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Economic instruments for mitigating carbon emissions: scaling up carbon finance in China's buildings sector

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Abstract The relevance and cost-effectiveness are key criteria for policymakers to select appropriate policy and economic instruments for reducing carbon emissions. Here we assess the applicability of carbon finance instruments for the improvement in building energy efficiency by adopting the high efficiency standards as well as advanced energy supply systems, building on a case study in a northern city in China. We find that upgrading the current Chinese BEE standard to one of the best practices in the world coupled with the state-of-the-art energy supply system implies an abatement cost at 16US$/t$CO_2$, which is compatible with the international carbon market price. The institutional reorganization turns out to be indispensable to facilitate the implementation of the proposed scheme of local government-led energy efficiency programme in the form of programmatic CDM in China's buildings sector. We show that with international support such as carbon finance, the BEE improvement will facilitate city's transition to low-carbon supply in the longer term. More importantly, it is argued that demand-side energy performance improvement in buildings should be considered a prerequisite to shifting low-carbon energy supply technologies such as fuel-switching, renewable power generation and Carbon Capture and Storage to address climate mitigation in light of cost-effectiveness and environmental integrity.

1 Introduction

The buildings sector offers promising prospects for the long-term climate change mitigation as huge potentials for cost-effective reduction in greenhouse gases (GHG)

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emissions still remain untapped. The Intergovernmental Panel on Climate Change (IPCC)'s Fourth Assessment Report estimates that there is an opportunity to cut global CO_2 emissions cost-effectively in nearly 30% of the existing buildings by 2020 (Levine et al. 2007; Ürge-Vorsatz et al. 2007). The global effort to combat climate change will inevitably rely on improving the energy efficiency of buildings in the coming decades (International Energy Agency 2006; UNEP 2007b), with buildings responsible for one-third of global CO_2 emissions (Intergovernmental Panel on Climate Change 2007; UNEP 2007b; Ürge-Vorsatz et al. 2007).

China is engaged in a vast programme of urban development. The urbanisation rate is expected to reach 55% in 2020 and 60% in 2030, the population in urban zones is projected to increase to 830 million in 2030 from 460 million in 2000, with an average annual growth rate of 2% (Toth et al. 2003). The average per capita living area in cities is expected to reach 30 m^2 by 2020, roughly equivalent to that in developed countries in the 1990s (Ministry of Construction of China 2003). More than 2 billion square meters of buildings are constructed annually since 2000, making China the country adding the most buildings area in the world. More than 60% of buildings existing in 2030 will be built after 2006 (Liu 2009), and China's Ministry of Construction (MOC)[1] has estimated that around 15–20 billion m^2 of urban-zone housing will be built between 2005 and 2020 to accommodate newcomers to the cities—equivalent to the entire existing building stock in the EU-15.

The design and construction of long-life urban infrastructure, the buildings among others, will shape the energy and emissions trajectory for several decades. Due to the strong inertia, a house will remain untouched for at least 50 years before being demolished or renovated. Inefficient construction will result in tremendous energy and climate implications (it will lock the large infrastructure in carbon-intensive pathways for at least several decades) and render climate and energy security more vulnerable due to the irreversibility.

Buildings (in particular energy efficiency) encompass great potentials in the global carbon market. The CO_2 emissions (both direct and off-site indirect from electricity) from China's buildings sector is around 1.16 Gt in 2004, representing 12% of global emissions from buildings (International Energy Agency 2008). A recent review paper found that carbon reduction potentials in China's buildings sector would average 700 Mt in 2030 with combined demand-side management measures and supply-side energy efficient technology (Li 2008). In addition, implementing carbon mitigation options in buildings is associated with a wide range of co-benefits, including social welfare benefits for low-income households, increased access to energy services, improved indoor and outdoor air quality, as well as increased comfort, health and quality of life, job creation and economic competitiveness (Levine et al. 2007, p.389).

Although improvements in energy efficiency may contribute to cost-effective reduction in energy demand and associated GHG emissions, the energy efficiency gaps still remain in all economic sectors due to a variety of market and non-market barriers: principal-agent problem, information asymmetry, high transaction costs (difficulty in acquiring unfolding relevant information about information and

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[1] The former MOC (Ministry of Construction) was recently replaced by MOHURD (Ministry of Housing and Urban-Rural Development).

often time-consuming),and bounded rationality.[2] Additionally, the energy efficiency uptake is often undermined by artificial low energy price and explicit or implicit energy subsidy (DeCanio 1997; Howarth and Andersson 1993).

The phenomenon of energy paradox (profitable energy savings investments are not undertaken)has been discussed in the literature. The uncertainty on benefits of energy efficiency, principle-agent problem, bureaucratic and organizational barriers and the fact that energy consumption still accounts for relatively small part of economic spending also give rise to reduced possibility of realizing optimal energy efficiency (DeCanio 1998; International Energy Agency 2007b; Intergovernmental Panel on Climate Change 2007).

Thus, one of the stumbling blocks in climate mitigation in the buildings sector is how all the actions will be financed. Therefore the question of how to leverage sustainable finance to achieve or beat the carbon emission reduction targets in the building sector is of key importance. Designing appropriate policy instruments requires information on costs and benefits of taking actions. International support coupled with the global carbon finance has emerged as an alternative to help developing countries to tackle the financial challenge in key sectors, such as urban infrastructure in the intensifying climate negotiations (Baron et al. 2009; Neuhoff 2009). This paper attempts to answer two key questions: (1) What are the implied cost of enhancing energy efficiency standards (with the best practices) in the building sector in China? The results allow us to judge if the cost lies within the reasonable range of the carbon price in the global carbon market (issue of compatibility and eligibility). (2) To what extent can the international support mechanism such as Clean Development Mechanism (CDM) contribute to accompany the ambitious mitigation targets and how to adapt it in order to leverage sustainable carbon finance?

This paper investigates the way of implementing policy and economic instruments to encourage the uptake of higher efficiency standards in the buildings sector in Chinese cities. As the window of improving the energy efficiency through carbon finance and technology transfer is opening, we discuss specifically how to harness great potentials of carbon emissions reduction in China's building sector through a city-wide building efficiency improvement programme. The approach proposes aggregating individual building development projects in a programmatic manner by bringing different stakeholders on board. Carbon finance awarded from a programmatic CDM-like mechanism will be used for the implementation of building efficiency strategies and policies with the involvement of local authority whose governance can directly influence the development pathway in both buildings and energy supply, unlike the traditional CDM instrument by which carbon credits are issued against measured and verified emission reduction for an individual project. Furthermore, CDM project's credits are issued only after long delays and in unpredictable quantities, whereas the scheme proposed here use carbon finance to facilitate technological transition within the framework of the intervention of public policies. This can reduce significantly the uncertainty of CERs quantity and

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[2] In the real world, perfectly rational decisions are often not feasible due to the finite information and instruments available to economic agents for decision-making. Bounded rational agents experience limits in formulating and solving complex problems and in processing (receiving, storing, retrieving, transmitting) information (Simon 1991).

the transaction costs associated with CDM mechanism. An adaptive institutional framework is arguably indispensable to achieve the cost-effective GHG mitigation objective.

The paper is organised as follows. The next section reviews different instruments used for enhancing energy efficiency in buildings. Section 3 investigates the implied costs of improving significantly energy efficiency in buildings based on a case study in a northern city in China. Section 4 proposes a way of mainstreaming carbon finance through scaling up CDM in order to change the trajectory of building energy efficiency and energy supply technologies in Chinese cities. Section 5 discusses the institutional arrangements and the underlying energy pricing issues. Section 6 concludes the paper and provides the research perspective.

2 Policy and economic instruments for BEE

2.1 Instruments to mitigate climate change

There is a growing interest in the potentials for public policies to reduce energy intensity in all economic sectors because of concerns about global climate change linked with the combustion of fossil fuels (Newell et al. 1999). Policymakers are then regularly confronted with the dual tasks of choosing environmental goals (e.g. greenhouse gas emission mitigation) and selecting policy instruments to achieve these goals (Stavins 1996). There is a wide range of economic instruments or incentives which can be used to internalise externality of economic activities. Economic instruments have an important role to play to cope with transboundary and global environmental issues in the plea for a sustainable development path (Panayotou 1994). Every incentive that aims to induce a change of behaviour on the part of economic agents by internalizing environmental or depletion costs qualifies as an economic instrument.

Indeed, as climate change is the foremost global externality that the world has ever seen, a carbon tax is necessary to correct the market failure and inefficiency along with other command-and-control governing instruments (Stern 2006). Thus, clear property right of carbon emissions and appropriate carbon price are needed to correct the market failure. Emissions trading and carbon tax are the two most common market-based approaches int terms of economic incentives in carbon emissions regulation. Since Weitzman derived conditions under which one or the other policy is preferred in expected efficiency terms based on the relative slopes of the curves for the marginal cost and marginal benefits of emissions control (Weitzman 1974),numerous studies have been published concerning prices versus quantities tools in economic literature on environmental impacts management (see for example Goulder et al. 1999; Nordhaus and Boyer 2000; Oates 1996; Pizer 2002). Most of these studies argued that price-based policies are preferred for the purpose of economic efficiency (Murray et al. 2008). Given the importance of buildings in tackling the climate change, there are intensive literature on how to use policy instruments to bridge the efficiency gap and to tap the great carbon emission reduction potentials in the built environment, including Chinese cities (International Energy Agency 2007b; Intergovernmental Panel on Climate Change 2007; Li and Colombier 2009; Ürge-Vorsatz et al. 2007).

While efficiency measures in buildings are mostly unsophisticated and available on the construction market, the issue of financing and the inherent split incentives represent a major barrier to scale up the good practices to improve significantly the energy performance in buildings (Intergovernmental Panel on Climate Change 2007; International Energy Agency 2007b). In theory, houses complying with the building codes that defines thermal performance design standards are supposed to be energy efficient and should lead to energy savings. However, experiences reveal that the actual performance of the constructed buildings is systematically lower than designed value (Durbin et al. 1986; Haas and Biermayr 2000). This is in part due to the overly optimistic estimation of the BEE's measures, but also to the ignored change in consumption behaviour after the EE measures have been introduced. In fact, improved energy efficiency implies reduced costs of energy services and subsequently encourages the energy use,commonly referred to as rebound effect which has been discussed largely in economic literature (Brookes 1990; Saunders 1992; Schipper and Grubb 2000; Scott 1980). Therefore, appropriate policy and economic instruments need to be designed to overcome these market and non-market barriers to improvements in energy efficiency of buildings.

2.2 Regulatory measures versus economic instruments for BEE

Regarding the building sector, most governments used to use standards to regulate energy consumption through improved energy efficiency. In a recently published UNEP's report (UNEP 2007a), different types of policy and economic instruments were assessed, including regulatory versus incentives-based tools. Mandatory building codes have been considered one of the most cost-efficient instrument to regulate the building energy performance. Since the first oil crisis, a number of developed countries have implemented mandatory building codes to impose the minimum efficiency standards for residential and commercial buildings. Mandatory buildings codes have also been increasingly adopted in a number of developing countries, as pointed by Lam and Hui (1996).

In addition to the regulatory approach, market-based instruments can be appealing to help manage carbon emissions from buildings in a cost-effective or efficient manner (Brown et al. 2002; International Energy Agency 2007a; Intergovernmental Panel on Climate Change 2007). To achieve higher efficiency standards, incentives-based instruments can be used as a supplement to regulations. Previous studies investigated different possible policy instruments to enhance the energy efficiency in buildings in the OECD countries such as tax credits, soft loans and energy performance labelling (Brown et al. 2002; Shorrock and Coward 2007; International Energy Agency 2007a). In the case of China, Zhong et al. (2009) discussed the policy framework of introducing incentives mechanism to improve the energy efficiency in Northern China based on a modelling approach, they recommended the performance-based incentives should be preferred in the first place. In comparison, some studies (UNEP 2007a; Lee and Yik 2004) explored the possibility of using both regulatory and voluntary approaches to enhance energy efficiency in the building sector.

The emerging climate finance mechanism may contribute to an alternative of harnessing the energy savings potentials in the built environment in developing countries. However, few empirical studies have examined the role of carbon finance in improving energy efficiency in buildings. Cheng et al. (2008) explored the feasibility and challenges of implementing Kyoto flexible finance mechanism in the building and construction sector from both technical and institutional perspectives. Indeed, China has become increasingly active in the global carbon market (Capoor and Ambrosi 2009) and is expected to play an essential role in carbon emissions mitigation in the context of rapid economic development and surging urbanisation. Our study aims at filling the gap of inadequacy in quantifying the required international support needed to improve the energy performance of the urban infrastructure in Chinese cities.

2.3 The issue of building code enforcement

Legally speaking,when a mandatory building code relating to energy efficiency is enforced by the government,compliance with these regulations is mandatory, and failing to comply will lead to monetary or other kind of penalties, even juridical consequence in some cases depending on specific instances. China has adopted several BEE standards since the mid-1990s. The first building energy efficiency standard that regulates the heating consumption in residential buildings in the north of China (cold winter zone)was implemented in 1995 (initially non mandatory), other climate zones have also adopted the BEE codes successively, both for residential and commercial buildings. Since 2003, the central government has launched national initiatives to reinforce effective energy savings. The former Ministry of construction is in charge of implementation. Implementation of BEE standards becomes mandatory for local houses builders. Note that one specific issue in the Chinese context is that BEE standards consist of two parts, one dealing with energy efficiency in buildings, the other setting mandatory targets for the heat supply (most cities in the north of China is distributed with centralised heating networks, owned and operated by municipal or private companies). So far, the foremost incentive relies on the fact that the building energy efficiency design is a prerequisite for property developers to submit application to the land use and construction permits.

The implemented buildings codes did contribute to considerable energy savings in the buildings sector (Lang 2004). However, many municipalities encountered systematic difficulty in effective implementation due to lack of technical and institutional capacity (e.g. monitoring and evaluation). It is reported that the actual compliance rate of efficiency standard is still unsatisfactory. A comprehensive survey conducted by the MOC in 22 major Chinese cities in 2007 revealed that the actual implementation of the current BEE standard was still quite low, only one-fifth of buildings complied effectively with the national efficiency standards in 2006[3] (Qiu 2007).

Property market in China still encounters many barriers to large-scale deployment of BEE techniques and products due to lack of financial and workforce

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[3] This should NOT be interpreted as if the remaining four-fifth of buildings did not comply with the buildings codes at all, rather they fail to reach all the prescriptive values of mandatory efficiency. In effect, most new buildings' design comply with the BEE standards,otherwise the construction permits would not have been granted. However, during the construction and execution stage, the implementation of BEE does not necessarily match the initial requirements in the design document, the actual compliance rate is thus significantly compromised.

capacities. There also exists regional difference in terms of degree of energy efficiency implementation strategy and measures across a number of actors in the construction sector depending on local climate and economic situation (Liang et al. 2007). The survey makes it clear that there is systematic gap between the initial energy-saving design document and the practical execution in situ due to low-skilled workforce and lack of technical capacity as well as developers' cost-minimisation tentative at the expense of materials quality.[4] More specifically, the lack of skilled construction and installation workers has led to modest rate of compliance with energy efficiency standards. Therefore, there is an urgent demand for the dissemination of knowledge on building energy efficiency, as expertise and training for professionals, building and energy facility operators and management personnel are largely unavailable.

2.4 The existing public policies in China

Since the mid-1990s, the Chinese government has formulated a series of energy efficiency policies to encourage energy savings in the building sector, in particular in heating zone in the north of country. The *Energy Conservation Law*, promulgated in 1998 and revised in 2007, laid the ground for the fundamental principle of saving resources and promoting efficient energy use in the whole economy. In 2004, the NDRC issued the *Medium and Long-term Energy Conservation Plan* which set specific energy efficiency improvement targets for industry, transport and residential sectors by 2010 and prospect for development by 2020 (National Development and Reform Commission 2004; International Energy Agency 2007a). In 2007, the Ministry of Construction adopted an Action Plan aiming at achieving 100 Mtce energy savings in the buildings sector during the 11th 5-year plan period (2006–2010)[5] in accordance with the national target of 20% reduction in energy/GDP intensity by 2010. Table 1 summarises the major regulations and standards elaborated to promote energy efficiency in buildings in China since 2006.

The current regulatory framework is essentially based on the command-and-control approach although there exists some specific economic or fiscal instruments (the scale is quite low) to encourage the implementation of high EE policy in buildings. In addition to the national policy and standards, some municipality designed local policies by introducing non-monetary incentives for encouraging energy efficiency in buildings such as land use advantages.[6] However, the effect is quite

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[4] In the context of regulatory framework in Chinese construction market, buildings materials (including the insulation materials) selection and procurement in general is not decided by the architect in charge of architectural design, rather validated and monitored by an independent project supervision firm (or third-party in charge of project quality monitoring) who is remunerated directly by property developer. Under this organisational structure, the third-party (her role is like an agent) tends to choose the option in favour of the developer (principal).

[5] According to this plan, new residential, public buildings and retrofitting the existing stock will contribute respectively 60%, 9% and 16% of total energy savings, the remainder coming mainly from promoting the renewable energy and green lighting.

[6] For example, Shanghai commission of construction stipulated that insulation area of buildings envelope is exempted from plot ratio calculation in the application document to construction permits.

Table 1 Recent Chinese policies to promote energy efficiency in buildings

Regulatory items	Date of issuance	Main objective and contents
Scheme of promoting renewable energy in buildings in pilot cities	July 2009	Floor area supplied by renewable energy-integrated buildings should be no less than 3 million sq.metres in the 2 following years for prefecture cities applying for project demonstration
Regulation of Energy Conservation in Civil Buildings	July 2008	The incentive and constraints mechanisms relating to energy efficiency in buildings are specified in this regulation
Regulation of Energy Conservation in Public Buildings	July 2008	Specific provisions on planning, management, monitoring and enforcement of implementation of energy conservation in public buildings
Circular of heating consumption metering of civil buildings	July 2008	Installation of metering and temperature regulation equipment is mandatory in new build and retrofitted buildings, heat consumption should be billed based on actual consumption
Circular of information disclosure of energy consumption in civil buildings	July 2008	Transparent information on energy consumption, energy efficiency measures taken in buildings should be disclosed in civil buildings
Notice on financial subsidy on high efficient lighting appliances	May 2008	Guideline for promoting efficient lighting appliances
State Council's notice on mandatory government procurement of energy efficient products	July 2008	Strengthen the leading role of government institutions in energy efficient products promotion
State council's notice on indoor temperature regulation for air conditioned buildings	June 2007	Indoor temperature should be no lower than 26°C in summer, and no higher than 20°C in winter for all public buildings except for hospital and other specific units, door-opening is not allowed during AC is operating
Circular of management of specific fund for renewable energy application in buildings	May 2006	Fund used to support building-integrated PV, renewable heating and cooling (geothermal, heat pump etc)

Source: Wang et al. (2009, p.347–350)

limited and many housing developers are likely to circumvent the regulation and thus bring about adverse effects.

The investigation into the current situation shows the limitations of the command-and-control approach since the regulations are not always respected or well implemented. A more comprehensive package integrating different policy and economic instruments needs to be made available to complement the regulatory approach. There is often a lack of domestic institutional capacity as well as market barriers impeding the uptake of the energy efficiency technologies in most developing countries. Lining the local construction practices and products performance up with the international standards requires a fundamental market transformation within a sound institutional framework. In this regard, international support can help overcome these constraints by providing additional resources for incremental costs,technical assistance and capacity building support, as well as for facilitating technology cooperation (Neuhoff 2009). The following section will examine the extent to which international support such as carbon finance could be relevant for energy performance improvement in the context of built environment in Chinese cities.

3 Relevance of carbon finance for BEE in China

3.1 Implications for climate policy: the need of an integrated demand/supply efficiency approach

Before the Copenhagen Conference of the UNFCCC in 2009, China announced an official target of 40–45% reduction in GDP carbon intensity (which is measured by CO_2 emissions per unit of GDP) by 2020 relative to 2005 level. To achieve this target, a broad spectrum of policies and measures will need to be deployed across all economic and energy sectors: optimise economic structure (gradually shift to low energy-intensive and high value-added sectors), enhance energy efficiency in both industry and residential sectors, switch gradually from high-carbon fuels (coal) to less carbon-intensive or carbon-free fuels (e.g.natural gas, renewable), and deployment of more sophisticated technologies for carbon dioxide removal/control from fossil fuels combustion such as carbon capture and storage (CCS) in the longer term.

It must be pointed out that both immediate fuel switching and the deployment of CCS in coal-fired power plants will pose challenges to Chinese decision makers. Massive substitution for coal by cleaner fuel such as natural gas in energy supply in China will raise concerns about security of energy supply,since coal is abundant throughout the country, whereas natural gas reserves are scarce and only located in the extreme west of China and far from demand centres. More importantly, the price of natural gas is still much higher (on average three times higher) than coal in domestic market. Meanwhile, a handful of Chinese cities have already adopted the coal/gas substitution policy, not necessarily for GHG emissions mitigation but rather for local environmental quality improvement.[7] In 2002, the municipality of Beijing passed a local regulation which stipulated that all coal-fired boilers less than 14 MW (20t/h) in the central city had to be retrofitted to use natural gas or other clean fuels. This regulation was revised in 2007 extending the geographic area under restrictive emissions standard (Beijing Environmental Administration 2007). Given the announced objectives of air pollution and climate change mitigation by

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[7] Coal combustion is a major cause of air pollution in many Northern cities in China.

the central government, it is predictable that more cities are likely to adopt similar strategies to reduce local pollutants emissions in the foreseeable future. From a national energy policy perspective, the central government has also been promoting natural gas use by building long-distance West-East gas pipeline to transmit gas from sparsely-populated western regions to the densely-populated industrialised provinces on the Eastern and Southern coasts. Further, several Eastern and Southern provinces have been scrambling to build the liquified natural gas (LPG) terminals to import LPG from the South-East Asia and Australia due to the saturated inland railborne coal transport.[8]

In the longer term, the large coal-fired power and heat generators (CHP) will need to be decarbonised by using carbon sequestration technology such as CCS to meet more ambitious carbon reduction objective. Nevertheless, these supply-side solutions will prove insufficient and difficult (increased supply costs) to carry out if energy efficiency is ignored in buildings constructed today (they are supposed to exist when China needs to implement large-scale fuel switching and/or CCS policy in energy supply in the future). Implementing either the near-term fuel-switching or long-term CCS implies increasing energy supply costs and rising prices for end-users.[9] Lower-income households living in the inefficient houses will be heavily affected with the increased energy price, and inefficient buildings infrastructures are less likely to cushion the energy price shock. Such a consequence is socially unacceptable. This is why we take into account both demand-side energy efficiency improvement and fuel switch in energy supply in the calculation in the following section to anticipate the future carbon constraints in the upstream energy supply. The results supports the thesis that improving energy efficiency is the prerequisite to decarbonising energy supply in a further step.

3.2 Cost of mitigating CO_2 from buildings through enhanced BEE

International support for a cleaner and sustainable development in developing countries can include a variety of components including technology transfer and financial aid. To get a full understanding of the driving factors of sectoral transformation towards low-carbon pathway, it is important to know what will be the incremental costs associated with more ambitious targets of climate mitigation in developing countries.

To examine the extent to which the international financial support (presumably meaning carbon finance hereinafter) can trigger buildings energy performance improvement and lower emission energy supply, we use a World Bank's pilot project in the city of Tianjin as the quantification subject. Suppose that a Chinese housing developer in Tianjin decides to build houses (say 10,000 multi-family apartment houses) in a large residential district, located in a new urban development zone of the city. We assume that property developers are not allowed to pass the incremental costs associated with adopting a higher BEE standard on to the home purchasers, in

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[8] Coal transport accounts for nearly half of Chinese rail freight capacity.

[9] In Northern China, most buildings are connected with a local district heating network: apartment-based individual heating system is rare.

other words, no housing price escalation will be envisaged to absorb the incremental costs. The developer may trade-off between two strategies:

1. a business as usual case, which complies with the current building energy efficiency code (TJ-2004) and connects to conventional coal-fired heating supply system, whereby no extra cost will be generated since the underlying BEE standard is mandatory for every new construction in the city
2. adopting one of the best available technologies (BAT) of efficient building design and construction as well as the state-of-the-art gas-fired supply system (we use the efficiency standards equivalent to the Swedish building code coupled with the natural gas combined cycle (NGCC)) if the extra cost in investment can be paid back by a third party, such as an international carbon credit buyer, on the condition that both sellers and buyers agree on the transaction price

For strategy 2, the developer will be interested in adopting the non mandatory higher efficiency standards and state-of-art energy supply systems[10] without profits being compromised *ceteris paribus*. In this specific case, the housing developer will be motivated if the incremental costs may be covered by the carbon finance. Using the climate finance mechanism implies that carbon emission credits resulting from the improvement of energy efficiency in buildings can be generated and transacted at a competitive price on the international carbon market.[11]

A simple calculation can justify the relevance and applicability of this carbon financing mechanism. Property developer would consider adopting strategy 2 ($S2$) if the project is to be supported by international technical and financial support, strategy 1 otherwise. In other words, the price (for example, the CERs price in the case of CDM) should be higher than the discounted cost of carbon emissions reduction over the entire operation period (20 years).

A builder adopts $S2$ (compliance with Swedish standard equivalent requirement + NGCC)if and only if

$$P_{sub} \geq EAC \tag{1}$$

and

$$EAC = \frac{IC}{\int_{i=0}^{T} (E_{TJt} - E_{SWEt}) \cdot e^{-rt} dt} \tag{2}$$

$$IC = LC_{pol} - LC_{ref} \tag{3}$$

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[10] In Northern Chinese cities, housing developers are required to build heat supply infrastructure directly or pay a connection charge to the municipal heat supply companies when district heating is available.

[11] Although there are a lot of uncertainties about the global carbon market's prospects, the carbon price is expected in most of climate and energy literature to continue to rise over the next decades as the climate policies are very likely to be toughened in the post-Kyoto regime.

where

P_{sub}	is the climate financial subsidy (e.g.CERs price in a CDM project) (US\$/tCO$_2$)
EAC	is the discounted emissions abatement cost (US\$/tCO$_2$)
IC	is the present value of incremental cost of strategy 2 (US\$/m^2)
LC_{ref}	is the present value of life-cycle cost of buildings (captial+operation costs) in baseline case[12] (US\$/m^2)
LC_{pol}	is the present value of life-cycle cost of buildings in BEE improvement case (US\$/m^2)
E_{TJi}	is per floor space emission in year i in baseline scenario (tCO$_2$/m$^2 \cdot a$)
E_{SWEi}	is per floor space emission in year i in strategy 2 scenario, update to equivalent of Swedish building code standard coupled with NGCC (tCO$_2$/m$^2 \cdot a$)
r	is discount rate: 6% which is equal to the long-term mortgage interest rate settled by the Chinese central bank

Equation 1 says that the price of carbon credits issued from the international support project dealing with improvement in building energy efficiency and supply system in Chinese cities should be higher than the incremental costs of mitigation project as compared to the *business as usual*. It follows the philosophy according to which the carbon finance in offset projects is considered a means to subsidizing the demonstrated additionality.

The data from Liu (2006)[13] is used here to estimate the cost of strategy 2. It must be noted that the incremental cost IC is the difference in the life-cycle costs which consists of expenditure in both initial investment stage: buildings construction[14] and supply infrastructure installation and operation (fuel consumption and maintenance and overhead during 20 years). It is assumed that the upstream heat supply system will switch from coal-fired district boilers with 65% efficiency to NGCC with 80% heat efficiency under the technical intervention package of strategy 2.

The overall envelope cost (wall, window, roof) of a typical multi-storey apartment under the baseline scenario (built in compliance with the current building code in Tianjin) is around 280 Yuan per square metre of floor space in 2005 price (36 US\$ per m^2). Updating to the equivalent Swedish efficiency performance in the same building entails an incremental cost of 61 Yuan /m^2 (7.9 US\$/m^2 in 2005 prices), including the optimised building design, and the cost of an improved ventilation and heat recovery system. Final annual heating consumption of a house complying with the two BEE standards are 49 kWh and 18 kWh per square metre, respectively. The technical details on building thermal analysis and heat supply technologies in the Chinese context can be found in Jiang et al. (2007), Lang (2004), Li et al. (2009), MOC (1995).

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[12] In the baseline case (strategy 1), buildings will comply with the current Tianjin building codes.

[13] Economic analysis in this report is based on a pilot BEE project conducted by Chinese Ministry of Construction, Tianjin's local government in collaboration with World Bank/GEF.

[14] We use here the envelope cost as a proxy since the basic building engineering costs remain identical in reference and enhancement cases.

The respective emission factor in strategy 1 and 2 is 49.8 kg $CO_2/m^2 \cdot a$ and 10 kg $CO_2/m^2 \cdot a$ in the base year, and 59 kg $CO_2/m^2 \cdot a$ and 11.5 kg $CO_2/m^2 \cdot a$ in 20 years (the increase in demand for heating service is taken into account to mirror the rise in living standard; full data for the calculations is available upon request). Thus the total estimated emissions reduction over the 20 years of CDM crediting period (shorter than the actual building lifetime) is 873.4 kg CO_2/m^2. The life-cycle costs per square meter in BAU and intervention cases are respectively 574 Yuan (74 US$) and 636 Yuan (82 US $). With Eq. 2, it can be calculated squarely that the EAC is around **16** US$/t$CO_2$ (2005 prices), which is slightly higher than average CERs price of China's CDM projects, but still significantly lower than the the EU-ETS Allowance (EUA) price which averaged 20 €/tCO_2over the first phase (Point Carbon 2008). There is a general consensus in recent literature that carbon price will increase steadily in the coming decades as a response to the strengthened climate mitigation targets (Baron et al. 2009; Capoor and Ambrosi 2009; Point Carbon 2008).

For example, the carbon price in the European market should continue to rise over the next decades as the European Union is expected to tighten the emission reductions objective for the post-Kyoto regime. Recent literatures on the economics of climate change and energy modelling all suggest that the benchmark CO_2 price such as the EUA price and the marginal abatement cost (MAC) of CO_2 in the European countries and other parts of the world are likely to range between 30 and 40 US$/t CO_2 in the 2020–2030 time frame (Anderson 2006; Intergovernmental Panel on Climate Change 2007; Stern 2006; Colombier et al. 2008). Our calculation shows that the price of carbon credits to cover the upgrading of residential BEE in Northern Chinese cities is compatible with the carbon price on the international market and acceptable for carbon financiers and investors. The potential demand for emissions reductions (CERs) in EU countries could increase to 300 Mt CO_{2eq} per year to attain the European target of reducing GHG emissions by 30% relative to 1990 levels by 2020 (Capoor and Ambrosi 2009). Under these assumptions, the carbon price implied in a well-designed carbon finance scheme in China's building sector turns out to be competitive on the international carbon market and attracting investors in the future.

4 Towards a programmatic CDM model in Chinese buildings market

4.1 Key elements for CDM's success

Not surprisingly, it is by no means easy or costless to update BEE standards by adopting the state-of-art techniques in the building sector in China. Adoption of the best practices necessarily implies technological transfer and learning process in the local construction market. The lack of technical and financial capacities will constitute the major barriers to BEE penetration. In this respect, the international financial support mechanism such as the CDM can bridge the gaps by linking the advanced BEE technology application with local capacity building in developing countries. Enacted by Article 12 of the Kyoto Protocol aiming at reducing climate change mitigation more cost-effectively through co-operation between Annex 1 and non-Annex 1 countries, CDM could be a meaningful instrument in the alternative financing portfolios regarding energy efficiency improvement projects in the building sector, in collaboration with the international financial actors.

Nevertheless, the current CDM design is project-based by nature, whereas sectors characterised by dispersed emission source such as buildings have been hardly touched upon. Improvement in energy performance of buildings require a comprehensive approach which involves a series of interventions (design,insulation, ventilation, energy use management, renewable energy supply). Thus the current offset mechanism does not enable financial support to realise the potentials of emission reduction in buildings at scale, although some specific CDM programmes deals with buildings such as lighting efficiency improvement (e.g. replacing incandescent light bulb by energy-saving compact florescent bulbs). In the meantime,local governments have quite limited experiences in developing city-based carbon finance projects. As pointed out in a recently released World Bank report (World Bank 2010), "*broader climate change mitigation priorities and actions have been discussed at the level of national governments, individual city-level GHG emissions reduction activities are not enough to warrant the transaction costs associated with carbon finance*." As mentioned in a comprehensive review paper (Olsen 2007), CDM has not contributed significantly to SD in developing countries since it was launched in 1997 due to imperfect mechanism design and various barriers. Thus, the project-based CDM must be reformed to channel the carbon finance appropriately and make effective contribution to sustainable development.

The inclusion of building energy efficiency in the carbon markets can be of interests if a large part of new buildings programmes (bundling) can be aggregated and put together in the same compliance scheme, otherwise the transaction costs would be too high to be implementable for the stakeholders, including government and private entrepreneurs. Nonetheless, using CDM for building energy efficiency improvement needs to address the following issues simultaneously.

- consensus of baseline definition
- high transaction costs in project-based CDM
- efficient and sustained financing
- long-term involvement of public and private actors

A robust methodology must be used to define the project baseline against which the intervention measures of energy efficiency improvement will be tailored. The bottom line in carbon finance (CDM in particular) is that actions taken in the project should demonstrate the additionality or real emission reduction. As mentioned earlier, an individual building development project has relatively too small emission reduction to counterbalance the transaction cost. It is difficult and costly for a local housing developer to collect relevant information and address directly the carbon financiers and vice versa. Therefore a sound mechanism should be designed such that barriers of transaction costs can be overcome. In the same way, the third and fourth points put emphasis on the importance of consistent finance and supportive policies to give incentives to developers and energy suppliers to commit to constant improvement in infrastructure efficiency in order to facilitate technological transition in the energy sector, otherwise the distorted market will give rise to opportunist behaviour that will compromise the deployment of higher efficiency standards and add risk of lock-in effect for the longer term.

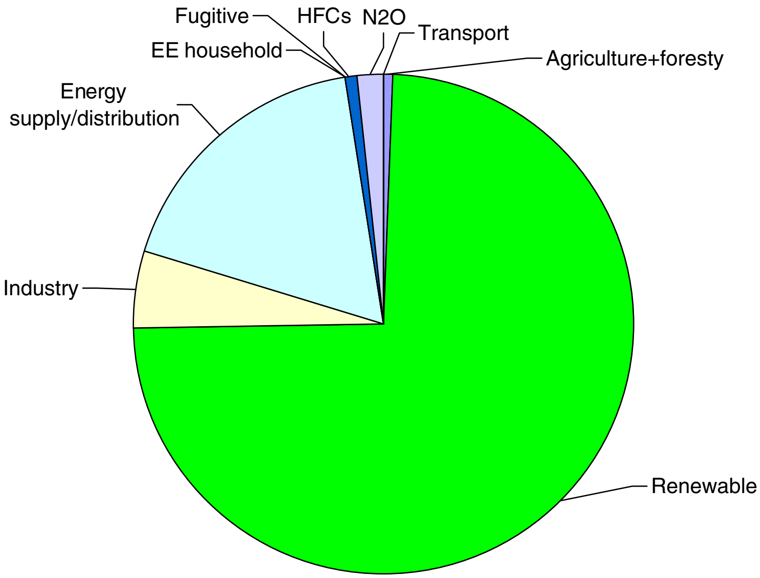

Fig. 1 Breakdown of CDM projects types in China total (UNEP 2009; International Energy Agency 2007a)

4.2 Current situation of CDM in China

Notwithstanding its contribution to the clean technology transfer to developing countries like China, some limitations are pertaining under current CDM operation framework. China is dominating the global CDM market and accounts for more than 80% of share of confirmed transactions in the primary CDM market as of 2008 (Capoor and Ambrosi 2009). According to the recent publication of the CDM Pipeline of the UNEP Risø centre, more than half of the world's CERs by 2012 would be issued from CDM projects in China (UNEP 2009). However, most CDM projects in China focus on renewable energy projects development, projects in the CDM pipeline that deal with the energy efficiency keep growing, but primarily focus on the supply-side and few of them is concerned with the BEE improvement (see Fig. 1.). Moreover, most CERs of CDM have been accredited to reduce non- CO_2 GHG emissions, in particular the HFC-23 accounting for more than 70% of CERs (UNEP 2009), with detriment to energy efficiency projects in particular. This is mainly due to the huge disparity between different GHG in terms of global warming potentials (GWPs) and the easiness of mitigation measures implementation.

The current CDM already has flaws in the sense that it may give incentive to Non- Annex I countries to use inefficient or higher carbon-intensive technology in the baseline scenario so as to generate more carbon credits. For instance, the paper of Wara (2007) pointed out the problem of baseline manipulation of the CDM projects that produced "credits" resulting from non-CO_2 gases abatement, whereby projects developers have incentives to encourage unnecessary increases of HFC-22 production that generates HFC-23 byproduct[15] (It is much cheaper to abate HFCs than carbon dioxide) in order to gain windfall CERs. In this regard, it is necessary to emphasize the importance of the coordination between the Kyoto and Montreal Protocols which regulate the emissions of GHGs and substances that deplete the ozone layer, as suggested in the discussions in Norman et al. (2008), Veldersa et al. (2009).[16] Although the Chinese government has issued taxation instruments to de-incentivise the HFC[17] emission mitigation-oriented projects, there is yet a long way to go to scale up the downstream energy efficiency or demand-side energy management projects instead of concentrating on advanced technologies of upstream power generation.

A recent UNEP research report (Cheng et al. 2008) identifies major stumbling blocks and catalyzers to scaling up energy efficiency investment via CDM in buildings, such as fragmentation and complexity of construction projects, the small scale and disperse emission points (spreading over hundreds of millions of housing) make the registry and MRV costly and time-consuming under the current CDM framework. Furthermore, as noted in Ward et al. (2009), the current project-based approach requires the CDM methodology, including the baseline and additionality definition to be established for each individual technical intervention measure for each project, resulting in high transaction costs for the project participants. Also the rigid rule that the combined technological intervention cannot be considered in the same methodology makes CDM less attractive for investing in BEE since the energy performance of buildings often require integrated technical and managerial measures: heating & cooling system optimisation, efficient lighting, double or triple-glazing, enhanced ventilation, efficient appliances etc (Cheng et al. 2008). In addition, some "soft" measures taken (e.g. optimised architecture design for passive heating or cooling) are not quantifiable in terms of GHG mitigation thus not recognised and credited in the project provision. It is both very expensive and technically difficult to develop and implement methodologies on a project basis, as the proposed methodologies face a high risk of rejection (Ward et al. 2009).

One of the key points in CDM is the additionality in the project assessment and approval process. In the example illustrated above, the *CERs* price implied by introducing the CDM in the residential BEE upgrading in Chinese northern cities appears to be quite competitive and attractive for carbon financiers and investors. However, a critical view at the property market and at the way CDM projects work suggests that the price *per se* can hardly trigger any effective uptake of this kind of initiative in individual manner, opposite to what carbon finance advocates may imagine. This is due to the specific situation in China's building and construction sector. First, it is almost certain that property developers and builders are unlikely to be interested in developing a project with long payback period involving the

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[15] Manipulation occurs in the case of HFC-23 abatement since HFC-22 is regulated by the Montreal Protocol but not under the Kyoto Protocol.

[16] Thanks to an anonymous referee for suggesting this point.

[17] GWPs of HFC gases are more than ten thousands times that of CO_2. The central government imposes differentiate tax rate according to project nature and sort of GHG mitigated.

long-term investment risk, our calculation implies that the carbon credits will be issued over the 20-year period after houses have been built, although the payback time will be much shorter if the energy savings are also taken into account by the developer. The difficulty is that energy savings benefits are generally not reaped by housing developer unless the energy supply facility is directly operated by him. Second, the rate of return on capital investment in the property market is generally very high and far more lucrative for the developers and speculators in the Chinese property market, characterised by short payback time. The interest rate used in the calculation in Section 3 is the social discount rate (6%) that can hardly justify the individual decision on taking measures in the construction such as enhanced buildings efficiency, whereby the carbon credits are expected to be issued over a long period (more than 10 years) that entails high uncertainty that is generally avoided by rational private investors based on risk aversion preference. Moreover, the transaction costs associated with complex procedure (methodology formulation, registration, monitoring and evaluation, verification, issuance) and required technical competencies make the project-based CDM unattractive and hardly implementable in the real environment of property development project. The next section explores the way of scaling up carbon finance in BEE and energy supply infrastructure as well as relevant institutional issues.

5 How to scale up climate finance for improvements in energy efficiency of buildings

5.1 Energy performance-based financial support programme

The debates amid different stakeholders in the global climate negotiations tend to support the idea that the currently short-term and project-based carbon finance will need to shift to the long-term policy planning including programmatic and sector-based approach, and the carbon offset mechanism will continue to operate in the post-Kyoto climate regime (Baron et al. 2009; UNFCCC 2008). The underlying question is how to smartly use these financial instruments to help developing countries to transform their urban infrastructure in compliance with sustainable socioeconomic development objectives.

The difficulties related to CDM for the BEE identified in the preceding section give rise to the necessity of changing the course and mindset in the current CDM mechanism. We suggest an alternative BEE financing scheme which will bring CDM in buildings energy efficiency improvement and energy supply advancement package by means of an integrated approach. Local government will formulate a medium or long term political objective and action plan with regard to the improvement in BEE standards and regulation updating, enforcement and implementation, with support of rigorous technical intervention measures and emission reduction metrics. Instead of applying the abatement-centered CDM projects individually, a programmatic approach needs to be employed in that local authority will centralise the integrity of potentially issuable carbon credits from distributed individual house builders and property developers, and then bargain the issues relating to financing public policies such as implementing the policy of building energy efficiency improvement with international climate negotiators and carbon financing institutions. This approach is characterised by leveraging international support at city or sector level. Schematic representation of programmatic CDM operation in buildings is illustrated in Fig. 2.

Under this scheme, all would-be carbon credits issued in the individual BEE improvement projects will be aggregated to the repository pool, managed by the local government that commits itself to financing (by means of public bank or social development funds) the policy implementation costs associated with both physical and institutional infrastructure for efficiency improvement in buildings and construction, including upfront extra cost of construction, qualified workforce skill raising, efficient components manufacturing capacity and learning of practices of new construction techniques. In fact, local authority plays an intermediate role as carbon credits trader on behalf of distributed individual house builders and property developers in negotiating with international CDM financial institutions and private actors. The aggregate carbon savings from improvements to all candidate buildings will be transacted with international CDM credits traders (e.g. World Bank Carbon Fund or other carbon trust etc) by the local government. In other words, the CDM transaction activities are concentrated in the upstream stakeholders (local government, private investors (traders), bankers and other rating or consulting companies). In contrast to the project-based private investment, the discount rate used is interpreted as in the social development plan. It is then plausible that the public banks (National and Local Development Bank among others) which supply the long-term soft loan for the local government to finance the policy programme of buildings carbon savings will be willing to accept a 6%-rate of return on investment as financing a public-utility improvements project. The carbon finance is mainly used as a leverage to bridge the gap between current domestic capacity and best practices by covering the costs incurred with taking actions commensurate with the optimal trajectories during the transition period, the high efficiency buildings construction

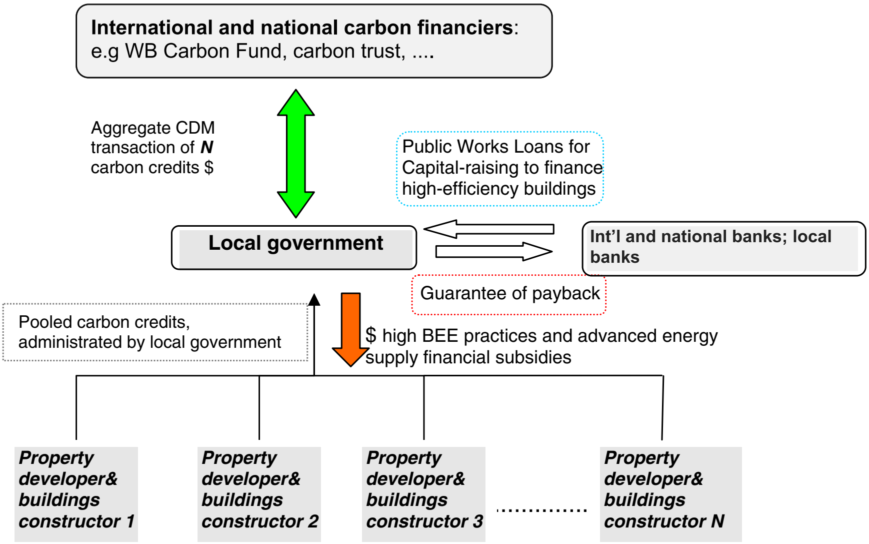

Fig. 2 Schematic representation of programmatic CDM for BEE in the Chinese municipality-level (compiled by authors)

programme initially subsidised will eventually be standardised and generalised after the technological diffusion through learning process.

The extent to which this scheme differs from the traditional CDM is that the carbon credits revenues will not be confined to individual ultra-efficient buildings or one specific technology for demonstration purpose, instead local government needs to establish a strategic policy programme to induce the sectoral transition. Unlike the project-based CDM, this scheme is related to financing public policy and urban development strategy. In this case, the local government will commit itself to financing the extra cost of programmed housing construction during a transition period (say 10 years) before imposing higher level of mandatory BEE standards (e.g. more performing that the current Swedish code requirement). Moreover, the issue of multiple baselines, which is considered one of the major impediments in CDM projects,can be overcome in the city-wide comprehensive approach which aggregates all individual emissions to avoid time-consuming information collection of individual buildings performance characteristics.

During the transition period, carbon finance will contribute to building codes upgrade, best practices learning and diffusion, building up the value chain of buildings and construction and greening buildings-related jobs and working skills. In this respect, a policy-oriented CDM aims at financing the public policy implementation rather than a purely monetary gain of private equity investment in carbon emissions abatement projects. Further, both the so-called transaction costs and non delivery risk (e.g. conflict of additionality) implied in the project-based CDM model can be significantly reduced since the local government will ensure the implementation of policy package consisting of performance compliance and credit delivery and revenue distribution as defined in the provisions of the underlying scheme and terms of carbon credits transaction contract. Indeed, this policy financing scheme will need to engage as many property development programmes as possible to create economies of scale to eventually drive down the upfront costs of high-efficiency buildings construction relative to the prevalence of techniques practiced today.

The incremental costs associated with BEE are subsided by local authorities by means of subsidy or awards through public financial institutions, local authorities in turn trade the recognized emissions reduction credits with international carbon financiers. Housing developers are not concerned with the downwind carbon credits transactions and the transactions costs and associated risks will be significantly reduced compared to those of individual CDM projects. The carbon trade is actually served as a financial tool to accompany the Chinese building industry to transform the sector into a high-efficiency and low-carbon infrastructure by anticipating the BAT construction techniques, instead of a purely project-based financial tool that generates additional carbon credit in the narrow sense.

5.2 Heat pricing reform and implications for institutional innovation

Achieving higher energy performance of buildings and carbon emissions reductions requires a comprehensive approach consisting of DSM and supply technology optimisation,in the case of inefficient and wasteful energy production and supply, it is unlikely that energy savings can be realised with the improvement of the thermal performance of buildings alone. Appropriate heat metering, billing and pricing mechanisms are indispensable to accompany successful infrastructure performance enhancement. As noted in Laponche et al. (1997) "*to encourage the efficient operation of energy companies and to improve their performance, to reduce government expenditure and to assist the economy to operate efficiently, it is essential that energy prices reflect energy costs* (p.63)". Ideally, energy price should be cost-reflective and take into account costs of externality such as CO_2 emissions.

Likewise, the past experiences in the OECD countries show that energy efficiency improvements since 1973 mainly resulted from ongoing technological progress and also response to rising energy prices (Geller et al. 2006). However, energy prices for end users in China are often subsidised by the government and do not reflect the real cost of production. The estimated energy subsidy amounted to 11 $ billion in 2006 (International Energy Agency 2007a). Billing and pricing systems are particularly inconsistent with the objective of improving energy efficiency in buildings and district heating. Heat supply in most Northern cities is heavily subsidised by local government. End-users do not necessarily pay the heating service based on actual consumption due to the absence of relevant metering system, instead a fixed annual payment proportional to heated area is charged by heat companies (heat price is determined by local pricing authority), therefore consumers do not have incentives to save energy. The rising price is a condition for the success of the carbon finance scheme we propose. Should the higher efficiency standards of buildings are adopted and supplied by a cleaner supply technology, it is expected that the quantity of heat supplied will decrease (the objective of saving energy), and that end-users in buildings will be better-off as they perceive the price of heating service cheaper than in lower efficient buildings, whereas the heat company will be worse-off if the heat price remains unchanged compared to the BAU case. Raising heat price will be a necessary condition to achieve a win-win situation. In the longer term, the incremental revenue received by heat supply companies (as a result of escalation of final price) will be reinvested in amelioration of supply technology.

However, the subsidised heat price under the current circumstances constitute a major barrier for local government and heat company to adopt advanced energy supply technologies. Transparent and effective energy pricing mechanism must be set up to reflect the actual economic cost and internalise environmental externalities. Apart from government intervention and industry mobilisation in energy efficiency programmes in the building sector, private consumer-side initiatives should also be encouraged through energy pricing mechanism combined with fiscal incentives. Consumers will not be interested in energy efficiency programmes without a clear price signal or other market incentives. In the longer term, a combinatory energy and carbon-tax could be imposed in the heat price (e.g. This pricing structure has been practiced in Northern European countries such as Sweden and Denmark). Heating price will need to reflect the implied CO_2 externalities and reorient house builders and heat suppliers' investment decisions, this will also give incentives for end-users to change gradually their consumption behaviour.

An integrated approach of the public policy which consist of BEE improvement and appropriate pricing mechanism will drive the market towards a low-carbon development trajectory. Most importantly, the incentives need to be conceived as a companion or facilitator of the public policy for improvement in efficiency standards to drive the construction market to move towards high efficiency and low-carbon trajectory as a long term sustainable development strategy (Neuhoff 2009).

6 Conclusion and perspectives

In this paper, we reviewed the major economic instruments and policy portfolios to address the institutional barriers to BEE update in Chinese cities from both theoretical and implementation perspectives. We assessed the possibility of introducing Kyoto carbon financing tool in form of programmatic CDM in buildings. We found that cost of emissions abatement relative to baseline scenario would be around 16 US$/t CO_2 avoided, which is compatible with the global carbon market indices. To achieve the energy efficiency target, the heat price rise for end-user is a necessary condition for the commitment of heat supply company. The price increase will enable the heat company to create benefits without any loss of welfare of end-users who will still pay the same energy bill and benefit from improved thermal comfort condition. Price increase will also be used implicitly as a countermeasure to the potential rebound effect which may undermine the energy efficiency gain, as asserted by energy economists. The benefits could be served to finance the retrofitting of inefficient district boilers and adoption of new environmentally friendly supply technology such as NGCC or CCS in the long run.

Indeed, the CDM's CER price is expected to be competitive and to attract investors in investing in energy efficiency in China in the future. Nevertheless, the market price of carbon alone can hardly trigger the sectoral transition in the property market. The inherent high-rate payback in the property market is likely to undermine the attractiveness of CDM finance for the buildings developers under the current CDM implementation model. Success of implementation of economic instruments necessarily requires a coherent policy framework, and institutional innovation will also be required. For example, it was argued that implementing programmatic CDM in buildings must incorporate local authority and public financial institutions otherwise the barriers of high transaction costs and uncertainty about benefits of BEE investment would hardly be overcome.

Our analysis illustrates the important policy implications of enhancing BEE and modernising energy supply system, requiring that local builders and energy suppliers keep in abreast the up-to-date technology and non-mandatory standards. Indeed, domestic stakeholders initiate and support these actions, not only because of their climate impact, but mainly because of non-climate benefits such as energy savings, security and reduced local pollution levels. As argued in Neuhoff (2009), the carbon finance can be mainstreamed in the BEE promotion in line with the far-reaching domestic environmental policies.

A key criterion of financing BEE in China by CDM is that the international fund should be used as a stimulus to make local government update to higher-efficiency BEE standards through regulatory tool, i.e. local authority commits to enforcing stricter standards in all new buildings in the next step by using CDM as a facilitator for domestic capacity (both technical and institutional) building during the transition period. This transition model can be a sustainable way of CDM financing in energy efficiency in developing countries since it will enable local authorities to build up a strategy to anticipate the future carbon constraints by mainstreaming gradually the most efficient practices in large infrastructure.

The policy-based instrument like programmatic CDM introduced in property market and energy sector to improve BEE performance can help overcome the perverse effect of traditional project-based CDM in which carbon credits seller tends to hold back the implementation of efficiency technology in the baseline to inflate the additionality. In the programmatic BEE-energy supply scheme, the incentives are designed for the local government to commit to continuous building energy performance improvement and transition to high efficiency energy supply technology. More importantly, BEE implementation also requires active co-operation between the government, developers and other stakeholders in the form of public-private or private-private partnership to achieve a global target. As such, the subsidy attributed to high-efficiency buildings developers in initial stage can be used as a provisional incentive and transitional tool that allow the developers to accelerate their learning and innovation capacity of efficiency techniques, subsidy is granted during the preparatory process before the introduction of the next generation of new building efficiency standards.

A holistic approach should be adopted by integrating the quality of energy infrastructure, building design and efficiency optimisation in the public policies design. Our analysis shows that improvement in energy efficiency in buildings is an imperative to realise the long term strategy of decarbonising energy supply. The financial support scheme proposed in this research can help overcome the difficulty embedded in conventional project-based offset mechanism such as CDM. The innovative aspect of this policy programme is that local authority will be able to leverage carbon finance as an instrument to accompany city's development strategy, and financial gain from increased efficiency in buildings will enable the municipality to carry out pricing reform and drive the technological transition in energy supply while meeting the increasing demand for residential comfort and environmental target in the Chinese cities in the coming decades.

Finally, our analysis provides meaningful implications in the area of international climate negotiation. Chinese policymakers could use the international carbon financing tool as a means for promoting energy supply decarbonisation and sectoral transformation in buildings, for example, through fuel-switching policy. The government-led BEE and supply system modernisation action plans, backed by the international support, are expected to scale up carbon finance into buildings sector in China more efficiently. The buildings sector needs to be included in the ongoing international climate negotiations with regard to sector crediting approach, sustainable development policies and measures (SD-PAMs), Sectoral Non-lose Target(SNLT) and programmatic CDM or sectoral CDM schemes. For instance, under a Nationally Appropriately Mitigation Action(NAMA) or SD-PAM scheme, sustainable buildings policies implementation in China may not be climate-oriented but driven by economic growth and environmental pollution reduction. Nevertheless, these actions will have actual and measurable contribution to GHG mitigation and should be recognised and supported by Annex I countries through financial assistance and clean technology transfer. As argued in Neuhoff (2009), the international support mechanism should contribute to robust domestic regulatory and policy frameworks to attract private-sectors (such as housing developers) investment at the scale that is necessary to tackle climate change. The suggested instrument in this paper could be integrated into the forthcoming NAMAs framework in China in the climate negotiations. In this regard, institutional capacity building will be an important component to integrate the buildings into the SD packages and national climate change policies formulation.

In conclusion, establishing the long-term BEE objective with appropriate economic and institutional scheme is of critical importance in energy and climate policy making in China. A dynamic link needs to be created to encourage both upstream and downstream stakeholders within the whole building supply chain to facilitate city's move towards low-carbon buildings pathway.

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