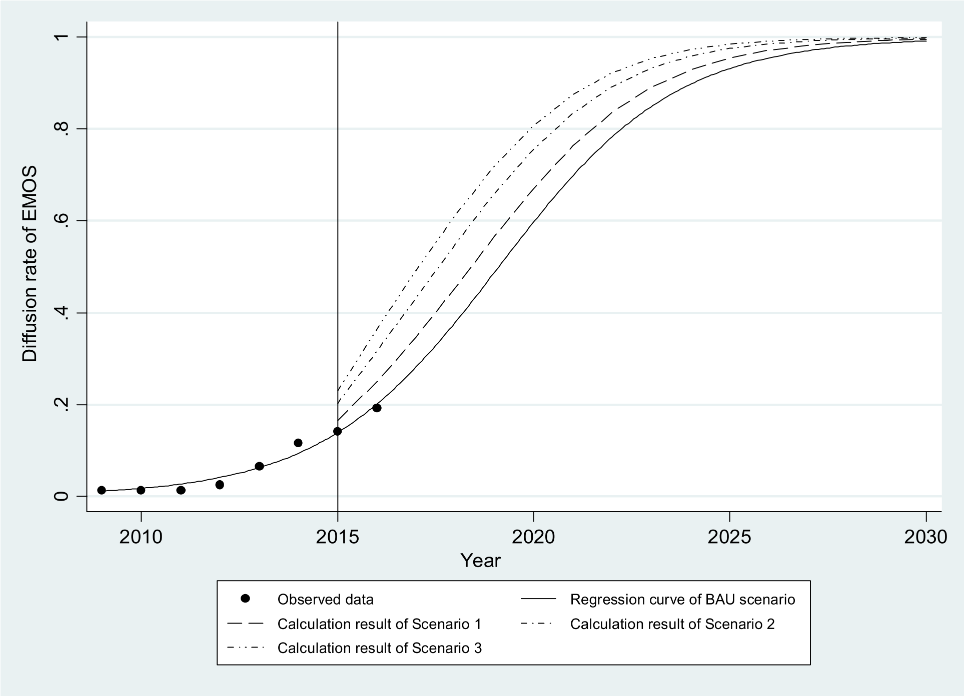

Figure 2: Diffusion of EMOS technology in China's cement industry at various carbon prices[3].

modest improvement in energy efficiency. Thus, a policy which immediately raises energy prices without allowing the companies to anticipate the changes might lead to a slowdown in the adoption of technology if companies' financial health is adversely affected (Pizer et al., 2002). In addition, companies are much more responsive to a project's initial costs than its annual savings. This implies that financial subsidies may be more effective than an increase in energy prices for promoting the deployment of energy-saving technologies (Anderson and Newell, 2004). Therefore, both the price effect and the budget effect of carbon pricing policies need to be considered in developing policies to promote LCT diffusion[4].

Besides policy uncertainty, other factors also influence the adoption of technologies even in the presence of favourable policies (Liu et al., 2016). For example, the lack of financial resources is a critical barrier for the adoption of LCT which requires high upfront costs. Market structure and information flow within a sector may also constrain the diffusion of LCT, for example through business alliances. The adoption of LCT in a specific company may depend on its capacity and on the timing of company-specific business cycles (Liu et al., 2016). This implies that comprehensive measures, including carbon pricing, need to be implemented to overcome the barriers blocking the investment of various LCT.

[3] The same as above, the data was collected by the author in collaboration with China Cement Association (CCA).

[4] Budget effect of a carbon pricing policy may be achieved by using the revenues for climate-specific investment, such as support for low carbon energy deployment and energy efficiency, research and innovation, climate friendly infrastructure, and international commitments, etc.

4 Carbon pricing practices globally and in China

Carbon pricing practices are growing globally. As of September 2015, nearly 40 national jurisdictions and over 20 cities, states and regions have adopted or were planning explicit carbon prices, covering an estimated 7 Gt-CO_2 (around 12% of global emissions). The number of carbon pricing instruments implemented, scheduled or to be chosen at the national level has almost doubled from 20 to 38 since 2012 (WB and ECOFYS, 2015). Relatively higher carbon prices have been imposed in some European countries[5], but overall global progress has been slow in comparison with the great needs and potential effectiveness of this type of policy for LCT diffusion. Around 85% of the covered emissions are priced at less than USD 10 /t-CO_2. The projected costs of climate change suggest that much higher carbon prices are needed globally. For example, the US government recommended a 'social cost of carbon' at around USD 36 /t-CO_2, rising to USD 50 /t-CO_2 in 2030 (Rydge, 2015). Current carbon prices are even at the low end of the spectrum of internal prices applied by businesses. The Carbon Disclosure Project (CDP) confirmed that some oil and gas companies adopted higher prices, i.e., USD 40 /t-CO_2 at Shell and USD 80 /t-CO_2 at ExxonMobil (CDP, 2015).

Carbon pricing policies are very important for China, which is the largest GHG-emitting country. The previous experience of other countries shows that carbon pricing is time-consuming and not easy to implement. In Japan, a developed country, the initial discussions about carbon tax within the Ministry of the Environment can be traced back to the early 1990s, while this policy was not formally started until 2012 with low tax rates (Liu et al., 2014). This implies that carbon pricing in China, as a developing country lacking experience and capacity, will be a long and difficult process.

The experts at research institutes under the related ministries in China, the Ministry of Finance (MOF) and Ministry of Environmental Protection (MEP), discussed carbon tax proposals several years ago. However, instead, China decided to prioritise the development of the GHG ETS for carbon pricing. Learning from the lessons and experiences of the EU-ETS and local programmes in Japan and the US, China's GHG ETS was piloted in five municipalities (Beijing, Shanghai, Tianjin, Chongqing and Shenzhen) and two provinces (Guangdong and Hubei) from 2011. The pilot markets formally started in 2013 and these local carbon markets have been successively operated. As summarised in Table 2, a total of 78.94 Mt-CO_2 were traded on China's pilot carbon markets as of 16 August, 2016, with a turnover of CNY 1885.2 million (about USD 287.4 million at the exchange rate of CNY 6.56 /USD). The average carbon price was CNY 23.9 /t-CO_2 (about USD 3.6 /t-CO_2).

China announced the launch of a nationwide GHG ETS in 2017, focusing on the most energy and carbon intensive industries, such as iron & steel, power generation, chemicals, building materials (mainly cement and glass), paper-making and nonferrous metals, etc. This scheme will be the largest in the world, covering around 3 to 4 billion t-CO_2, an equivalent to the total annual emissions of the EU, or the combined emissions of India, Brazil and Japan.

[5] For example, carbon taxes in Ireland, Denmark and British Columbia range from between USD 22 to 24 /t-CO_2. France adopted a carbon tax at EUR 7 /t-CO_2 in 2014, raised to EUR 14.5 /t-CO_2 for 2015 and EUR 22 /t-CO_2 for 2016. This rate will be further raised to EUR 56 /t-CO_2 in 2020 and EUR 100 /t-CO_2 in 2030. Sweden has a carbon price of USD 130 /t-CO_2 for some sectors (Rydge, 2015).

Table 2: A summary of carbon traded in China's GHG ETS pilots (As of August 16, 2016)[6]

Item	Shenzhen	Shanghai	Beijing	Guangdong	Tianjin	Hubei	Chongqing	In total
Starting date	Jun. 18, 2013	Nov. 26, 2013	Nov. 28, 2013	Dec. 18, 2013	Dec. 26, 2013	Apr. 2, 2014	Jun. 19, 2014	
Traded amount (10,000 t-CO_2)	1,584.7	751.0	465.7	1,567.9	184.4	3,300.4	39.9	7,894.0
% of total amount traded	20.1	9.5	5.9	19.9	2.3	41.8	0.5	100.0
Turnover (10,000 Yuan)	54,396.3	12,987.6	23,612.6	25,362.6	3,083.6	68,343.3	737.9	188,523.9
Average price (Yuan/t-CO_2)	34.3	17.3	50.7	16.2	16.7	20.7	18.5	23.9

5 General framework of a policy mix toward low-carbon technology diffusion

The social cost for low-carbon transition may be reduced by the implementation of a policy package, combining various policies including energy efficiency regulations, carbon pricing mechanisms and other programmes supporting technology development and demonstration. Figure 3 illustrates the general framework of a mix of these core climate policies, in which carbon pricing functions as an economy-wide instrument.

Energy efficiency regulations overcome the barriers of cost-effective investment in energy-saving technologies, i.e., businesses' lack information about specific LCT, some tendency by businesses not to behave in an economically rational manner (such as avoiding profitable investments in energy-saving). A typical example is the minimum efficiency performance standards (MEPS), either mandatory (e.g., standards of efficient motors in the US and Canada) or not mandatory (e.g., similar equipment standards in the EU). Research shows that MEPS have been the most effective means to improve the industrial energy efficiency (Price and McKane, 2009).

Positive economic incentives for LCT investment include financial grants or subsidies, tax relief and soft loans. Financial measures have been the dominant policy addressing industrial energy efficiency in EU countries (Schlomann et al., 2015). In Northeast Asia, Japan provides a corporate tax rebate of 7% of the purchase price of energy-efficient equipment for small and medium-sized enterprises (SMEs). A 5% income tax credit is available for energy efficiency investments in Korea, like the replacement of old industrial kilns, boilers and furnaces (Price and McKane, 2009).

In reality, financial subsidies are effective for a very narrow range of individual projects. This incentive is useful for LCT introduction, but it is not sufficient to sustain their long-term diffusion. However, carbon pricing contributes to dynamic efficiency and may function as the basic element sustaining the diffusion of LCT. Stable and long-term carbon pricing should be implemented to properly incentivise the adoption of climate-friendly technologies. In summary, an appropriate policy package should comprise energy efficiency regulations as well as economic incentives ('stick and carrot'), where the regulatory instruments define the technology baseline, as well as other policies encourage investors to comply with this baseline or exceed the requirements by adopting more advanced technologies.

[6] Compiled by the author and sourced from: http://www.tanpaifang.com/

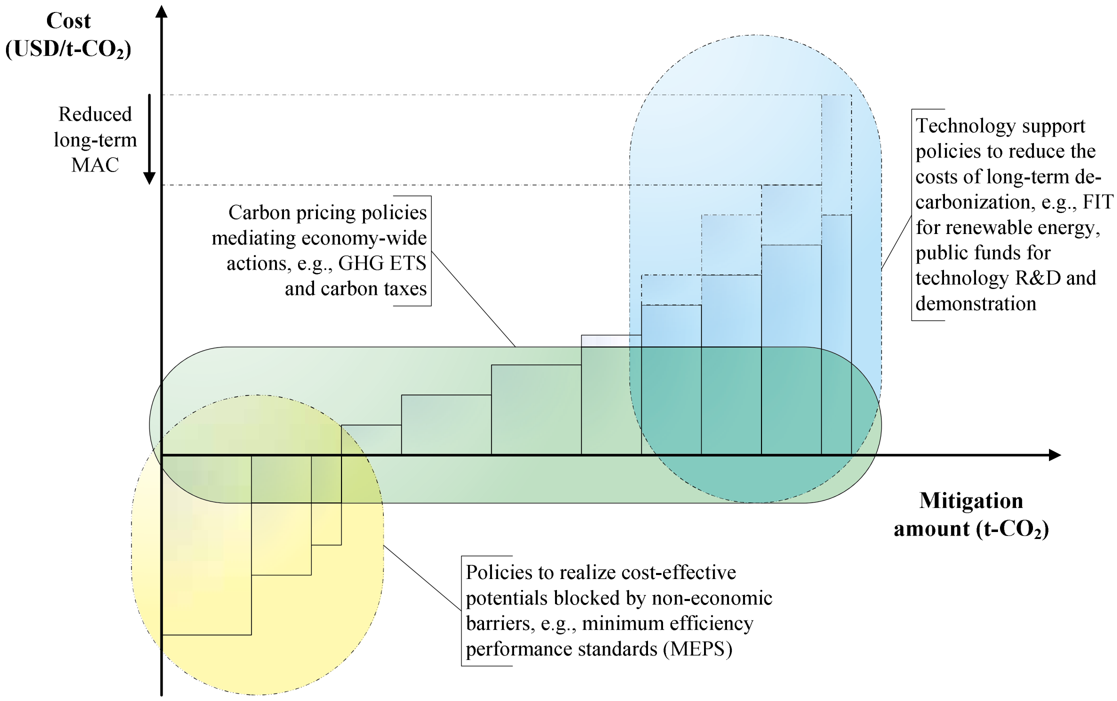

Figure 3: **Framework of a mix of core climate policies with carbon pricing as the basic element.**

6 Suggestions for using carbon pricing to promote low-carbon technology diffusion in China

Similar to many other countries, a comprehensive mix of climate policies already has been emerging in China, especially during the 12th FYP period (2011-2015). The package consists of policies specific for various sectors, and the major components are the renewable energy feed-in-tariff (FIT), energy-saving target disaggregation system and the GHG ETS pilots. Along with the implementation of energy efficiency instruments, China already has picked almost all the low-hanging fruits for energy-saving and carbon mitigation. Liu et al. (2017) showed that the remaining carbon mitigation potential of low-cost energy-saving technologies in China's cement industry is about 10%. China's future climate efforts would benefit from policies beyond the command and control approaches. Carbon pricing is a key prerequisite for the country's GHG emissions to peak by 2030 or even sooner (NCSC et al., 2015). Based on the experiences of local pilots, a nationwide ETS has been under preparation and formal operations will start from 2017. So far, the coverage of China's national GHG ETS, like the target sectors and the emissions threshold determining the target entities, has been clarified.

NCSC et al. (2016) recommend a future carbon price of at least CNY 60 /t-CO_2 to increase emissions reductions. A previous study by IGES Kansai Research Centre suggested that this price level could be acceptable to Chinese companies. China's most energy-intensive sectors, cement, iron & steel, and chemicals, may be able to afford a carbon price at around CNY 40 to 80 /t-CO_2 (Liu et al., 2014). Currently, the average price in China's pilot carbon markets is far lower than this level, so a higher carbon price seems quite economically feasible.

For the formation of stable and moderate carbon prices, it is generally necessary to define a quantitative and absolute cap for the allowance allocation of the GHG ETS scheme. In practice, China's national GHG ETS will apply a bottom-up approach for setting the cap during the initial phase. Among the 8 sectors and 20 subsectors to be covered, the industries with homogeneous and comparable products and technologies, like electric power supply, cement clinker and electrolytic aluminum, will use benchmarking methodologies. For the sectors with complex and diverse production processes, such as copper smelting and pulp and paper making, historical emission intensity reduction methodologies will be applied (Tong, 2016). Emissions allocations under intensity targets would likely lead to over-allocation or liquidity problems for the ETS (Swartz, 2016). To overcome the over-allocation problem, ex-post adjustment of the emissions allowances should be carried out according to verified production levels. China aims to peak its GHG emissions by approximately 2030 or sooner. NCSC et al. (2015) even suggest that China should be able to cap its energy-related emissions at around 9 to 10 billion t-CO_2 by 2020 with stronger policies. The government will need to clarify the relationship between the allowances allocated to ETS target sectors and the country's GHG growth trajectory to stay on track to meet the emissions peak pledge.

During the initial phase of China's national GHG ETS, there is a strong possibility that the emissions allowances will be allocated fully for free. This policy brief suggests that the allowances should be determined more strictly, by using either more advanced benchmarks or higher reduction factors, in order to generate moderate prices in the carbon market. The emissions allowances should be allocated gradually through auctions. This may enhance the price of carbon allowances and generate revenues that could be used to support low-carbon projects. Great efforts already have been made to strengthen data transparency and accuracy in China, while the measurement, reporting and verification (MRV) systems needs to be further improved. China has set up robust MRV programmes under the ETS pilots, but the very large number of potential entities to be covered in the national ETS will make it very challenging to scale up MRV across the country. It might take years for the MRV process in China to become sufficiently reliable (Swartz, 2016).

Coordination between GHG ETS and energy efficiency policies is essential. The energy-saving target disaggregation at the company level mandates businesses to take direct actions for energy saving. This reduces the demand for emissions allowances even when the costs for self-mitigation are much higher. The underlying economic rationale of the ETS would be undermined without the policy coordination. Allowing the companies to use emissions allowances of the ETS to fulfil energy-saving obligations, or simply substituting energy-saving targets with emissions allowances, would improve the synergy of these two policies.

In addition to the GHG ETS, China is recommended to consider introducing a carbon tax sooner, especially for the emitters outside of the national ETS under development. Liu et al. (2014) argued that in China, levying a carbon tax with low rates is feasible from the point of view of business. The 'Law of Environmental Protection Tax', aiming to convert the current pollution fee system to environmental taxes, was approved by the National People's Congress on 25 December, 2016 and will be implemented from the beginning of 2018. An easier way would be to add the carbon tax as a specific category of environmental taxes under this regulatory regime. Levying a modest carbon tax, such as USD 5 /t-CO_2, may generate a price floor for the national GHG ETS. The effect of the GHG ETS on investment in LCT, i.e., wind power, may be improved with a carbon tax added as a price stabilisation mechanism, although the critical carbon price floor needed to spur new investment is much higher than the price on China's current pilot markets (Mo et al., 2016).

Even a carbon tax with low rates could generate huge amounts of public budget revenue for China. Based on the experience of Japan, the budget effect of carbon tax could be much more powerful in reducing emissions than the price effect (Hood, 2013). China is also recommended to use the carbon tax revenue to support research, development, demonstration and early stage commercialisation of key climate technologies, i.e., renewable energy, clean coal utilisation, industrial energy-saving and carbon capture and storage (CCS), etc. This is especially important for China as a late developer of climate-friendly technologies. China is trying to promote international cooperation on production capacity and equipment manufacturing as a national strategy. Carbon tax revenue may become an important financial resource to support low-carbon production facilities and infrastructure construction overseas.

7 Conclusions

This policy brief recommends how China could use carbon pricing to accelerate the diffusion of LCT, based on the findings from the PIDT project of the IGES Kansai Research Centre. The business sector in China is highly concerned about the economic benefits and payback period of low-carbon investments. This policy brief argues that putting moderate prices on carbon emissions (i.e., at around CNY 60 /t-CO_2) would be an effective and economically feasible way to accelerate the diffusion of LCT in the long term in China's most energy-intensive industries. In addition, this policy brief proposes that economy-wide carbon pricing should be coordinated with other core climate policies in a policy mix to promote the diffusion of LCT. For example, for the national GHG ETS prioritised by the central government, it is necessary to determine a quantitative and absolute cap of emissions to ensure that the country is on track for its emissions peak pledge. The MRV system should be further improved accordingly. In addition, the GHG ETS and the existing energy efficiency policies should be coordinated to maximise the economic efficiency and effectiveness of the ETS. China is also recommended to levy a carbon tax earlier for emissions outside of the ETS. The tax revenue shall be utilised to support the research, development, demonstration and early commercialisation of key climate technologies to change the status of China as a later technology developer. Finally, it is recommended to expand the implementation of carbon pricing across the country as soon as possible, not only to reduce GHGs more quickly, but also so that companies can benefit sooner from the returns on their LCT investments.

· Acknowledgements
This policy brief is an output of the PIDT project of IGES Kansai Research Centre. The author wishes to thank Hyogo Prefectural Government of Japan for the financial support to this research. The insightful comments from Prof. Hidefumi Imura, Dr. Mark Elder and Dr. Satoshi Kojima in IGES, and Prof. Can Wang at Tsinghua University of China are highly appreciated.

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Institute for Global Environmental Strategies
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