

# Policy Options for Low-Carbon Power Generation in China

*Designing an emissions trading system for China's electricity sector*

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## Executive Summary

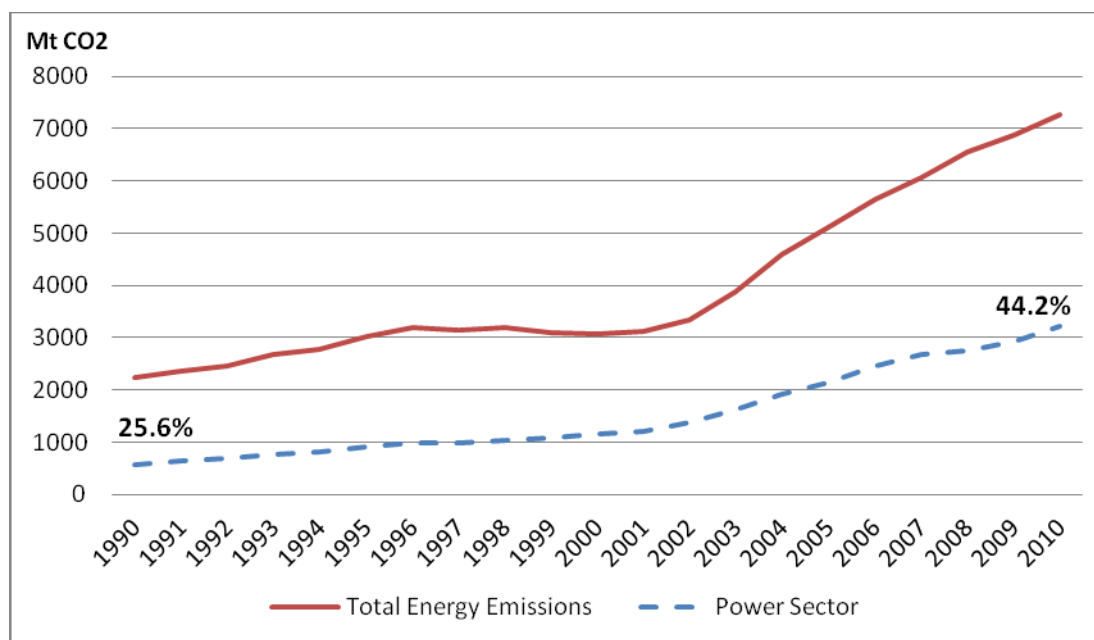
China faces the dynamic of rapid economic development that drives ever increasing energy use, primarily electricity, and consequently increasing CO<sub>2</sub> emissions. It has taken a pledge to curb its emissions intensity, and is exploring various policy approaches to fulfil that aim, including emissions trading. **This report explores the conditions needed for effective functioning of a CO<sub>2</sub> emissions trading system in China's electricity generation sector.** It is based on extensive discussions with power generation stakeholders and observers of the electricity sector in China, as well as quantitative analyses of the impact of a CO<sub>2</sub> emissions trading system (ETS) at plant, company and provincial levels.

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## Climate policy and the role of electricity in China

China recognises the threat posed by climate change on its development objectives. In 2009, before COP 15 in Copenhagen, it adopted a unilateral pledge to reduce the CO<sub>2</sub> intensity of its Gross Domestic Product by 40-45% from its 2005 level by 2020. This pledge was reiterated at COP 17 in Durban. **Economic growth remains an imperative for the country, and its aspiration to a low-carbon economy presents a significant policy challenge.** As its economy has grown at impressive rates over the last twenty years, China's energy-related CO<sub>2</sub> emissions grew by 50% between 1990 and 2000, and doubled in the last decade, reaching 7 billion tons of CO<sub>2</sub> in 2010.

Figure 1: Energy and electricity-related CO<sub>2</sub> emissions in China (1990-2009)



Source: IEA statistics.

**The electricity sector is at the heart of the country's development and climate change challenge.** Dominated by coal, electricity generation accounted for 44% of China's total CO<sub>2</sub> emissions in 2010 – a higher share than the global average. China has adopted very ambitious goals to control electricity sector emissions going forward: the installed capacity of carbon-free sources of electricity is expected to more than double between 2010 and 2020, reaching 600 GW, higher than total coal-

fired capacity in 2008.<sup>1</sup> Even with these additions, however, new coal capacity will be needed to meet rising electricity demand, and part of the solution will indeed lie in controlling growth on the demand-side. For China, lowering the high carbon intensity of electricity remains central to meeting its climate goals. China is interested in exploring means such as an emissions trading system, to confront this issue. Under an emissions trading system, emissions sources (facilities, plants or firms) are capped, and allowances are provided to each source to reflect the agreed emissions target.

Page | 6 Sources have then the possibility to buy and sell these allowances, but must surrender allowances matching their actual emissions in order to be in compliance.

**China's 12<sup>th</sup> Five Year Plan (2011-2015) introduced emissions trading as a possible instrument to manage the country's emissions.** The National Development and Reform Commission (China's key ministry in charge of economic policy and planning) has launched seven carbon market pilots, currently in development in two provinces and five cities. After the experience gained from these pilots and further adaptation to provincial level issues and constraints, a nationwide system could follow, based on experience from these pilots. These pilot programs are likely to focus on the electricity sector both because of its importance in China's emissions but also for practical and efficiency reasons. Experience in other countries confirms that power generation is a natural candidate for inclusion in emissions trading.

## How emissions trading can help achieve growth objectives

**Emissions trading is promoted for its theoretical potential to achieve an environmental goal at least cost, through an efficient allocation of efforts among sources to reduce emissions.** Once an emission source is granted an emission objective and a matching number of emission allowances, it can pursue measures to meet this objective at least possible cost, with the possibility to buy allowances from, or to sell allowances to other sources in the system. As every source should compare the cost of reducing its emissions with the cost of buying allowances, the system generates a uniform price for emission reductions, reflected in the market price for allowances.

**Emissions trading systems control emissions principally through their impact on two key dynamics in the power sector, *i.e.* dispatch of existing plants and generation mix (through decommissioning and new construction).** The electricity sector in all countries contains a mix of cleaner and less clean plants, among them base-load plants and a reserve of less-used, often the most polluting plants which meet peak demand and provide a reserve margin. How these plants are called upon to provide power to the grid ('dispatched') determines how much CO<sub>2</sub> the sector emits, and an ETS can alter dispatch patterns, favouring lower-carbon generation units. An ETS can also alter the composition of the installed generation base by changing the economics of decommissioning existing plants and constructing different types of new plants.

**Emissions trading – whether for CO<sub>2</sub>, SO<sub>2</sub> or other pollutants - has a proven track record in delivering a price signal and allowing full integration of the cost of pollution into economic activities.** These systems – like taxes on pollution – are in theory more cost-effective than command-and-control approaches, which tend to either mandate technology choices which deter innovation, or to fix emission limits without consideration for differences in cost among sources. This combination of flexibility and cost-effectiveness explain the interest of many countries in this instrument as a means to curb greenhouse gases.

China has some experience with emissions trading, with a domestic SO<sub>2</sub> trading system, and through its participation as a host country to many projects under the Clean Development Mechanism. Based on this experience, and its ambitious emissions targets, **China is interested in analysing how an ETS could work to reduce emissions while improving efficiency in electricity supply.**

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<sup>1</sup> Hydro, nuclear, wind and solar totaled 257 GW in 2010, and are projected to reach 610 GW in 2020.



## Features and challenges of China's electricity sector

**China's electricity sector has certain characteristics that will affect the design and operation of any trading system**, arising from the development path of the sector, and from the highly planned and regulated nature of a sector dominated by companies majority invested by the national and local governments. Generation capacity is concentrated in a small number of these companies. Recent policy developments have sought to improve the efficiency of the sector, particularly coal-fired generation but also transmission and distribution, and to encourage new capacity development to maintain secure, uninterrupted supplies. Despite massive closures in recent years to raise efficiency and reduce pollution from the sector, a large number of relatively small, inefficient local coal plants remain in operation.

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### A coal-dependent power mix

**Coal remains the fuel of choice in power generation, in spite of long-standing efforts to reduce its share.** Objectives for the development of nuclear, hydro, wind and solar are not enough to obviate the need for growth in coal-based capacity, projected to reach 1190 GW by 2020, against 710 GW in 2010. Even with efficiency gains through the construction of larger, more efficient ultra-supercritical plants (USC) and continued closures of small plants, substantial growth in CO<sub>2</sub> emissions will follow during this period. The rise in coal use for power generation, due to electricity-intensive economic growth and the relatively cheap access to domestic coal resources, is likely to offset any decline in overall coal consumption in other sectors.

### State-owned enterprises dominate

The power generation sector of China is dominated by five state-invested companies (frequently referred to as state-owned enterprises or SOEs): Huaneng, Datang, Guodian, Huadian, and China Power Investment Corporation. This group of five companies owns 50 to 60% of generation assets. Other major power companies include China National Nuclear Corporation, China Three Gorges, Guangdong Yuedian Group, Zhejiang Provincial Energy, Shenhua, and China Resources Power Holdings, also state-owned. These 10 companies totalled 450 GW of installed capacity in 2008, out of a total of 780 GW for China as whole. They were responsible for 1.4 GtCO<sub>2</sub>.<sup>2</sup> The remaining half of the sector's CO<sub>2</sub> emissions are emitted by other power companies of a much smaller size, invested by provincial or municipal governments throughout the country. The two main grid companies, State Grid Corporation of China and China Southern Grid, are also state-owned.

The dominance of state-owned enterprises presents both challenges and opportunities in the context of controlling CO<sub>2</sub> emissions with emissions trading. On the one hand, state-owned enterprises typically have direct access to funding, including for low-carbon investments. On the other hand, state-owned enterprises may not always respond to economic incentives like enterprises driven by profit maximisation. This makes the operational and investment responses to market-based policy instruments, such as an emissions trading system, unpredictable.

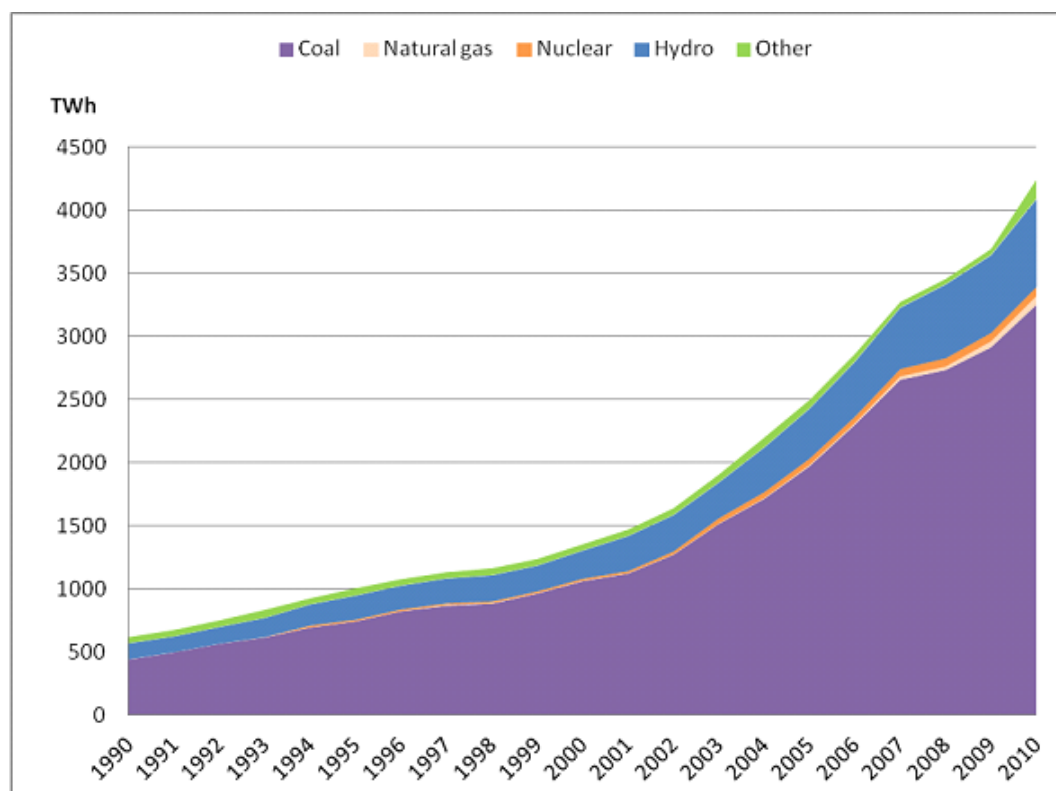
### Many small and inefficient generators

**The sector still hosts significant capacity comprised of small and mid-size, less efficient coal plants.** China has adopted a program to address these inefficient plants, the so-called "Building big, closing small" programme. This has led to the closure of 77 GW of small, inefficient coal plants over the course of the 11<sup>th</sup> Five-Year Plan (2006-2010), and their substitution by large high-efficiency generating units, including USC plants. Decommissioning of this magnitude in such little time is

<sup>2</sup> Greenpeace (2009); IEA (2010)

unmatched in any country in the whole history of the electricity sector. However, as of 2010, there still remained 68 GW of small coal plants (unit sizes below 100 MW), and 138 GW of medium-sized plants (100 MW to 300 MW), also targeted for closure, but meanwhile a source of significant emissions.

Figure 2: Electricity in China: the unabated dominance of coal



Source: IEA Statistics, 2012; ERI, 2012

## Regulatory framework

China has an extensive regulatory framework governing the operation of electricity sector agents, including state-owned companies. Some rules are set at the national level, while other actions are controlled at provincial or lower local levels, for instance:

- **Construction and commissioning of large power plants are authorised by NDRC, which, through its Price Department, grants a price for electricity that allows an adequate financial return.** Coal plants face a price set on a province-by-province basis. Plants relying on other technologies (hydro, gas, nuclear, solar and wind) are granted a specific price.
- **Each provincial Development and Reform Commission (DRC) draws an annual generation plan specifying the dispatch of each of the plants on its grid.** Adjustments are made during the year to balance supply and demand. Provinces also have the power to approve construction of small plants, so long as they conform to national guidelines regarding minimum size, fuel, technology and other characteristics.

These rules have allowed the government to encourage capacity additions while keeping prices under control. However, they do not necessarily lead to least-cost generation for any given power mix, as dispatch also has to balance the economic interest of all the plants that have been commissioned. **Any ETS would need to work effectively with this regulatory framework.**

## Key challenges for electricity under an ETS: dispatching of plants and electricity prices

The electricity generation sector faces two key challenges of particular relevance to a CO<sub>2</sub> control policy: resolving inefficiencies in its dispatch system and managing electricity price increases. As discussed below, these are important to the design and the acceptability of an ETS in China.

Under China's regulatory framework, dispatch is driven principally by local mandates on generation time, which leads to economic and technical inefficiencies when plants are not operated on the basis of their costs. The dispatching of plants, based on local governments' annual plans that prescribe the running hours of each plant, does not typically provide for least-cost dispatch within the regions served by system operators. Recognising this issue, the Chinese government issued trial rules to test a more 'rational' dispatch of plants, designed to save energy and to reduce local pollution, the "Energy Saving Dispatch Rule Method (Trial)" (ESDR). The trial was carried out in five provinces starting in 2008. This method favours the most efficient coal plants and low-emission technologies. It has achieved remarkable energy savings and CO<sub>2</sub> reductions in some of the five provinces; however, implementation at a national level has not happened yet and is facing potential barriers.<sup>3</sup> **In particular, the new dispatch method raised an important equity issue: the compensation for those plants that would be dispatched less, and hence face a reduction in earnings compared to prior practice.** Central to the effective operation of any ETS in controlling emissions is its interaction with the dispatch system and resulting impact on actual dispatch, and thus emissions.

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**Second, without a means of passing on to customers the higher generation costs resulting from a CO<sub>2</sub> price, there is a risk that generation could be curtailed.** This is already an issue of some sensitivity, as prices have played a role in some past outages. While coal prices have mainly been de-regulated, electricity prices have not. The financial losses incurred by some coal generators facing high coal prices has at times led them to curtail output, leading to past instances of power shortages, at the expense of economic activity. After protracted negotiations, electricity prices have been adjusted upwards a number of times, typically by small increments, usually only for certain classes of users, and often only in certain regions. This experience makes it clear that under China's current regulatory and ownership structure, generating companies cannot count on rising tariffs to respond to increasing costs, and so may feel compelled to reduce generation. **This is of particular relevance in designing an ETS system, which is typically meant to achieve its aims by influencing generators' costs of production.**

## Can an ETS address China's electricity challenges?

An effective and sustainable ETS must be designed to minimize adverse impacts on the operation of the electricity sector to ensure political acceptance and operational sustainability. **In China, the key structural issue is that generators cannot simply respond to price signals by adjusting their tariffs.** In addition, the aim of state-owned generation companies is not to maximize shareholder equity, but rather to balance financial sustainability with a mandate to provide a secure electricity supply for sustained and equitable economic and social development. Moreover, to be effective in China, an ETS should address the challenges noted above, namely the persistence of small, inefficient coal plants, as well as rigidities in the pricing system that can lead to power shortages. **Thus, introducing an ETS in the electricity sector presents an opportunity and a challenge for China:**

- **The large number of less efficient, small coal plants is an important opportunity for emission reductions.** The 65 GW of total generation capacity represented by these plants of <100 MW is equivalent to France's nuclear capacity. These represent a potential for CO<sub>2</sub> emission reductions

<sup>3</sup> Zhang, Schreifels, and Yang (forthcoming)

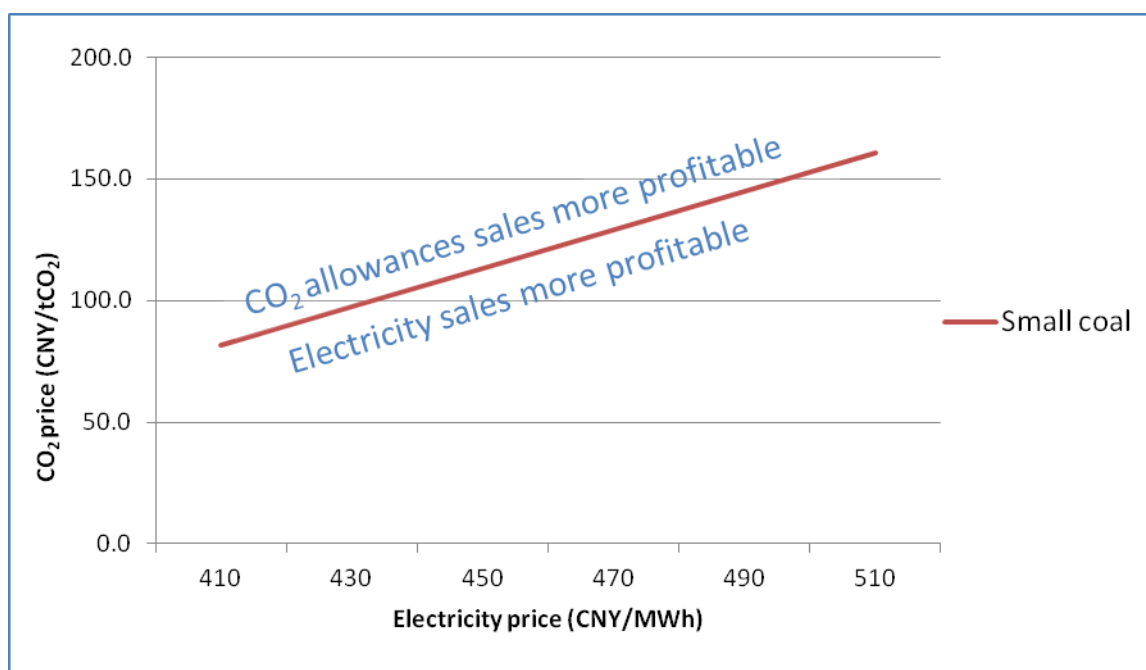
that could be tapped by an ETS, provided it addresses the above-mentioned issue of compensation.

- **The toughest challenge to an ETS (and most other carbon control mechanisms) may be the additional cost that a constraint on CO<sub>2</sub> emissions will represent for fossil-fuelled generation units.** This discussion comes at the time where increasing coal prices have undermined the economic viability of plants and led them to interrupt production.

### Enhancing efficiency of coal-based generation: addressing small coal

China has ambitious plans for the deployment of carbon-free electricity sources (nuclear, hydropower and other renewables), with dedicated policy instruments and incentives. **The ETS would only directly affect fossil-fuelled generators, namely the coal, oil and gas plants that emit CO<sub>2</sub>.** One obvious potential for CO<sub>2</sub> reductions among these plants is to continue the switch away from less-efficient, small coal plants towards larger, centralized, more efficient coal plants, up to large-scale ultra-super-critical plants. As of 2010, large, more-efficient coal plants were run about 5000 hours per year on average, leaving some margin for increased output. Less-efficient units of 300 MW and below were run at least 4000 hours on average. **Experience shows that improvements from this sub-optimal dispatch (from an energy efficiency, cost and emissions perspective) are possible, provided that compensation is given to small coal plants.**

Figure 3: CO<sub>2</sub> switching price: compensating less-efficient plants for loss of revenues



Note: This assumes a coal price of CNY 700/tce.

**Key message: At current coal prices, the sale of CO<sub>2</sub> allowances at a price of CNY 100-150/tCO<sub>2</sub> could compensate small coal plants for reduced revenues from lower electricity sales.**

Emissions trading could be the vehicle for such compensation. **This requires granting free allowances to existing plants, allowances they could sell if they decided to lower output.** The price of CO<sub>2</sub> allowances, if it were restricted to power generation, would need to reach a level where it compensated these plants for the loss of electricity revenues minus fuel cost. **Figure 3 shows the CO<sub>2</sub> price range that would adequately compensate a small coal plant, as it makes way for electricity from a USC plant – reflected as a CO<sub>2</sub> ‘switching price’.**

## The impact of CO<sub>2</sub> costs on electricity prices

**The main challenge for the power sector under an ETS is the management of the carbon cost and the potential electricity price impact.** The price of CO<sub>2</sub> will add to the financial burden of most power generators – even if some technical efficiency gains and economic gains may be achieved in the near term by large companies.

Whenever an ETS has been applied to power generators in a deregulated wholesale electricity market, it has led to a pass-through of the CO<sub>2</sub> price to the electricity price. However, electricity prices are regulated in China, and the question is how the regulated electricity prices could be adapted, in a way that supports the system's acceptance and effectiveness. If prices remain at their level without the CO<sub>2</sub> cost, an additional cost is borne by generators that cannot be recouped through higher prices. Past curtailments of electricity generation as coal prices increased showed the significance of this problem. **An ETS would be untenable if power generators were led to curtail output due to economic losses from CO<sub>2</sub> costs. On the other hand, how the CO<sub>2</sub> cost would be reflected in electricity prices must be carefully considered.**

In order to balance the simultaneous needs to sustain investment in new capacity, to meet the CO<sub>2</sub> intensity objective, and to provide the incentive to generators of a higher electricity price, **China could consider adjustments to the way electricity prices are set for fossil-based generation.** While this challenging topic is beyond the scope of this paper, Table 1 provides orders of magnitude of the CO<sub>2</sub> cost that would be borne by a high-efficiency coal plant under various assumptions<sup>4</sup>.

**Table 1: How large could the cost of CO<sub>2</sub> be for an ultra-super-critical coal plant?**

| CO <sub>2</sub> costs<br>(% of electricity revenues) |                     | CO <sub>2</sub> price assumption<br>(CNY/tCO <sub>2</sub> ) |       |
|--|---------------------|---|-------|
|  |                     | 40  | 150   |
| Allocation scenario                                  | 90% free allowances | 0.7%  | 2.7%  |
|  | 0% free allowances  | 7.3%  | 27.4% |

Note: The CO<sub>2</sub> costs are illustrated combinations of assumptions: low and high CO<sub>2</sub> price (CNY 40-150/tCO<sub>2</sub>), and 90% and 0% free allowances. The power plant is assumed to run 5100 hours a year. Higher running hours would increase CO<sub>2</sub> allowances cost, but also revenues.

**Key message: The cost of buying allowances to cover emissions appears moderate with a high level of free allowances (90%), and much higher when the plant has to buy all its allowances.**

## Features of an ETS for power generation in China

**A working ETS, for China or elsewhere, is composed of various elements. The following are especially critical: (a) an overall cap, (b) rules for the allocation of allowances to sources, (c) a system for monitoring, verification and reporting of emissions (MV&R), (d) predictable rules on the timing and nature of potential revisions to the system.**

This section first outlines the key elements of a typical ETS scheme and indicates some of the specifics of an ETS system adapted to the Chinese context. The preceding analysis of existing

<sup>4</sup> In November 2011 the NDRC increased on-grid electricity prices for nonresidential consumers by CNY 0.026 /kWh in a response to rising coal prices. This represented an estimate price increase of about 6.8% (Wall Street Journal, 30/11/2011). This is higher than the estimated CO<sub>2</sub> cost assuming 90% free allowances and a CO<sub>2</sub> price of CNY 150 per ton as illustrated in Table 1.

electricity regulations has some bearing on how an ETS ought to be designed, if it is to drive least-cost mitigation and to overcome the challenges faced by China's generation sector. Issues include the way allowances are distributed to plants, how to treat the many new plants that will be entering the ETS, and the need for a strong emission measurement system, a prerequisite of any credible ETS.

## Page | 12 The core elements of an ETS

The ETS will include several key aspects, some of which are discussed in more detail below:

- **A cap on emissions.** This is the starting point of the ETS, as it defines the environmental goal that the ETS will deliver. It defines the overall level of effort that applies to all covered emission sources. The level of the cap will determine the cost imposed on emission sources and the price of CO<sub>2</sub>.
- **Plant-level allocation of emission allowances.** The total emission cap is then allocated to individual sources in the sectors covered by the ETS. Each source has the obligation to surrender enough allowances to match its emissions during the commitment period.
- **Ability to trade.** No ETS will function, and no robust price will emerge unless sources are allowed to trade allowances on a wide basis – in China's case, across sectors and provinces. This requires an information infrastructure (a registry for transactions) and a specific legal framework – both issues not covered here.
- **An MV&R system for CO<sub>2</sub> emissions.** This is the cornerstone of a credible emissions trading system.
- **A credible enforcement mechanism,** i.e. a penalty to deter non-compliance with emission goals.
- **The price is generated through the implementation of the above elements.** The price will more or less differ from forecasts, as abatement costs are not known with precision and economic and other price developments (for coal, gas, alternative electricity technologies) may differ from expectations.

### Overall cap: key elements in power generation

**The cap defines the environmental effort of the ETS, as it sets the scarcity of emissions, and creates an economic value for these emissions.** It is itself defined by the both the coverage of the system (which sectors and which plants are included), and the overall emission reduction effort required. While the effort can be set 'politically' – a percentage reduction from a baseline, in line with to a country-wide emissions goal – it requires at least some information for its elaboration: an inventory of plants to be covered and historical energy and emissions data. The decision on the cap can also be informed by the projected cost of reducing emissions – the cost of abatement in various sectors, the impacts on prices and on the macro-economy, and socio-economic costs and benefits.

In the case of electricity, creating CO<sub>2</sub> scarcity requires taking into account several elements. For instance, **CO<sub>2</sub> emissions in electricity generation depend on the achievement of plans for new capacity in nuclear, hydro, wind, and solar,** as these will affect the reliance on fossil-fuel based capacity. Further, **whether small and less efficient coal plants will be included in the ETS is critical in defining the near-term potential for emission reductions.** Last, **the future of natural gas in China could have a significant impact on the power sector CO<sub>2</sub> intensity.**

Looking beyond the supply side, end-use energy efficiency holds much promise to curb future demand for electricity, and China is leading a number of efforts in this area as well, such as the newly announced Top 10,000 enterprises programme.

**The CO<sub>2</sub> goal for power generation risks being either too lax or too stringent depending on the success of other policies in the electricity sector. Decisions on the cap therefore need to be made**



**with as much information as possible on the projected contribution of generation technologies and policies that can affect CO<sub>2</sub> emissions from electricity.**

The cost of the overall system, driven by the price of CO<sub>2</sub>, will of course depend on which other sectors are included, an issue not covered in this project. There is also a design question of the coverage of emission sources within the electricity sector. The challenge is to balance the opportunity of including small coal plants, and thus accessing the mitigation potential presented by such plants, with the search for a manageable measurement, verification and reporting system.

## Suggestions for an initial allocation method to fossil-fuel plants

### A. Existing plants

**The allocation of allowances is a major design feature in any ETS; it defines the distribution of emission reduction efforts across plants. In the case of China, addressing climate change is largely about addressing emissions from new plants – their treatment will be critical.**

We have shown above that in the near term the cost of compliance with the emission cap could essentially be the cost of acquiring CO<sub>2</sub> allowances freed-up by small and less efficient coal plants.<sup>5</sup> **This implies a sufficient allocation of allowances to these existing and less efficient plants, in the initial phase of the ETS.** These allowances would, in particular, compensate these plants financially as they progressively close and leave room for more efficient, low-CO<sub>2</sub> technologies.

### B. New plants

New plants ought to be subject to a different treatment. Granting them free allowances based on their projected emissions would not lead to emission reductions. **For new plants, we suggest an allocation below the level needed to cover emissions corresponding to standard operating hours so as to encourage the purchase of CO<sub>2</sub> allowances from existing, less efficient plants.** Allocation to new plants should be based on a benchmark, combining a standard performance (tCO<sub>2</sub>/MWh), ideally uniform for all fossil-fuel plants, based on standard running time, with an reduction factor.

### C. A reserve for new plants

With an 11% growth in electricity output in the last ten years, the number of new plants potentially coming under the ETS is much higher than in any other existing or planned ETS. **The Chinese ETS would need to plan the inclusion of an uncertain number of CO<sub>2</sub>-emitting plants, balancing the need to encourage mitigation with the imperative of the reliability of the electricity system as demand grows.**

In existing systems, regulators have established a limit over the total quantity of allowances that can be attributed to new entrants, called the new entrants reserve. The risk, in the case of China, is that the reserve of allowances is set too low, stopping the addition of new power generation when it may be needed (an untenable proposition). The opposite risk (too high a reserve) can be managed without compromising the environmental goal: all allowances remaining in the reserve at the end of the commitment period could be retired by the government. Alternatively, the quantity of allowances in the reserve could also be indexed on actual GDP growth.

## Monitoring, verification, reporting, and the enforcement of CO<sub>2</sub> objectives

**Emissions trading requires a robust, credible and verifiable system to measure emissions from the covered sources, i.e. the cornerstone to assess compliance with emission goals. The report**

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<sup>5</sup> For plants that curtail output to sell emissions, the cost will be the loss of electricity sales, minus the revenues from CO<sub>2</sub> allowance sales.

identifies two possible routes towards that goal. First, power generators are subject to an extensive reporting task on their fuel use, which contains sufficient information to estimate CO<sub>2</sub> emissions from combustion – a method that has been experimented on an ultra-supercritical coal plant in a CDM project. Second, power generators must operate continuous emissions monitoring systems to measure SO<sub>2</sub> emissions; these systems can be upgraded at limited additional cost to also measure CO<sub>2</sub> emissions.

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There is however no systematic verification protocol in place for either measurement methods. Whichever option is deemed acceptable for China, **it will require a robust system of certification to ensure the validity of reported emissions, which is currently lacking.** The sources subject to the emission cap will otherwise question the value of allowances traded, and could potentially oppose to paying a price for such allowances if any doubt is cast on the underlying measurement.

**In addition, the ETS must include a financial penalty for non-compliance, both to deter cheating, and to encourage the reliance on cheaper alternatives – including the purchase of allowances – to comply.** Penalties have traditionally been set at a much higher level than the projected price of CO<sub>2</sub> - in the EU ETS the penalty is currently €100/tCO<sub>2</sub> plus future surrender of missing allowances, while in the proposed Australian ETS the penalty will start at 1.3 times the relevant permit price and increase over time.

### Managing the evolution of the system

**Emissions trading systems are effective, yet complex policy tools. They are prone to surprises, triggered by external or internal events. They must be designed with a possibility to review design features at regular intervals.** External shocks have clearly affected other ETS, e.g. in the European Union as low economic activity, and a generous allocation to some sectors early on, created a surplus on the supply side, leading to a low price, which was disconnected from the system's long term goal. China may learn from its province and city pilots, but a prompt start nation-wide system that contributes to its 2020 goal may not allow for learning and experience to be taken from the pilots. In any event, the design of a Chinese ETS should plan for revisions, including accounting for any unexpected developments in the way the electricity generation sector operates and reacts to the system.

Establishing rules for banking and borrowing of allowances across trading periods is another way to build in flexibility in the ETS. However, the rules, in particular for banking, need to be developed so as to avoid potential build-up of surplus allowances in case of an over-allocation during a specific trading period.

China could consider how the Five-Year Plan process could allow for the needed revisions of key elements and build timelines and adjustable processes. These may include:

- The overall cap and, possibly, an associated long-term goal.
- The coverage of the ETS and the possible inclusion of other sources of emission reductions.
- The mode of allocation to various sectors (e.g. the treatment of new entrants and closures).
- Possible linking between its ETS and other systems.

### Making an Emissions Trading System Work in China

As an economic instrument, an ETS is meant to change behaviour and lower pollution through changes in relative costs; this could happen through three channels:

- **First by making fossil-fuel generation less attractive to the grid operators.** The grid would face an increase in the purchased electricity price as a result of the CO<sub>2</sub> cost faced by fossil generators;

- **Second, by lowering the profitability of fossil-based generation through a lower level of free allocation and/or a rising price of CO<sub>2</sub>;**
- Third, following from the previous point, **by enhancing the relative profitability of low-CO<sub>2</sub> technologies.**

As indicated above, some changes will be required to fully exploit these channels:

- A change to the regulation of plant dispatch to allow shifting from high-CO<sub>2</sub> to low-CO<sub>2</sub> sources as the price of CO<sub>2</sub> changes their respective profitability;
- An adjustment of electricity prices to reflect the cost of emission caps on generators.

Last, it will be important to monitor how the allocation of CO<sub>2</sub> caps and the price put on emissions affects power generators in China, both for operations and investment choices. ETS experience so far has mostly been with companies driven by the maximisation of shareholder-value. **How the State-owned power generation sector will actually react to the price incentive will require attention to gauge the effectiveness of the system.**

## Conclusions

**An emissions trading system can be an effective tool to mitigate CO<sub>2</sub> from power at low cost in China, provided that some of the challenges of applying a market instrument to this regulated activity are addressed.**

To be effective in power generation, **the introduction of the ETS should be accompanied by enhanced flexibility in power plant dispatch, and some adjustment to prices faced by fossil-based generation in the near term.**

**The main question down the line will be whether the price of CO<sub>2</sub> and the cost generated by the ETS will directly affect future investment decisions in cleaner generation sources.**

Further analysis, monitoring and evaluation of actual implementation experience in China, with Chinese institutions and companies, will bring lessons needed to further develop and refine an effective ETS, to control emissions while supporting China's growth objectives

## Next steps

**There are important issues to be confronted by China climate and energy policy-makers in preparation of an ETS that would include electricity generation:**

- How to introduce flexibility in plant dispatch, from the current practice of annual dispatch plans? How to best use the ETS as a tool for a transition away from small and less efficient coal plants?
- How can the cost of complying with a CO<sub>2</sub> cap be reflected in the price of electricity paid to fossil-fuel plants?
- What are prospects for mitigation in power generation and what are critical technical areas for intervention to realise that potential (e.g. transmission, integration of renewables)?
- What verification procedures would be best suited to ensure the accuracy of CO<sub>2</sub> emissions data in power generation? The rules developed under the domestic carbon offset market (China Certified Emission Reductions) may offer guidance in this area.

**How China will pursue the implementation of a nationwide emissions trading system will partly hinge on the lessons from the carbon market pilots currently under development.** Whether and how these pilots address power generation will provide essential lessons for any broadening of the system. A nation-wide system could also be developed in parallel, with power generation at its core; **the large state-owned enterprises that have access to a diverse set of generation technologies**

**could start exploring internal CO<sub>2</sub> transactions, with limited financial liability, and report on issues they have identified.**

Looking beyond China, a number of countries have established, or are in the process of building their own emission trading systems. In parallel, Parties under the United Nations Framework Convention on Climate Change seek to develop a new market mechanism as well as a framework for market-based and other approaches to emission mitigation. At the moment, China's effort to develop a carbon market appears to be driven by the need to meet its domestic greenhouse gas objectives. In the future, the international carbon market will increasingly look to China as a major player – and China's power generation emissions in 2010 amounted to more than one and a half times the CO<sub>2</sub> emissions covered by the European Union system, the largest ETS to date. China's experience on this front is bound to influence both how other countries (especially emerging economies) approach this instrument, and how the international carbon market will develop, through bilateral links and/or in a more integrated fashion under the UNFCCC.

Issues in CO<sub>2</sub> emission trading and electricity: international experience and suggestions for China

| Design / policy issue  | International experience  | Suggestions for China from IEA-ERI project  |
|--|---|---|
| <b>Setting the cap and coverage</b>                          | <p>The ETS cap can be drawn from the country's overall emission goal</p> <p>A percentage from base year emissions.</p> <p>A bottom-up estimate of emission reductions required from all existing plants, plus a reserve for new plants.</p> <p>Existing systems have used a minimum capacity threshold (e.g. 20 MW or 25 MW) for participation, to minimise total number of participants, administrative cost and compliance cost for plants that account for a small share of overall emissions.</p> | <p>The very dynamic nature of the country's electricity sector requires a careful assessment of future growth and the contribution of all, including CO<sub>2</sub>-free, technologies. The cap on emitting plants should represent an emission reduction effort additional to current plans.</p> <p>Setting the cap will require a thorough inventory of existing plants, combined with an estimate of their projected lifetime, (e.g. projected closure date for small and less efficient plants).</p> <p>A cap in China's electricity sector may combine a bottom-up approach (inventory of existing plants' emissions), a projection of expected electricity growth, and an emissions benchmark for new plants that will create emission scarcity and encourage more efficient fossil-based technologies.</p> <p>A threshold for participation (expressed as x MW of capacity) to be set to keep the system manageable from the viewpoints of the regulator and plants.</p> |
| <b>Allocation to existing CO<sub>2</sub>-emitting plants</b> | <p>Free allocation based on past emissions or a benchmark, usually limited to the first period.</p> <p>Auctioning: sale of emission allowances by the government (this can also include a compensation mechanism using auctioning revenues).</p>  | <p>Existing plant could receive a high share of free allowances initially, to minimise the electricity price impact. This allocation could be based on a single benchmark (e.g. tCO<sub>2</sub>/MWh x historical operating hours), or on historical emissions, which would facilitate participation by these plants.</p>  |
| <b>New plants</b>  | <p>New plants receive allocation based on planned capacity usage and technology.</p> <p>Or: new plants must purchase allowances from the market/government to cover all their emissions (auctioning).</p>   | <p>New plants could receive an allocation below their expected emissions under standard operation conditions. A single benchmark could be used for all coal-technologies, encouraging more efficient ones, or for all fossil-fuel burning plants, which would benefit natural gas plants.</p> <p>Given the rapid growth in electricity output, the system should account for possible revisions, including the treatment of new entrants and closures.</p>  |
| <b>Electricity price</b>                                     | <p>In deregulated electricity markets, marginal cost pricing implies a pass-through of the CO<sub>2</sub> cost to the electricity price. The wholesale electricity price increases whenever a fossil-plant is the marginal supplier. The CO<sub>2</sub> cost is passed through regardless whether allowances have been distributed for free or sold at an auction.</p>  | <p>A constraint on CO<sub>2</sub> emissions in power generation will eventually raise power generation costs, which need to be reflected in prices.</p> <p>Electricity prices are set by the Government on the basis of total costs. A free allocation to existing plants could help keep the cost increase low, hence reducing the needed adjustment to electricity prices.</p>  |

| Design / policy issue                                    | International experience   | Suggestions for China from IEA-ERI project  |
|--|--|---|
| <b>Electricity dispatching</b>                           | <p>Different dispatch models exist.</p> <p>In deregulated electricity markets dispatching is typically done based on a least-cost merit order.</p>   | <p>Flexibility needs to be introduced into the current quota-based dispatching system to be able to access the efficiency and mitigation potential in switching from small inefficient plants to larger more efficient plants.</p> <p>Free allowances to existing plants would allow high-emitting plants to sell allowances to new and more efficient plants. The sale would be a compensation for operating fewer hours.</p>  |
| <b>Offsets</b>   | <p>Emissions trading systems allow some use of offsets to manage the costs of compliance for covered entities.</p> <p>The level of offset use allowed differs between systems, some of which allow unrestricted use of offsets.</p>  | <p>The use of domestic offsets in an ETS should be driven by considerations of: cost imposed on sources in the ETS; the emissions trend expected from ETS sources going forward (e.g. risk of lock-in).</p>   |
| <b>Measurement, verification and reporting</b>           | <p>Continuous emissions monitoring systems or estimates based on fuel purchase and calorific value have been used to monitor CO<sub>2</sub> emissions.</p> <p>Verification can be done by certified third party, or through self-assessment subject to spot checks from regulator.</p>   | <p>China could rely on either its extensive energy reporting system or its mandatory continuous emissions monitoring systems in power plants to report CO<sub>2</sub>.</p> <p>Verification by third-party is a prerequisite to ensure data quality, and build the trust necessary to a well-functioning ETS.</p>  |
| <b>Renewable / low-CO<sub>2</sub> technology support</b> | <p>Low-CO<sub>2</sub> generation technologies may benefit indirectly from the ETS through higher electricity market prices.</p> <p>Other support measures (feed-in-tariffs, green certificates) complement the ETS, as CO<sub>2</sub> price is often not high enough to make renewables or carbon capture and storage competitive.</p> <p>There is a risk that over-achievement in deployment of renewables undermines the ETS through the delivery of higher than expected CO<sub>2</sub> reductions.</p> | <p>With dedicated prices by technology, there is already a means to support the deployment of low-CO<sub>2</sub> technologies.</p> <p>Integration of CO<sub>2</sub> costs in electricity prices would further encourage low-CO<sub>2</sub> technologies by making fossil-fuel generation less attractive to the grid.</p> <p>The stringency of the ETS allocation to electricity should take full account of expectations of development of low-CO<sub>2</sub> technologies through other incentives.</p> |



## Introduction: objectives and scope

This report describes how emissions trading (or 'cap-and-trade') could contribute to China's plans to curb CO<sub>2</sub> emissions, in the context of both its international pledge to reduce the CO<sub>2</sub> intensity of its economy by 40-45% from 2005 level by 2020, and its ambitious domestic goals on the penetration of non-fossil fuel energy, with the bulk of it expected in the electricity generation sector. The focus is on the electricity sector, most frequently identified as the activity most compatible with an emissions trading approach:<sup>6</sup> it features large, stationary sources, a range of alternative sources of generation and associated costs, and as a result some potential for CO<sub>2</sub> emission reductions possibly in the near term, and more certainly in the medium to long term.

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In the case of China, power generation is also, by far, the largest, and a fast growing source of CO<sub>2</sub> emissions, with a risk of locking-in a carbon-intensive development path as generation units are typically long-lived (30+ years). Even if CO<sub>2</sub> mitigation efforts should not apply exclusively to power generation, it is a sector that warrants special attention, all the more so as increased electricity use is also seen as an important contributor to lowering CO<sub>2</sub> emissions in end-uses.<sup>7</sup> The present analysis focuses exclusively on the supply side of this equation.

In China's case, the usual challenges of introducing an emissions trading system to limit CO<sub>2</sub> emissions are augmented by the regulatory environment of electricity generation: investments, electricity pricing and plant dispatching have mostly, so far, followed a planning approach, even if competition on investments has been encouraged. **In spite of some very ambitious policy improvements, there remain limited flexibility in the country's power generation regulatory system. Most of the effort of this work has gone into identifying some of the changes required to introduce the flexibility needed to make emissions trading a success in China's electricity sector.**

The report includes the following critical elements in this discussion:

- The role of power generation in China's climate change objectives, including policy objectives and tools at play in China's electricity sector at present.
- Basic conditions for the success of emissions trading in China, including the monitoring, verification and reporting of CO<sub>2</sub> emissions.
- Enabling conditions: issues for the regulation of power generation in China.
- Qualitative and quantitative insights based on scenario analysis at the level of:
  - a power company (based on publicly-available projections from China Power Investment Corporation, one of the five large state-owned enterprises operating in this sector)
  - and a province (Guangdong, one of the 7 provinces and cities currently developing carbon market pilots in China).

On this basis, the report suggests options for an effective, least-cost implementation of a carbon market instrument in China's power generation sector, in support of the 12<sup>th</sup> Five Year Plan goal of tackling CO<sub>2</sub> emissions through emissions trading.

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<sup>6</sup> Ellerman, Convery, de Perthuis, eds. (2010)

<sup>7</sup> IEA (2011)

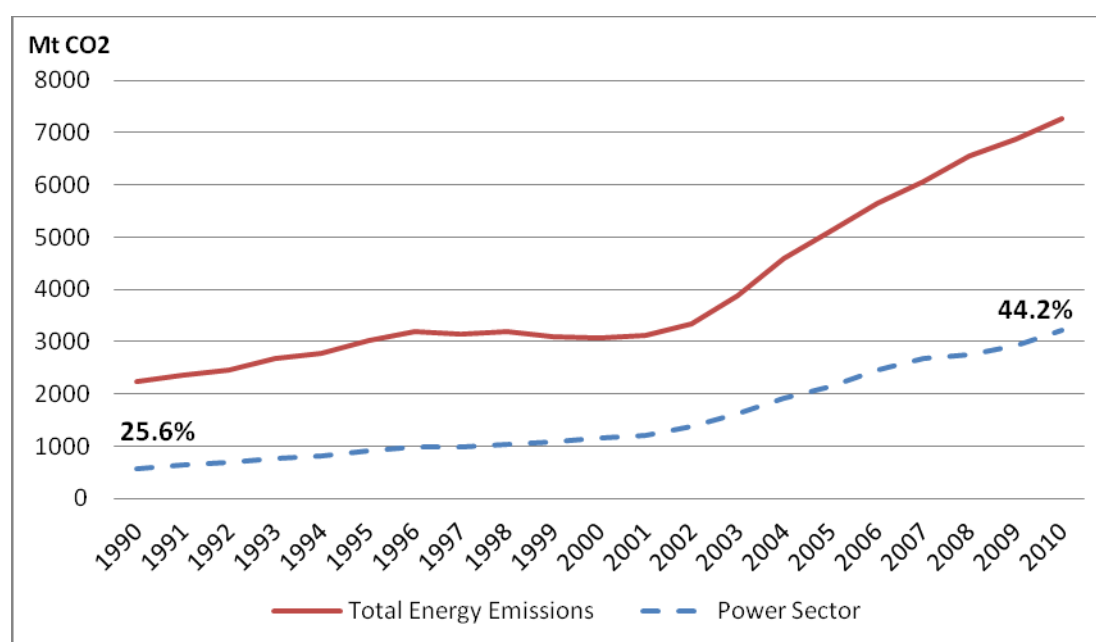
## Context

### Key figures, projections on electricity

Page | 20 *Electricity and CO<sub>2</sub> emissions in China*

On an aggregate basis, China has been the largest emitter of CO<sub>2</sub> emissions from energy globally for the last few years. **Electricity output, an important factor in the growth of China's economy, has contributed a growing share of the country's total emissions since 1990**, as electricity generation relies extensively on coal (79%) – the other important generation source at present being hydro (16%), with nuclear, gas, oil and non-hydro renewables providing the remainder.<sup>8</sup>

**Figure 4: Total energy-related and electricity-related CO<sub>2</sub> emissions in China, 1990-2009**



Source: IEA statistics, 2012.

**Key message: The power generation represents a growing share of China's energy-related CO<sub>2</sub> emissions since 1990. With 2932 MtCO<sub>2</sub> emitted from electricity and combined-heat-and-power plants, it accounted for 44.2% of the country's total of almost 7 GtCO<sub>2</sub> in 2010.**

The extensive use of coal is a major feature of China's power generation sector, although this masks important differences in the efficiency with which coal is used to produce electricity. An important theme throughout this study is the important efficiency potential – and CO<sub>2</sub> reduction potential – that can be tapped through more reliance on high-efficiency coal-generation technologies, an area of much interest already in China. Indeed, small coal plants emit some 53% more CO<sub>2</sub> per megawatt-hour (MWh) than most recent, ultra-super-critical plants in China, and three times as much CO<sub>2</sub> per MWh as combined-cycle gas turbines.

The following table shows the share of different unit types in total coal-based power generation in China. It reveals a **still substantial share of power generation provided by smaller, less efficient units**. It is noteworthy, however, that China managed to close some 76.8GW of small coal plants

<sup>8</sup> IEA (2012)

during the 11<sup>th</sup> Five-Year Plan. It remains to be seen if the same approach could be replicated for the remaining capacity, or if indeed there are barriers to a similar achievement in the 12<sup>th</sup> Five-Year Plan.

**Table 2: Breakdown of coal-based power generation in China, by plant type in 2010**

|                  | Capacity   |       | Generation   |       | Operating hours |
|------------------|------------|-------|--------------|-------|-----------------|
|                  | GW         | Share | TWh          | Share | (annual)        |
| Less than 100 MW | 68         | 9.5%  | 300          | 8.7%  | 4,430           |
| 100-300 MW       | 138        | 19.5% | 622          | 18.1% | 4,500           |
| 300 MW           | 210        | 29.6% | 1,029        | 29.9% | 4,900           |
| 600 MW           | 245        | 34.5% | 1,237        | 36.0% | 5,050           |
| 1000MW           | 49         | 6.9%  | 250          | 7.3%  | 5,100           |
| <b>Total</b>     | <b>710</b> |       | <b>3,438</b> |       |                 |

Source: Energy Research Institute, 2012

**Key message: In spite of a recent decline in capacity of small coal units with low efficiency, plants of less than 300 MW in size still amount for 26.8% of total generation in 2010.**

The efficiency potential in coal-based generation and the growing use of gas in power generation are not the only areas to improve the CO<sub>2</sub> footprint of power generation in China; hydro, other renewables and nuclear are other possibilities.

### ***Decarbonising electricity: plans and projections***

China has embarked on a vigorous path towards the development of carbon-free generation technologies. It is projecting 80 GW of capacity in nuclear, 180 GW of wind, 20 GW of solar, in addition to 330 GW of hydro (from already 197 GW today) – see Table below.

There is, however, a correspondingly high outlook for coal-based capacity, with 1190 GW, from 710 GW in 2010, which is higher than earlier business-as-usual projections from ERI. Overall, the growth of coal-based generation (and to a much lesser extent gas) will not be significantly impacted by the massive development of carbon-free generation. **The challenge in tackling CO<sub>2</sub> emissions lays clearly in the area of coal-based generation: ensuring that highest efficiency technology is used, and that there is a signal to curb growth in capacity.** The other side of this coin is of course an effective set of policy instruments to curtail demand growth through energy efficiency gains.<sup>9</sup>

<sup>9</sup> Regulatory Assistance Project and Natural Resources Defense Council (2009)

Table 3: Current plans for generation capacity by technology in 2020: comparison with ERI climate policy scenarios

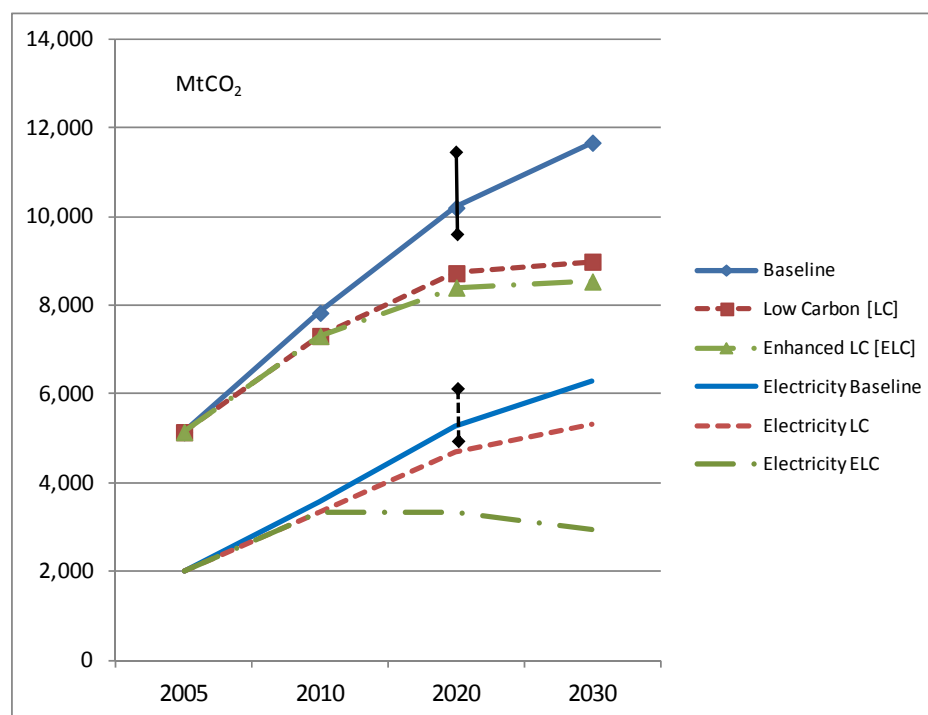
| 2020<br>(in GW) | Current goals | Energy Research Institute Scenarios |            |                     |
|-----------------|---------------|-------------------------------------|------------|---------------------|
|                 |               | Business-as-usual                   | Low Carbon | Enhanced Low Carbon |
| Coal            | 1,190         | 1,031                               | 1,049      | 688                 |
| Gas             | 60*-40**      | 35                                  | 35         | 67                  |
| Hydro           | 330           | 268                                 | 270        | 365                 |
| Nuclear         | 80            | 29                                  | 29         | 64                  |
| Wind + Solar    | 200           | 40                                  | 25         | 80                  |

Sources: Jiang, Hu, Zhuang (2009)

\* Objective for gas in the 12<sup>th</sup> Five Year Plan 2011-2015, CNPC; \*\* 2020 projection according to China Electricity Council.

**Key message: China has adopted very ambitious goals for the development of low-carbon generation by 2020 – matching or superseding earlier ERI climate policy scenarios. The challenge remains on the growth in coal-based power generation.**

Figure 5: ERI climate policy scenarios for China



Source: Jiang, Hu and Zhuang (2009). Note: The 2020 ranges (black bars) indicate the latest emission estimates for China's - 40-45% CO<sub>2</sub>/GDP pledge, based on 7.5%-8% average GDP growth rates projected to 2020.

**Key message: Electricity accounts for more than half of China's projected emissions – and would contribute significantly to the achievement of a low-carbon scenario for China.**

## *The role of power generation in delivering a low-carbon economy in China*

All projections concur on the essential role of power generation in China's future CO<sub>2</sub> emissions.

In the near term, the evolution of power generation has to be seen in the light of China's unilateral objective to cut the CO<sub>2</sub> intensity of its economy (GDP) by 40 to 45% from 2005 level by 2020. Much uncertainty will remain on the actual stringency of this objective, given the high GDP growth rate recorded in China previously and how variations in such growth could affect the economy's CO<sub>2</sub> intensity. With some 42% of energy-related CO<sub>2</sub> being emitted by power generation and an annual growth of 11.4% between 1999 and 2009, it is clear the carbon intensity goal will require efforts to contain growth in electricity demand and a lowering in the carbon content of electricity as well.

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An assessment of the magnitude of the effort required from electricity and other sectors – in other words, the appropriate level of allocation of emission allowances - is beyond the scope of this project, and a matter for political decision at high level. In any event, power generation has a key role to play in lowering the carbon content of the Chinese economy. How much flexibility this sector has to deliver on this possible goal is a question with economic and regulatory ramifications. The next section turns to the latter.

## **Electricity generation in China: structure, regulation and policies**

### *Organisation and regulatory framework of power generation in China*

The power generation sector of China is dominated by 5 state-owned enterprises (SOEs): Huaneng, Datang, Guodian, Huadian, and China Power Investment Corporation. Other major power companies include China Three Gorges, Guangdong Yuedian Group, Zhejiang Provincial Energy, Shenhua, and China Resources Power Holdings. This group of 10 companies totalled 450 GW of installed capacity in 2008, out of a total of 780GW for China as whole; they were responsible for 1.4 GtCO<sub>2</sub>.<sup>10</sup> About half of the sector's CO<sub>2</sub> emissions are emitted by other power companies of a much smaller size, often with local government ownership.

Even if SOEs and other companies are allowed to compete for establishing new capacity, **power generation remains largely a regulated activity in China:**<sup>11</sup>

- Each new power plant requires obtains an authorisation from the government, with an associated electricity price for the power it will deliver to the local grid. The price is established by the NDRC pricing department.

The grid sets an annual plan with a minimum number of hours that it will draw from each plants within its purview. It is essential a fixed quota system for the delivery of power. Higher than expected demand will require drawing on the available capacity over and above the initial plan.

Similar coal-plant types usually receive similar treatment (price), although Provincial differences exist based on the level of economic development. Smaller power companies owned by local governments are also known to enter into non-economic or subsidised pricing deals for favoured local power consumers further complicating the overall pricing structure<sup>12</sup>. Although there is a big effort on the part of SOEs to install large, high-efficiency ultra-super-critical plants of 1 GW of capacity, there are instances where lower-efficiency plants have been built recently to keep electricity prices low.

<sup>10</sup> Greenpeace (2009); IEA (2010)

<sup>11</sup> Regulatory Assistance Project (2011); Zhang, Schreifels, and Yang (forthcoming)

<sup>12</sup> GaveKal Dragonomics (2008)

A critical element in this picture is the fact that **coal prices have been allowed to move to reflect market prices**. With fixed electricity prices, this has led some power plants to stop operations as these were no longer profitable. Faced with the growing risk of supply interruptions, the government has adjusted electricity prices to reflect the increase in fuel cost for coal units. There is, however, not an automatic mechanism to adjust electricity prices in such circumstances.

Natural gas, nuclear, hydro, wind and solar plants are also granted a specific price that allows them an appropriate return. In the case of nuclear plants, after an initial period, the price is calibrated on a typical coal-plant electricity price.

The Chinese electricity generation business **is therefore not governed by a least-cost approach**, the way wholesale electricity markets tend to operate in the USA or Europe: the annual plan set by the grid defines the level of activity of all plants, with only a limited advantage granted to more efficient plants – this is reflected in the similarity running hours across all coal-plant types shown in Table 2). If plants were 'bidding' on the basis of their marginal cost, large, ultra-super-critical plants would be dispatched more, at the expense of smaller units.

### Policy instruments

The power generation sector in China, like those of other countries, is subject to a range of policy objectives and regulations that have bearing on the sector's CO<sub>2</sub> emissions and operations more generally. On the CO<sub>2</sub> front, the main objective remains the nation's goal of a 40-45% improvement in CO<sub>2</sub> intensity of GDP from 2005 levels by 2020, which translates into a 17% CO<sub>2</sub> intensity reduction during the 12<sup>th</sup> Five-Year Plan – this target has been further allocated to each Province. In addition, China recently set caps for 2015 on absolute energy consumption (4.1 billion tons of standard coal equivalent) and power generation (6400 TWh – to be compared with 4700 TWh in 2011, and about 3700 TWh in 2009).

Other more direct policy interventions in the electricity sector include the following, of particular relevance for CO<sub>2</sub> mitigation:

- The **closure of small coal plants**, often combined with the building of large, high-efficiency coal plants.<sup>13</sup> The 11<sup>th</sup> Five-Year Plan achieved the closure of nearly 77 GW of small coal capacity.
- A **mandatory renewable energy obligation of 3% of output for power companies** (excluding hydro).
- New **feed-in-tariffs** for the penetration of wind and solar (e.g. 4 different wind tariffs have been implemented, ranging from CNY 0.51/kWh to CNY 0.61/kWh; the FIT for solar is set at CNY 1.15/kWh until 2011, and CNY 1/kWh thereafter).
- **NO<sub>x</sub> emissions control** – an 8% reduction goal from 2010 levels by 2015, most of which falls onto the power sector; this includes de-NO<sub>x</sub> equipment for all new coal plants, and existing plants above 300MW of capacity, and restrictions on new plants in urban areas.
- **SO<sub>2</sub> emissions control** – a summary of the SO<sub>2</sub> emissions trading trials is provided below.
- An earlier trial of an **Energy Saving Power Dispatch Method (ESPD)**.

The last two policies bring interesting lessons for the prospects of CO<sub>2</sub> emissions trading in power generation.

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<sup>13</sup> Also known as "*building big, closing small*", an authorization to build a large USC unit is sometimes granted on the condition that two small units be closed, the workforce be re-employed in the new plant, and some training provided to enhance the operation of other plants in the district (Electricité de France, personal communication).



## SO<sub>2</sub> control and emissions trading

Policies to reduce SO<sub>2</sub> emissions have proven quite successful during the 11<sup>th</sup> Five-Year Plan, after many years of difficulties in curbing emissions triggered by increased industrial and electricity output. The goal was to reduce total emissions by 10% from 2005 by 2010, a goal that was overachieved, with a 14% reduction. This success is explained by a combination of command-and-control (flue-gas desulphurisation, FGD), a premium for electricity produced with FGD, absolute caps on pollutants by Province, levies and penalties, and, last but not least, the accountability of political leaders at the Provincial level.<sup>14</sup> An earlier attempt was made at piloting SO<sub>2</sub> trading, in part inspired by the success by the US SO<sub>2</sub> allowances program. The pilots suffered from their original design – different regions experimenting each with one element of SO<sub>2</sub> trading – but also from more fundamental problems:<sup>15</sup>

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- There was a **lack of clarity on the role of emissions trading** in complying with existing goals.
- **Financial penalties for emitting above the target were capped** at a level that made it more expensive to buy SO<sub>2</sub> allowances than to pay penalties for over-emitting.
- Local governments interfered in, and sometimes stopped transactions, **considered by the seller as a surrendering of its future right to emit**, and therefore constraining future economic activity. In fact, transactions were meant to offset emissions in one year only.

This experience shows that clarity is needed at the outset on the precise role of emissions trading – i.e. an instrument to minimise cost, and not to transfer permanent “rights” – and on its legitimacy vis-à-vis policy goals. Last, proper incentives are required so as not to deter trading for compliance.

## Introducing an energy saving dispatch rule

There has been an attempt at introducing a dispatch rule that would reflect the relative efficiency, and local pollution-intensity of plants in a grid; namely the “**Energy Saving Power Dispatch Method (Trial)**” (ESPD).<sup>16</sup> The ESPD aimed at maximising renewables dispatch, nuclear, combined-heat-and-power units, gas units, which would be granted priority over all coal plants; coal plants should then be selected on the basis of their energy consumption (i.e. efficiency). In cases of supply shortage, all plants would be dispatched without distinction. Five provinces experimented the ESPD. Zhang, Schreifels, and Yang (forthcoming) have drawn lessons from the experiments, with important insights for the implementation of a carbon market in the power generation sector. The ESPD has triggered observable energy savings (and associated CO<sub>2</sub> and SO<sub>2</sub> emission reductions) in some Provinces, through a change in the running hours of coal plants based on relative size (and, presumably efficiency), and enhanced renewable production. However, Zhang, Schreifels, and Yang noted **the following barriers to the successful implementation of the ESPD**:

- **Cost** of electricity purchased by the grid: the policy grants higher access to more expensive generation sources.
- **The compensation of less efficient plants** that would be dispatched less than anticipated under the standard planning approach and therefore face a loss of revenue. Balancing the interest of the small plants with that of larger facilities would be facilitated if undertaken at the level of large holding companies.<sup>17</sup>
- The ESPD should not impede the **safe operation of the grid**.

<sup>14</sup> Schreifels, Yu, Wilson (2012)

<sup>15</sup> Jeremy Schreifels, personal communication.

<sup>16</sup> Zhang, Schreifels, and Yang (2012)

<sup>17</sup> “One interviewee mentioned that the ESPD experiment in Henan is most difficult because the large number of power plants makes balancing interests nearly impossible. According to this expert, the ESPD implementation has not gone very far in Henan” in Zhang, Schreifels, and Yang (forthcoming).

- The **real-time monitoring of coal consumption** at the plant level, which indicates which plants should be dispatched first, was not always accurate and could be manipulated.

As the ESPD has sought to introduce some flexibility in the way power plants are dispatched, it provides important insights on obstacles that need to be overcome for a successful emissions trading system:

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- **Price issues:** the ESPD confirmed the reluctance to increase power prices. Minimising price impacts ought to be a near term priority for the introduction of a cap-and-trade system.
  - **Cost distribution issues:** addressing the problems of plants that will be affected by lower running hours than agreed earlier when they were established.
  - **Monitoring issues:** the real-time monitoring of coal use does not appear to be reliable enough. Other means of CO<sub>2</sub> measurement, verification and reporting will be required.

### *In summary*

The following features stand out in thinking about how an emissions trading system (ETS) could be an effective approach to CO<sub>2</sub> emission reductions in China's power sector:

- Power generation, the largest CO<sub>2</sub>-emitting sector in China, is regulated (prices and production quotas), and dominated by state-owned enterprises.
- It is however responding to price signals, e.g. the recent coal price surge has led to power shortages as plants were on the verge of bankruptcy.
- Electricity prices are closely watched, by local grids and central government.
- There is a potential for an improvement in the overall efficiency of coal use in power generation, through further closure of less efficient coal plants, and a plant-dispatch that reflects cost and energy efficiency.
- An earlier attempt in this area (Energy Saving Dispatch Rule) revealed the importance of addressing the distribution of cost among existing plants, as small plants stand to lose in the process, unless proper compensation is found to smooth the transition.
- Existing plans for the development of nuclear, hydro, and renewable capacity seem to supersede earlier projections for low-carbon growth in China. Coal-based capacity, however more efficient it may become, points to rising CO<sub>2</sub> emissions.

## Emissions trading: basics & lessons learned

### *Basic design of an emissions trading system*

#### Economic instruments: from theory to practice

Emissions trading, like pollution taxes, has been conceived by economists with an aim to optimise environmental control. The theory is simple, but requires the government to have information on both the cost to society of various levels of pollution and on the cost of abating this pollution. Under emissions trading, the government sets a quantitative limit on emissions, corresponding to the level where the cost of avoiding pollution is equal to the benefit of reducing this pollution to society (in economic jargon: the marginal cost of emission abatement is equal to the marginal benefit of the avoided pollution). In the case of an environmental tax, the tax is set at the level where the marginal cost equals the marginal benefit.

In the case of climate change, the precise magnitude of the costs imposed by the accumulation of greenhouse gases is unknown, but the international community is now resolved to act in the face of the irreversible risks involved and of the observable damage to date. Most countries, including China, have adopted national greenhouse gas emission pledges and are implementing measures to reach these levels. But if there is no precise information on the social cost of climate change, why does emissions trading (and carbon taxes) remain an instrument of choice?

#### Instrument choice: why an emissions trading system?

In addition to delivering optimal pollution control, emissions trading is also designed to **achieve a given environmental goal at least cost to society** as a whole – it achieves what is known as allocative efficiency. Under perfect market conditions, all polluting sources will reduce their emissions to the point where it costs all of them the same amount of money to reduce emissions by more ton of emissions (i.e. the level of the tax, and the price of the tradeable quota, under emissions trading). In the case of emissions trading, this is achieved through the allocation of emissions allowances to each source (see definitions below), and the possibility to buy and sell these allowances. At the end of the period, each source must surrender a number of allowances matching its emissions over the period.

**This approach is economically advantageous when compared to command-and-control.**<sup>18</sup> It is also more practical: several sectors and thousands of activities are responsible for CO<sub>2</sub> emissions. Mandating a specific technology for each type of source is a very cumbersome solution, unlikely to pick the right technology, and likely to freeze technology innovation.

Alternatively, emissions trading allows a source to find an appropriate solution to reduce its emissions, with **the possibility to acquire an emission allowance from another source instead of reducing its own emissions**, if the allowance price justifies it. The multiplication of such choices among all sources covered by the ETS generate a liquid market for emission allowances, and, with it a price for these allowances that will guide all sources' investment choices for emission control.

**In the face of the projected cost of curbing CO<sub>2</sub> emissions in China's rapidly growing economy, it is not surprising that China identifies emissions trading as worthy of consideration.** Its success will hinge on a number of implementation details. As mentioned above, it is the power generation

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<sup>18</sup> Under command-and-control, all sources are mandated to use a given technology or to achieve an identical level of pollution control without any flexibility, a costly measure when some other technology could perform better, or some sources could have reduced emissions further at low cost, while others face a high cost for little reduction.

sector's ability to introduce flexibility that will be the key to the success of emissions trading as a tool to minimise cost.

### The key pillars of a successful emissions trading system (ETS)

Page | 28 Experience to date indicates the following elements as essential to the ability of an ETS to deliver least-cost emission reductions:

- The emission cap must represent a **constraint on emissions** from 'business-as-usual'. This is a basic requirement of environmental policy: no instrument is needed if the environmental goal is to be met under normal circumstances.
- There has to be a **clear allocation of emission allowances to sources** (whether they are individual sources or companies), and clear rules for compliance with the system.
- As an ETS creates a financial asset, in the form of emission allowances, strict measures must be applied to discourage cheating on the measurement of emissions, through **robust third-party verification**.
- **Financial penalties** in case of non-compliance, to encourage participants to pursue mitigation options and/or emissions trading for compliance.
- A **robust trading infrastructure** to track ownership of emission allowances among entities allowed to trade.

### How emissions trading works

The establishment and functioning of an emissions trading system can be summarised in the following steps (technical terms are defined in Box 1 below):

- **The government decides on the coverage of the ETS:** sectors (e.g. electricity, steel, cement) and points of obligation (in the case of electricity, generation units above x MW of capacity).
- **The government sets the overall cap** (in MtCO<sub>2</sub> or CO<sub>2</sub> equivalent if other gases are included) for a given commitment period.
- **The cap is allocated to individual entities**, usually the points of obligation.<sup>19</sup> The allocation to individual entities can be based on past emissions (grandfathering), on the sector's performance (benchmarking). The allowances can also be sold by the government to the points of obligation, through an auction.
- **Points of obligation can trade their emission allowances** via established platforms (exchanges) or "over the counter" (bilaterally). This activity sets a price on emission allowances, which represents the marginal cost of emitting one tonne of CO<sub>2</sub>. Other actors (market intermediaries) can be allowed to engage in trading as well.
- At the end of the commitment period, each point of obligation has to **surrender a number of allowances matching its verified level of emission** for the period.
- Failure to do so will imply: either the payment of a **financial penalty**, with obligation to surrender corresponding allowances in the following period; or the payment of a 'price cap'<sup>20</sup> per tonne above the surrendered allowances, without obligation to surrender missing allowances.

<sup>19</sup> It is also possible to allocate the allowances to other parties, e.g. to the grid company. Power generators, the points of obligation, would then have to buy the allowances from the grid company in order to be in compliance.

<sup>20</sup> This mechanism does indeed 'cap' the price of allowances, as no point of obligation has a financial interest in buying allowances at a price higher than the 'price cap'. Note that this differs from an earlier practice in China of capping the total payments for not meeting an environmental target. In the 'price cap' case, every additional tonne above target has to be paid for.

- Points of obligation may be allowed to **bank** unused allowances for use in a future commitment period. They may also be allowed to **borrow** from a future period's allowances to comply with their present commitments (a less common and usually more restricted feature).

The trading activity (i.e. volumes of allowances that are traded on an exchange) is not in itself a measure of success of the system, but is important as limited trading is unlikely to deliver a **robust price of CO<sub>2</sub>, which is the essential component of the ETS**. A common price credible to all sources is the sole guarantee that the emission goal (the cap) will be met at least cost.

### Box 1: Glossary of terms used for emissions trading

The following terms refer to various design features of emissions trading systems:

**Allocation:** the quantity of allowances distributed to a source.

**Allowances:** the right to emit one tonne of CO<sub>2</sub> in the commitment period.

**Auctioning:** the sale of emission allowances by the government to sources.

**Benchmark:** the performance indicator on the basis of which plants will be allocated CO<sub>2</sub> emissions allowances (e.g. x tCO<sub>2</sub>/MWh). A benchmark could be set by plant type (subcritical, super-critical, etc.), by fuel (coal, gas, oil), or more generally for all emitting plants (all fossil burning plants).

**Cap:** the total level of emissions allowed under an emission trading system.

**Commitment period:** period of time over which compliance with the emission goal is measured.

**Compliance:** a point of obligation is in compliance when it has surrendered enough allowances to match its emissions during the commitment period.

**Coverage:** the totality of sources covered by the emissions trading system.

**Grandfathering:** allocation of emission allowances to a source using its historical emissions as a basis.

**Monitoring:** the measurement of emissions by a source.

**New entrants:** new plants built and entering the ETS during the ETS commitment period after the introduction of the ETS.

**Offset:** a right to emit one tonne of CO<sub>2</sub>, generated by a source or activity outside the coverage of the ETS.

**Operating hours:** total annual output in MWh divided by plant capacity

**Point of obligation:** the plant or company that must surrender allowances matching its emissions, at the end of the commitment period.

**Penalty:** the price paid, and/or other consequence, faced by a source that fails to surrender enough allowances to match its emissions, or falsifies its emission report to lower its compliance cost.

**Reporting / report:** the information on emissions provided by a point of obligation to the ETS regulator.

**Verification:** action conducted by a third party to ensure the accuracy of the emission report of a source, prior to the communication of the report to the regulator.

**Vintage:** year during which an allowance can be used. For instance, one can refer to a vintage-2012 allowance. When banking is allowed, an earlier year's vintage allowance can be used to cover present emissions.

## CDM and ETS: a caveat

China's participation in the Kyoto Protocol's Clean Development Mechanism has been remarkable. In 2002, NDRC, with the cooperation of international organisations and foreign governments launched the "China's clean development mechanism ability construction project" (CDM Project). China's activities in support of CDM projects started in June 30, 2004. In 2005, the first batch of CDM project was approved by the CDM project review board, based on one of Inner Mongolia's wind power projects. **This was the first CDM project in the electricity sector.** In 2008, China had 2732 registered CDM projects, among which 1249 projects were in electricity sector.

This is a clear indication that an international carbon price can help to drive improvements in clean energy investment. Indeed this has motivated many analysts to think about how scaling up from the CDM toward a broader, sector-based approach, could support more ambitious mitigation action in China's power generation sector. The present report does not venture into the design of such a "sectoral approach", although **the mechanics required to cost-effectively reduce CO<sub>2</sub> emissions in power generation would need to be similar, whether the price of CO<sub>2</sub> is driven by the international or by the domestic market.**

A caveat is required here, to stress the marked difference between the Clean Development Mechanism projects in China's wind sector and an ETS (or a sector-wide goal) applied to electricity generation. CDM has essentially rewarded low-CO<sub>2</sub> emitting technologies in power generation. It is argued that these projects provide electricity that would otherwise be supplied by a CO<sub>2</sub> intensive generation mix; as such they avoid more generation, including from coal-based power generation. CDM, however, does not directly penalize CO<sub>2</sub>-emitting plants, neither through a price on carbon, or an explicit limit on these plants' total emissions. As we will make clear below, an ETS would operate in the exact opposite fashion in China's setting today: by setting a cap on fossil-fuel plants, it will introduce an additional cost on these plants, affecting their profitability, but **encouraging only indirectly, if at all, low-CO<sub>2</sub> generation technologies** – the added CO<sub>2</sub> cost would reduce the profitability gap between these technologies and fossil-based ones.

## A primer on ETS experience<sup>21</sup>

There is now ample experience with emissions trading systems, and lessons that China can benefit from as it thinks through implementing such a system, whether on power generation and/or on other CO<sub>2</sub>-emitting activities. We first provide general policy lessons and then turn to elements of relevance to the electricity sector in particular.

## General lessons from existing and proposed ETS

The first phase of the European Union ETS has made it clear that the setting of the cap and the allocations are difficult to get "right" in the beginning. **Good historical emissions data are fundamental** for both, but robust data may only come after a proper monitoring, reporting and verification system has been established. Historical data may not have the same quality as it will be reconstructed from information that was not appropriately organised or checked. Any fast start of an ETS runs this risk – which can be addressed, e.g. by launching a proper emissions monitoring system ahead of the allocation phase. The Australia carbon pricing system has benefited from an early data gathering mechanism.<sup>22</sup>

<sup>21</sup> Sources for this section are: Hood (2010), (2011); Ellerman, Convery, and de Perthuis (2010); Ellerman, Buchner, and Carraro (2007), presentations at the informal IEA-ERI November 2010 Beijing workshop, and workshops organized by the World Bank Partnership for Market Readiness.

<sup>22</sup> James White, 2012 Presentation at World Bank PMR



**The allocation phase requires addressing broad 'equity' issues, i.e. the distribution of cost for various sectors covered by the system.** In the EU, allocations have been rather stringent for the power generation sector, because generators are in a position to pass-through the cost of the emissions cap onto consumers – see next section. Energy-intensive industries that are subject to competition from uncapped regions have argued for the risk of 'carbon leakage' – emission reductions in Europe would lead to increased emissions elsewhere. As a result of this, and probably of inaccurate historical data, industry has received rather generous allocations in the first Phase of the EU ETS. Page | 31

It is difficult to imagine an ETS design that would not require adjustments as new information is made available. **Adjustments should be expected**, as shown recently in the EU ETS experience. As a result of an initial over-allocation and, mostly, the economic recession and ensuing low levels of industrial activity, there is now a significant surplus of emissions allowances in the EU ETS. This has led to a significant drop in the price of CO<sub>2</sub> allowances, with the risk that the investments to curb long-term emissions will not be made and more carbon-intensive productive capacity will be locked in, in the mean time. The Australian ETS has adopted a **rolling allocation system**, whereby the cap is first set for five years; the cap for each year beyond that point is set five years ahead by an independent authority, providing an opportunity to respond to unexpected changes affecting the ETS.

### Emissions trading and power generation

Because power generation consists of large point sources of emissions, it has always been considered as a natural fit for cap-and-trade systems, whether on NO<sub>x</sub>, SO<sub>2</sub> or CO<sub>2</sub>. The experience of the power sector under an ETS is very informative when considered from a China policy perspective, because of the differences in electricity sector organisation with the EU, in particular. Before we turn to these points, some common features will require careful considerations.

First, **the electricity sector is usually subject to a range of regulations and policies that affect its CO<sub>2</sub> emissions.** On the supply side, most countries have support systems in place to deploy renewable energy sources, often in the form of price subsidies (feed-in-tariffs). The experience in the EU is that these policies, when they perform beyond expectations, run the risk of undermining the price on the ETS, as they deliver more emission reductions than originally anticipated. It is therefore crucial to establish the overall emission cap with as much certainty as possible on the delivery of other policy instruments, such as RE deployment. An identical point can be made about end-use efficiency: limiting the growth in electricity demand automatically limits emissions. There are good economic arguments in favour of combining ETS, technology support and energy efficiency measures,<sup>23</sup> but **it is essential that the decision on the electricity sector cap be made in coherence with these other goals – and vice versa.**

Secondly, the organisation of the electricity sector (wholesale market, regulated) has a significant impact on how it will operate under an ETS – and on how the ETS will provide incentives to reduce emissions. This is an area of striking difference between China on the one hand, the EU and what can be expected from the Australian system on the other hand. **In countries with a wholesale electricity market** – i.e. free pricing – generators bid on the basis of their marginal cost of operation. With a cap on emissions, every additional MWh produced from coal, oil or gas carries a CO<sub>2</sub> cost. For illustration, assume a coal plant emitting 1 tCO<sub>2</sub> per MWh, and a price of CO<sub>2</sub> at EUR 10/tCO<sub>2</sub>. As the plant bids its electricity price, it needs to add EUR 20 per MWh: it is the cost of buying an allowance to cover the CO<sub>2</sub> emission of that MWh if it does not have an allowance. It is also the cost of not being able to sell an allowance that the plant owns, which it would do if the MWh were not produced.

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<sup>23</sup> Hood (2011)

As a result, **whenever the marginal generator is based on fossil fuels, the wholesale electricity price is increased by the CO<sub>2</sub> cost** (the current price of CO<sub>2</sub> allowances modulated by the carbon content of the generated electricity). The first effect of this is that the most CO<sub>2</sub>-intensive plants should be dispatched less as the CO<sub>2</sub> price increases their price the most. However, all CO<sub>2</sub> emitting plants that are dispatched receive a price for their sales that is increased by the CO<sub>2</sub> cost, even if they received their CO<sub>2</sub> allowances for free. While this pricing effect is economically and financially justified, it generates additional profits for some CO<sub>2</sub>-emitting plants, which runs against the principle of a polluter paying for (and not benefitting from) its pollution. This has led to some heated debates and some questioning of the rationale of the ETS in certain EU countries. This has also motivated the regulator to sell allowances to power plants in the third phase of the EU ETS, as opposed to a free allocation of allowances in the first two phases.

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**On the low-CO<sub>2</sub> generation side: hydro plants and nuclear plants then enjoy a higher financial return on their generation.** For renewables that get revenues from the electricity market and a premium from the government, revenues are automatically increased as well. Consumers carry the full cost of CO<sub>2</sub>, including the additional profits provided to carbon-free sources. In time, these carbon-free sources have an incentive to expand, while fossil-based generators are impacted by the CO<sub>2</sub> cost.

**In a regime with a fixed electricity price on a technology-by-technology basis, this incentive to enhance the penetration of low-CO<sub>2</sub> generation is lost** unless corrective measures are taken. On the other hand, **the automatic impact of the CO<sub>2</sub> price on overall electricity prices is also avoided** (and the resulting additional profits for some fossil-fuel based plants). This may be an advantage for the acceptance of the ETS in the near term. **These two points indicate that electricity pricing should be at the core of the discussion of the implementation of an ETS in China.**

## Implications of emissions trading for China's power generation

This section presents a technical analysis of how power plants may be affected by a price on CO<sub>2</sub> driven by an emissions trading system, in the setting of China's power generation sector today. Qualitative and quantitative analyses were conducted to explore this question:

- at the level of typical individual fossil-fuel plants (switching generation from low-efficiency coal to ultra-super-critical and gas plants);
- for a state-owned enterprise, based on public information for the China Power and Investment Corporation; and<sup>24</sup>
- for a province, Guangdong, where low-carbon scenarios were used to illustrate the implication of various profiles for the allocation of allowances to power plants.

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The analysis at the level of individual plants is presented in this section while the latter two analyses can be found in appendices I and II, respectively.

We first consider how the power generation can reduce CO<sub>2</sub> emissions from business-as-usual, essentially through a more rational use of projected fossil-fuel generation capacity. The issue of how a cost for CO<sub>2</sub> will be borne by power generators is then reviewed.

### *Triggering near-term CO<sub>2</sub> reductions: at what price?*

The starting point for mitigation in power generation in the near term is a more efficient running of the fleet of coal-based power plants, and an enhanced usage of gas plants. The reason for this focus on fossil-fuel plants is the assumption that plans to deploy more hydro, nuclear and other renewables are fully operational already, and that the grid would dispatch them in priority, to the extent of its technical capacity. It is also difficult to envision a major change to relative electricity prices in the near term, and a change in the attractiveness of various technologies in a way that would seriously enhance investment in clean technologies.

We first offer an aggregate illustration of the extent of CO<sub>2</sub> mitigation through plant optimisation, albeit a limited one, as it is based on a single company's portfolio (based on public information about China Power Investment Corporation), which happens to be less reliant on small and sub-critical coal plants than the Chinese power system as a whole.

We then explore an incentive structure, based on CO<sub>2</sub> trading, that would allow compensation for the lower output of less efficient plants.

Last, we provide quantitative information to frame a discussion on the possible effects that an ETS will have on generation costs, based on various CO<sub>2</sub> price and allocation scenarios and generation technologies. This is a critical part of the discussion on the development of an ETS, as the cost will have to be somehow passed through to the grid, first to avoid the curtailment of power by plants financially vulnerable to the CO<sub>2</sub> cost, and second to encourage other technologies to compete with fossil-fuel plants. While the latter may be a longer-term question, it has to be considered early, when a relatively low price increase may be tested more easily.

### *An aggregate view of near term mitigation through improved plant dispatch*

**The current practice of dispatching plants based on generation quotas rather than one based on operating efficiency is economically inefficient.** In addition the emissions profile of plants is not taken into account in dispatching decisions. Dispatching could be organised so as to enhance economic efficiency and lower CO<sub>2</sub> emissions, provided there is excess capacity among the less CO<sub>2</sub>-intensive capacity.

<sup>24</sup> The scenarios run at the company level do not reflect the views of the China Power Investment Corporation and are the sole responsibility of the authors.

This section is based on public data related to the China Power Investment Corporation (CPIC), one of the five large state-owned generation companies. We illustrate how a move away from more or less equal production quotas across coal plants, toward dispatching the more efficient fossil-fuel plants for longer hours would affect CO<sub>2</sub> emissions. Such a move has the potential not only to lower CO<sub>2</sub> emissions, but also to enhance profitability overall.

Page | 34 **Table 4: Changes in operating hours under the efficient dispatching scenario, 2010-2015**

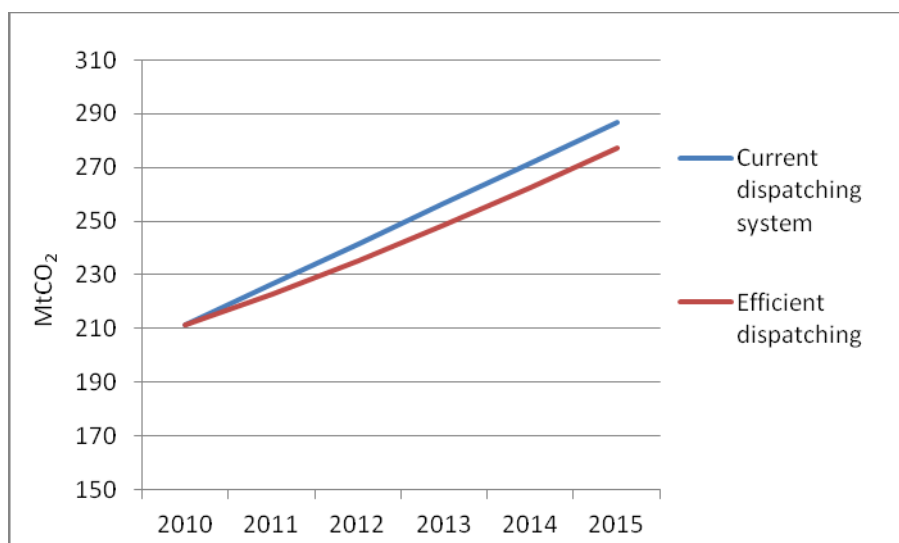
| Technology           | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|----------------------|------|------|------|------|------|------|
| Small coal           | 4800 | 4140 | 3480 | 2820 | 2160 | 1500 |
| Sub-critical         | 5050 | 4680 | 4310 | 3940 | 3570 | 3200 |
| Super critical       | 5100 | 5100 | 5100 | 5100 | 5100 | 5100 |
| Ultra-super critical | 5100 | 5300 | 5500 | 5700 | 5900 | 6100 |
| Natural gas          | 2000 | 2320 | 2640 | 2960 | 3280 | 3600 |

Note: The current dispatching scenario assumes that dispatching hours remain at their 2010 level until 2015.

Figure 6 illustrates the difference in CO<sub>2</sub> emissions from implementing the changes in operating hours shown in Table 4. By gradually increasing the running hours of ultra-super critical coal and gas, at the expense of less efficient coal plants, CO<sub>2</sub> emissions go down by 3.2% in 2015 for a similar output level. Profits are slightly higher in the efficient dispatching scenario – in 2015, 7.9% higher, excluding any impact of a CO<sub>2</sub> constraint. A CO<sub>2</sub> constraint would reinforce the impact on profits as the difference in CO<sub>2</sub> emissions increases costs in the case where all plants are dispatched for the same number of hours (the current dispatching system).

This example based on the generation profile of CPIC shows that **there are potential efficiency gains from increasing the flexibility in the system for dispatching power based on economic and environmental efficiency of plants.** In fact, the effect would probably be stronger: CPIC actually has a smaller share of small and sub-critical coal plants than the average in China. Table 2 showed that coal plants of less than 300 MW still amount 26.8% of total generation in 2010 while CPIC's share of small coal and sub-critical plants, some of which may also be larger than 300 MW, is 19%. This means that there is probably room for a more ambitious switching of generation from the least efficient coal plants to more efficient fossil-fuel plants than illustrated in the CPIC example above, leading to larger CO<sub>2</sub> mitigation and efficiency gains. However, one difficult question in this context is the potential need to compensate power plants that will operate fewer hours. China has attempted to solve this problem through generation rights trading, by which operators could buy and sell their allotted hours of operation. However, this scheme has apparently not worked well in practice as there is a lack of transparency and information on variable costs and transaction costs tend to be high.<sup>25</sup>

<sup>25</sup> Regulatory Assistance Project (2011)

Figure 6: Near-term CO<sub>2</sub> mitigation – the effect of more efficient plant dispatch

**Key message:** Based on the generation and investment profile of CPIC a relatively modest change toward more efficient dispatching mitigates CO<sub>2</sub> emissions.

**A carbon price would disclose the intrinsic operating inefficiencies of different plants and create a potential instrument for compensating plants that operate less.** With emissions allowances issued through a cap and trade system, plants wanting to increase their output would have to purchase emission allowances. A market price on emission allowances resulting from an ETS would also provide plant operators with a choice to reduce operation, allowing them to sell their allowances should the market price of these allowances justify this.

### *Pricing CO<sub>2</sub> to compensate lower electricity output*

We next illustrate the carbon price needed to make it economically attractive for less efficient coal plants to reduce their output, and to sell their CO<sub>2</sub> emission allowances. The methodology is the following:

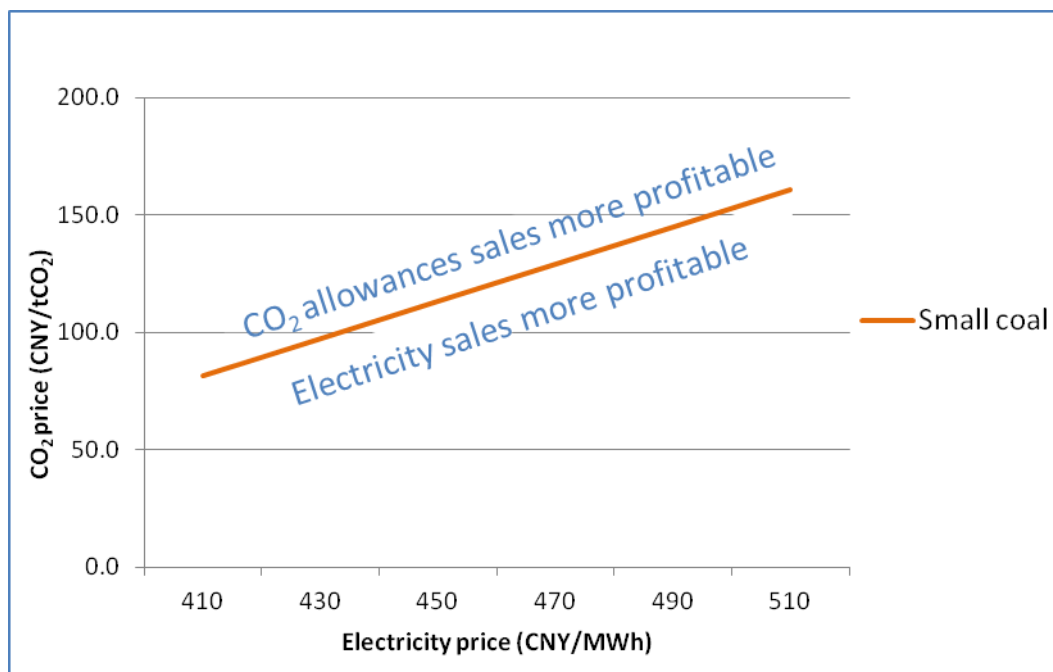
- Electricity price per MWh minus cost of coal per MWh gives the gross operating revenues;
- Dividing the gross operating margin by the CO<sub>2</sub> intensity of less efficient plants gives the minimum CO<sub>2</sub> price needed to make it financially attractive for these plants to reduce output and sell their emission allowances – for given electricity and coal prices.

Figure 7 and Figure 8 show the CO<sub>2</sub> 'switching' price needed under different electricity and coal price assumptions for small coal and sub-critical plants, respectively. The figures show the CO<sub>2</sub> price level needed to make it financially attractive for the small coal and sub-critical operators to sell unused CO<sub>2</sub> allowances as a result of lower electricity production. However, it also needs to be financially attractive for the more efficient plants to purchase allowances in return for the possibility to increase their generation. This depends on two factors:

- The CO<sub>2</sub> intensity of the more efficient plants, and
- The difference between electricity price and fuel costs (gross operating margin) for a coal plant and gas plant, respectively.

The CO<sub>2</sub> intensity matters because it will determine how much the purchasing plant can increase its generation with the allowances it has bought from less efficient plants.

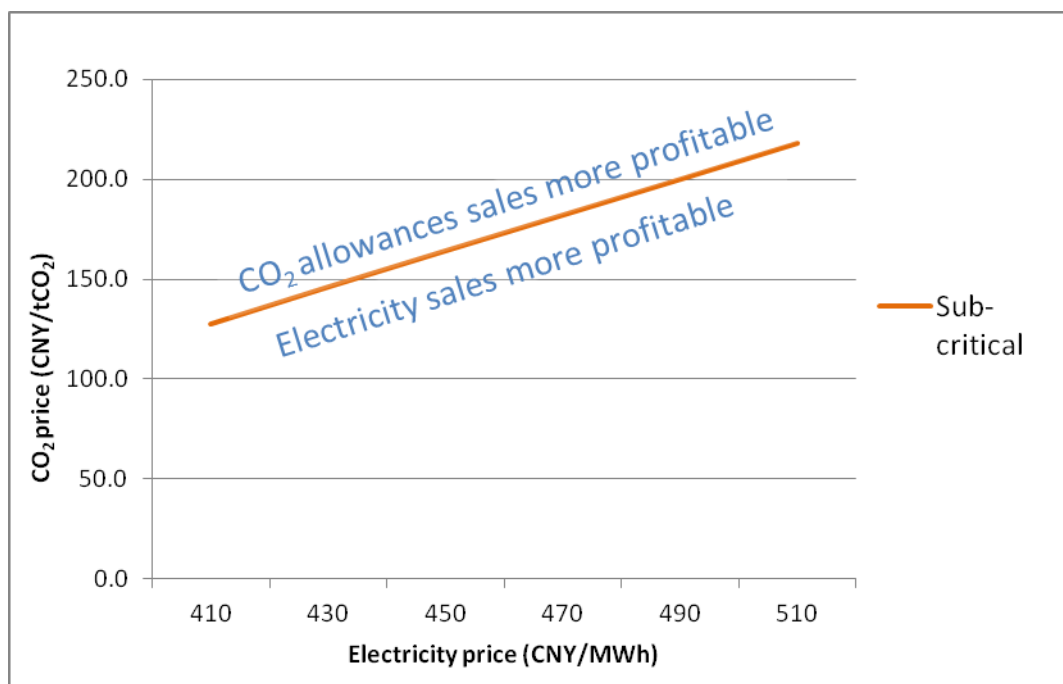
Figure 7: CO<sub>2</sub> price necessary to curtail small coal plant generation without loss of revenue



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Note: Assumes a coal price of CNY 700/tce.

Figure 8: CO<sub>2</sub> price necessary to curtail sub-critical coal plant power without loss of revenue

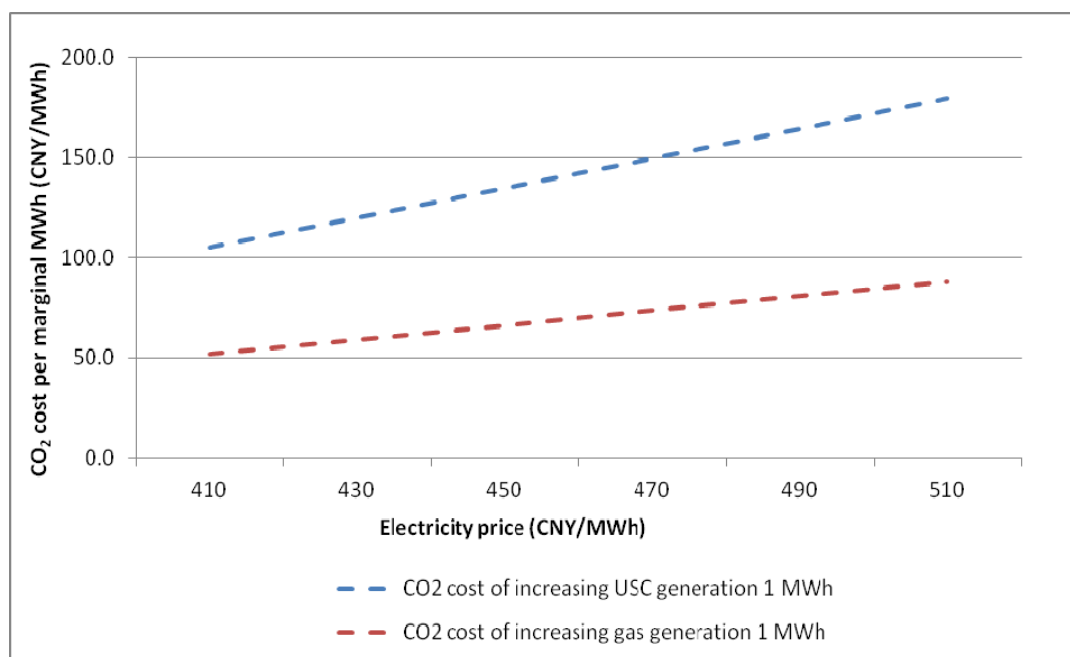


Note: Assumes a coal price of CNY 700/tce.

**Key message:** Small coal plants would need a CO<sub>2</sub> price of CNY 80-175/tCO<sub>2</sub> depending on the electricity price, to make it financially attractive to sell CO<sub>2</sub> allowances instead of producing additional electricity. Sub-critical plants would need a CO<sub>2</sub> price of CNY 125- 225/tCO<sub>2</sub>.

For example, based on the CO<sub>2</sub> intensity data from our company-level analysis an ultra-super critical coal plant could increase its generation by 1.22 MWh for every allowance to emit one tonne CO<sub>2</sub>; a gas plant could increase its generation by 2.48 MWh for one additional allowance. Assuming a coal price of CNY 700/tce, and that CO<sub>2</sub> allowances are bought from a sub-critical plant, Figure 9 illustrates the corresponding marginal CO<sub>2</sub> cost of increasing USC and gas generation by 1 MWh.

**Figure 9: CO<sub>2</sub> cost for a marginal MWh produced by USC and gas plants**



Note: The underlying CO<sub>2</sub> price is based on CO<sub>2</sub> allowances sold by a sub-critical plant, as shown in Figure 8.

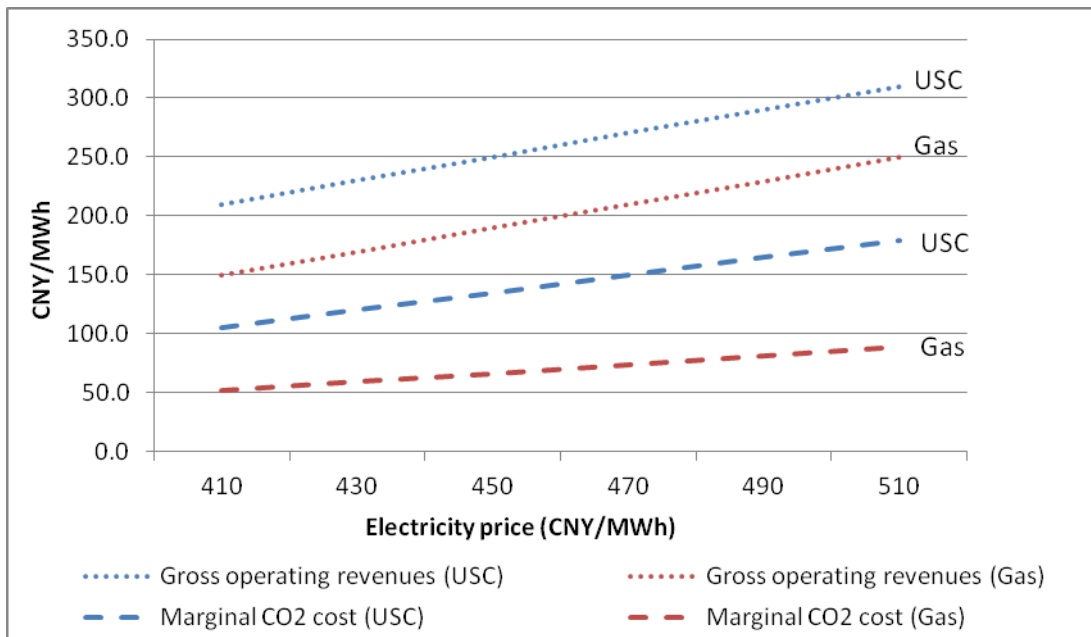
**Key message: Due to the differences in operating efficiency the CO<sub>2</sub> price needed to compensate a sub-critical plant for lowering output by 1 MWh is higher than the corresponding CO<sub>2</sub> cost to USC and gas plants that will need to produce one more 1 MWh to satisfy overall demand.**

A comparison of this CO<sub>2</sub> cost with gross operating revenues (the electricity price minus fuel cost) shows that **for both USC and gas plants**, assuming a coal price of CNY 700/tce and gas price of CNY 1060/tce, **it would be financially attractive at the margin for plant operators to produce more power, as the expected revenues would remain superior to the fuel and CO<sub>2</sub> allowance costs** (see Figure 10).

Comparing the net operating revenues (gross operating revenues minus CO<sub>2</sub> costs) of USC and gas shows that, except in the case of a low electricity price, net operating revenues are higher for gas based generation (see Figure 11).



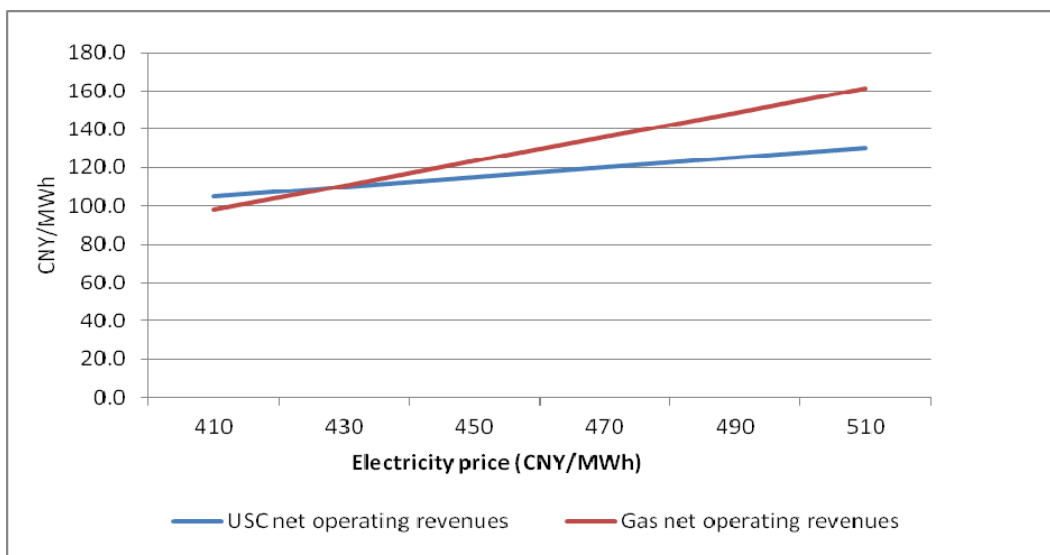
Figure 10: Comparison of CO<sub>2</sub> cost with gross operating revenues: USC and gas plants



Note: Assumes a coal price of CNY 700/tce and gas price of CNY 1060/tce.

**Key message:** The marginal cost of CO<sub>2</sub> from an additional MWh would be more than offset by increased operating revenues for both USC and gas plants – assuming CO<sub>2</sub> allowances purchased from a sub-critical plant (price range: CNY 125-225/tCO<sub>2</sub>)

Figure 11: Operating revenues adjusted for CO<sub>2</sub> costs: USC vs. gas plants



Note: This assumes a coal price of CNY 700/tce and gas price of CNY 1060/tce.

**Key message:** The CO<sub>2</sub> price signal is more favourable to a gas plant than to a USC plant: at the margin, under most electricity price assumptions, the net marginal revenues from power generation are higher for gas than for USC, with account taken of the CO<sub>2</sub> allowance cost.

The picture for switching generation from small coal plants would be similar but with a lower price of CO<sub>2</sub> and consequently a larger difference between gross operating revenues and the CO<sub>2</sub> cost.

### *From theory to practice*

The above argument represents a theoretical analysis and there is for example **no guarantee that less efficient plant operators will act economically rationally. If emission allowances are handed out for free the operator may choose to continue operating for various reasons and ignore the opportunity costs represented by the market value of the allowances.** Most of the less efficient coal plant operators will already have recovered their plants' capital costs and may continue their operations, for example for social reasons, in spite of reduced profit margins. In cases where locally-owned power companies have entered into non-economic pricing agreements with preferential power consumers, the financial incentive created by the price of CO<sub>2</sub> and the holding of free allowances may not trigger the expected change in dispatching behavior.

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As free allowances would normally be allocated based on the combined benchmark for emission intensity and capacity factor, one option would be to make the capacity factor benchmark explicit in the allocation process. For future allocation levels, announced from the outset, the regulator could keep the emission intensity benchmark constant while announcing that the capacity factor benchmark would fall over time for less efficient plants. This would allow smaller less efficient coal plants to continue to make some profits for some time, although gradually lowering total generation and profits.

Alternatively, if the free but diminishing number of allowances is guaranteed for a fixed period of time, operators could close down their plant early and make some profits from selling allowances over the period for which they are still receiving free allowances. Given the typically lower profits of smaller inefficient coal plants, such plants may not be in a position to purchase allowances in order to maintain their generation level. This again would depend on the overall emission reduction ambition in the ETS, and the resulting CO<sub>2</sub> price.

### *In summary*

There is a CO<sub>2</sub> emission reduction potential available through switching inefficient coal plants towards the more efficient ones and towards gas plants. **The above cost analysis identifies the price of CO<sub>2</sub> that should be enough to trigger lower output from small inefficient plants and sub-critical plants** – the loss of electricity revenues would be compensated by the sale of unused CO<sub>2</sub> allowances and lower fuel costs.

This of course assumes that more efficient plants both increase their output to compensate for lower generation from small and sub-critical plants, and pay for the additional CO<sub>2</sub> they will emit then. The same cost analysis shows that **USC and gas plants would generate a marginal benefit, i.e., the additional CO<sub>2</sub> cost would be lower than the gross operating revenues from increased electricity sales.** As is expected, under current price conditions, efficient combined-gas cycle turbines would derive a higher marginal revenue than the more CO<sub>2</sub> intensive USC plants.

**The above analysis shows that the introduction of a CO<sub>2</sub> constraint could realise near-term CO<sub>2</sub> and economic efficiency gains from switching power generation from smaller inefficient plants to ultra-super-critical and gas plants.**

## **From a CO<sub>2</sub> cost to higher electricity prices?**

Another critical element of this scenario is the role of electricity prices. The Chinese government has been very careful when increasing electricity prices, in times of rising coal prices. Power generators have faced dire economic circumstances, sometimes leading them to lower operations as they could

not cover operating costs (let alone investment) through sales. It is therefore unlikely – and undesirable from an economic signal perspective – that an additional cost in the form of the purchase of CO<sub>2</sub> allowances would leave electricity prices untouched. **Not reflecting the cost of carbon policy in the electricity price would probably lead to the termination of the ETS: the system would be seen as putting a cap on power generation volumes, and therefore on economic development. In many respects, the main policy question for the inclusion of the electricity sector in an ETS is the evolution of electricity prices as the carbon cost is introduced in power generation.**

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### *CO<sub>2</sub> cost under various policy scenarios*

Based on the above plant-level analysis, we can illustrate the direct impact of the CO<sub>2</sub> cost and compare it with the current electricity price for coal plants and gas plants. Three parameters come into play in these illustrations:

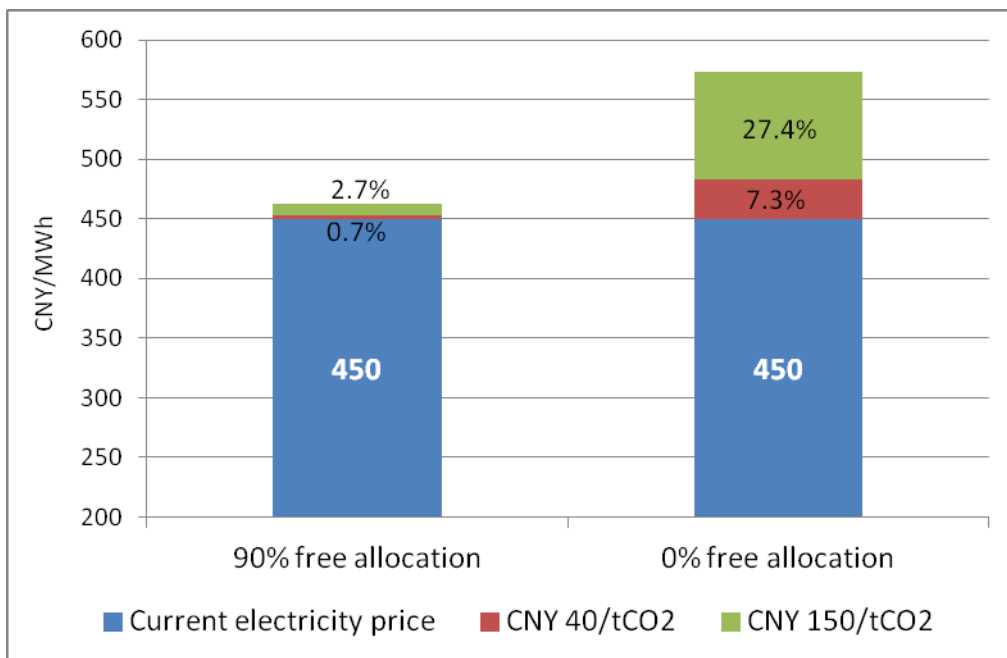
- The quantity of free allowances distributed to a new plant. This has a direct effect on the plant's cost, as it determines how many CO<sub>2</sub> allowances it needs to purchase to cover its emissions under normal operating circumstances.
- The number of operating hours. Following the above logic, USC and gas plants would be encouraged to produce more electricity, picking up on the lower operation of less efficient plants. This will in turn increase their emissions and their purchase of allowances.
- The price of CO<sub>2</sub>.

In what follows, we use the following assumptions for a USC plant:

- Two carbon price scenarios: CNY 40 and 150/tCO<sub>2</sub>.
- Two allocation scenarios: 90% and 0% free allowances of what is necessary to operate a plant for 5100 hours a year – corresponding to average 2010 data.
- A high-operation scenario in which USC plants operate 6500 hours.

Similar scenarios are run for a gas plant, with operating hours in the 2000-3000 range. The following graphs indicate the range of cost increases under these scenarios, using a price of CNY 450/MWh for electricity from coal plants and CNY 530/MWh for electricity from gas-fired plants.

Figure 12: Cost impact of CO<sub>2</sub> price on a USC plant (running time: 5100 hours)

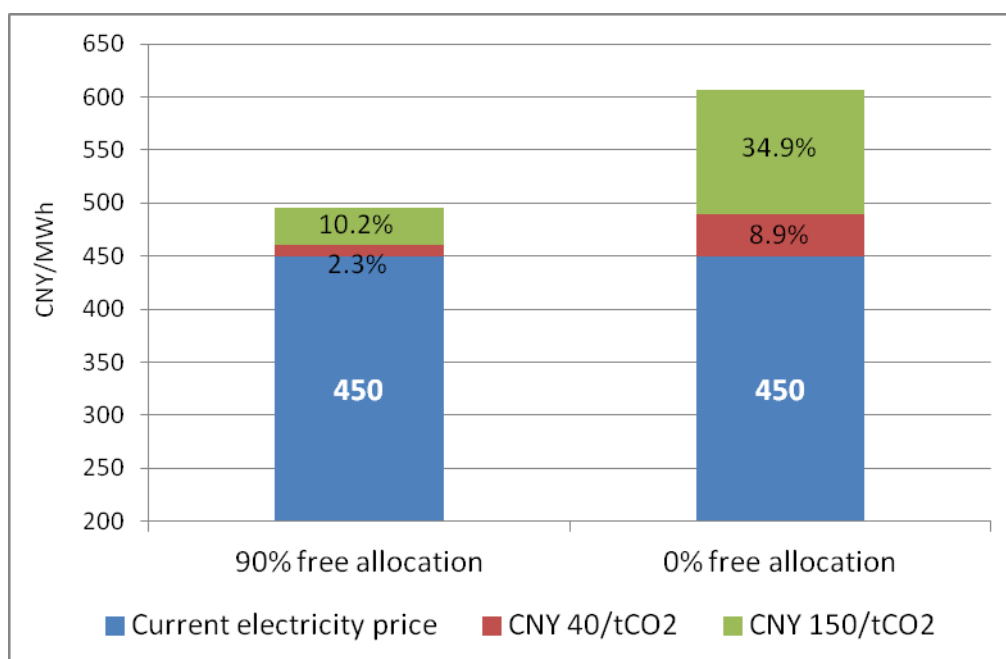


Notes: Assumes operating hours of 5100/year. Percentages for CO<sub>2</sub> allowance costs are shown cumulatively, i.e. the highest percentage noted on each bar represents the total effect of a CO<sub>2</sub> price of CNY 150/tCO<sub>2</sub>.

**Key message: CO<sub>2</sub> allowance costs are modest under a 90% free allocation scenario - only representing 2.7% of the electricity price even with a CO<sub>2</sub> price of CNY 150/tCO<sub>2</sub>. Under a 0% free allocation scenario CO<sub>2</sub> allowance costs become very significant if the CO<sub>2</sub> price is CNY 150/tCO<sub>2</sub>.**

The next illustration shows the same scenarios but with the assumption that operating hours increase to 6500 hours annually. Assuming free allowances are provided based on the original load factor of 5100 hours per year implies that all emissions resulting from the increase to 6500 hours will have to be covered by purchased emissions allowances.

Figure 13: Cost impact of CO<sub>2</sub> price on a USC plant (running time: 6500 hours)

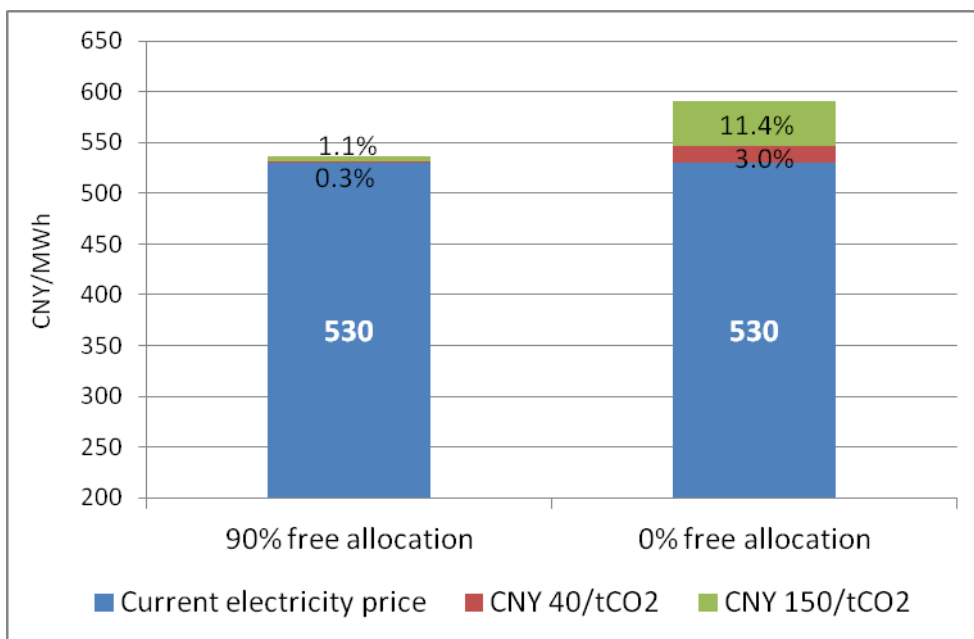


**Key message:** Increasing operating hours to 6500 hours per year means CO<sub>2</sub> allowance costs become significant with a CO<sub>2</sub> price of CNY 150/tCO<sub>2</sub> even under a 90% free allocation scenario. The difference between the 90% and 70% free allocation scenarios becomes somewhat less pronounced under this scenario as allowances to cover emissions from increased generation need to be purchased in full under both scenarios.

CO<sub>2</sub> allowance costs become significant for a USC plant in the above scenario where operating hours are increased, i.e. above what the initial allocation level assumed (5100 hours). However, the previous financial analysis (see Figure 10) showed that at the margin gross operating revenues (price minus fuel cost) per MWh exceed the cost of purchasing CO<sub>2</sub> allowances from a small coal or sub-critical plant covering an increase in generation by 1 MWh. **In other words, requiring new efficient fossil fuel plants to purchase allowances to increase output as others lower theirs will still allow them to make a profit from the increased generation.**

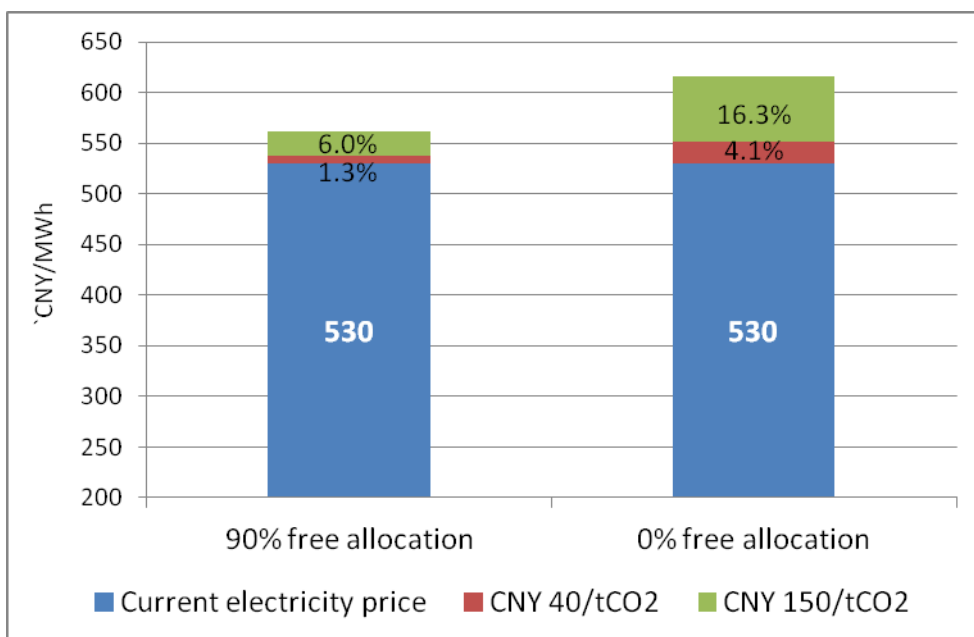
The following two figures show the same scenarios in the case of a combined cycle natural gas turbine plant. The lower CO<sub>2</sub> emissions from gas-fired power plants implies a lower CO<sub>2</sub> allowance costs, compared to a USC plant. In addition, gas-fired plants currently receive a higher grid electricity price which means that a lower percentage impact from the CO<sub>2</sub> allowance costs, if the price were to reflect this cost.

Figure 14: Cost impact of CO<sub>2</sub> price on a natural gas plant (running time: 2000 hours)



Note: Assumes operating hours of 2000/year

Figure 15: Cost impact of CO<sub>2</sub> price on a natural gas plant (running time: 3000 hours)



**Key message:** For gas plants the CO<sub>2</sub> allowance cost as a percentage of the electricity price remains relatively modest under a range of scenarios.

## The need to address electricity pricing under an ETS

Lowering CO<sub>2</sub> emissions in a sector where coal is providing the majority of cheap electricity will add a cost to electricity generation. As discussed in *Part II, Emissions trading and power generation*, the organisation of the **electricity market impacts who carries this CO<sub>2</sub> reduction cost**.

### Page | 44 In a wholesale electricity market:

- When the last dispatched generator is burning fossil fuels, the electricity price is automatically increased by the unit CO<sub>2</sub> cost (the market price of a CO<sub>2</sub> allowance times the carbon content of that last dispatched unit).
- This price increase occurs whether or not CO<sub>2</sub> allowance have been distributed for free to power generators or sold to them.
- The higher electricity price benefits all power sources, and makes non-fossil fuel sources more competitive.
- A higher electricity price should also increase end-use efficiency – while this is not covered in this report, end-use efficiency is a critical element in being able to cost effectively reduce emissions.

**The absence of a wholesale electricity market in China**, while it is a barrier to a more efficient operation of power generation resources, **does provides a means to control electricity price movements as a result of CO<sub>2</sub> pricing**.

**This opportunity could have both detrimental and positive effects on the acceptability of the ETS:**

- Not reflecting any of the CO<sub>2</sub> cost in the electricity prices would directly affect the profitability of fossil-based generators, which could result in plants choosing not to operate as they incur losses – see the effects of rising coal prices in the recent past.
- Controlling the cost increase caused by the ETS will limit the government's worry about inflationary pressures driven by growing electricity prices.

## Suggestions for electricity pricing in response to the emissions trading system

**Against this background it seems desirable to allow for a limited electricity price increase for plants facing a CO<sub>2</sub> constraint.** In the cost-based pricing of electricity that applies in China, the CO<sub>2</sub> cost for a coal-plant would be the cost of buying allowances to cover emissions – and any cost to improve efficiency through maintenance, refurbishment measures, or fuel switching (brown to hard coal). As for the allowance cost, the magnitude will depend on the initial level of allocation to individual plants. The regulator could easily monitor CO<sub>2</sub> prices to estimate the range of cost incurred by plants and adjust the benchmark coal price accordingly.

We illustrated the several allocation modes that can be applied in this context. Our analysis showed that, unless allowances are sold to generation installations, the level of the CO<sub>2</sub> costs relative to the electricity price may not be high. For a high-efficiency ultra-super-critical plant that receives 90% of its allowances for free, the cost increase would amount to 2.7% of today's electricity price, for a high CO<sub>2</sub> price of CNY 150/tCO<sub>2</sub>. To put this in perspective, a recent upgrade of the SO<sub>2</sub> and NO<sub>x</sub> emission limits has led to rise in electricity prices paid by industry by CNY 30/MWh, or about 7%.<sup>26</sup>

Some refinements may be needed in how such price changes are introduced. Part IV will propose that existing and new plants are treated differently from an allocation perspective:

- A free allocation covering past emission levels for existing, less efficient plants, for a limited period of time. These would create a source of supply of CO<sub>2</sub> allowances on the market in the near term.

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<sup>26</sup> ChinaFAQs (2012)



- An allocation below projected emission levels for new plants. This would create an immediate demand for CO<sub>2</sub> allowances as new plants come in operation.

This differentiated treatment could result in a different electricity price applied to each category:

- **Less efficient plants that would curtail generation to sell CO<sub>2</sub> allowances do not need a higher electricity price**, as their remaining allowances would be enough to cover their emissions at no cost. Further, as illustrated earlier in this section, increasing their electricity price would also increase the CO<sub>2</sub> price needed for them to curtail power.
- **New plants that face the financial cost of CO<sub>2</sub> allowances purchase would need to see it passed on to their electricity price**, which could be increased as a result. This increase may need to be mitigated if these high-efficiency plants get to run longer hours after the cap is introduced. The higher load factor and increase in electricity sales would indeed enhance the profitability of the investment.

All in all, a CO<sub>2</sub> constraint has the potential to realise efficiency gains in the power generation sector. However, the CO<sub>2</sub> cost, and the resulting pressure to increase electricity prices, will have to be managed through a combination of free allowances and a differentiation in how different plants are treated.

## Design Options for an Effective Emissions Trading System

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This section turns to the actual design of an ETS in the context of power generation in China, drawing on the previous section insights on the economics of fossil-based generation under an emissions cap. It also touches on monitoring, verification and reporting of CO<sub>2</sub> emissions in the power sector.

For any domestic market mechanism for GHG mitigation there are certain building blocks that need to be in place to make the market mechanism operational. **Building blocks can be categorised as technical** (i.e. the nuts and bolts of a market mechanism needed to make it operational), **policy** (i.e. setting the environmental goals and boundaries for market mechanisms, etc.), and **institutional and legal** (i.e. defining institutional responsibility for compilation of inventory data, issuance of allowances, compliance, etc.)<sup>27</sup>

**We focus in this section on the technical building blocks and the associated policy decisions on issues like coverage and environmental goal of the ETS. The actual level of allocation to the power generation sector is beyond the scope of this report.** It would require combining assumptions on the sectoral coverage of the ETS (does it include other industries and if so which?), on offsets (are they allowed, is their use limited?), and most importantly, a guess about what would be politically acceptable in terms of a sector-by-sector allocation of effort under the system. **Our approach remains focused on the power generation sector, with the assumption that the ETS would require an effort from the electricity sector in order to depart from its 'business-as-usual' CO<sub>2</sub> emissions trend.**

### Setting the emissions cap: creating CO<sub>2</sub> scarcity in power generation

Setting the cap is perhaps the most critical decision in designing an ETS. The cap needs to be set at a level that creates scarcity on emission allowances; in other words, the initial allocation of allowances (the right to emit) is lower than expected emissions and requires plants to either lower their emissions or to buy allowances from other plants, eventually putting a price on CO<sub>2</sub> emissions.

Setting an absolute cap in the Chinese electricity sector, with its rapid capacity growth, represents a challenge in this respect as the future size of the sector is likely to be both very different from today's, and difficult to project with any precision. In technical terms, this uncertainty affects the reserve of allowances for new entrants, that is the quantity of allowances that the regulator sets aside and distributes or sells to new sources to be included in the system. In principle **the total emissions cap is the sum of the initial allocation of allowances to existing plants and the reserve for new entrants.** The treatment of new entrants in the ETS therefore becomes a crucial element in setting the cap (see Appendix II).

Creating CO<sub>2</sub> scarcity in the power generation system of China will require taking the following elements into account:

- CO<sub>2</sub> emissions in electricity generation will depend on how effective the drive for low-carbon technologies will be, namely:
  - Will 80 GW of nuclear be installed and running by 2020?
  - How much wind and solar capacity will be triggered by the existing and projected feed-in-tariffs? How quickly will this capacity be dispatched to the grid?

<sup>27</sup> Aasrud, Baron and Karousakis (2010)

- What is the expected growth of gas-based power generation, given new developments in the gas sector?
- Will the closure of small coal plants be driven by the ETS, or by administrative decisions upon the introduction of USC plants?
- Beyond supply, end-use energy efficiency holds much promise to curb future demand for electricity. The following questions come to mind when trying to project future energy efficiency gains in electricity usage:
  - What end-use efficiency will come from the recently announced caps on total primary energy use?
  - What is the magnitude of the expected electricity savings under the 10,000 Enterprises programme, introduced in the 12<sup>th</sup> Five-Year Plan?
  - How will the development of electric vehicles affect overall electricity demand in the medium term?
  - More generally, how 'electricity-intensive' will the Chinese economy become in the next 10-20 years?

Experience in the European Union has shown that higher-than-expected delivery of wind and solar capacity, thanks to significant targeted subsidies for these technologies, has affected generation from fossil-based plants, driving CO<sub>2</sub> emissions and CO<sub>2</sub> allowance prices down, with negative repercussions on incentives to invest in cleaner technologies that are not supported by subsidies. Such interactions should be taken into account at the outset, or otherwise run the risk of unsettling the carbon price down the line.

**It is crucial that the overall effort put on power generators under the cap be made with as much information as possible on the projected contribution of other policies that affect CO<sub>2</sub> emissions from electricity. In particular, the establishment of an ETS only makes sense if it requires a departure from emission trends, once all other policies have been factored in.<sup>28</sup>**

## Coverage

The question of coverage is relevant at two levels:

- the selection of sectors covered by the ETS within the economy and
- the coverage of emission sources within a sector under the ETS.

In terms of coverage within the electricity sector, information on the distribution of plants provides a useful starting point. Table 2 above showed that plants smaller than 300 MW represented 26.8% of total generation in 2010 and among these 9.5% of output came from plants of individual capacity below 100 MW. While there are advantages, mainly from a monitoring perspective, to put in place a minimum threshold in terms of size of the installations included in the ETS, this may be less relevant in the electricity sector than in some other sectors with a large number of very small operators, or where the burden of emissions monitoring may be too significant when compared to the environmental gain from inclusion.

Furthermore, as explained above, excluding small coal plants from the sector coverage of the ETS would reduce the potential for CO<sub>2</sub> emission reductions. The previous section showed that the CO<sub>2</sub> cap and the free allocation of allowances to existing small plants ETS could also be a powerful instrument to drive the phase-out of these less efficient and small coal plants.

<sup>28</sup> For an in-depth treatment of this issue, see Hood (2011)

The decision to include relatively small coal plants in the ETS will have implications on what measures can be used to monitor CO<sub>2</sub> emissions, e.g. if not all plants are equipped with continuous emissions monitoring systems (CEMS). There is an alternative to this costly technology, i.e., to estimate CO<sub>2</sub> from fuel use and calorific value, so this would not represent a technical barrier (see section: *Measurement and reporting systems for CO<sub>2</sub> emissions – in need of verification*). Based on data in Table 2, there are more than 3000 coal-based generation units that could be included in the ETS, in addition to some 230 gas plants and oil generation plants.

## Allocation of CO<sub>2</sub> allowances

### *The mode of allocation: a critical issue for China's power generators*

Once the coverage is determined and the cap set, another critical question is the choice of allocation mode, i.e. the way sources will receive their emission allowances. Allowances can be allocated for free or sold at an auction; a combination of the two is also possible. In the current setting of China's electricity regulations, the allocation mode will directly impact the financial cost that plant operators will face.

### Allocation under a liberalised electricity market

**In the European Union ETS**, most generators bid their output on a wholesale electricity market. When the last dispatched generator is burning fossil fuels, the electricity price is increased by a CO<sub>2</sub> cost (the current price of CO<sub>2</sub> allowances multiplied by the carbon content of the MWh produced by that last dispatched unit). In other words, generators that are dispatched and emit CO<sub>2</sub> charge the consumers for the cost of their CO<sub>2</sub> emissions, a reflection of sound economic principles. Furthermore, their bidding price is increased by that same cost, regardless whether they have been allocated allowances for free or had to purchase them. This follows a strict economic optimisation (profit maximisation) logic: an additional MWh that emits CO<sub>2</sub> requires the use of an allowance, which would otherwise be sold on the market at the prevailing CO<sub>2</sub> price. From the perspective of the plant operator's finances, the allowance carries the full value indicated by the market price.

**In a liberalised wholesale electricity market like the EU, the electricity price should increase by the same amount whether the allowances are distributed for free, or are sold to the power generators. This would not be the case in today's electricity regulatory environment of China.**

**Box 2: Free allowances or auctioned allowances?**

Two allocation modes are available to distribute allowances to emission sources:

A free allocation, either based on historical emissions modulated by a cut in emission (grandfathering), or by a benchmark (i.e.  $x \text{ kgCO}_2/\text{MWh}$ )

Auctioning: the government or other entity puts an overall quantity of allowances for sale. All “points of obligations” – i.e. emission sources – can purchase allowances at an auction, or on the market at a later stage.

There are advantages to auctioning: the regulator does not need a precise knowledge of plant's past emissions in order to allocate allowances: each unit will acquire allowances according to its expectation of future emissions and costs. Secondly, the auction brings financial revenues to the regulator. These can be used, for instance, to offset some of the negative economic effects of the cap, or go to the general budget.

The downside of auctioning is that it imposes an immediate cost on those economic activities covered by the ETS, likely to trigger opposition from these stakeholders. This explains why, in most cases – but not all, see Australia – a free allocation is preferred in the initial phase, as it facilitates acceptance of the system.

The free allocation can also be justified on the ground that, for a capital invested at a time where no CO<sub>2</sub> regulation was in sight, it is legitimate to ask for some compensation as the economic viability of its original investment is affected by the new constraint on emissions.

**Allocation does matter for cost and price in China's regulated environment**

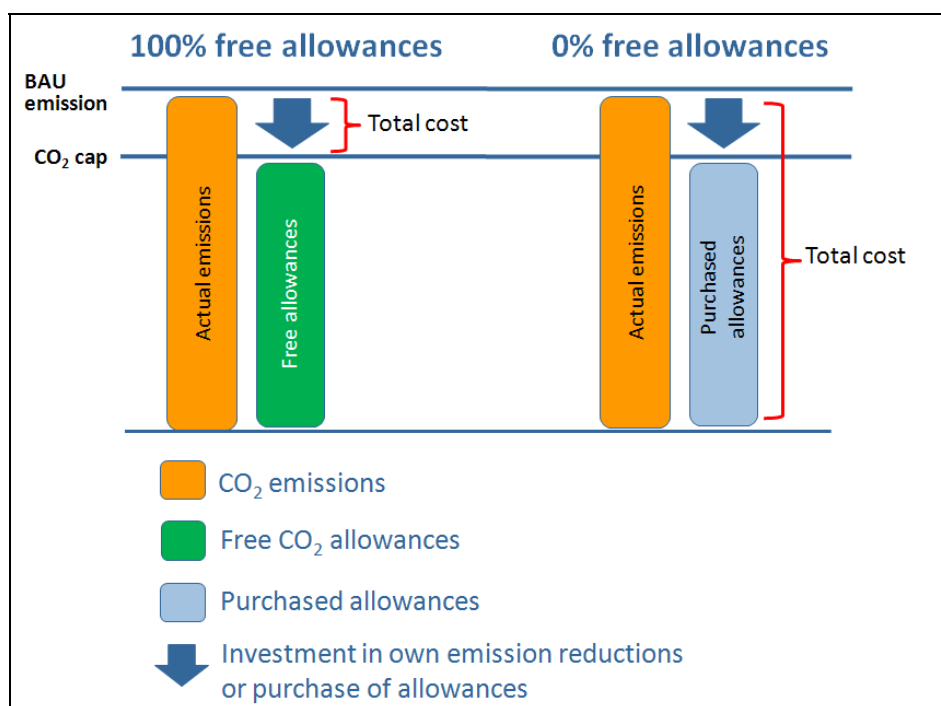
The organisation of China's generation sector puts it in a markedly different position when it comes to the link between allocation and cost to generators. **China's electricity is not sold on a wholesale electricity market: the cost of CO<sub>2</sub> cannot be automatically passed through by generators to the electricity price.** While the opportunity cost of holding an allowance is identical in both regulatory environments (wholesale or regulated market), the Chinese regulator is unlikely to allow the electricity price to include the full opportunity cost for the generator of holding CO<sub>2</sub> allowances to cover its emissions. It may, instead, consider the *actual* cost to the generator, and seek to reflect that cost into the price

Figure 16 illustrates the cash cost implications of different allocation modes, setting aside the opportunity cost. A high share of allowances distributed for free would minimise the direct cost to generators. This should by no means imply that the free allocation should cover all of a plant's expected emissions – no CO<sub>2</sub> reductions would take place if so. But a higher share of free allowances is a way to minimise the initial cost imposed on generators, as they are not required to buy most of the emission allowances to cover emissions.

**Benchmarking allocation to power generators**

The expected growth of electricity demand and supply in China requires that new CO<sub>2</sub>-emitting plants be treated in a transparent and systematic fashion. This implies a clearly established definition of the conditions of their participation in the ETS. Such a method will avoid bargaining between the promoters of the new plant and the regulator, and the ensuing risk of higher allocation levels and higher emissions.

Figure 16: Different modes of allocation and cost implications



**Key message: In financial terms, free allowances lower the cost to a generator: it only needs to invest to reduce emissions down to its allocation or to purchase allowances to cover excess emissions. With no free allowances, the generator needs to buy allowances to cover all its remaining allowances.**

We set aside for now the question of allocation to existing plants, and focus on a method to allocate allowances to new plants. In general, the allocation to new entrants, as they are usually called, is based on some emission benchmark.<sup>29</sup> The benchmark is then combined with the load factor and the capacity of a plant, and possibly an additional reduction factor to establish the annual allocation level for any given plant. The formula for the allocation of CO<sub>2</sub> allowances to a plant, on an annual (or multi-year) basis, can be expressed as:

$$\text{Allocation (tCO}_2\text{)} = \text{tCO}_2\text{/MWh} * \text{capacity (MW)} * \text{load factor (hours/per year)} * (1 - \text{reduction factor (\%)})$$

Where:

- 'tCO<sub>2</sub>/MWh' is the CO<sub>2</sub> benchmark,
- 'capacity' is defined by the actual plant (e.g. a 600 MW coal plant, a 300 MW combined-cycle gas turbine),
- 'load factor' can be based on current practice for a similar plant in the region. To avoid over-allocation, the 'load factor' should seek to reflect the expected running time of the plant in a year; it can also be differentiated by technology.
- 'reduction factor' represents an overall cut in the allocation level from the CO<sub>2</sub> benchmark. The overall stringency of the allocation is a combination of the CO<sub>2</sub> benchmark and the reduction factor.

<sup>29</sup> This section is based on Matthes et al. (2005), which reviews the practice of new entrants allocation to power generators under the EU ETS.

Several options have been used in other systems to define the CO<sub>2</sub> benchmark (tCO<sub>2</sub>/MWh):

- **The plant's own design efficiency, combined with the CO<sub>2</sub> intensity of the fuel.** In this case, the ETS does not provide an incentive to choose a lower-emitting and more efficient technology, because all technologies have to undertake the same level of effort, i.e. the reduction factor.
- **The best available technology's performance for the fuel used by the plant** (e.g. for coal, the CO<sub>2</sub> performance of an ultra-super critical plant). This encourages the uptake of that best available technology, as any less efficient technology faces a larger gap between its emissions and its allocation. This approach, however, does not particularly encourage investment in gas instead of coal (see Appendix I for a company-wide case based on this approach to allocation).
- **A single performance factor for all fossil-fuel based plants**, which could be defined in different ways, including:
  - **The average performance of all existing thermal plants in the country.** This encourages the plants that are more efficient than average. In the case of China, where coal-based generation dominates thermal power, a gas plant which emits about 50% less CO<sub>2</sub> per MWh, would receive allowances far above its emissions. This would enhance the profitability of gas plants, as they can sell these excess CO<sub>2</sub> allowances.
  - **The best available technology for all thermal plants** (e.g. a combined-cycle gas turbine). All thermal plants, except CCGT, would be granted far fewer allowances than their expected emissions.

**An allocation based on the last option (a single performance factor regardless of the plant's technology) provides the highest incentive to invest in low-emitting technologies.** The first two options would provide less incentive to switch technologies or fuel. In the end, however, the **reduction factor** could be the most important driver of the ETS environmental ambition.

Figure 17 provides an illustration of a benchmark based on a single performance factor, looking at various fossil-based plants. It shows their emission levels compared with the allocation level, on an annual basis. The CO<sub>2</sub> benchmark is based on the efficiency of a typical ultra-super critical coal plant in China. The illustration also assumes a 10% reduction factor. The emission levels are shown for 1 GW of capacity of each technology and assume that all plants operate the same number hours (4500 hours/year); for natural gas, the emission level for a load factor of 2500 hours is also displayed, as it is closer to current practice in China.

**Any of the benchmark options described here could also be applied to set the level of allocation for existing plants. In the particular case of China, however, we will argue that the first option could be appropriate, i.e., the allocation is in line with the plant's past performance.** The CO<sub>2</sub> allowances would be a valuable asset (CO<sub>2</sub> allowances) for these plants, to be used as financial compensation as they operate fewer hours and sell unused allowances to new entrants that face stricter constraints on their CO<sub>2</sub> emissions.

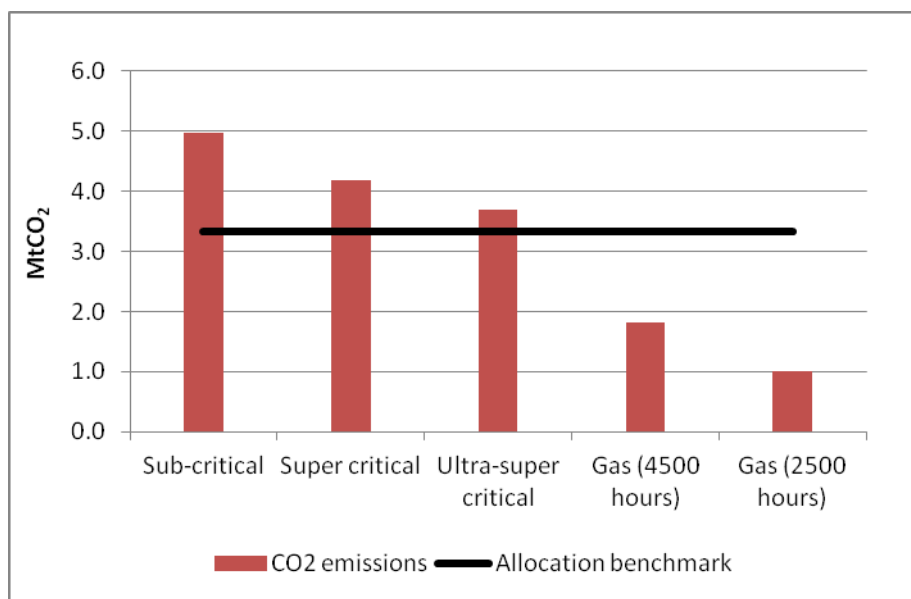
## **Key dynamics in allocation: the treatment of new entrants and plant closures**

### **New entrants reserve**

A reserve for new entrants is a typical – and needed – feature of an ETS. It defines the total quantity of allowances that will be available for plants that start operating after the beginning of the ETS. The previous section described how individual plants may be treated. However, the overall size of the new entrants reserve also matters as it represents the ultimate cap for new entrants.



Figure 17: Annual emissions and allocation benchmark for various fossil-based technologies



**Key message:** Using a typical Chinese ultra-supercritical coal plant as performance factor and a 10% reduction factor, the single emission benchmark creates an allowance shortfall for all coal plants (10%, 20% and 33% for USC, super-critical and sub-critical, respectively). Gas plants would have a substantial surplus of allowances even under a high load factor. This single benchmark therefore creates a strong incentive to switch from less efficient coal to the most efficient coal or gas.

**One possibility would be to cap the new entrants reserve, but with sufficient room for growth.** As the growth of the electricity sector and the economy in general is difficult to predict for a long period into the future a cap may have to be generous, so to avoid setting a binding constraint on the construction of new plants. At the same time, there has to be a constraint on overall emissions – which we argue can be done by systematically under-allocating new entrants, who will have to seek mitigation from existing plants, or other sectors under the ETS.

**A different option would be to index the total quantity of allowances available in the reserve (i.e. the cap on new entrants) on economic growth.** The underlying assumption is that higher than expected economic growth will put pressure on emissions and trigger an increase in the cost of CO<sub>2</sub> reductions. Indexing the reserve on growth would act as a safety valve on the system. Symmetrically, the index would reduce the overall quantity in the reserve if GDP grows less than anticipated. Such an indexation can only be worked out once the sectoral coverage is known – the adjustments would be quite different if the ETS covers only electricity, or if it also covers industrial activities.

The issue of the new entrants reserve will arise in the carbon market pilots, in connection with the CO<sub>2</sub> intensity goals that also apply to Provinces like Guangdong and Hubei. Box 3 explains how a cap-and-trade system may function without hampering the achievement of CO<sub>2</sub> intensity goals.

### Plants closure

**The treatment of allowances from plants that are closing also influences the system's effectiveness.** In most existing systems (in various EU countries in particular), allowances are taken back by the government upon closure. Likewise, a significant reduction in a plant's activity sometimes triggers a cut in the initial level of allocation.

**Box 3: How Provincial CO<sub>2</sub>-intensity goals could work with cap-and-trade**

There is an apparent contradiction between province-level CO<sub>2</sub>-intensity goals of the 12<sup>th</sup> Five-Year Plan, (i.e. expressed in changes in tCO<sub>2</sub>/Gross Domestic Product), and the guidelines from NDRC on the piloting of 'cap-and-trade' systems, with goals set as an absolute quantity of CO<sub>2</sub>. In what follows, the assumption is that the sources under the cap-and-trade system represent only a subset of all emission sources in the Province/city.

In theory, two risks may arise from the combination of these two goals: (i) the cap in the trading system is too tight and as the GDP grows faster, allowing higher emissions in the Province, the capped sources are facing higher CO<sub>2</sub> costs as their emission limits are fixed; (ii) the cap in the trading system is too generous, and a lower than anticipated GDP growth would result in a tight constraint on emissions outside the trading system.

These risks may be hypothetical only, when considering the dynamics of an ETS in rapidly growing economies such as those of China's provinces and cities. To a large extent, the growth in emissions will come from new sources. More growth will imply more new sources coming into the emissions trading system, adding their cap to the total allocated so far. If economic growth is less than expected, fewer new sources will come as new entrants.

The total cap could in fact be made flexible by creating a large reserve for new entrants, while still applying 'pressure' on new plants to reduce their individual emissions as they come into operation. The unused allowances of the reserve could be cancelled at the end of the period, to avoid carrying forward too large a reserve.

However, as **early closure of inefficient plants is potentially an important source of CO<sub>2</sub> reductions in the Chinese context**, the question here is whether the allowance could be retained – and sold – for the remaining years of a plant's natural life or for a shorter period. For instance, an existing, less efficient plant could receive allowances for a number of years ahead, in line with an intended schedule for its closure. It would be able to sell unused allowances even if it were to close ahead of schedule. As has been illustrated in section III, the sale of CO<sub>2</sub> allowances may provide sufficient compensation to the plant owner for the early retirement of the plant and the loss of revenues from foregone electricity sales.

The length of time over which a closing plant could sell allowances will of course have an impact on the overall supply of allowances in the ETS.

**Illustrating the dynamics of new entrants and plant closures**

Appendix II provides illustrations of parameters that would need to be considered carefully in granting a free allocation to existing plants, and a reduction goal to new plants. ERI's low carbon scenario for power generation in the Guangdong province is used to illustrate how different allocation parameters can affect the supply and demand of allowances. Allowance supply in this analysis comes from the early retirement of inefficient coal plants assumed in the low carbon projections, assuming that plants retain the unused allowances for the duration of their original lifetime. For the same emission path, changes in the allocation parameters for existing and new plants moves the power generation sector from a net seller of CO<sub>2</sub> to a net buyer of CO<sub>2</sub>.

Table 5 summaries three different allocation parameters and the net allowance supply and demand balance over the whole scenario period from 2011-2025 (see Appendix II for further details on the results of the different allocation parameters).

Table 5: Different allowance allocation parameters applied to ERI's Guangdong low carbon scenario

| Allocation scenario | Existing plants  | New plants   | Net allowance balance                               |
|---------------------|--|--|---|
| Scenario 1          | 100% of base year (2010) emissions for free, with a reduction in allocation of 0.5% per year from 2016 onward for low efficiency coal plants.  | New plants are allocated free allowances for 90% of base year emissions. | Net supply of allowances (66 MtCO <sub>2</sub> )    |
| Scenario 2          | Same as Scenario 1 but with free allowances to existing plants falling by 1% (rather than 0.5%) per year from 2016 for all fossil-fuel plants. | Same as Scenario 1.  | Net demand for allowances (-45 MtCO <sub>2</sub> )  |
| Scenario 3          | Same as Scenario 1   | New plants are allocated free allowances for 70% of base year emissions. | Net demand for allowances (-141 MtCO <sub>2</sub> ) |

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The three scenarios above demonstrate the sensitivity of allowance supply and demand to the choices made with regard to the level of free allowances for new and existing plants and the treatment of allowances for closing plants. These scenarios suggest that as the system unfolds and there is clarity on the number of new plants entering the system, adjustments may be required to align allocation plans with the overall mitigation goal of the system.

### Suggestions for allocation method

**The allocation of emission caps is the cornerstone of any emissions trading system.** It defines the overall environmental effort, as well as efforts by individual plants. A number of considerations come into play when deciding on allocation in China's power generation sector:

- **The near term mitigation potential lays in substitution among plants burning fossil fuels** with different levels of efficiency (from very low efficiency coal to ultra-super-critical coal and natural gas plants). Other low-carbon technologies are currently supported by dedicated price measures.
- **Concerns over electricity price increases argue in favour of some free allocation** of allowances to plants.
- Less efficient plants have limited incentives to lower their operations at present. **A price on CO<sub>2</sub> emissions combined with the sale of unused CO<sub>2</sub> allowances would encourage inefficient plants to lower their electricity output**, and address the otherwise negative effect of their lower level of operation.

Several factors argue in favour of **putting a more ambitious CO<sub>2</sub> constraint on new entrants than on existing plants**:

- Under current electricity demand growth projections, **new plants are critical to drive a change in the country's future emission profile.**
- Investors in new plants have the choice of technologies, while existing plants do not. **New investment may therefore respond more to the new cost on CO<sub>2</sub> emissions.**
- As stated above (Box 2), **existing plants were built without knowledge of a future cap on CO<sub>2</sub>.** A higher allowance would be a compensation for the policy goal – the CO<sub>2</sub> cap – that would otherwise radically change their financial viability.

Based on the above, an ETS allocation in the Chinese power sector could be as follows:

- **Existing low-efficiency plants are granted free CO<sub>2</sub> allowances reflecting their past emissions, for only a limited number of years**, consistent with a phase-out of these plants.
- **New coal plants are allocated emission allowances below their expected emissions under normal operations.** This low level of allocation will create demand for CO<sub>2</sub> allowances available at less efficient plants, and will introduce a clear CO<sub>2</sub> cost on coal-based power generation.
- **Allocation to new plants are based on a benchmark**, combining a standard performance (tCO<sub>2</sub>/MWh) and standard running time, with an emission reduction factor. An ideal approach would be a similar benchmark for all fossil-fuel using power plants, regardless of fuel (coal, oil and gas). **Differences in running times for coal and gas plants may need to be reflected in the benchmark.**

## Banking, borrowing, and managing adjustments to allocation

Recent experience, especially in the EU, shows that caps and allocations to entities are rarely perfect in the initial phase of an ETS. The underlying data may be misleading, industrial actors tend to over-estimate their growth prospects and are over-allocated as a result. There will also be surprises coming from outside the ETS: for instance, there may be higher or lower delivery of plans for low-carbon generation capacity (hydro, new renewables, nuclear), and differences between expected and actual GDP growth, and resulting changes in overall electricity demand growth.

The management of these uncertainties calls for the following considerations in design:

- **Banking of unused allowances.** If there is uncertainty on data used for initial allocations, banking of surplus allowances from the initial period may be restricted, so as to avoid adding undue emission 'rights' to the future emission constraint as a result of initial 'mistakes'.
- **Borrowing allowances from next period.** If there is a perceived risk that allocations may be too tight in the first phase, allowing entities to borrow from a future allocation may be a solution. However, we have indicated earlier that this question may be addressed through the reserve for new entrants.
- **Allowing for adjustments in design.** The authority in charge of the ETS, and especially in the area of allocation, ought to set times for a periodic review of the system. One such area is obviously in cap-setting (i.e. the overall stringency of the cap), another is the mode of allocation. Other elements could include the access to emission offsets outside the ETS, the possibility to link to other emission trading systems, etc. **In China's case, it makes sense to have these reviews conducted during the elaboration of the next Five Year Plan.**

## Measurement and reporting systems for CO<sub>2</sub> emissions – in need of verification

As the world's largest energy consumer, China faces particular challenges in managing the impact of its booming domestic energy generation sector. In an effort to address the local pollution problems attributable to increasing reliance on coal-fired power generation, the Chinese government has taken various steps over recent years to increase controls on emissions from this sector. Energy policy makers began, in 2001, by targeting sulfur dioxide (SO<sub>2</sub>) emissions – a key pollutant that contributes to both ambient air pollution and acid rain. Over time, the policy approach has evolved considerably, with increasing obligations for clean production and stronger audit and enforcement rules so that, by 2010, SO<sub>2</sub> emissions had declined 14.3 % nationwide (Wen, 2011) and by 31.8% in the power sector.

Comprehensive systems for gathering and reporting energy consumption, generation and emissions data have been developed in China and all power plants in China are obliged to engage in regular

data reporting. **Power companies are required to report data, including indicators relating to fuel input, power production, unit energy cost, energy consumption and environmental management** (Zhuang Xing, 2011), to the Department of Statistics and Information at the China Electricity Council (CEC) for analysis and distribution to the National Bureau of Statistics and, where appropriate, for public release. The process for energy data collection has recently been streamlined, so that data distribution to various stakeholders is now coordinated through a set of electronic report forms, as outlined below.

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Despite clear objectives on pollution prevention and a simple reporting procedure, **significant room for improvement remains in terms of the level of detail, commitment to regular reporting, and release frequency in the current system. Questions as to the accuracy of some data also need to be addressed through the stricter application of standardised monitoring, reporting and auditing rules.** In addition, due to the historical focus on local air quality impacts, data on carbon dioxide (CO<sub>2</sub>) emissions are rarely included among the pollutants subject to Chinese emissions standards<sup>30</sup> and are rarely directly reported by power generation companies in China. Reliable data on CO<sub>2</sub> emissions is the essential foundation for a robust emissions trading system.

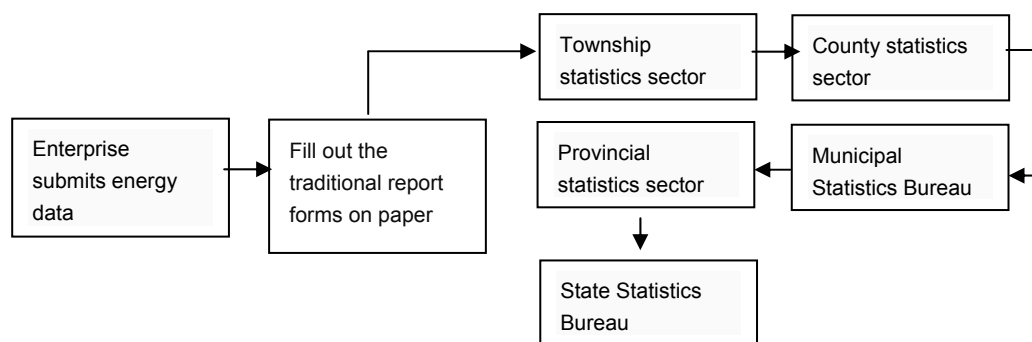
Nevertheless, the breadth of data currently collected provides in principle a good basis for the estimation of CO<sub>2</sub> emissions. The Clean Development Mechanism provides directly relevant information in this area: in the case of projects covering ultra-supercritical units, there appears to be little difference between the data required by the CDM methodology and domestic requirements for monitoring and audit of the project's energy consumption. This indicates that statistics currently available in China's power industry are indeed sufficient to calculate CO<sub>2</sub> factors. Thus, the application of a unified data management model to assess and audit CO<sub>2</sub> emission reductions, at least in the case of ultra-supercritical units, should be feasible. However, CDM imposes third-party verification of emissions, a critical step that is not included in the current energy data collection system of China. Standards for how such verification activity ought to be conducted already exist, and could be applied to China. Note that in New Zealand, no third-party verification is required, but random checks are conducted and companies caught in the act of misreporting face severe penalties. Given the size of China's power generation sector and the number of plants, a systematic, standardised approach to verification may be preferable.

In addition, installation of continuous emissions monitoring systems (CEMS)<sup>31</sup>, which monitor and transfer real-time data on flue gas emitted from thermal power plants to the government, became mandatory for all thermal plants connected to China's national electricity grid under the 11<sup>th</sup> Five Year Plan. CEMS can provide the most accurate and consistent data needed to assess compliance with emission control requirements and, **in 2010, more than 85% (over 10,000) key polluting plants in China were operating CEMS. The parameters monitored by CEMS in China are generally soot, gaseous pollutants (mainly SO<sub>2</sub> and NO<sub>x</sub>) and other parameters (mainly temperature, oxygen content and flow of flue gas).** The amount of CO<sub>2</sub> emitted can be computed via the oxygen content of flue gas.

**Figure 18: Flow of energy statistics information reporting in China**

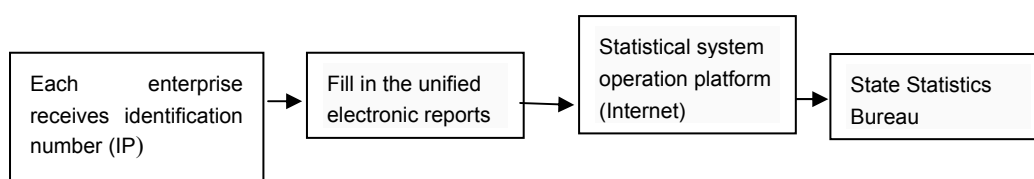
<sup>30</sup> CO<sub>2</sub> is left out of several key monitoring and audit regulations including: the Thermal Power Cleaner Production Audit Guidelines (DL / XX 2010); the Emission Standard of Air Pollutants for Thermal Power Plants (GB13223-2011); and the Monitoring and Testing Method for Energy Saving of Industrial Boilers (GB/T15317-1994).

<sup>31</sup> A CEMS is a system of sampling and conditioning, using analytical components and software that is designed to provide direct, real-time, continuous measurements of pollutant concentration by analyzing representative samples of the flue gas. (Zhang and Schreifels, 2011)



The statistical data reporting flow at present

The statistical data reporting flow after the reform



Again, CO<sub>2</sub> measurement has been left out of technical planning in the power industry, but **CO<sub>2</sub> monitoring capability can be added to these systems at a very low additional cost**<sup>32</sup>. There are unique challenges associated with ensuring the accuracy of CEMS data and compliance with existing standards. A recent study identified several opportunities to enhance CEMS operation and supervision in China's power industry, including through strengthening of regulations and technical guidelines by the Ministry of Environmental Protection, establishment of formal onsite inspection criteria and enforcement procedures, support for improved calibration practices, and broadening of data collection to additional operating parameters in order to better identify any equipment failures.<sup>33</sup> While central and local governments have initiated a number of regulations and guidelines to improve data accuracy in relation to SO<sub>2</sub>, more work is needed, including expansion of monitoring and reporting standards to CO<sub>2</sub> in due course.

China has established good quantitative planning and management objectives on pollution prevention and significant progress has been made in improving the measurement and reporting of emissions data in China's power industry. However, the quality of the data available, both through standard monitoring methodologies and through installed CEMS systems, remains the subject of significant uncertainty. **Verification is the heart of the matter, and steps should be taken to improve the accuracy and comparability of data collected**, in order to provide a solid basis of reliable CO<sub>2</sub> emissions data - a prerequisite for a reliable emissions trading system.

There is, fortunately, much policy experience in the area of verification now. The existing standards could be easily transferred to China. The scale of this activity, however, may represent a challenge as China seeks to systematically verify emissions and energy reports from CO<sub>2</sub> emission sources in the power generation sector.

<sup>32</sup> The cost of adapting a CEMS to monitor CO<sub>2</sub> is roughly USD 8000 per stack, compared to the initial cost for installation of a CEMS measuring SO<sub>2</sub> is around USD 80,000 (Schreifels, personal communication).

<sup>33</sup> Zhang & Schreifels (2011)

## ETS design: proposed next steps

There are a number of challenges related to the technical and policy building blocks for the design of an effective ETS. It is too early to indicate what an 'optimal' set of options may be in the context of the Chinese power sector. It is nonetheless possible, and useful, to indicate what may be important next steps to inform a future debate on an ETS applied to electricity. Table 6 summarises next steps in ETS design based on the preceding discussion.

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**Table 6: Proposed next steps in ETS design**

| Design element                                   | Main challenges  | Proposed next steps  |
|--|--|--|
| <b>Setting the cap</b>                           | Uncertainty on the impacts of existing and planned policies on future CO <sub>2</sub> emissions from electricity.  | Estimate policies that may impact the CO <sub>2</sub> emissions and conduct sensitivity analyses. Evaluate further required reductions from electricity through ETS cap in context of national emission goal.  |
| <b>Coverage</b>                                  | Balance between the opportunity of including small coal plants and the search for a manageable emissions measurement, verification and reporting system (MV&R).  | Identify the number of power-generating plants that would be covered based on different capacity thresholds.<br><br>Estimate the cost of the various methods for MV&R.<br><br>Analyse the cost/benefit of including plants of various sizes in light of their MV&R cost.               |
| <b>Allocation: existing plants</b>               | Balance between the cost implications of the CO <sub>2</sub> constraint and the need to introduce CO <sub>2</sub> scarcity for a successful ETS.   | Evaluate the desired phase-out period for existing low-efficiency coal plants.<br><br>Estimate level of free allowances based on past emissions, to be allocated during the phase-out period.  |
| <b>Allocation: new plants</b>                    | Allocation benchmark ambitious enough to drive investments towards low-carbon technologies without restraining growth.<br><br>Assess the future growth in the electricity sector as basis for capping the reserve of allowances to new entrants. | Develop parameters for the new entrants reserve based on growth projections.<br><br>Consider feasibility of a more flexible reserve based on indexation.<br><br>Develop a uniform allocation benchmark for all new fossil-fuel plants.   |
| <b>Banking, borrowing and design adjustments</b> | Provide a long-term predictable ETS while allowing for revisions as new information is revealed (e.g. over-allocation, price shocks, etc.)   | Develop rules for banking (and possibly borrowing) to avoid potential build-up of surplus allowances in case of over allocation.<br><br>Consider which elements of the ETS design could be revised as part of the Five-Year Plan and define transparent criteria to trigger revisions. |



## Conclusions and Looking Forward

China has embarked on an ambitious programme to explore emissions trading as a means to curb its rapidly rising CO<sub>2</sub> emissions, and power generation could well be the core of an ETS in the future. **This would mean applying a market instrument to address pollution in a regulated activity, where market incentives would not automatically work.** This report seeks to address this contradiction by identifying areas where action is necessary to allow the carbon market to drive emission reductions at lowest possible cost.

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### Emissions trading in China power: resolving the contradiction

The Chinese power generation sector offers some scope for CO<sub>2</sub> mitigation in the near term: less efficient coal plants could progressively make way for enhanced use of USC plants and gas plants, a solution that is already acknowledged by Chinese policy-makers to reduce the coal intensity of their generation. The ETS could remove the main obstacle to this efficiency improvement, with the possibility to compensate plants that curtail power via the sale of CO<sub>2</sub> allowances to cleaner plants that increase their own electricity output. The extent of the mitigation that this switch could deliver is unknown, as it would require a grid-by-grid analysis: any reduction in output would have to be compensated by supply from plants operating in the same grid area. Earlier experience with a new way of dispatching plants has revealed the potential. **An effective ETS would in fact reveal the full extent of the energy and CO<sub>2</sub>-saving potential, provided that generators operating inside the same grid organise to “trade” their generation obligation.**

A crucial question relates to the additional cost represented by a CO<sub>2</sub> constraint, for those plants that have to cover their emissions to remain operational. **We argue that new plants could be allocated fewer emission allowances than they would normally need:** this would create the necessary demand for CO<sub>2</sub> allowances, and hopefully trigger supply through mitigation – and lower output – among the less efficient plants. **A free allocation matching current emission levels of existing plants would allow these plants to manage the transition financially as they are being pushed out by newer, larger and more efficient plants.** The question of allocation is a technical and a political one, as it determines which parts of the sector will carry the cost of reducing emissions; from a purely technical perspective, if some mitigation must take place in the power sector, then some constraint must be applied on fossil-fuel plants' emissions.

Newer plants with an allocation below their needs therefore bear an additional cost, the cost of acquiring CO<sub>2</sub> allowances to cover their emissions. The following points come out of this study:

- **For high-efficiency plants, the cost of covering emissions with additional allowances from the market looks moderate,** for a CO<sub>2</sub> price as high as CNY 150/tCO<sub>2</sub>.
- In addition, **these plants would benefit financially from being dispatched longer hours.** This implies a higher return per capital invested (at the margin, our calculations show that the costs of coal and CO<sub>2</sub> are lower than the electricity price).

As electricity pricing is a strategic question for China and the Chinese government, the question of whether and how to pass the cost of CO<sub>2</sub> onto electricity prices, through regular adjustments, will require careful analysis. **The question of electricity pricing under a carbon constraint is both political (what is affordable for China's economy) and technical (on which basis should the price of electricity be increased?).** The question cannot be ignored, however. The risk is that plants face a cost that they cannot recoup and decide to curtail power, at the expense of consumers and local economic activity.

In summary, it is critical that ETS design help rather than hamper the push for more efficiency in the power generation sector, given the relative importance of the two issues in China (reliable electricity and CO<sub>2</sub> mitigation). In that sense, experience with other emissions trading systems is only of use to a point, even if basic building blocks (cap, allocation modes, measurement, verification and reporting, enforcement) remain the same.

In designing an ETS for China, there are some important observations to make which reflect the prospective interplay of an ETS mechanism with the specificities of China:

- A market instrument like an ETS will be all the more effective as it can fully exploit the flexibility potential of the generation sector. **In the case of power generation, the flexibility will in great part come from an adequate transmission system** – the physical infrastructure required to move towards a more optimal dispatching of plants. This also assumes the availability of some excess generation capacity.
- There will continue to be a need for massive investments in new generation: many ETSs have been designed for systems where much of the power generating infrastructure is in place. In the Chinese context, much of the future generation capacity has yet to be built. As a consequence, issues of new build gain in importance relative to the dispatching issues that are key in Europe, for example. It is suggested here that a flexible approach be taken to the reserve of allowances that new entrants could access.
- ETSs generally operate in sectors where most actors are private sector enterprises responding to a combination value-share mobilization for shareholders and regulatory mandates. The heavily state-owned nature of China's electricity sector presents a different context. It will be important to evaluate the potential differences in incentives frameworks in the Chinese system as compared to other sectors where the ETS operates to assess the effectiveness of this CO<sub>2</sub> pricing and trading tool.

## From provincial targets to emissions trading?

Any CO<sub>2</sub> goal imposed on electricity generation will occur in the context of broader CO<sub>2</sub> emission objectives (provincial, national), as well as energy efficiency and energy objectives that may fall onto some of the same entities, in particular state-owned enterprises. The articulation of some of these multiple goals may be an issue in itself. Further, it raises the issue of how flexible compliance with these goals will be, in light of the flexibility that ought to be provided by an emissions trading system. A simple question can illustrate this: is it legitimate for a Province to slightly exceed its CO<sub>2</sub>/GDP goal if this reflects higher emissions by entities that are subject to the ETS, and happen to be in compliance? Maybe a more fundamental question is whether inter-provincial transactions would be allowed.

China climate policy-makers will need to ensure the coherence of their approach – e.g. an ETS – with other measures that apply broadly to energy production and use, and are therefore likely to influence CO<sub>2</sub> emissions as well.

## Addressing uncertainties

The present analysis does not offer a comprehensive analysis of how a Chinese ETS may develop, instead focussing on one, arguably very important, sector – electricity generation. This has some bearing on what conclusions can be drawn from this analysis.

Regarding the price of CO<sub>2</sub>: we indicated a price range that should be enough to trigger the curtailment of small coal plant operations, as they would gain more from the sale of CO<sub>2</sub> allowances than from electricity generation (see Figure 7 and Figure 8), at about CNY 100-200/tCO<sub>2</sub>. This would

represent an equilibrium CO<sub>2</sub> price under fairly restricted conditions: a system where electricity would represent the marginal potential for CO<sub>2</sub> reductions, i.e. all other, cheaper potentials would have been exhausted.

Current discussions on the generation of Chinese Certified Emission Reductions (CCERs), to be used by sources as offsets already indicate that a cheaper potential would be available – power generation would then incur a lower CO<sub>2</sub> allowance price. The activities and sectors that are eligible as offsets will also affect the cost of compliance under the Chinese ETS.

Secondly, the inclusion of other emitting sectors will also change the economics of greenhouse gas mitigation in China. Under one extreme scenario, an upstream system would cover all fossil fuel consumption in the country, through allocation at the level of primary energy suppliers. Under another extreme, power generation would be the only sector included. The CO<sub>2</sub> market price under the two systems would differ radically.

Thirdly, the border of the Chinese carbon market could expand beyond domestic sources and offsets. This could happen in several ways:

- The Chinese CERs could be eligible under other ETS. Their purchase on the international market would imply a higher demand than would otherwise be, and hence increase the cost of CCERs for Chinese sources under the ETS.
- The Chinese ETS could also be linked directly to the international market, either through bilateral agreements with other ETSs,
- or under the aegis of the UNFCCC new market mechanism or 'framework'. These two options are discussed under the Ad hoc Working Group on Enhanced Action under the Durban Platform (ADP).

Last, a range of other developments outside climate policy itself could influence the cost of reducing CO<sub>2</sub> emission, from international energy prices to variations from expected GDP growth, and the effectiveness of other policy instruments in lowering CO<sub>2</sub> emissions.

For all these reasons, the quantitative illustrations in this report are meant to draw the attention to important policy aspects of implementing an ETS in China's power generation sector, and not to provide forecasts.

## China's domestic ETS and international climate policy

In the run-up to Copenhagen, policy discussions on the carbon market addressed the need to broaden the scope of the Clean Development Mechanism, as a way to support further mitigation action in developing countries. Parties agreed in Cancun and in Durban on a new market mechanism that would rest on ambitious emission objectives and apply to broad segments of the economy. Assuming significant demand on the carbon market going forward, the new market mechanism is meant to drive more global mitigation than allowed by the CDM, by basing crediting on whole policies or sectors, rather than on a selection of well-performing projects, while other greenhouse gas emitting activities are left to grow unabated.

The scaling-up implied by moving from a project to a sector-wide basis implies a complete change of perspective on the role of the international carbon market in driving mitigation. Aasrud et al. (2009) have established the need for strong domestic policy frameworks to foster GHG mitigation under sector-based market mechanisms, where CDM required fairly little engagement from the host country. This view is confirmed here. Although the present report does not assume that the international carbon market will drive policy in China, it nonetheless shows that a carbon market instrument is not likely to drive CO<sub>2</sub> reductions without important adjustments to the regulatory framework of the power generation sector. The latter requires a more holistic approach to climate mitigation goals, and full integration of the policy objectives that govern emitting activities. This

point is worth stressing as the power generation sector is the most rapidly growing source of CO<sub>2</sub> world-wide. How China integrates its CO<sub>2</sub> objectives, including the introduction of emissions trading into the development of its power generation sector should be watched closely. It will provide important lessons for other countries on the choice of policy instruments in mitigating CO<sub>2</sub> emissions from electricity.

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## Appendix I – Case Study: Illustrating Compliance Cost at Company Level

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Although an ETS would apply on an installation-by-installation basis, it is interesting to illustrate how a large generation company operating in China would “manage” its portfolio under a carbon constraint. The company-level illustration in this section is based on publicly available data on the existing and projected power generation profile of one of the five large state-owned enterprises, China Power Investment Corporation (hereafter CPIC). Importantly, the current and projected fuel mix of CPIC will differ from the general landscape of the Chinese electricity sector. As a result some of the effects of different carbon constraints illustrated using CPIC as an example could therefore be different when considering it at a national level. For instance, CPIC's current portfolio of coal plants is not as dominated by small coal plants, representing about 8.5% of their coal-based capacity in 2010, compared to the average for the Chinese electricity sector of about 29% as illustrated in Table 2.

### Analysing different investment choices and compliance strategies

Because of the many uncertainties inherent to this exercise (fuel, electricity and CO<sub>2</sub> price evolution, capital costs, etc.) two clearly distinct cases were identified to clarify the implications of different strategic choices of a power generation company that has to operate under a CO<sub>2</sub> constraint applied to its fossil-fuel generation:

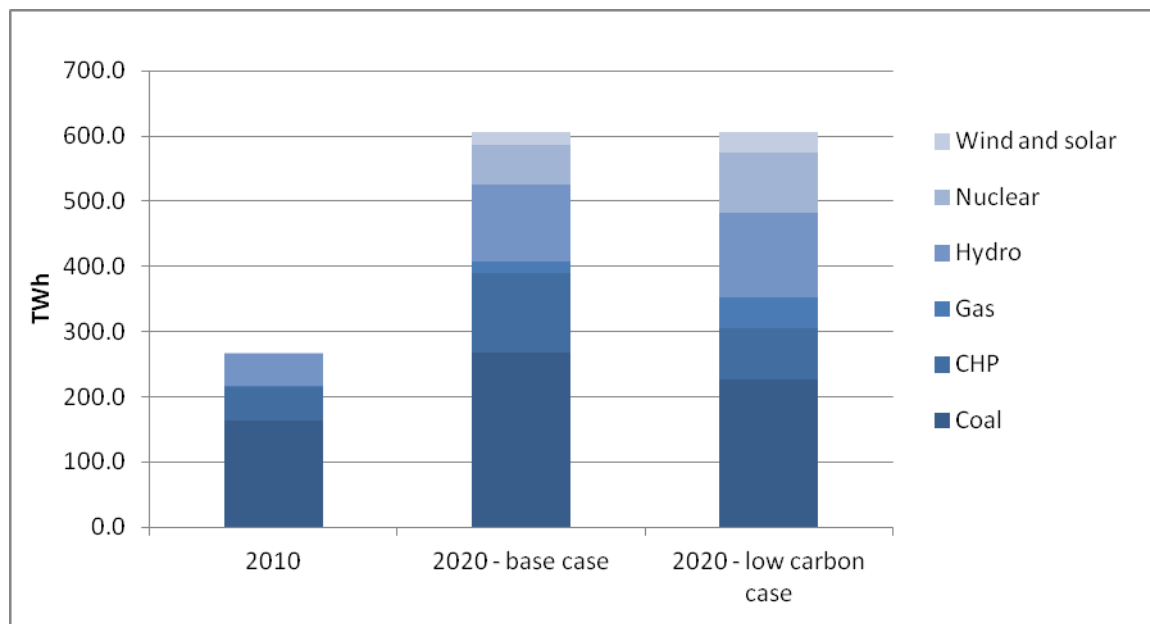
- A **Base Case**, reflecting CPIC's current investment plans up to 2020 and an extrapolation of these plans out to 2025. This case assumes that the current running hours are kept constant (from 2010 level) over the whole scenario period.
- A **Low-Carbon Case**, with more ambitious investments in non- or low-emitting capacity. Under this case running hours are gradually adjusted to improve the efficiency of generation. The overall electricity output (TWh) are kept the same as in the base case.

Under both cases, the company buys CO<sub>2</sub> allowances for all emissions above the target.

The analysis rests on specific assumptions about fuel costs, on-grid electricity prices, and capital costs for different generation technologies, as well as on running hours for various capacities. In particular:

- Electricity and fuel prices are kept constant at 2010 levels over the scenario period.
- Capital costs fall for some technologies over time (wind, solar and nuclear).
- The CO<sub>2</sub> price increases gradually from CNY 40/tCO<sub>2</sub> to CNY 150/tCO<sub>2</sub> over 2011-2025.

Figure 19: Different company-level fuel mix scenarios by 2020 (TWh)



**Key message:** In 2010 the share of coal-based generation is 80%, in the 2020 base case it is 64% while in the 2020 low-carbon case it is 51%. This lower share of coal-based generation in the low-carbon case is replaced by in particular more gas and nuclear but also a higher share of wind and solar.

In addition to differences in the deployment of various types of capacity (e.g., more gas and nuclear in the low-carbon case), the two scenarios reflect different assumptions in terms of running hours: the base case assumes a quota-based dispatching system while the low-carbon case assumes some improvement of dispatching assuming a search for enhanced economic efficiency and lower emissions, not unlike the Energy Saving Dispatch Rule mentioned earlier. The differences in assumptions about future capacity and running hours are illustrated in Table 7.



Table 7: Capacity and running time assumptions for the base case and low-carbon case

|   | 2020 - base case |                 | 2020 - low carbon case |                 |
|---|------------------|-----------------|------------------------|-----------------|
|   | MW               | Operating hours | MW                     | Operating hours |
| Small coal (net efficiency 28%)           | 1,200            | 4800            | -                      | -               |
| Sub-critical (net efficiency 32%)         | 2,700            | 5050            | 2,700                  | 4600            |
| Super critical (net efficiency 36%)       | 25,100           | 5100            | 19,400                 | 5100            |
| Ultra super critical (net efficiency 43%) | 23,700           | 5100            | 19,700                 | 5850            |
| Gas (net efficiency 50%)                  | 9,717            | 2000            | 13,100                 | 3500            |
| CHP (coal based)                          | 23,900           | 5050            | 15,700                 | 5050            |
| Hydro                                     | 35,634           | 3300            | 39,334                 | 3300            |
| Nuclear                                   | 8,117            | 7400            | 12,700                 | 7400            |
| Wind (on-shore)                           | 7,385            | 2000            | 11,485                 | 2000            |
| Solar PV                                  | 2,400            | 1900            | 3,700                  | 1900            |
| <b>Total</b>                              | <b>139,853</b>   |                 | <b>137,819</b>         |                 |

**Key message:** Keeping overall power generation roughly equal, the low carbon case represents a combination of a move toward cleaner technologies as well as dispatching priority of more efficient fossil-fuel plants (e.g. from 5050 to 4600 hours in subcritical units, and 2000 to 3500 hours for gas units)

## From capacity projections to allocation

An ETS is then 'implemented' on top of these two scenarios. The critical point in rolling out an ETS in the case of China is the treatment of new entrants. As these two scenarios reflect different investment choices, they would not face the same CO<sub>2</sub> constraint, which is the sum of individual caps to individual plants. Put differently, one could not assume that the low-carbon case is a strategy to meet the cap applied in the base case: the profile of various capacities is different, and so is the overall emission constraint that would apply to this particular company in the real world.

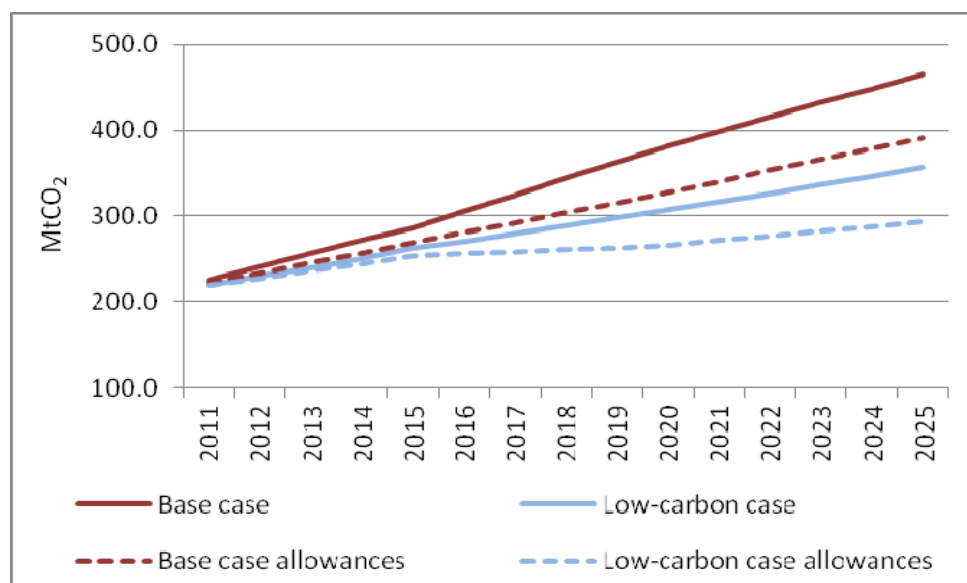
The subsequent illustrations assume the following rules for allocation of allowances to existing and new plants:

- In general, plants in operation in 2010 receive allowances covering 100% of their 2010 CO<sub>2</sub> emissions level for free, but:
  - The free allocation to small coal plants gradually phased out by 2020
  - The free allocations to other existing fossil fuel plants falling by 1% per year from 2016.
- New plants built after 2010 receive allowances based on a benchmark:
  - Coal-based plants receive allowances per MW of new capacity corresponding to the efficiency (emissions factor) of an ultra-super critical plant (43%) and a level of operation of 4500 hours per year (below the assumed 2010 running hours of between 4800 and 5100 hours for the different coal technologies).
  - Gas-fired plants receive allowances corresponding to the assumed efficiency of gas plants (50%) and an assumed level of operation of 3600 hours. This level of operation is higher than the assumed 2010 level of 2000 hours, but provides for a level of operation that would make new investments in gas profitable.

In the base case the above allowance allocation rules implies that on average over the scenario period about 89% of allowances are given for free. For new entrants only about 80% of allowances are free.

Figure 20 shows both the emissions and the level of allowance allocation to this particular company under the base case and the low-carbon case. In the rest of the discussion, we consider the cost implications of having to comply with these allocation levels, assuming that no further adjustments are made to the dispatching of plants.

Figure 20: CO<sub>2</sub> emissions and allowances under different fuel mix scenarios



**Key message:** By 2025 CO<sub>2</sub> emissions in the low-carbon case are about 23% below the base case. As the two cases assume different capacity additions (less coal in the low-carbon case), they lead to different levels of allowances for this company.

## The cost of covering excess emissions with the purchase of allowances

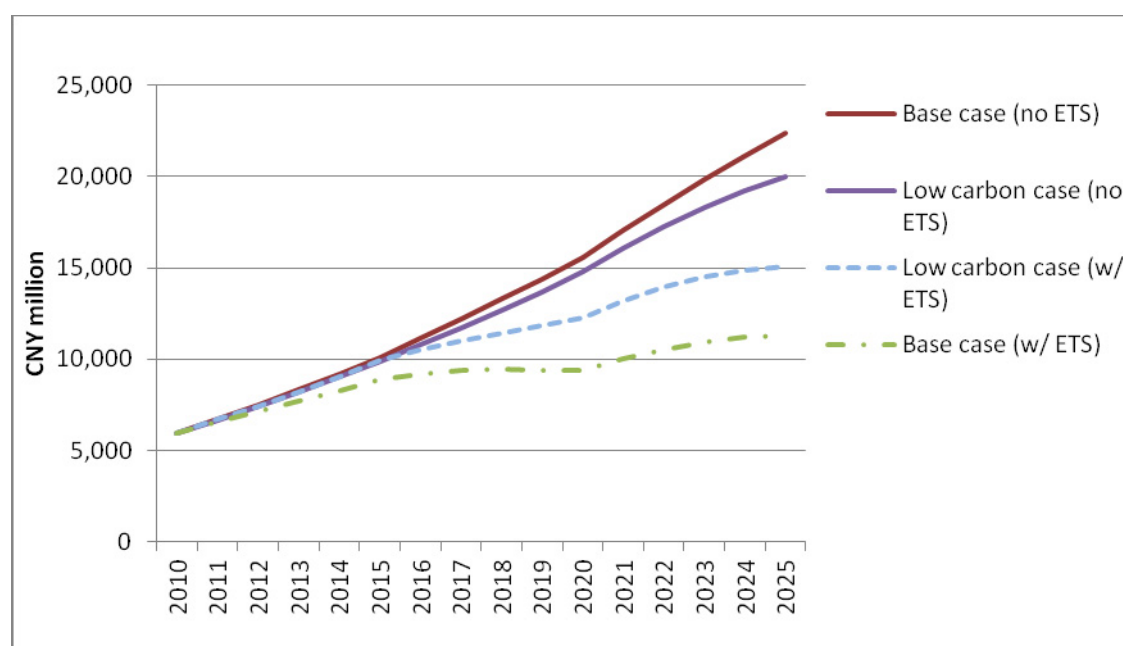
As anticipated, the cost of complying with the target is higher in the base case, where more new coal capacity exposes the company to an increasing shortage of CO<sub>2</sub> allowances (new plants only receive allowances for free corresponding to 4500 running hours and USC plant efficiency). As a result, we find that CO<sub>2</sub> costs – **the cost of covering excess emissions with allowances** – are **23% higher in the base case than in the low-carbon case**. In the low-carbon case, faster retirement of small coal plants plus the lowering of operating hours for sub-critical coal plants reduce emissions and narrow the gap between the initial benchmark allocation level and actual emissions throughout the period. In other words, while fossil-fuel plants are treated equally under both scenarios, the shifting towards more efficient plants in the low-carbon case results in a lower cost under that scenario. In addition, although all fossil-fuel plants are treated equally, the higher share of fuel-based plants in the base case also implies a higher overall level of CO<sub>2</sub> costs.

How would each scenario turn out in financial terms? The impact of a cap and trade policy in this company-level example is illustrated by comparing profits in the base case and low-carbon case, with and without the implementation of the ETS (see Figure 21). Without any CO<sub>2</sub> policy in place,

and assuming the same operating hours (dispatching) in both the base case and the low-carbon case, the base case is the more financially attractive option. However, with a CO<sub>2</sub> policy in place the low-carbon case becomes the more profitable option as a result of more efficient dispatching and lower cost of CO<sub>2</sub> allowances in the low-carbon case. The difference in cost of purchasing allowances for emissions above the benchmark level between the two cases represents about 52% of the total difference in profits illustrated in Figure 21. This is based on a CO<sub>2</sub> price assumption that the price increases gradually from CNY 40 to 150/tCO<sub>2</sub> over the scenario period. Different CO<sub>2</sub> price assumptions would have a large impact on the relative profitability of the two cases. The remaining difference in profits is a result of the more efficient dispatching in the low-carbon case.

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Figure 21: Impact of CO<sub>2</sub> policy on total profits by scenario (89% free allowances to new plants)



**Key message:** The introduction of a cap and trade policy combined with more efficient dispatching changes the relative profitability of the different investment scenarios making the low carbon case financially more attractive than the base case.

The above illustrations show that an ETS focused on putting a CO<sub>2</sub> constraint on new plants only, combined with increased dispatching flexibility would create incentives for a company to meet future generation demand through increased investments in clean technologies.

A word of caution is necessary however: as electricity prices are kept constant over the scenario period the introduction of a CO<sub>2</sub> cost directly impact profits. This is illustrated by the much lower profits in the CO<sub>2</sub> policy scenarios compared to the two scenarios without the ETS.

The critical question, not elucidated here, is whether plants would go as far as to curtail generation – putting the grid in a dire situation – if CO<sub>2</sub> costs were entirely borne by generators (our working assumption in these scenarios), and not by consumers (i.e. the grid).

## Appendix II – Case Study: Allocation Choices for New and Closing Plants

ERI has developed two main scenarios for power generation for the Guangdong province: a **Low Carbon Scenario** and an **Enhanced Low Carbon scenario**. Using these to 2025 for installed capacity and power generation, we explored the implication of different scenarios for allocation, showing how different choices can greatly affect the supply and demand of allowances. These are only partial pictures, as other sectors may be covered and would contribute to supply and demand as well. Furthermore, we make no assumption about the price, and any impact that the price would have on driving mitigation efforts by the covered plants. What follows is more simply an accounting of allowances, based on differentiated allocation modes that we believe are sensible in China's context, and applied to a well-defined, realistic picture of the Guangdong province power generation sector.

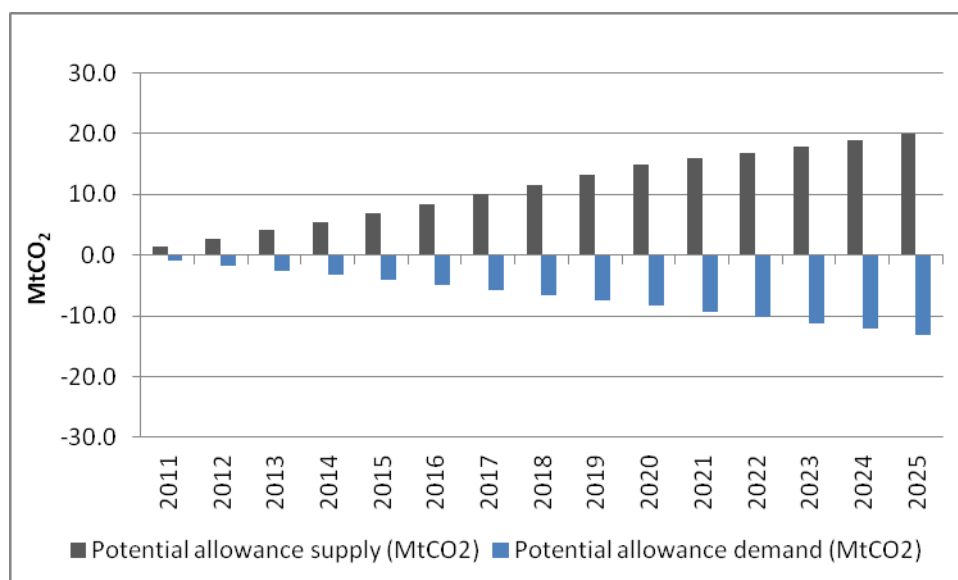
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**The two key parameters in the following scenarios are, first, the extent to which new, highly efficient plants, will receive free allowances; and second, the schedule of free allowances (quantity and duration) to existing plants.** We applied three different allowance allocation scenarios with different assumptions for these two key parameters:

- **Scenario 1:** New plants are allocated free allowances for 90% of base year emissions; existing plants receive 100% of base year (2010) emissions for free, with a reduction in allocation of 0.5% per year from 2016 onward for low efficiency coal plants.
- **Scenario 2:** Scenario 1 with free allowances to existing plants falling by 1% (rather than 0.5%) per year from 2016 for all fossil-fuel plants. This means that by 2025, plants in operation since 2010 that are still in operation receive 90% of their base year emissions allowances for free.
- **Scenario 3:** Scenario 1 but with new plants only allocated 70% of base year emissions for free.

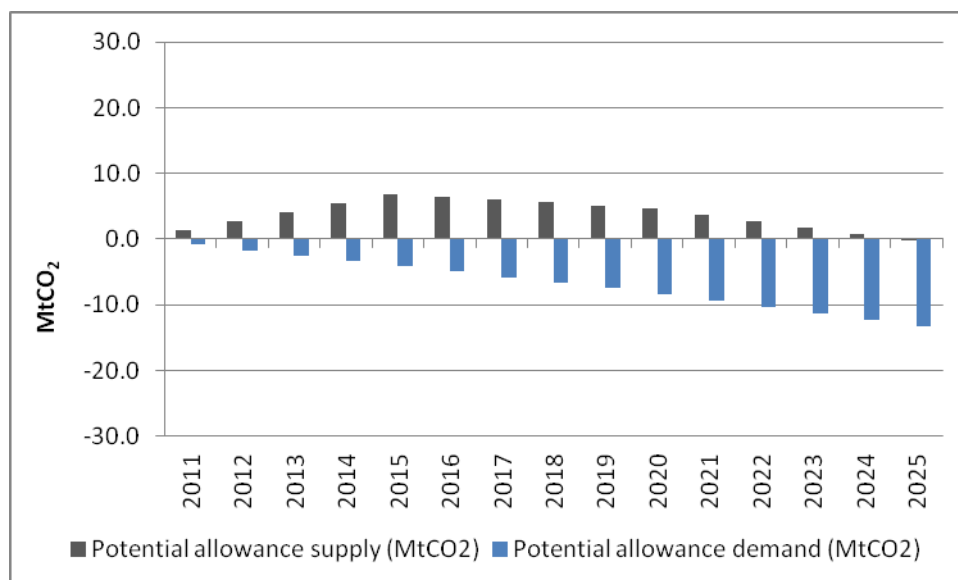
Allowance supply in this analysis is a result of early retirement of inefficient coal plants assumed in the low carbon and enhanced low carbon projections, and assuming that plants keep allowances from early retired plants. It is important to note that this supply and demand analysis limits itself to the electricity sector, while in an ETS covering several sectors the different sectors will have different supply and demand positions meaning that overall supply and demand position in the ETS may be very different. **The following illustrations reflect the ERI Low Carbon climate policy scenario.**

Figure 22: Scenario 1 – New plants allocated 90% for free; existing plants allocated 100% declining by 0.5% from 2016

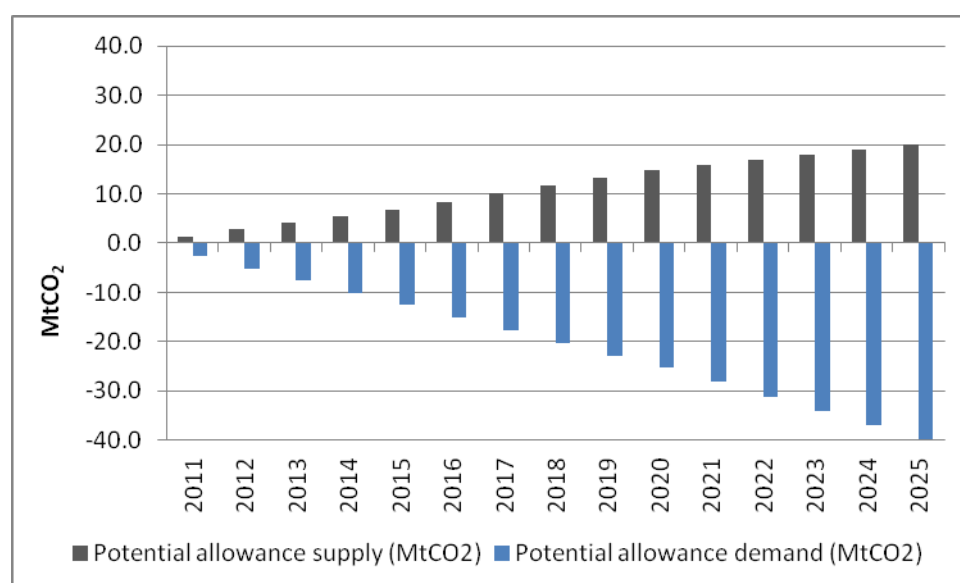


**Key message: With existing plants receiving 100% of allowances for free, the supply of allowances remains higher than demand over the scenario period.**

Figure 23: Scenario 2 – New plants allocated 90% for free; existing plants allocated 100% declining by 1% from 2016



**Figure 24: Scenario 3 – New plants allocated 70% for free; existing plants allocated 100% declining by 0.5% from 2016**



**Key message: Modestly reducing the level of free allowances for existing plants, by 1% per year from 2016 (Scenario 2), rapidly increases the net demand for allowances. Reducing the level of free allowances for new plants to 70% also creates a net allowance demand position (Scenario 3).**

The three scenarios above demonstrate the sensitivity of allowance supply and demand to the choices made with regard to:

- The level of free allowances
- The differentiation in treatment of existing and new plants and
- The rules applied in the case of plant closure:
  - Can plants retain their allowances if they close early? If so for how long?
  - Should there be a declining schedule for the free allocation to existing plants, so as to enhance efficiency improvements, and slowly increase cost?

These questions should be addressed once there is clarity on the coverage of the system, and on the population of plants that the system would include (age, efficiency, schedule for retirement). One word of caution should be added on the question of plant closure: allowing plants to receive free allowances as long as they keep operating and cancelling these allowances when they close is equivalent to granting a subsidy to production, encouraging even the less efficient plants to keep operating as they do not carry a direct cost for their emissions.



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