Understanding the Impact of an Emissions Trading System on Building Energy Reductions in China

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I. Executive Summary

Rapid economic development in China has led to a significant increase in the number of buildings and building energy usage. According to ASHRAE, buildings in China account for approximately 25% of total energy use and its share is expected to increase as urbanization persists (Zhou et al, 2014, p. 26). Given the growing emphasis on sustainability, China has committed to the United Nations that it will aim to cut its greenhouse gas (GHG) emissions per unit of gross domestic product by 60-65% from 2005 levels (Xinhua, 2015, p. 1). Many of the policies that China has devised to reach this goal pertain to carbon reductions in the building sector. Numerous researches have been done on individual policies that target building carbon or energy reductions such as new building design standards, building retrofit demonstration projects and incentives, and emissions trading systems (ETSs). Few studies, however, have discussed the impact or effectiveness of these policy categories in relation to each other. As such, this research is intended as a comprehensive, coherent study on the building sector's carbon reduction performance under the influence of related policies and mechanisms, with a specific focus on emissions trading.

Carbon trading has served as an effective mechanism to curb carbon emissions in many countries. As one of the largest carbon emitters in the world, China started experimenting with carbon trading since 2011 by implementing local carbon trading in major cities and provinces as part of the "Two Provinces and Five Cities" plan. The ultimate research question that this paper explores is: Has emissions trading been effective in promoting energy and carbon reductions in the building sector in China? What features of program design or other policies would enhance the building sector's overall energy efficiency? In answering this question, this study will provide an overview of the building stock in China, analyze historical trade data for local ETSs

in China that involve building participants, compare the results with those of ETSs that involve buildings, and discuss other policy mechanisms that can complement emissions trading systems in promoting energy and associated carbon reductions in buildings in China. Findings of this paper preliminarily conclude that emissions trading has the potential to induce initial energy reductions in buildings, and its long-term impact on building energy efficiency can be further enhanced if combined with other policy mechanisms that provide tools and resources for relevant stakeholders to undertake deeper retrofits for their facilities.

II. Literature Review

Overview of China's Building Stock and Energy-Related Policies

Buildings are a significant source of energy consumption in China. Some scholars estimated that total lifecycle building energy consumption accounts for nearly 45% of the country's total annual energy consumption and carbon emissions, with 25% from the construction phase and 20% from the operational phase (Fu et al, 2013, p. 316). One study found that the total floor area in China more than doubled between 2000 and 2008 as a result of urbanization and is projected to triple by 2030 (Amecke et al, 2013, p. 9). Over half of the existing floor area is rural residential buildings, and urban residential and commercial spaces constitute approximately 27% and 17% of the floor area, respectively. Energy expenses are paid by tenants (or owners of residential units) for residential buildings and by property owners or property management companies for commercial buildings.

Despite the low average building energy consumption per capita and energy intensity (Btu/sq-ft) in China compared to those in developed nations, it is projected to grow rapidly for two reasons (Shenzhen City Development Research Center, 2015, p. 5). First, economic growth and urbanization are expected to continue, which would result in an increase in living standards and associated increase in energy consumption per capita. Second, the operation of most of the buildings in China involves periodic shut-down of energy-consuming equipment at certain times of the day and for different building areas (Amecke et al, 2013, p. 11). If the building operation patterns evolve and start resembling those in developed nations—where space is automatically conditioned all the time—overall energy consumption and energy intensity of the building sector will increase considerably. Given the building sector's significant contribution to the overall energy consumption of the nation, policies that regulate buildings' energy usage are an essential factor for controlling and reducing China's overall carbon emissions.

The Ministry of Housing and Urban-Rural Development (MOHURD) of China issued energy codes for new buildings in the 1990s and has been updating them since. There are codes for both public and residential buildings. The public building codes pertain to design standards for public buildings throughout China that are categorized as new construction, construction expansion, or building renovation. The energy consumption in new and refurbished public buildings implemented after the energy code release needs to be reduced by 50% compared to that in 1980s. These design standards address energy-related construction processes or system features and, to some extent, energy management strategies (MOHURD, 2005, p. 9). Use of materials or systems such as the building envelope needs to meet certain thresholds (e.g. heat transfer coefficients), and energy management practices include seasonal temperature set points amongst other adjustments building occupants can control. Similarly, the residential building codes contain three types of design standards, each targeting a different climate zone (MOHURD, 2008 & 2010).

While the policy is largely defined and supervised by the MOHURD at the national level, implementation is carried out by provinces and municipalities and extent of compliance may vary by region. In fact, provinces municipalities can develop more stringent commercial and residential building codes of their own. For example, Beijing and Tianjin have developed and executed standards that are roughly 10-15% more efficient than the national counterparts (Feng et al, 2015, p. 2). Noncompliance by finished projects is subject to penalties including revocation of licenses, imposition of fines, and requirements to rectify the noncompliant components of buildings. While evidence shows that compliance rates have constantly improved and held steady at > 93% over the last 15 years, compliance in smaller cities could be low given a lack of knowledge and expertise of the local enforcement entities (Feng et al, 2015, p. 4).

Other policies exist to promote energy-efficient new buildings in China. According to a GBPN (2012) report, China began to establish its system of building energy efficiency labeling and evaluation in 2006, which the MOHURD began promoting in pilot projects that involve newly built government office buildings and large-sized public buildings since 2009 (Bin et al, 2012, p. 11). Similarly, China established green building labeling programs for both the design and operational stages of buildings, and over 270 buildings were awarded with green building evaluation labels to date.

Unlike new buildings, existing buildings are not subject to energy code compliance. China has undertaken several initiatives, however, to target energy reductions in existing buildings. A study conducted by the Climate Policy Initiative (2013) summarized initiatives in which buildings can participate. Such initiatives include: (1) a voluntary appliance energy efficiency labeling program covering over 40 products including water-saving products (Zhou, 2008, p. 1), which is similar to Energy Star in the United States; (2) incentives promoting energy efficiency or renewable energy measures, including corporate income tax incentives and fiscal incentives for implementation of pilot projects; (3) subsidies for energy-efficient appliances, energy service companies (ESCOs), and district heating retrofit or reform programs; (4) an array of financing mechanisms that promote retrofit projects in the residential and government sectors; and (5) pilot emissions trading programs, which are the focus of this paper (Feng et al, 2015, p. 12).

Emissions Trading Systems in China

Carbon trading has served as an effective mechanism of curbing carbon emissions in many countries. Many of the existing emissions trading systems are cap-and-trade programs where the regulators set a decreasing cap on the total amount of carbon emissions allowed in a particular year (i.e., allowances) and allocates these allowances to regulated entities based on a multitude of factors including historical emissions levels, projected production, and auctioning. As one of the largest carbon emitters in the world, China started experimenting with carbon trading in 2011 in major cities and provinces covering Beijing, Tianjin, Shanghai, Shenzhen, Chongqing, Guangdong Province, and Hubei Province. Unlike ETSs in other countries, these pilot programs target carbon emissions reductions based on energy intensity reduction instead of a total cap. The energy-intensity approach was chosen largely due to considerations of future economic development and associated potential increase in total carbon emissions. Four of the pilots—Beijing, Shanghai, Tianjin, and Shenzhen—involve buildings (Qi et al, 2015, p. 11). The nature and extent of involvement of the building sector, however, varies by program.

Beijing’s ETS covered 543 business entities including public buildings with direct or indirect emissions of at least 10,000 tons of CO_2 annually. Starting 2016, Beijing’s ETS coverage expanded to include mobile emissions sources such as railway transportation and electric buses (China Beijing Environment Exchange, 2016, p. 12). Beijing also allowed trading of Chinese Certified Emission Reduction (CCER) up to 5% of the amount of allowance surrender for a particular year. CCERs are the product of eligible offsets, which in Beijing include forest restoration and energy performance contracting projects in the city as well as hydroelectric and non-industrial gas projects in other regions.

It is worth noting that energy performance contracting (EPC) projects typically involve building energy efficiency retrofits, which implies that the building sector can participate as regulated entities or offset sources in Beijing's ETS. In addition, public buildings are not the only regulated buildings in Beijing's ETS. Regulated entities include property management companies and real estate companies, which trade allowances at the entity level but likely curb carbon emissions at the building level (National Energy Administration, 2014, p. 1).

Shanghai's ETS covered approximately 190 industrial facilities emitting 20,000 tons of CO_2 and service sector entities emitting 10,000 tons CO_2 annually including shopping malls and hotels, and commercial buildings. The Shanghai ETS covers the following entities involving buildings (Shanghai Municipal Development & Reform Commission, 2016, p. 1):

Entity Name	**Type of Facility**
Shanghai Pudong District Shangri-La Hotel Ltd.	Hotel
Shanghai Jinjiang Oriental Hotel Ltd.	Hotel
Jing'an Hilton Hotel (Shanghai)	Hotel
Shanghai Tomorrow Square Co., Ltd.	Shopping Mall
Shanghai Everbright Convention & Exhibition Center Co., Ltd.	Exhibition Center
Shanghai SIIC South Pacific Hotels Ltd. Shanghai Four Seasons Hotel	Hotel
First Shanghai Yaohan Co., Ltd. (Yaohan)	Shopping Mall
Shanghai New World Co., Ltd. (New World City)	Shopping Mall
Shanghai Pacific Department Store Co., Ltd. (Xujiahui)	Shopping Mall
Shanhgai Jiu Guang Department Store Co., Ltd. (Jiubai City Square)	Shopping Mall
Shanghai Long Dream Shopping Mall Management Co., Ltd. (Zhongshan Park)	Shopping Mall
Grand Gateway Real Estate Development Co., Ltd. (Grand Gateway Plaza)	Realty
Shanghai Real Estate Development Co., Ltd. (Constant State Plaza)	Realty

Shanghai's ETS is unique in several aspects. While other pilot ETSs employ a two-year compliance period, Shanghai's ETS employs a three-year compliance period. In addition, Shanghai's compliance rate is 100% in both 2014 and 2015, a record unmatched by the other three pilot programs involving buildings (Shanghai Environment and Energy Exchange, 2016, p. 4). Lastly, while Shanghai restricted CCER use to 5% of an entity's compliance obligation just like Beijing, it embraces CCERs generated in other regions. According to the report by Shanghai Environment and Energy Exchange (SEEE), Shanghai's CCER trade volume in 2015 constitutes 74% of the total CCER trade volume in the nation (SEEE, 2016, p. 6). Since more granular trade data is not available, it is hard to discern the building sector's reliance on CCERs versus allowances for compliance. The 100% compliance rate in two consecutive years, however, implies that the building sector is capable of emissions reductions in a medium-length compliance period.

Shenzhen's ETS covered 635 businesses and 197 buildings, which include government-owned, commercial, multi-use, shopping malls, and restaurant buildings. The ETS covers 40% of the city's total carbon emissions in the manufacturing, electricity generation, and building sectors (Shen et al, 2014, p. 564). The city government targeted the building sector for it consumes 23% of the total energy used by the city and 43% of the city's total electricity supply (Shenzhen City Development Research Center, 2015, p. 5). Unlike other regions in China, the energy intensity of buildings in Shenzhen is three times as high as the average building energy intensity in developed countries. The Shenzhen ETS sets a precedent in that it is the first ETS in the world to experiment with allowance allocation by benchmarking before the compliance period (Jiang et al, 2014, p. 19). The covered public buildings, however, are exempt from such allowance allocation method and receive 100% of their allowances for free during the current compliance period. According to 2014 statistics, 99.4% of the 635 regulated entities have met their energy intensity reduction goals (Shenzhen City Development Research Center, 2015, p. 27). Note, however, that building participants were incorporated in the ETS for experimentation only to date and their compliance status is not reflected in the overall compliance rate (Shenzhen Institute of Building Research, 2014, p. 43).

Tianjin pursued a different route for reducing carbon emissions of the building sector. Instead of directly requiring buildings to surrender allowances, it created a sub-platform within the ETS for energy efficiency trading. According to its registration and record management methods (2010), property management companies, energy service companies, heat suppliers, private building owners are eligible to participate in trading. If a registered private property exceeds Tianjin's energy efficiency standards, the amount of energy avoided or saved can be converted to equivalent carbon emissions reductions and then traded in the typical ETS (Tianjin Municipal Government, 2010, p. 1). Both new and existing buildings can participate in trading as long as they can demonstrate below-the-standard energy intensity. For existing buildings, carbon emissions are typically reduced as a result of retrofit projects.

The energy efficiency trading platform in Tianjin is not only a beneficiary of retrofit projects but also helps facilitate retrofit projects such as energy performance contracts. For example, Tianjin Climate Exchange (TCE) entered into an energy performance contract in December 2009 with PetroChina, a Chinese oil and gas company, and an energy service company (Wang, 2012, p. 6). This contract specifies that the quantity of carbon reductions associated with the guaranteed energy savings from the energy performance contract will be traded on TCE. Therefore, Tianjin has explored innovative ways of incorporating the building sector into the carbon trading system.

The compliance rate has been relatively high across all four ETS pilots and increased between 2013 and 2014 (Shanghai Environment and Energy Exchange, 2016, p. 4):

Program Location	**Compliance Rate for 2013**	**Compliance Rate for 2014**
Beijing	97.1%	100%
Shanghai	100%	100%
Shenzhen	99.4%	99.7%
Tianjin	96.5%	99.1%

All four ETS pilots allow the use of CCERs toward compliance. CCERs can fulfill up to 5-10% of an entity's compliance obligation; wind energy, hydroelectric energy, and methane gas use in rural areas constitute the majority of the CCER projects to date (Partnership for Market Readiness, 2016, p. 7). Building energy efficiency upgrades contributed little to the audited CCER project types, and Beijing's ETS is the only pilot that accepts energy efficiency credits in addition to allowance and CCERs. As discussed, Tianjin's case is unique as energy reduction credits from the building sector are traded as allowance equivalent rather than a separate trading commodity.

Since facility-specific trade data is not available for any of the four programs, it is difficult to track the compliance rate of the building sector in these pilots or the breakdown among allowances surrendered, voluntary carbon reductions through retrofits, and CCERs purchased by regulated facilities. Since quantitative data is insufficient for analysis, a comparative analysis will be conducted to draw insights from other existing emissions trading systems that involve the building sector.

III. Research Method

This study will compare and contrast major ETSs in the world that regulate buildings. Specifically, it will analyze key program features, historical trade data, carbon reduction goals, and compliance rates across the emissions trading systems. To better understand whether emissions trading has driven building energy reductions, carbon prices will be evaluated against building retrofit costs among other factors that may influence the decision between self-reduction and allowance purchase toward compliance. In addition, this paper will review other building policies implemented in these regions to better understand their impact on building energy efficiency compared to that of emissions trading.

Data collection focused on public, commercial, and residential buildings in the urban setting. While more than half of the floor area in China is located in the rural area, rural buildings' energy consumption is often not clearly tracked or documented. Furthermore, persistent urbanization might indirectly stall the increase of energy consumption of rural buildings. Lastly, energy efficiency improvements are also more likely to occur in urban settings than in rural settings. Therefore, a focus on buildings in the urban area can provide valuable insight into the overall trend of building sector's energy use in China.

IV. Data Analysis

Two other regions in the world directly regulate the building sector's GHG emissions through emissions trading: Tokyo and Saitama, Japan (Kossoy, 2014, p. 52). On the other hand, some other ETSs regulate the building sector indirectly. That is, they regulate entities that supply fuel to buildings (e.g., the power sector). California's ETS is such an example and, unlike others, it explicitly targets the commercial and residential sectors through indirect regulation starting 2015. Since the Tokyo and Saitama program designs are similar, only Tokyo's ETS will be discussed along with California's ETS. Both programs will be analyzed to determine the effectiveness of distinct program designs in curbing building energy use and derive factors that should be considered to enhance engagement of the building sector in ETSs in China.

Tokyo ETS

According to a report by the Bureau of Environment of Tokyo Metropolitan Government (TMG), the residential and commercial building sectors' contribution to Tokyo's carbon emissions has steadily increased from 52.8% in 1990 to 64% in 2007 (Nishida, Unknown, p. 5). Given the significance of the building sector to both the economy and energy usage, TMG issued two policy initiatives that target the building sector. The Green Building Program was introduced in 2002 and requires newly built or expanded buildings whose total floor area exceeds 5,000 square meters (approximately 54,000 square feet) to submit their building environment plans (Tokyo Metropolitan Government Bureau of Environment, 2014, p. 1). The program was amended in 2010 to encourage the installation of renewable energy technologies. A study by TMG revealed that the Green Building Program covers about 40% of new buildings in Tokyo. Two related resources are the Green Labeling Program for Condominiums issued in 2005 and the Energy Performance Certificate Program launched in 2009, both of which provide tools for evaluating the different aspects of building energy usage for different building types (Nishida, Unknown, p. 8).

The other initiative, the mandatory reporting and cap and trade program for existing buildings, was launched in 2010. Tokyo's ETS is the world's first urban cap and trade program that covers and targets buildings (MOHURD, 2013, p. 7). Facilities with annual energy consumption of crude oil equivalent of 1,500 kiloliters or more are regulated under the program (Environmental Defense Fund, 2015, p. 1). The program covers approximately 40% of the commercial & industrial sectors' emissions, or approximately 1,350 facilities including offices, commercial facilities, lodging, educational facilities, medical facilities, and distribution centers. The total reduction goal for the program is 25% CO_2 reductions below the 2000 levels by 2020, and the base-year emissions were calculated using the average emissions of freely selected three consecutive fiscal years in FY2002-FY2007 (Tokyo Metropolitan Government Bureau of Environment, 2012, p. 19). Specifically, there are two five-year compliance periods, and the CO_2 reduction goal for the first compliance period (2010-2014) was 8% for business facilities and 6% for industrial facilities. During the second compliance period (2015-2019), the reduction obligations increase to 17% for business facilities and 15% for industrial facilities.

The program seems relatively successful based on the performance data from the past five years. Below is a summary of the compliance data published by TMG (Tokyo Metropolitan Government Bureau of Environment, 2012-2016):

	1st Year (FY2010)	**2nd Year (FY2011)**	**3rd Year (FY2012)**	**4th Year (FY2013)**	**5th Year (FY2014)**
Base Year Emissions (t-CO_2)	13,627,000				
Actual Emissions (t-CO_2)	11,824,000	10,595,000	10,636,000	10,530,000	10,267,000

Reduction from Base Year (%)	13%	22%	22%	23%	25%
Covered Facilities	1,348	1,392	1,325	1,232	Not Reported
GHG Reports Filed	1,159	934	1,302	1,221	Not Reported
Reporting Rate* (%)	86.0%	67.1%	98.3%	99.1%	N/A
Reported Compliance Rate (%)	64%	93%	92%	90%	Not Reported

**Reporting facilities are inclusive of compliance facilities.*

There are a few highlights of the report. First, the number of covered facilities fluctuated from year to year. This is reasonable given that the number of facilities that meet the compliance criteria can change, but this approach may result in inconsistent baselines to track reductions. In addition, emissions from buildings that were previously regulated but were no longer required to report GHG emissions in subsequent years could not be tracked, and it is unclear whether they contribute to the 25% reduction goal of the ETS. Second, the reporting rate is calculated as the percentage of covered facilities that submitted GHG emissions reports on time and whose emissions have been verified *before TMG publishes its annual reports*. If additional reports were submitted after the TMG official report release, the overall reporting rate would be higher than provided in the table.

The third key observation is that the CO_2 reductions were not entirely attributed to covered facilities' active pursuits of energy efficiency improvements. While the 13% reduction in the 1st year of the program is said to be the result of active energy-saving upgrades undertaken by covered facilities, the additional 9% reduction in the 2nd year was largely triggered by the power crisis and the Great East Japan Earthquake (Tokyo Metropolitan Government Bureau of Environment, 2013, p. 1). In fact, the total emissions reduction between FY2011 and FY2012 was negative; so was the average reduction per reporting facility between FY2012 and FY2013. The annual CO_2 emissions level also consistently stayed at approximately 10 million tons of CO_2

between FY 2011 and FY2014, which implies that the covered facilities might have reached a bottleneck in further emissions reduction. Below is list of reduction measures summarized by TMG undertaken during the first compliance period (Tokyo Metropolitan Government Bureau of Environment, 2012-2016):

1st Compliance Period	**Key Energy-saving Measures**	**External Factors that Influenced GHG Emissions**
1st Year (FY2010)	HVAC, lighting, management of heat source, management of hot water supply systems, occupant engagement for demand reduction.	N/A
2nd Year (FY2011)	Temperature set point adjustments and LED installations.	Power Crisis Great East Japan Earthquake
3rd Year (FY2012)	LEDs, high-efficiency HVAC equipment, high-efficiency heat source equipment, high-efficiency pumps and fans *Note: Reduction measures implemented after the earthquake and power crisis in FY2011 were relaxed as they were seen as overburdening to occupants.*	N/A
4th Year (FY2013)	Continuation of post-crisis reduction measures, introduction of energy service company services and operation management.	N/A
5th Year (FY2014)	Continuation of post-crisis reduction measures, cooperation with tenants in reducing energy demands, enhanced awareness, and assignment of eco-managers.	N/A

Carbon prices may provide hints on whether the ETS can drive emissions reductions in the long run. Facilities are allocated emission allowances according to their base year emissions. To comply with the program, they need to either reduce emissions beyond allowance coverage or purchase offset credits for these “disallowed” emissions. There are five types of offset credits: excess emission reduction credits, small and midsize facility credits, renewable energy credits (RECs), outside Tokyo credits, and Saitama credits (IETA, 2015, p. 4). If allowances are not fully exhausted for a facility, the unused portion can be traded as excess credits and used by the end of the second compliance period. Participants can choose any combination of the credits and self-reduction for compliance. As of May 2015, approximately 570,000 tons of CO_2 credits have been supplied or contracted for supply to the market, and the majority of participants purchased excess credits and RECs for compliance. While trading prices are not publicly available, a survey conducted by TMG found that RECs traded at \$45-\$54/tCO_2 in October 2014 and excess credits traded at \$36-\$45/tCO_2 (IETA, 2015, p. 8). The prices for both have been steadily declining since December 2011, when they were initially traded at \$130-\$160/tCO_2.

Despite a high carbon price compared to other ETSs in the world, trading constitutes a small percentage of the total allowance surrendered. Considering 3.36 million tons of CO_2 reduction achieved to date, 570,000 tons of CO_2 credit supply translates to 17% of the reduction. This indicates that regulated facilities primarily chose self-reduction to meet reduction goals. If self-reduction reflects that energy retrofits are more cost effective than offset credit purchase, why aren’t participants incentivized to generate and sell excess credits as part of their retrofits for sale in the ETS? There are three possible explanations. First, based on the summary chart above, reduction measures mainly fall into three categories – lighting upgrades, equipment replacement, and occupant engagement to reduce demand or equipment operating hours. These upgrades can achieve sizable savings without necessarily requiring third-party services and thus incurring significant costs, which can explain that carbon prices were not needed to motivate the retrofits. Another force is the potential difficulty of registering and processing an offset credit in the ETS. Facilities are required to apply for certification to TMG before credits can be issued for sale in the ETS (IETA, 2015, p. 4). While the length and specific requirements of the application process are unknown, it typically involves two major steps—offset certification and documentation of credits under the Registry (TMG, 2014, p. 31). Lastly, unlimited banking across compliance periods may have encouraged retention of unused credits. Participants would behave more conservatively and thus retain excess credits generated from retrofits if it is allowed and future carbon prices remain unknown or are expected to rise.

Tokyo's program has achieved the 2020 reduction goal essentially five years ahead. Its seeming success to date can be partly attributed to good program design, which entails the following elements (Tokyo Metropolitan Government Bureau of Environment, 2012, p. 10-16):

- Strict penalties for non-compliance: a penalty of up to 500,000 Yen and 1.3 times the amount of the shortage has to be reduced;
- Clear definitions of key terms (i.e. what is considered a single facility and thus covered by the program);
- Detailed program rules that address how changes in building conditions, ownership, and other aspects are handled;
- Flexibility built into the five-year compliance period that offers facilities sufficient time to respond to unexpected changes in building use that might increase emissions; and
- Flexibility built into the numerous means of compliance: self-reduction and five types of offset credits.

Nonetheless, given limited trading activities and steady emissions of covered facilities during FY2011-FY2014, the extent of success of Tokyo's ETS warrants further scrutiny. Early achievement of reduction goals could imply that the absolute cap was set too high (Rudolph, 2012, p. 357). However, the program does seem capable of encouraging building retrofits and energy reductions. Trading might also become more active with further reduction requirements. Under a tightened cap for the second compliance period, further emissions reductions could be more challenging and require deep retrofits. Deeper retrofits, in turn, may be more costly than "low-hanging fruit" upgrades, and may rely more heavily on carbon prices to help offset the implementation costs. In addition, deeper retrofits may require more expertise than what building managers typically possess, which reinforce their costliness and potential reliance on carbon prices to partially offset the upfront cost. Overall, while it is premature to conclude that Tokyo's ETS has been an evident success, it has stimulated some degree of self-reduction by building participants. To further the ETS's impact on building energy efficiency, a strong carbon price signal, a more active trading floor, and building participants' improved access to necessary resources to participate with confidence would be needed.

California ETS

California's ETS was established in 2012 as a key component of complying with the Assembly Bill 32 (AB 32), a state law that requires the reduction of statewide GHG remissions to 1990 levels by 2020 (Shen et al, 2014, p. 551). The trading scheme is expected to contribute to 22.5% of the expected total GHG emissions reduction under the Bill and the following complementary measures are expected to result in the remaining 77.5% of the total reduction: 1) a renewable portfolio standard targeting 50% power generation from renewables by 2030, 2) strengthening energy efficiency for buildings and appliances, 3) a Clean Vehicle Plan, 4) a Low Carbon Emission Fuel Standard, 5) refrigerant leakage reduction, and 6) forestry protection (Shen et al, 2014, p. 554).

California's ETS covers about 350 businesses involving 600 facilities that account for approximately 85% of the state's GHG emissions in 2011. The design of the trading scheme is summarized in the following graphics (Shen et al, 2014, p. 555):

Compliance Period	**Reduction Goal (% below 2012 emissions level)**	**Covered Entities**
2013-2014	4% (2% annually)	In-state electricity generation, power imports, and large stationary sources that emit >25,000 metric tons of CO_2/yr
2015-2017	9% (3% annually)	All entities covered in the 1st period plus suppliers of fuels and other fuel combustion
2018-2020	9% (3% annually)	Same as the 2nd period

Based on published compliance reports, emissions data is available for 258 entities in 2013 and 263 entities in 2014. Only five university entities can be inferred to have buildings as some of their main assets. The compliance data for these five universities is summarized as below (California Air Resources Board, 2014-2015):

Entity Name	**2013-2014 Surrender Obligation**	**Total Allowances Surrendered**	**Total Offsets Surrendered**	**Obligation Status**
Regents of the University of California	1,227,755	1,129,535	98,220 (8% of total obligation)	Fulfilled
Loma Linda University	124,281	124,281	0	Fulfilled
California Institute of Technology	113,984	113,984	0	Fulfilled
California State University	341,975	341,975	0	Fulfilled
The Board of Trustees of the Leland Stanford Junior University	435,281	424,146	11,135 (3% of total obligation)	Fulfilled

A few conclusions can be drawn from the data. First, direct regulation of buildings constitutes a small portion of the covered entities. In fact, they only account for 0.77% or less of the total allowances to be surrendered in 2013 and 2014. In addition, compliance is evaluated at the entity instead of the facility level, which reduces the visibility into which entities include or deliver fuel to buildings and whether such buildings contributed to compliance through energy reductions.

Unlike Tokyo's ETS, California's trading scheme is not necessarily designed to enforce emissions tracking at the facility level. In addition, many entities that supply energy to buildings may also supply energy to other types of constructs (e.g. industrial plants). Both factors make it difficult to quantify the building sector's impact on overall compliance. Currently, the building sector's indirect impact in the ETS could be limited as industrial facilities constitute a majority of the covered facilities. This is not surprising considering the composition of California's GHG emissions. Out of the 459 million tons (Mt) of CO_2 emissions in California in 2013, only 43.5 Mt came from the commercial and residential sector, or a 9.5% contribution (ICAP, 2016, p. 1). It is important to note, however, that the residential and commercial sectors are covered by the ETS starting 2015 (or the second compliance period), the compliance data for which is not available at the time this research is conducted (Bugnion, 2015, p. 6). Similar to the first compliance period, buildings do not directly participate in the ETS. Instead, facilities with more than 25,000 tons of annual CO_2 emission that supply natural gas or other types of fuel to buildings (among other end users) are directly regulated (ICAP, 2016, p. 2). At that time, more buildings' footprint may be incorporated into the ETS and regulated at the source level, and it is possible to better understand the extent of energy reductions in buildings through the ETS depending on the types of data available in the near future.

Comparative Analysis

Below is a summary of major ETSs analyzed in this study that cover the building sector:

	Beijing ETS	**Shanghai ETS**	**Shenzhen ETS**	**Tianjin ETS**	**Tokyo ETS**	**California ETS**
Compliance Period	2 years	3 years	2 years	2 years	5 years	2 to 3 years
Avg. Compliance Rate*	98.55%	100%	99.55%	97.8%	87.63%**	99.9%
Avg. # of Covered Entities/Facilities	479	191	633	113	1,324	261
Regulation Level	Entity	Entity	Entity & Facility	Entity	Facility	Entity
Banking Allowed	Yes (expires on June 30, 2016)	Yes	Yes	Yes (expires on May 31, 2016)	Yes	Yes
Borrowing Allowed	No	No	No	No	No	Yes (intra-period only)
Unique Program Features	Energy Performance Contracts allowed as offset sources	Building sector participants are primarily hotel chains, shopping malls, and realty	Building sector participants are public buildings only	Building efficiency trading as indirect emissions trading	Vast majority of participants are buildings in the commercial and residential sector	Building sector participants seem to involve universities only

**All compliance rates refer to the overall compliance rates of covered entities/facilities, not the compliance rate of the building sector.*
***The compliance rate for the Tokyo ETS is estimated and the average calculated reporting rate is used instead.*

Statistical analyses may not yield an accurate understanding of how an ETS impacts the building sector. The first reason is that the sample size is too small to derive a statistically significant result. Second, the sources of compliance rates—one of the only two quantitative variables relevant and available to this study—are inconsistent across the trading systems. Tokyo’s compliance rate is estimated only and the reporting rate is used, which does not include facilities that reported their compliance performance after the deadlines and does not equate the compliance rate. In addition, the California data is available only through 2014, which implies that it does not track the commercial and residential sectors’ compliance (since they joined the ETS starting 2015) and there could be a sizable change to the data composition and the extent of the building sector's participation due to program changes. The third reason is that very limited building-specific trade data is available. All compliance rates are calculated based on the total number of regulated facilities or entities—California's ETS is the only trading scheme that publishes compliance data for individual facilities or entities. Therefore, statistical inferences cannot be drawn from the limited dataset.

Simple calculations, however, can still be done to demonstrate whether the building sector has been able to meet reduction targets through emissions trading. While compliance data for individual entities or facilities is not available, a worst-case compliance rate for the building sector can be calculated assuming a maximum number of non-compliant entities from the building sector (i.e. either the total number of non-compliant entities or the total number of building participants, whichever is smaller). Out of the six ETS analyzed in this paper, the estimated number of building participants is known for California, Shenzhen, Shanghai, and Tokyo. The maximum non-compliance rates calculate as follows:

- For California, a 0.1% non-compliance rate translates to less than 0.261 non-compliant facilities, which in turn calculates to a maximum 5.2% non-compliance rate for entities known to involve buildings.
- The compliance rate for buildings covered in Shenzhen's ETS is not available since building participants' compliance status is not incorporated into the overall compliance rate calculation.
- An average 100% compliance rate for Shanghai's ETS implies that all potential entities with buildings have met their reduction targets.
- The overall compliance rate for Tokyo's ETS mirrors that for buildings only as the vast majority of the covered facilities are buildings.

While it is reasonable to conclude that building participants were largely capable of meeting their reduction targets, the extent of self-reduction cannot be inferred from these rates because building participants might have purchased allowances or offsets to meet their reduction goals. Conversely, participants are not required to disclose the means of compliance, which could imply that self-reduction is not tracked or reported. Without additional quantitative data, it is challenging to prove that emissions trading is capable of driving building energy efficiency. Since most of the pilot ETSs in China directly regulate facilities just like Tokyo's ETS, however, we can gauge interest in self-reduction versus allowance purchase by analyzing carbon prices.

Below is a summary of allowance and CCER prices for the four pilots:

Pilot	**2015 Avg. Allowance Price**	**2015 Allowance Trading Volume (tCO_2)**	**2015 Avg. CCER Price**	**2015 CCER Trading Volume (tCO_2)**
Beijing	￥46.69/tCO_2	3.16MM	￥21.53/tCO_2	5.12MM
Shanghai*	￥10-30/tCO_2	2.94MM	￥10-18/tCO_2	25.4MM
Shenzhen	￥69.11/tCO_2	4.80MM (estimate)	N/A	1.62MM (estimate)
Tianjin	￥12.3-25.2/tCO_2	1.05MM (estimate)	N/A	1.15MM (estimate)

Sources: (1) China Beijing Environment Exchange, '16; (2) SEEE, '16; & (3) Tianjin Climate Exchange, '16.
**Average carbon prices are not available for Shanghai's and Tianjin's ETSs. Price ranges are used instead.*

Building retrofit costs vary by technology, region, and type of contract. For EPC projects, the average building retrofit cost to date is 1218 RMB per ton of equivalent CO_2 reduction, or a magnitude of ten greater than carbon prices in emissions trading (China Construction Bank, 2013, p. 4). Since purchasing an allowance is much more cost effective than self-reduction through retrofits, building participants would lean toward the former, which in turn implies that emissions trading might have had a limited impact on driving building energy reductions. This conclusion, however, is based on the assumption that price is the only influence on building retrofits and that carbon prices are critical in offsetting building upgrade costs. Neither is necessarily true and, as will be discussed in the next section, other political and fiscal stimulants exist to incentivize emission reductions in the building sector.

While the extent of emissions trading’s impact on building energy reductions cannot be determined, specific program features can be improved to enhance the impact of emissions trading on building energy consumption. Several types of building participation in ETS have surfaced during the analysis—indirect regulation of buildings at the source level, direct regulation of facilities, voluntary participation in ETS through offset projects, and other types of voluntary participation. The next section of the study will further evaluate ETS design or related policies that can enhance the impact of each of the four means of driving building energy efficiency through ETS.

V. Results & Discussions

ETS Program Design for Indirect Regulation of Buildings

The pilot ETSs in China have only experimented with direct regulation of buildings. Since the compliance rate has been high, they will likely continue with direct regulation of buildings instead of switching to pure indirect regulation. A more pertinent question is how to avoid double counting of emissions as a regional or national ETS incorporates a more diverse range of entities in the near future. The four pilot programs currently use different and sometimes mixed points of regulation. For example, while the Beijing, Shanghai, and Shenzhen programs primarily regulate facilities and businesses, the Tianjin program covers electricity and heat production besides facilities (Shen et al, 2014, p. 564). Regulating both emitters and end users can result in double counting of emissions, excessive allowance supply, and increased cost of regulation (Shen et al, 2014, p. 569). Nonetheless, the risk of double counting can be controlled when allowances are determined from energy intensity-based reduction. While it is true that the energy consumed by buildings is the same energy delivered by a utility, energy intensity reduction in buildings does not necessarily target the same energy as emissions reduction in utilities. Specifically, energy intensity reduction in buildings refers to less energy use and emissions per square foot. Yet energy intensity reduction in utilities does not necessarily mean reducing energy output per power plant. Instead, it can mean using less energy to generate the same amount of energy output and reducing energy consumed for energy generation. In other words, energy intensity reduction can drive end use energy savings in one sector and input energy savings in the other, which do not overlap. Therefore, as long as ETS rules clearly specify that emissions under regulation are only based on energy usage that supports an entity’s functions (e.g. serving tenants, producing energy, etc.), double counting can be avoided in an ETS with diverse sector coverage including indirect regulation of buildings.

ETS Program Design for Direct Regulation of Buildings

Several studies of the pilot ETSs—Shenzhen's ETS in particular—provided suggestions on improving ETS program design for direct regulation of buildings. For example, the Shenzhen Institute of Building Research conducted an in-depth study of the infrastructure Shenzhen built to facilitate the building sector's participation in emissions trading, which highlighted both strengths and weaknesses. Currently, total allowance in Shenzhen's ETS is calculated by multiplying the energy use limits standards by building types with total surface areas and an emissions coefficient (Shenzhen Institute of Building Research, 2014, p. 10). The municipal government published the Shenzhen Building Energy Consumption Limits Standards for public buildings, hospitality industry, and shopping centers, which provide the basis for calculating energy use limits standards, or the first component of the formula. Similarly, official documents govern the determination of surface areas from which allowance is calculated. Clear documentation by the government of assumptions and sources of inputs in the calculation of allowance surrender can help improve administrative efficiency and thus lower the cost of operating an ETS.

Certain weaknesses exist in the calculation of the allocation and actual carbon emissions of a building. Specifically, Shenzhen's ETS currently employs a calculation methodology where all fuel consumption is converted to equivalent electricity consumption first, and the total equivalent electricity use is then multiplied with the emissions coefficient corresponding to electricity (Shenzhen Institute of Building Research, 2014, p. 15). This, however, yields a different emissions amount than if different fuel consumptions are multiplied by their corresponding emissions coefficients and then summed. These two calculation methods would yield different amounts of allowance, which can create potential controversies regarding whether a facility's current emissions would be entirely covered by allowance under one of the methods and thus do not have to be reduced for compliance.

Outdated emissions coefficients could be another issue. Munnings' (2014) stated that using a dated default emissions rates over multiple compliance periods can result in over-allocation, which in turn reduces the allowance market price and can discourage further energy retrofit initiatives in the building sector.

In addition, the municipal government has chosen a percentage of the covered public buildings that would likely fail to meet the building energy efficiency standards during the first phase of emissions trading (Shenzhen Institute of Building Research, 2014, p. 16). This percentage plays an important role in balancing the supply and demand of allowances from the building sector. The higher the percentage, the stricter the implied standards and the higher the likelihood of buildings not meeting the standards. A typical result of a stricter standard is an increase in demand for allowance in the market and a corresponding increase in allowance prices. The current percentage places 157 of the 197 covered facilities at or exceeding the standards, and the remaining 40 performing worse than the standards, resulting in about 328,100 tons of allowance supply and 225,000 tons of allowance demand within the building sector (Shenzhen Institute of Building Research, 2014, p. 16). How Shenzhen plans to adjust this percentage in the near future is subject to a range of factors including the economy, existing status of building energy consumption, and cost of implementing energy-efficient technologies. It is worth noting, however, that the contribution of the building sector to the overall market balance can be limited depending on the building sector's contribution to the total amount of emissions reductions required by emissions trading.

A third weakness highlighted in the report—which is particular to the building sector—relates to eligible trading entities on behalf of buildings. Some buildings have clear ownership accountability: some are owned by multiple parties, and still others are run but not owned by property management firms. Among the 197 public buildings regulated under the Shenzhen ETS, 27% have single owners, 46% have multiple owners, and the remaining 27% have not registered with the City and have no owner identifications (Shenzhen Institute of Building Research, 2014, p. 20). Because of these three situations, three types of stakeholders are allowed to trade allowances on behalf of buildings: building owners, property management companies, and property users, respectively. Clear identification of trading entities proved to be difficult during program implementation, especially for buildings with multiple or no identified owners. As a result, trading for building participants warrants further considerations as Shenzhen's ETS plans to expand its coverage of the building sector to include additional public buildings and residential and commercial properties in subsequent compliance periods.

Commercial buildings in China are similar to public buildings in that their energy usage is typically metered at the building level. Allowance surrender for commercial buildings requires clear allocation of compliance responsibilities amongst owners and effective engagement of occupants to incentivize energy reductions at the tenant level. Residential buildings, on the other hand, present another layer of complexity. Operation of residential buildings in China varies drastically by region. For example, in Southern China, individual units of a residential building are owned and metered at the unit level. (Source) Each tenant-owned unit also has its own HVAC system. In northern China, however, heating—which is in greater demand than cooling—is commonly provided from a district heating system (Xu et al, 2014, p. 909). Furthermore, a lot of the older residential buildings are not metered for their heat consumption (Liu et al, 2014, p.

899). This presents two challenges. First, infrastructure may be lacking for tenants to track changes in their energy consumption levels and corresponding emissions changes for the purpose of compliance. Inability to track usage in turn may dampen tenant owners' motivation or eligibility to participate in emissions trading as tenant owners would have little visibility into the impact of their energy reduction initiatives.

Furthermore, it would be difficult to obligate residential buildings to comply with emissions reductions for several reasons. Unmetered residential buildings in China create a problem of fairness. Metered buildings may get "punished" for having the ability to track their energy usage and having to surrender allowances. Second, setting a threshold that defines regulated residential buildings' energy usage could be problematic. Regulating buildings that exceed certain energy consumption per unit of floor space might not account for the differences in family sizes; on the other hand, setting energy consumption threshold per tenant imposes the question of whether individuals are required to comply with certain energy consumption limits. Lastly, given the size of the population and the number of residential buildings in China, conducting due diligence on all residential units may not be realistic.

Regardless of the building type, providing sufficient resources to aid building owners in participating in allowance trading is a critical step toward successful incorporation of the building sector into ETSs. Besides generic guidance documents on official websites, it is important for the government to publicize rulings, baseline calculation and compliance review procedures, and trading eligibility documents targeting the building sector. Stable trends of allowance prices can also boost covered entities' wiliness to participate in the ETS.

Undoubtedly, all aspects of program design need to be standardized to establish a national ETS. Many existing features such as the three-year or longer compliance periods, clear rulings, and severe penalties for non-compliance may be emulated given the relative success of the pilot programs in meeting emissions reduction goals. To better target buildings as a sector, however, aspects including coverage of building type, methodology for calculating projected emissions and thus allowance allocation, trading entities on behalf of buildings, resources for individual building owners participating in an ETS, and infrastructural changes to accommodate a fair selection of regulated buildings need to be contemplated further.

Voluntary Participation in ETS through Offset Projects

Direct inclusion of building emissions in cap-and-trade programs is one option to drive building efficiency. Offset projects are another means of the building sector's participation in ETS. Offset credits can come from three sources: Certified Emission Reductions (CERs), Voluntary Emission Reductions (VERs), and Chinese Certified Emission Reductions (CCERs). CERs are a product of Clean Development Mechanism (CDM) projects, implemented under the Kyoto Protocol in developing nations with funding from developed nations to generate offset credits in return (Bugnion, 2015, p. 11). VERs are used in voluntary offset markets. Offset project types are common across the mechanisms and typically include renewable energy, energy efficiency, greenhouse gas (e.g. HFC and N_2O) capture, waste reduction and management, and afforestation and reforestation. When the pilot ETS went into effect in 2012, credits from all eligible offset projects were normalized to CCERs. A total of 88 CCER projects were completed as of November 2014. Very few of them, however, occurred in the building sector (Zhou et al, 2014, p. 4).

This mirrors the small contribution of building-related CDM projects to the global CDM project portfolio. A study found that the reliability of energy consumption data is a major roadblock to the adaptation of CCER projects for building efficiency improvements (Zhou et al, 2014, p. 16). For example, similarly sized office buildings in Beijing exhibit an extensively wide range of electricity consumption per square foot where the largest energy intensity is close to ten times the smallest. Such a gap increases the difficulty of benchmarking and setting standard emissions levels for a building type, which is necessary for calculating offset credits from CCER projects. Another potential challenge lies in the discrepancy of building efficiencies between the design and implementation phases of new construction or major renovation of buildings. A study by the MOHURD in 2005 of 3,000 ongoing construction projects found that while 80-90% of energy-efficient building design met the standards in northern China, only 50% executed these standards during implementation, 15% of which were put in active use (Zhou et al, 2014, p. 16). This phenomenon can be avoided if CCERs are issued after verification, but the inconsistency between design and implementation can hamper CCERs' impact in emissions trading. These two factors illustrate potential deficiencies in infrastructure and execution that may affect the feasibility of both offset projects and direct regulation of the building sector in emissions trading.

Lack of incentives to participate in ETSs is another cause for the relative ineffectiveness of offset projects in the building sector. For existing buildings, building retrofits is the primary way of attaining emission reductions. The cost of building retrofits, however, is relatively high per equivalent unit of CO_2 reduction compared to other sources of emission reductions (Chen et al, 2015, p. 132). "Low-hanging fruits" such as lighting retrofits and limited HVAC upgrades can achieve sizable savings at relatively low costs. Further upgrades required to achieve deeper emission cuts may cover a wide range of technologies and building systems such as the building envelope, the broader HVAC system (e.g., chillers, boilers, air handling units, etc.), and controls upgrades, which can result in limited incremental savings at higher incremental costs and thus worsened project payback and attractiveness. If the total cost of reducing a ton of CO_2 equivalent through building retrofits and registering it through CCER exceeds the prevailing CCER price, CCER projects for buildings may not materialize without substantial subsidies. Another factor that dampens interests in CCER building projects is the difficulty and associated cost of coordinating with relevant stakeholders, especially for residential buildings.

Currently, CCER building projects are not the most viable attempt to address building energy efficiency. An essential element that needs to be addressed is the prohibitive cost of CCER project implementation. That said, a potential cost-effective mechanism exists that can essentially substitute itself for CCERs. As discussed earlier, Beijing allows emission reductions from energy performance contracts (EPCs) to count toward the 5% CCERs toward compliance. The EPC mechanism can be explored further for alleviating the high upfront cost phenomenon that building retrofits may encounter.

Voluntary Participation in ETS through EPCs

Another form of voluntary participation is demonstrated by Tianjin’s ETS. Energy Performance Contracts (EPCs) are a contract vehicle that China adopted from Western countries in the early 2000s. EPCs represent an innovative financing mechanism for energy efficiency retrofits where investment costs of a retrofit project are recovered from the life cycle utility cost savings it achieves (Office of Energy Efficiency & Renewable Energy, Unknown, p. 1). Under this model, building owners, energy service companies (ESCOs), and third-party financiers work together to achieve project success. ESCOs are responsible for designing and implementing an EPC, and financiers provide the upfront capital. More importantly, the performance aspect of an EPC lies in the savings performance guarantee provided by ESCOs. In the case of a savings shortfall, ESCOs are responsible for rectifying the issues or make up the savings shortfall.

Between 2005 and 2012, EPC investment increased from 1.3 billion yuan to 55.3 billion yuan and has achieved an equivalent CO_2 reduction of 46 million tons (China Construction Bank, 2013, p. 4). The EPC model successfully addresses three common obstacles to building retrofits. The first obvious advantage is its ability to attract capital using the assurance of savings guarantee, thus overcoming the prohibitive cost of project development. Building owners welcome the savings guarantee concept and are more committed to project success. Lastly, the EPC model effectively leverages the capabilities and knowledge of energy efficiency professionals to implement comprehensive building retrofits and thus achieve significant energy savings. As a result, an expansion of the EPC application in China may be beneficial.

It is possible to find synergy between emissions trading and EPC projects for enhancing building efficiency. To drive long-term impact from emissions trading, reduction goals beyond 2020 will be needed. Such reduction goals in turn require further energy reductions in buildings, which could require involvement of more complex building upgrades at higher costs. Allowance prices might not increase in response to the rise of unit cost of building retrofits. The resulting gap can be filled by EPCs. In addition, the government has set aside fiscal incentives for EPCs (China Construction Bank, 2013, p. 5). In fact, the MOHURD and the Ministry of Finance allocated 1.7 billion yuan for fiscal incentives, only 18.4% of which were utilized (or 312 million yuan). As a result, coupling emissions trading and EPCs can also help enhance the utilization of existing resources for EPCs and further improve building retrofit economics, which in turn motivate self-reduction by building participants.

VI. Conclusion

Based on compliance results to date, the current design of emissions trading seems capable of engaging the building sector in energy reductions. The building sector also appears to be a good candidate for emissions trading in China given its steadily rising energy consumption and rapid urbanization, its relative resistance to fluctuations in external factors such as the economy, and the absence of carbon leakage risk in this sector. Key ETS features including a moderately long compliance period, a focus on reduction of energy intensity rather than overall emissions, and severe penalties for non-compliance may contribute to the ETS's impact on the building sector. Future success of the ETS, however, depends on a few factors. First, a solution needs to be identified to engage buildings with unclear ownership structure or no registered ownership. The same goes for residential buildings given the inconsistent metering infrastructure across regions in China. If ETSs prove not to be the most effective mechanism to engage certain building types, alternative mechanisms should be used to encourage or enforce their energy efficiencies.

Another aspect is the type of emissions accounted for by emissions trading. Certain pilot ETSs account for both direct and indirect emissions by buildings, or direct energy usage and the energy consumed at the source of generation (e.g. power plants) to deliver energy to building end users. Shenzhen's ETS, for example, incorporates both direct and indirect emissions into its calculation of the emissions coefficient, which is in turn used to calculate allowance surrender (Shenzhen Institute of Building Research, 2014, p. 11). This is not necessarily the case for other pilot ETSs and needs to be unified for the establishment of a national ETS. If both direct and indirect emissions are accounted for at the building level, the government needs to clarify which portion of energy reductions is targeted at the source level (e.g. energy consumption for energy generation by power plants) to avoid double counting of emissions and thus over-allocation of allowances at the source level. More importantly, energy use regulated by emissions trading is limited to that during the operational phase of a building. This, however, accounts for only half of the total energy consumption of a building, and urban buildings tend to consume more energy than expected due to a high demolition rate. The current lifespan of urban buildings in China is approximately 30 years (Huang et al, 2013, p. 92). If a building that has fulfilled its reduction targets through ETS is demolished, its successor—a new building—would consume additional energy during construction. If the demolition rate in China cannot be reduced, it may be more accurate to calculate allowance surrender based on the lifecycle emissions of a building including both the construction and operational phases. Doing so would require a corresponding update in allowance calculation methodologies.

Emissions trading's impact can be amplified over time and when coupled with other mechanisms. The current impact of carbon prices on driving building retrofits is unclear. As deeper retrofits are required to achieve future emissions reduction goals, however, allowance surrender can become more expensive, and hence higher carbon prices could play a more critical role in offsetting the initial costs of building upgrades. Strategies for improving buildings' efficiency, such as emissions trading, CCERs, EPC projects, and demand response work best when synchronized with the appropriate stage of a building's lifecycle. For example, minimizing emissions before buildings become an emissions source—that is, targeting building design standards for new construction—is likely more cost-effective than attempting to target new construction through ETS. Considering the relatively high new construction rate in the near future in China, enforcing rigorous design standards and overseeing compliance with these standards can certainly complement the impact of an ETS. Collaboration among different initiatives may also enhance the overall investment return and promote greater awareness and incentives among end users to participate in government initiatives and drive GHG emission reductions.

Literature Cited

Amecke, H., Deason, J., Hobbs, A., Novikova, A., Yang, X., & Zhang, S. (2013). Buildings Energy Efficiency in China, Germany, and the United States. *Climate Policy Initiative.*

Bin, S., & Jun, L. (July 2012). Building Energy Efficiency Policies in China. Retrieved from http://www.gbpn.org/sites/default/files/08.%20China%20Report_0.pdf

Bugnion, V. (March 2015). Lecture 9: California [PDF]. Retrieved from Johns Hopkins University Blackboard.

Bugnion, V. (April 2015). Carbon Management & Finance: Lecture 11 [PDF]. Retrieved from Johns Hopkins University Blackboard.

California Air Resources Board Cap-and-Trade Program. (2014, Dec 22). 2013 Compliance Report. Retrieved from https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=2&cad=rja&uact=8&ved=0ahUKEwiZ9sax5JTMAhUQID4KHf_dDmMQFggpMAE&url=http%3A%2F%2Fwww.arb.ca.gov%2Fcc%2Fcapandtrade%2F2013compliancereport.xlsx&usg=AFQjCNEHDjek9GyHxvRqoBXLia_lT4RWLA&sig2=X7SIyCqAlNQwrOxkpB2a3w

California Air Resources Board Cap-and-Trade Program. (2015). 2013-2014 Compliance Obligation Detail for ARB's Cap-and-Trade Program. Retrieved from https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=2&cad=rja&uact=8&ved=0ahUKEwjmuvjX5JTMAhWIOj4KHRtNC3oQFggkMAE&url=http%3A%2F%2Fwww.arb.ca.gov%2Fcc%2Fcapandtrade%2F2013-2014compliancereport.xlsx&usg=AFQjCNEybQXaSzuMi39csK5xA9Gk-eHp6g&sig2=oeIPKmgJTugAkKVdw0kdzQ&bvm=bv.119745492,d.cWw

California Air Resources Board Cap-and-Trade Program. (2015, Nov 4). 2014 GHG Facility and Entity Emissions. Retrieved from http://www.arb.ca.gov/cc/reporting/ghg-rep/reported-data/ghg-reports.htm

Chen, Y. C., Jiang, P., Dong, W., & Huang B. (2015). Analysis on the carbon trading approach in promoting sustainable buildings in China. *Renewable Energy*, *84*, 130-137.

China Beijing Environment Exchange & Beijing Emissions Trading Association. (2016). Annual Report of Beijing Carbon Market 2015. Retrieved from http://www.tanpaifang.com/tanguwen/2016/0203/50501.html

China Construction Bank. (2013, March 20). China's Energy Performance Contract Development Trend. Retrieved from http://store.ccb.com/cn/public/20130322_1363936131/201313.pdf

Office of Energy Efficiency & Renewable Energy. (Unknown publication date). About Federal Energy Savings Performance Contracts. Retrieved from http://energy.gov/eere/femp/about-federal-energy-savings-performance-contracts

Environmental Defense Fund. (May 2015). Tokyo: An Emissions Trading Case Study. Retrieved from https://www.edf.org/sites/default/files/Tokyo_ETS_Case_Study.pdf

Feng, W., Zhou, N., Rue du Can, S., Bendewald, M., & Franconi, E. (October 2015). Building Energy Codes in China: Recommendations for Development and Enforcement. Retrieved from http://www.paulsoninstitute.org/wp-content/uploads/2015/10/Building-Code-Roadmap-Oct-2015_vfinal_EN.pdf

Fu, F., Pan, L., Ma, L., & Li, Z. (2013). A simplified method to estimate the energy-saving potentials of construction and demolition process in China. *Energy, 49,* 316-322.

Huang, T., Shi, F., Tanikawa, H., Fei, J. & Han, J. (2013). Materials demand and environmental impact of building construction and demolition in China based on dynamic material flow analysis. *Resources, Conservation and Recycling, 72,* 91-101.

IETA. (May 2015). Tokyo: The World's Carbon Markets: A Case Study Guide to Emissions Trading. Retrieved from http://www.ieta.org/resources/Resources/Case_Studies_Worlds_Carbon_Markets/tokyo_case_study_may2015.pdf

International Carbon Action Partnership (ICAP). (Mar 2016). USA – California Cap-and-Trade Program. Retrieved from https://icapcarbonaction.com/en/?option=com_etsmap&task=export&format=pdf&layout=list&systems%5B%5D=45

Jiang, J. J., Ye, B., & Ma, X. M. (2014). The construction of Shenzhen's carbon emission trading scheme. *Energy Policy, 75,* 17-21.

Kossoy, A. et al. (2014). State and Trends of Carbon Pricing. *World Bank Group.*

Liu, X., Ding, Y., Tong, Y., Zhu, N., & Tian, Z. (2014). Research on the evaluation system for heat metering and existing residential building retrofits in norther regions of China for the 12th five-year period. *Energy, 77,* 898-908.

Munnings, C., Morgenstern, R., Wang, Z., & Liu, X. (2014). Assessing the Design of Three Pilot Programs for Carbon Trading in China. *Discussion Paper for Resources for the Future.*

National Energy Administration. (2014, Jan 3). Carbon Trading Market Promotes Real Estate Building's "Green" Conversion. Retrieved from http://www.nea.gov.cn/2014-01/03/c_133016049.htm

Nishida, Y. (Unknown publication date). Tokyo Cap and Trade Program & Strategic Reporting Requirements. Retrieved from http://www.unep.org/sbci/pdfs/Oct_symposium/Metropolitan's%20Tokyo's%20Cap%20and%20Trade%20Program_YN.pdf

Partnership for Market Readiness. (Feb 2016). China Carbon Market Insight. Retrieved from https://www.thepmr.org/system/files/documents/0203-PMR%20China%20Carbon%20Market%20Monitor%20%233-CN-final_0.pdf

Qi, S., & Cheng, S. (2015, August 12). China Emissions Trading Pilot Comparative Study. Retrieved from http://www.brookings.edu/~/media/research/files/papers/2015/08/12-china-carbon-trade/%E4%B8%AD%E5%9B%BD%E7%A2%B3%E4%BA%A4%E6%98%93%E8%AF%95%E7%82%B9%E6%AF%94%E8%BE%83%E7%A0%94%E7%A9%B6.pdf

Rudolph, S. (2012). Carbon Markets in Japan: Recent Experiences from CO_2 Cap-and-Trade at the National and Local Level. *Carbon & Climate Law Review*, *6 (4)*, 354-357.

Shanghai Environment and Energy Exchange. (Feb 2016). Shanghai Carbon Market 2015 Report. Retrieved from http://www.tanpaifang.com/tanguwen/2016/0315/51466.html

Shanghai Municipal Development & Reform Commission. (2016, Feb 22). Shanghai Carbon Trading Covered Entity List (2016 Version). Retrieved from http://www.tanpaifang.com/kongpaiqiye/2016/022250805.html

Shen, B., Dai, F., Price, L. K., & Lu, H. (May 2014). California's Cap-and-Trade Programme and Insights for China's Pilot Schemes. Retrieved from http://multi-science.atypon.com/doi/pdf/10.1260/0958-305X.25.3-4.551

Shenzhen City Development Research Center & Shenzhen Emissions Exchange. (March 2015). Shenzhen Emissions Trading System Anniversary Operation Result Summary Report. Retrieved from http://ets-china.org/wp-content/uploads/2015/05/ETS%E6%B7%B1%E5%9C%B3%E6%80%BB%E7%BB%93%E5%90%A7%E6%8A%A5%E5%91%8A.pdf

Shenzhen Institute of Building Research. (2014, May 25). The Trial Operation Assessment on Transaction Market of Shenzhen Municipal Building Carbon. Retrieved from http://www.efchina.org/Attachments/Report/report-cbp-20140525/%E5%BB%BA%E7%AD%91%E7%A2%B3%E4%BA%A4%E6%98%93%E8%AF%95%E8%BF%90%E8%A1%8C%E8%AF%84%E4%BC%B0%E7%A0%94%E7%A9%B6

The Ministry of Housing and Urban-Rural Development of the People's Republic of China. (March 2013). Feasibility Study on Establishment of Carbon Trading Scheme in Building Sector in China. Retrieved from http://www.efchina.org/Attachments/Report/report-20130330-

zh/%E4%B8%AD%E5%9B%BD%E5%BB%BA%E7%AD%91%E8%A1%8C%E4%B8%9A%E7%A2%B3%E6%8E%92%E6%94%BE%E6%9D%83%E4%BA%A4%E6%98%93%E5%88%B6%E5%BA%A6%E5%8F%AF%E8%A1%8C%E6%80%A7%E7%A0%94%E7%A9%B6.pdf

The Ministry of Housing and Urban-Rural Development of the People’s Republic of China. (2005, April 4). GB 50189-2005: Design Standards for Energy Efficiency of Public Buildings.

The Ministry of Housing and Urban-Rural Development of the People’s Republic of China. (2010, Mar 18). JGJ 134-2010: Design Standards for Energy Efficiency of Residential Buildings in Hot Summer and Cold Winter Zone.

The Ministry of Housing and Urban-Rural Development of the People’s Republic of China. (2008, Aug 1). JGJ 26-05: Design Standards for Energy Efficiency of Civil Buildings.

The Ministry of Housing and Urban-Rural Development of the People’s Republic of China. (2010, Mar 18). JGJ 26-2010: Design Standards for Energy Efficiency of Residential Buildings in Severe Cold and Cold Zones.

The Ministry of Housing and Urban-Rural Development of the People’s Republic of China. (2003, Oct 1). JGJ 75-2003: Design Standards for Energy Efficiency of Residential Buildings in Hot Summer and Warm Winter Zone.

Tianjin Municipal Government. (2010, Sept 1). Tianjin Civil Building Energy Efficiency Trading Registration and Management Methods. Retrieved from https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0ahUKEwjspef2lJbMAhUD4D4KHbk_CWcQFggdMAA&url=http%3A%2F%2Fwww.tjcac.gov.cn%2Fupload%2Fxingzheng%2Fjcb%2F%25E5%25BB%25BA%25E6%259D%2590%5B2010%5D634%25E5%258F%25B7%25E9%2599%2584%25E4%25BB%25B6.doc&usg=AFQjCNGDXJnQJCIta-K-PT1ik0CXBS80qg&sig2=LQzi24XIDN-fw7_bGVgq9Q

Tokyo Metropolitan Government Bureau of Environment. (2014). Green Building Program. Retrieved from https://www.kankyo.metro.tokyo.jp/en/climate/build.html

Tokyo Metropolitan Government Bureau of Environment. (2012, May 21). The Tokyo Cap-and-Trade Program Results of the First Fiscal Year of Operation (Provisional Results). Retrieved from http://www.kankyo.metro.tokyo.jp/en/climate/attachement/Result%20of%20the%20First%20FY%20of%20the%20Tokyo%20CT%20Program_final.pdf

Tokyo Metropolitan Government Bureau of Environment. (2013, Jan 21). The Tokyo Cap-and-Trade Program achieves 23% reduction in the 2nd year. Retrieved from http://www.kankyo.metro.tokyo.jp/en/climate/attachement/The%202nd%20Year%20Result%20of%20the%20Tokyo%20Cap-and-Trade%20Program.pdf

Tokyo Metropolitan Government Bureau of Environment. (2014, Mar 12). Tokyo Cap-and-Trade Program achieves 22% reduction after 3rd year. Retrieved from https://www.kankyo.metro.tokyo.jp/en/climate/attachement/Tokyo%20C%26T%203rd%20Year%20Results.pdf

Tokyo Metropolitan Government Bureau of Environment. (2015, Feb 19). Tokyo Cap-and-Trade Program achieves 23% reduction after 4th year. Retrieved from https://www.kankyo.metro.tokyo.jp/en/climate/attachement/Tokyo_CAT_4th_Year_Results.pdf

Tokyo Metropolitan Government Bureau of Environment. (2016, Feb 25). Tokyo Cap-and-Trade Program achieves 25% reduction after 5th year. Retrieved from http://www.kankyo.metro.tokyo.jp/en/files/3c08a5ad895b5130cb1d17ff5a1c9fa4.pdf

Tokyo Metropolitan Government Bureau of Environment. (2012, Mar 30). Tokyo Cap-and-Trade Program for Large Facilities. Retrieved from https://www.kankyo.metro.tokyo.jp/en/climate/attachement/C%26T%202012.pdf

Wang, J. (Jun 2012). Tianjin Climate Exchange’s Experimentation and Exploration of Market Building. Retrieved from http://www.tgpf.org.tw/event/file/20120626/issue4/4-4%E7%8E%8B%E9%9D%96%E2%80%94%E2%80%94%E5%A4%A9%E6%B4%A5%E6%8E%92%E6%94%BE%E6%AC%8A%E4%BA%A4%E6%98%93%E6%89%80%E5%9C%A8%E7%A2%B3%E5%B8%82%E5%A0%B4%E5%BB%BA%E8%A8%AD%E4%B8%AD%E7%9A%84%E5%AF%A6%E8%B8%90%E8%88%87%E6%8E%A2%E7%B4%A2.pdf

Xinhua Net. (June 2015). China Focus: China Announced New Target in Response to Climate Change. Retrieved from http://news.xinhuanet.com/politics/2015-06/30/c_1115774813.htm

Xu, X., You, S., Zheng, X., & Li, H. (2014). A survey of district heating systems in the heating regions of norther China. *Energy, 77,* 909-925.

Zhou, N. (March 2008). Status of China’s Energy Efficiency Standards and Labels for Appliances and International Collaboration. Retrieved from https://china.lbl.gov/sites/all/files/lbl-251e-appliance-eslmarch-2008.pdf

Zhou, N., Khanna, N., & Feng, W. (2014). China’s Building Energy Use. *ASHRAE Journal, July 2014,* 26-28.

Zhou, S., & Duan, M. (November 2014). Research of the Outlook of the Building Sector in the Chinese Certified Emissions Reductions (CCERs). Retrieved from http://ets-china.org/wp-content/uploads/2015/07/offsetting_building_CH_small_size_GHG-project-name.pdf