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Supportive governance for city-scale low carbon building retrofits: A case study from Shanghai

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Abstract:

There is significant potential for reducing energy use and emissions from buildings through energy efficiency retrofits. However, a number of barriers, including long payback periods and uncertainties around business models and technologies, still restrict large scale implementation. A recent joint project, piloting green energy schemes and low-carbon investments in public and commercial buildings in Shanghai, China, indicated opportunities to break through these barriers. This study conducted a cost benefit analysis and interviews to investigate how government subsidies have promoted retrofits in the joint project. In total, 44 retrofit sub-projects were carried out and achieved an energy saving of 30,217 tons of coal equivalent. The average payback period was 2.43 years, and subsidies can further reduce the payback period to 1.79 years. The Changning Low Carbon Office played a critical role in coordinating and supporting the uptake of retrofit measures. Non-economic factors continue to restrict investment by financial institutions and further restrict the implementation of retrofits on a larger scale.

Key policy insights:

- Public and commercial building retrofits in Shanghai are found to generate commercially acceptable payback periods while having achieved significant energy and emissions reductions.
- Subsidies from the city and district governments significantly reduced the payback periods of energy efficiency retrofits, but may also crowd out investment by financial institutions.
- Achieving the deeper retrofits needed to achieve China's climate targets may require more substantial financial incentives.
- The Changning Low Carbon Office has coordinated energy efficiency retrofitting efforts, provided access to information, helped to connect investment funds with project opportunities and support project management.

Keywords: Energy efficiency, cost-benefit analysis, public and commercial buildings

1. Introduction

Buildings in urban areas account for over 55% of electricity demand (IEA, 2017) and roughly one-third of the global energy consumption (Kammen and Sunter, 2016). The challenge of reducing the contribution of buildings to climate change is as much about the scope of energy use as it is about the scale of energy use.

Buildings use energy for lighting, cooling, heating, electronics, water heating, refrigeration and cooking, among other uses, leading to a complicated and interconnected set of points for intervention. Both the rebuild and retrofit of existing buildings have the potential to substantially improve the energy performance and sustainability. Replacing existing buildings may have higher potential to integrate more advanced technologies and achieve a deeper decarbonization (Schwartz et al., 2018), but will likely also be more time-consuming, costly and disruptive. Furthermore, embodied greenhouse gases released during the extraction, processing, transport and construction of materials used in buildings typically account for 10 to 20 percent of a building's lifetime emissions. This share becomes substantially larger if buildings are replaced before the end of their intended lifespan (Cabeza et al., 2014).

Cost-effective buildings retrofits are therefore seen as critical to mitigating dangerous climate change. In public and commercial buildings alone, implementing energy efficiency measures – for example, replacing lightbulbs with LEDs, insulating walls and heating systems, and installing energy-efficient appliances, can achieve 25 – 50 percent reductions in energy consumption (Lin and Liu, 2015; Lucon et al., 2014; Qian et al., 2019). Across global urban areas approximately one-quarter of the potential for greenhouse gases abatement can be found in buildings, in part because older and outdated buildings often have higher energy intensities than those constructed today (Sudmant et al., 2016). Beyond the benefits to the climate, such investments can generate substantial economic savings for businesses (Colenbrander et al., 2017, 2019; He et al., 2016), and wider non-economic benefits, including improved public health from clearer air and reduced exposure to heat and cold, increased employment, and higher workplace productivity (Gouldson et al., 2018).

While theoretical and forward-looking analyses of technical, policy, behavioural and practice-based measures have become relatively common (Colenbrander et al., 2016; Jones and Kammen, 2011; Sudmant et al., 2017), ex-post analysis of urban climate actions are relatively less common, and lacking for many types of interventions and regions of the world (Creutzig et al., 2019; Kallaos et al., 2018; Widerberg and Stripple, 2016). Furthermore, the cost-effectiveness of energy efficiency retrofits has in some places been closely related to the target of emission reduction. For example, Galvin and Sunikka-Blank (2013) pointed out that it was beyond the limit of economically viable technologies to reach Germany's stringent carbon reduction target of 80% carbon reduction by 2050 compared to 1990 levels. This increases the necessity of a quantitative assessment of the economic cases of practical retrofit projects.

Scaling up the improvement of energy efficiency in existing commercial and public buildings, however, can be more challenging. Barriers to a larger scale roll out of energy efficiency retrofitting include split incentives between owners and occupiers, lack of awareness about opportunities, lack of available information on the success of technologies in real-life settings, high upfront transaction costs and inadequate access to financing (Climate Policy Initiative et al., 2013; World Bank, 2019). Similarly, Hou et al. (2016) investigated the commercial building retrofit market in China and Japan. They found key barriers were difficulties with the coordination of actors, imperfect market mechanisms, and unpredictable energy savings. (Alam et al., 2019) used focused groups to investigate the key barriers to public building retrofits. In addition to the aforementioned aspects, they found complex and excessive approvals procedures in energy efficiency procurement is another barrier.

Government support has been undertaken to break these barriers, which can be generally categorised into:

1) Mandatory instruments

Mandatory instruments dominate climate governance in the urban building sector (Trencher et al., 2016). They include mandatory building codes and energy efficiency standards (Sun et al., 2016), and periodic energy audits (Annunziata et al., 2014). Despite being widely applied, mandatory instruments usually have shortcomings such as requiring substantial time and institutional capital to develop and implement (Van der Heijden, 2016).

2) Market-based and fiscal instruments

Market-based and fiscal instruments usually include tax- and subsidy-based incentives to encourage building owners to take actions. Similarly, carbon permits were found to motivate actions for building energy efficiency retrofits in Tokyo (Nishida et al., 2016). In other cases, market-based instruments seek to attract financing. For example, the Billion Dollar Green Challenge adopted a revolving loan fund that was repaid by the cost of energy savings in the universities in the United States (Mero, 2012). Another financing instrument was climate bonds in the 1200 Buildings in Melbourne (Wilkinson, 2018), where the government acted as a “middle person”, took the risk from financial institutions, and recouped the loan through a property tax on the retrofitted buildings.

3) Information generation and dissemination

Energy efficiency certification and labelling are popular measures to assess and demonstrate buildings’ achievements on energy saving and sustainability. In general, this would make those buildings stand out and raise awareness among other building owners, investors, and the public. Well known tools are the Building Research Establishment Environmental Assessment Method (BREEAM) and the Leadership in Energy and Environmental Design (LEED) (Cole and Jose Valdebenito, 2013); it should be noted that there are concerns about the difficulties of comparing between and across different assessment criteria (Van der Heijden, 2015). Voluntary instruments also help to bridge the gap between the government and private sector standards, such as by encouraging friendly competition in neighbours (Trencher et al., 2016), developing intermediaries (Magnani et al., 2020), and sharing information and experiences (Dowling et al., 2018).

In practice, these instruments are usually combined and found to have complex interactions (Trencher and van der Heijden, 2019). In China, the building retrofit has been mainly driven by subsidies (Huang et al., 2016), but few studies have focused on the effect of subsidies on promoting commercial and public building retrofits. Rather, literatures focus on broader topics. For example, government fiscal support including subsidies has been found to improve the economic case and attract private investment (Olmos et al., 2012; Polzin, 2017). The focus, however, was generally on innovative or disruptive clean energy technologies in all industries. Studies on the effect of government support on the investment of building energy efficiency retrofits, particularly from private sectors and financial institutions, have been less common.

These uncertainties have served to limit the opportunity for the feedback and learning that is needed for more ambitious low carbon action (Gouldson et al., 2015), for assessing how socio-technical transitions align with low-carbon pathways (Widerberg and Stripple, 2016), and more generally, for the development of a coherent global urban sustainability science (Creutzig et al., 2019).

With these factors and the growing urgency of the climate emergency in mind, there is a continued need for assessment of the business case for building retrofits in different contexts and to understand the wider policy and governance landscapes that can be supportive or inhibitive to retrofitting. In this context, this study applied a cost benefit analysis to assess the economic case of building energy efficiency retrofits, and a group of interviews exploring the role of government support in a joint investment project initiated in Changning, Shanghai. This study aimed to elucidate a) how much the subsidies have improved the business case; b) how Changning's local government combined the fiscal, technical, and coordinating support to promote building energy efficiency retrofits; and c) why an improved business case leveraged limited private investment by financial institutions in the Changning building energy efficiency retrofit project. This study contributes to the literature by providing quantitative evidence of the effect of subsidies on the cost-effectiveness of building energy efficiency retrofits, and identifying the key factors that lead to the limited participation of investment by financial institutions.

This paper is organized as follows. Section 2 provides an overview of the policy background including the national and municipal plans, the subsidy system, and a narrative of the World Bank-supported Project. Section 3 introduces the methodology and data sources. Section 4 presents the result of the cost-benefit analysis. Section 5 provides a further discussion on the successes and deficiencies of the case. Section 6 presents the conclusion and policy implementations from this study.

2. Background and context

2.1. The city and district level subsidy

China has been pursuing building energy saving for many years. In 2013, The Special Plan for Building Energy Conservation of China's 12th Five Year Plan set a target of completing the retrofit of 60 million square metres in public and commercial buildings by the end of 2015. Cities are major players in the nation's climate action strategy. In 2011, four cities (Tianjin, Shanghai, Chongqing, Shenzhen) were chosen to be key cities to promote energy conservation in public and commercial buildings. A baseline subsidy of CNY 20 per square metre retrofitted (approximately $3.05 USD) was promised to each city. Local governments were able to announce their own subsidy standard based upon this baseline.

As a municipality as well as a megacity, Shanghai has launched a set of policies to motivate energy efficiency projects in the built environment. In 2009, the Special Subsidy for Building Energy Efficiency Projects in Shanghai (Number 816) was established to create incentives for private investment in public and commercial building energy efficiency. Capital for the fund was provided in equal parts by the central and municipal governments. Central to the design of the project was to make the information generated by qualifying projects – known as "demonstration projects" – widely available to raise awareness about the potential for low carbon investment in buildings.

The subsidy was also designed to take into consideration changes in technologies and costs, and has seen a number of changes since 2009 (<Insert Fig. 1). Update Number 311, issued in 2013, supported building retrofits that

achieve a reduction more than 20 percent in energy consumption per square metre. Qualifying projects received CNY 40 (approximately $6.10 USD) per square metre if they applied energy performance contracting, in which an external energy savings company implements a project and recovers the costs from the savings, or CNY 35 (approximately $5.30 USD) per square metre) if projects did not involve energy performance contracting. In addition, the total amount of the subsidy was set to not exceed 50% of the total investment in the project.

<Insert Fig. 1. here>

Changning, the case area, is located in the west of downtown Shanghai (Fig. S1). It has a land area of 38 square kilometres and a population of 690,000 in 2015. The floor area of buildings in Changning is roughly 40 million square metres, 60% of which are residential buildings. The district can be roughly divided into three zones - west, middle, east - which are the transportation centre, the economic development zone, and the residential area respectively. In 2015, the GDP of Changning was CNY 104 billion (approximately $15.8 billion USD), dominated by service industry (93% of GDP in 2015) – mainly commerce and trade.

Independently, Changning established its own district-level subsidy for building energy efficiency retrofits with the support of the World Bank in 2013. The Changning District subsidy included CNY 1,000 (approximately $152 USD) per ton of coal equivalent (tce) avoided, or CNY 450 (approximately $68 USD) per ton of CO_2 equivalent (tCO_2e) emissions reduced on an annual basis for those building retrofits that saved at least 50 tce each year. It also provided 30% compensation for any losses incurred during a renovation project that interrupted normal business operations for 6 months or more. The total amount received by any one project was set to not exceed CNY 1 million (approximately $152,000 USD).

2.2. Overcoming barriers to public and commercial building retrofitting in Changning, Shanghai

Cooperation between the Shanghai Municipal Government and the World Bank began in 2012, with Changning District in Shanghai determined as an area of focus because of its concentration of relatively older buildings. A World Bank-supported project was carried out, bringing grants and loans to support the capacity building and leverage low carbon investments in the building sector.

The grant was provided by the Global Environment Facility (GEF). A dedicated Low Carbon Office was formed in Changning District to coordinate energy efficiency retrofitting efforts, provide access to information, help to connect investment funds with project opportunities and support project management. With strong representation from local government leaders, the Changning Low Carbon Office also liaises with the District Development and Reform Commission, the Municipal Finance Bureau and national agencies, and carries out research related to energy efficiency in buildings. It is now called upon to support projects in other districts, serving as a key conduit for knowledge transfer.

Additionally, a building energy monitoring platform was established and scaled up during the project phase. In 2007, Changning District pioneered the country's first online platform for monitoring the energy performance of public and commercial buildings, strengthening data collection and evaluation capacities. The monitoring platform collects and analyses real-time energy use data at the building level, allowing for the identification of inefficiencies and opportunities for targeted interventions. The platform was used as a model for the entire city in 2012 when, as part of the 12th Five Year Plan, the city government mandated that the programme should be scaled-up to the city level. With the support of the World Bank, the Shanghai State Office Building and Large Public Building Energy Monitoring Centre was successfully established and now monitors the energy consumption of 1,687 public and commercial buildings, accounting for 78 million square metres of floor space in Shanghai.

A loan was provided by The International Bank for Reconstruction and Development (IBRD). The loan was expected to leverage the co-financing of two participating commercial banks - Shanghai Pudong Development Bank (SPDB) and Bank of Shanghai (BOS). Disbursement of loans from IBRD was initially slower than originally planned, with challenges around coordinating the roles of financial intermediaries, finding suitable projects, and obtaining approvals from across member institutions. However, within three years funding for 67 sub-projects had been allocated. Most of the sub-projects were energy efficiency retrofitting (44), others were new buildings of high energy standard (16), distributed generation centres (4), combined interventions (2), and a net-zero emission building (1). These actions cover 5.87 million square metres of floor area (including outside of Changning District). The locations of the 44 energy efficiency retrofitting sub-projects were shown in Fig. S1.

3. Method and data

3.1. Case study characteristics

This analysis assesses 67 completed low-carbon building sub-projects supported by the project of International Bank for Reconstruction and Development Loan (ibrd-8233-cn) to the amount of US $100,000,000 and Global Environment Facility Grant (tf-14205-cn) to the amount of US $4,345,000 for the Green Energy for Low-carbon City in Shanghai (Project ID P127035). The geographical area of sub-projects was expanded from initially focusing on Changning District to also including 12 other districts out of the 16 districts of Shanghai Municipality. Those 67 sub-projects covered 10 types of public and commercial buildings, which we then categorised into five groups for convenience of comparison: office, hotel, industrial, school & hospital and other.

Analysis is conducted of energy efficiency (EE) retrofit activities in existing buildings, and new buildings, of large-scale distributed generation (DG) and of combined activities. “new EE buildings” refers to the new constructions of buildings with low carbon technologies beyond the requirement of the municipal building code. The investment of “new EE buildings” refers to the incremental cost of achieving such higher energy conservation standard relative to a scenario without the project. In Shanghai, such scenario is given by the Design Standard for Energy Efficiency of Public Buildings in Shanghai (DGJ 08-107-2012), which is equivalent to a 65% energy conservation rate compared with 1980s level. In the project, new buildings were upgraded to a 70% conservation rate compared with 1980s level (World Bank, 2019).

29 types of abatement technologies were deployed. These can be categorized into HVAC and hot water supply systems, power supply and lighting, power and other equipment, applications of renewable energy, monitoring and control systems, management measures and building envelope actions. The range of demand-side building EE technologies includes lighting, HVAC, insulation, envelope, and energy management systems. Actions to reduce building energy demand are complemented by actions to generate low-carbon energy, as well as wider activities affecting the intensity of emissions from the electricity grid. Distributed generation (DG) activities include on-site production of electricity,

and thermal energy.

3.2. Costs-benefit modelling

To evaluate the cost effectiveness for energy efficiency measures in buildings in Shanghai, an integrated building/sub-project based cost and benefit assessment was carried out which built on previous similar assessments in other contexts (He et al., 2016). The analysis involves aggregating potential economic savings from energy reductions by two kinds of energy types (namely, electricity and natural gas), and providing payback periods from energy efficiency measures adopted in the buildings in terms of reductions in energy bills. Due to a lack of data on the composition of energy use, estimates were based on data from the annual building energy consumption monitoring report from the Shanghai State Office Building and Large Public Building Energy Monitoring Centre (Shanghai Urban and Rural Construction and Management Committee, 2014). Specifically, we assumed that the energy savings of all sub-projects were 100% electricity, excluding hotels which saved 70% electricity and 30% natural gas (Wei et al., 2016).

The costs of measures were held constant at the year of investment (most in 2014 or 2015). As measures could be in place for many years, an annual increase in real energy prices, an annual discount rate and an annual inflation rate should be considered during the next 20 years life span of the measures. However, due to these numbers being relatively close (both around 5%) according to recent trends in China since 2015, no special handling has to be done to the data during estimation.

This study did not include the potential co-benefit of energy savings with regard to other externalities, such as the reduction of greenhouse gases, or air pollutions (Bin and Parker, 2012; Brown et al., 2013; Hasik et al., 2019), as this study only focused on financial costs and benefits. It is therefore expected that this study will to some extent underestimate the benefits.

3.3. Data sources

The research presented here draws on data from the Shanghai State Office Building and Large Public Building Energy Monitoring Centre (available at: http://www.shjzjn.org), and the World Bank's Implementation Completion and Results Report of the project "Green Energy for Low-Carbon City in Shanghai", hereinafter referred to as the "World Band report" (World Bank, 2019). In addition, qualitative analyses were supported by interviews (see interview information in Supplementary Material, Table S2) with project workers, academics, key NGOs, members of government, firms working in the retrofitted buildings and extensive document analysis of public policies, project documents, academic publications, and media reports. The interviews were conducted between Nov. 2018 to Oct. 2019. Experts were selected through a snowballing process that originated from contacts at Shanghai Jiao Tong University and the World Bank. Experts interviewed have a minimum of 5 years of experience working on issues related to urban climate action and/or urban governance, though standpoints may differ due to different backgrounds.

The data of subsidies from Changning District was derived from the World Bank report. The data of subsidies from Shanghai Municipality was derived from the information disclosure of the Shanghai State Office Building and Large Public Building Energy Monitoring Centre (available at: http://www.shjzjn.org/#/remouldshowcases). Some of the sub-projects were actually supported by both Shanghai and Changning subsidies, but the World Band report only included the subsidies from Changning District. Thus, we aggregated the subsidies from both sources (Supplementary S3). All monetary value in CNY is changed into USD with an exchange rate of 6.5795 CNY/USD, which is consistent with the World Bank report on the project.

4. Results

The efficiency of low carbon investment by the ratio of per area energy savings to the per area investment of each sub-project is presented in
<Insert Fig. 2.

<Insert Fig. 2. here>

Across all sub-projects, EE retrofits are notably less capital intensive than projects in new buildings, but also resulted in a larger impact on energy savings per unit area. EE retrofits have an average cost of 23.92 USD/m^2 and achieved an average energy savings of 10.73 kgce/m^2. A special case is the Hongqiao Airport Terminal 1, the only airport building in this project, which achieved 38.69 kgce/m^2 of energy saving annually from 157.51 USD/m^2 of investment. The average investment in new buildings was 67.10 USD/m^2, and the average annual energy saving was 8.51 kgce/m^2. While retrofitting existing buildings is found to be relatively more cost effective, the similarity in cost savings per unit area between options for retrofitting existing buildings options for “pre-fitting”[1] new buildings emphasises the range of possible intervention points for reducing the energy use from buildings.

<Insert Fig. 3. here>

Assessing the financial cases for retrofitting, the results reveal a notably shorter payback period for retrofit projects as compared with investments in new buildings. This can be seen by comparing “EE retrofit” with “EE new” in
<Insert Fig. 3, where average payback periods are 2.43 and 7.69 years, respectively. While variation between projects should be noted, the fact that new buildings had longer payback periods on average in part reflects the relatively high energy efficiency standard already applied to newer buildings. At the same time, the relatively shorter payback periods for existing buildings suggests an opportunity for cost effective investment.

Whether these investments could generate financial returns depends on the cost of capital for the investor. Assuming a 10-year lifetime, measures in this analysis would have an average rate of return ranging from 3 to 39 percent but if that lifetime is extended to 20 years (which would be much more typical), rates of return will increase to between 11 and 41 percent. These results are consistent with forward-looking modelling analysis of the commercial sector in Shanghai (He et al., 2016)

Assessing the ex-post retrofit data also provides an opportunity to assess the role of government subsidies in supporting retrofit investments. Results show that subsidies have had a substantial effect on the financial case for low carbon investment in both existing and new public buildings (
<Insert Fig. 3). The average payback periods of EE new and EE retrofit declined by 0.57 and 0.64 years, respectively. DGs and other sub-projects were not included in the government subsidy and thus have the same payback periods.

One case, the Near-Zero-Emission (NZE) building – Hongqiao State Guest Hotel Building 9 (marked on
<Insert Fig. 2) was excluded from the assessment as it applies a much higher

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[1] Pre-fitting refers to investments made to reduce in the environmental footprint of a building that would not otherwise be made and that are made before the buildings is complete. These are list as ‘EE new’ in the figure

retrofitting standard – no more than 35 kWh/m^2 of electricity consumption. The building achieved 49 tce/year of energy savings with USD 1.12 million of investment within the 3063 m^2 floor area. The payback period was 29.40 years without subsidy, and 16.03 years with subsidy, which is notably longer than other retrofits or even new buildings. The additional cost of this retrofit indicates the longer-term challenge of meeting the need for deep reductions in emissions.

<Insert Fig. 4. here>

Assessing the financial case of EE retrofit by building type, the strongest case is found on industrial properties and in schools and hospitals (
<Insert Fig. 4). For industrial properties, relatively short payback periods reflect the high energy needs of these properties and the intensity of property use: while other properties, including offices and homes are frequently unoccupied for a large portion of the day, industrial properties, by contrast, may be in use 24 hours a day. The relatively short payback periods for investments in schools and hospitals suggests an unrealised opportunity for public buildings to consider more aggressive retrofit options. On the other hand, offices and hotels have relatively longer payback periods, while also having a greater reduction in payback periods thanks to the subsidy (by 0.82 and 0.54 years, respectively). These findings suggest that subsidies have had the greatest impact on investments with relatively higher payback periods, which may potentially compensate the lower incentive for office and hotel owners on their energy bills: for example, offices and hotels may both see energy efficiency as a secondary concern to the comfort of their employees and guests. “Other” seems to have a quite long payback period, but this set comprises several diverse types of buildings, including the Hongqiao Airport Terminal 1 - a case that required much more investment than other retrofitting (
<Insert Fig. 2).

<Insert Fig. 5. here>

Assessing the composition of the investment on EE retrofits and EE new (Fig. 5), the loan from World Bank (IBRD) and investment from project developers clearly played a key role, while the two commercial banks (SPDB and BOS), were more active in investing EE new than EE retrofit. The total investment on EE retrofit and EE new were $105.23 and $242.04 USD, respectively (including government subsidies). The SPDB and BOS accounted for nearly half of the investment in EE new but less than 2% in EE retrofit.

Our findings are broadly consistent with other studies that have adopted a cost benefit analysis framework to explore the economically feasible opportunities for carbon reduction in building sectors in cities. For example, Krarti and Dubey (2018) estimated that a basic energy retrofit program applied to existing building stock in the United Arab Emirates (UAE) could achieve savings of 7550 GWh/year in electricity consumption, 1400 MW in peak electricity demand and reduce carbon emissions by 4.5 million tons on a yearly basis. The estimated average payback period was less than six months. Jo et al. (2010) conducted a 20-year cost benefit analysis to estimate the return on investment for solar reflective roof technologies on commercial buildings based on the energy simulation results. The results of the simulation modelling revealed that reductions of 1.3–1.9% and 2.6–3.8% of the total monthly electricity consumption can be achieved from the 50% cool roof replacement already implemented and a 100% roof replacement in the future, respectively. This corresponds to a saving of approximately $22,000 per year in energy costs at current prices and a consequent 9-year payback period for the added cost of installing the 100% cool roof.

5. Discussion

The World Bank-supported project (the Project) in Changning, Shanghai achieved modest building energy savings and revealed that for some investments the payback periods may be compatible with private investors' expected returns. Among all investment types, EE retrofits showed notably shorter payback periods and therefore could be considered a more cost-effective option for reducing greenhouse gas emissions, especially compared with setting up new energy-efficient buildings. If the average energy saving rate (approximately 20%) of this case can be realized at a city scale in Shanghai, with a rough estimation, the energy efficiency retrofitting of buildings would save 6 million tce of energy and reduce 12 million tons of carbon dioxide each year, which is about 6% of Shanghai's total carbon emission in 2015, and would require a further investment of CNY 90 billion (approximately $13.67 billion USD). A tremendous amount of investment needs to be financed by both government fiscal support as well as private investment to realize retrofits at such a scale. The collaboration developed between governments and NGOs in the Project seems to be a good start. In two keys areas, however, a review of the Project raises concerns around the potential for the Project to spur future financial institution involvement in commercial retrofits.

The first of these is with regard to the limited extent to which government support was able to leverage investment by financial institutions via participating commercial banks. While the investment by financial institutions contributed significantly to new building investments, less than 2% of retrofit investment in existing buildings came from financial institutions, in spite of the relatively higher return on investment these measures ultimately yielded. One explanation for this is that setting up new EE buildings is essentially real estate development rather than an energy efficiency measure, and thus may be more predictable, familiar and preferable to the banks. Investment in new buildings may therefore be considered to offer greater certainty for investors relative to investments in existing buildings. The second possible explanation is that the loan from the World Bank and subsidies from the government could be just enough for the relatively less costly retrofit of existing buildings, effectively crowding out other investment. Despite the fact that sub-projects showed a promising average payback period, there were widely different payback periods in each individual case. Other evidence was observed in the financing of China’s energy service companies (ESCOs) with an argument that the key barrier is at the operation level instead of policy level (Zhang et al., 2020). It is also pointed out that there has been a lack of tools and knowledge to assess the default risk of the retrofits, and a lack of verification and monitoring standards to evaluate the projects (Shen et al., 2013). Whatever the case, investment by financial institutions played a relatively limited role in EE retrofits during the program, at odds with the intention of the program and a missed opportunity for increasing the role of the financial institutions in financing building retrofits.

The second concern related to the Project’s influence on low carbon action in the building sector relates to the Shanghai carbon trading pilot. Carbon trading was found to be effective in creating incentives for reducing energy consumptions and driving behavioral changes in buildings (Nishida et al., 2016). The integration with the carbon trading system to stimulate investment was an objective of the Project, and was expected to bring greater economic incentives for building owners and financial institutions. However, almost all sub-projects were ultimately excluded from participating. This is in part a consequence of the small size of many sub-projects: Without sufficient annual energy consumptions and carbon emissions, most did not meet the minimum threshold of the trading market. Another possible contributing factor may have been intervention from the Changning government who may have had concerns about losing competitiveness to other districts or provinces (Interview 2, Interview 4), because property rent and real estate development would be more expensive in Changning due to the extra cost of reducing carbon if a carbon cap or benchmark was allocated to public and commercial buildings. The lack of competitiveness would have negative impact on regional GDP (Zhang and Duan, 2020) as well as tax revenue of the local government.

While the Project may have faced challenges increasing private investment in building retrofits, its influence on the wider governance of urban low carbon investment may both be more significant and lasting. Changning's Low Carbon Office played a critical role in the Project, acting as an "intermediary" that brought together the stakeholders (de Wilde and Spaargaren, 2019; Magnani et al., 2020). It provided technical support for ex-ante evaluations of the costs and benefits of the cases. It also helped identify cases with higher energy saving potential and financial viability and promoted coordination between local government, financial institutions, energy service companies and building owners, managers and users. At the same time the building energy monitoring platform developed in conjunction with the Project has significantly increased data availability on energy performance, helping investors to identify energy saving opportunities of each sub-project.

Scaling investment in building retrofits will require substantial increases in investment, almost by necessity requiring greater participation from private actors and less dependence on development organizations (such as the World Bank) and government subsidies. In equal measure scaling action will also require a tremendous increase in the availability and accessibility of information on low carbon actions, including information that is financial, technical, relating to energy use, and economic. In this context, the Project and its influence on the governance of low carbon action in Shanghai may help to establish the foundations for private actors to play a larger role in building retrofits in China.

Further, the so-called "shallow" measures adopted in the Project – for example the upgrade of heating, ventilation and air conditioning technologies – would not be sufficient facing the challenge of climate change. Although they generated modest energy savings, they missed the opportunities of deep decarbonising, which can usually realise energy savings of 65-75% (IEA, 2017), and may also lead to lock-in effects in the next few decades (Reyna and Chester, 2015). It is also important to note that a considerable amount of abatement potential comes from decarbonising the electricity grid. Therefore, the decarbonisation of electricity grids is crucial for achieving transformative change in the public building sector, and indeed for building low carbon cities more generally (Interview 1; Coalition for Urban Transitions, 2019).

6. Conclusion and policy implications

This study conducted an ex-post analysis and investigation on the World Bank-supported Project in Changning, Shanghai. The analysis showed that energy efficiency (EE) retrofits had a relatively short average payback period of 2.43 years, and government subsidies managed to significantly reduce the payback period to 1.79 years. The Low Carbon Office played an important role as an intermediary that provided technical and coordinating support. However, the subsidy and other government support did not leverage investment by financial institutions. Scaling up the case in Shanghai and realising wider impacts will require further action from urban and national policymakers in line with the following policy recommendations.

(1) Strengthening and improving economic incentives
Economic incentives could be strengthened by externality pricing, through the expansion of carbon taxation and/or the emissions trading market (Nishida et al., 2016). In this way concerns about competitiveness from cities and regions can be turned into opportunities for investment. Although government subsidies did not manage to bring the expected level of investment by financial institutions into EE retrofits, they are still critical for encouraging project developers. The government subsidies could be more flexible and dynamic. Since the cost of retrofit increases dramatically with higher energy saving targets, the government could further consider a progressive subsidy scheme that links the subsidy level to the energy savings achieved.

(2) Scaling up the intermediaries like Changning's Low Carbon Office
Economic incentives may not be sufficient to encourage investment by financial institutions, thus wider governance support or smarter financing is suggested to scale up building retrofits. Governments have a critical role to play in supporting coordination between the many and overlapping interests and needs of the stakeholders in retrofits. Local governments can help cities to establish dedicated umbrella agencies – like Changning's Low Carbon Office – which

provide technical and coordinative supports. These agencies could also help to build up the so called “one-stop-shop”, which packs a range of comprehensive services to reduce the transaction cost and diversify the risks (Pardo-Bosch et al., 2019). Further roles that such an office could assume in this context include facilitating research and knowledge transfer by identifying and communicating best practices, and raising awareness and education about green design. Overcoming those financial obstacles requires concerted action from urban and national policymakers, and stakeholders. A network of low carbon offices, facilitated by national actors, could create opportunities for knowledge transfer and learning.

(3) Better information on energy performance of building stock

While the Shanghai State Office Building and Large Public Building Energy Monitoring Centre serves as an example for other cities, better information on the energy performance of the building stock remains a barrier to academic inquiry and business activity in retrofitting. These barriers may be larger for buildings with the worst efficiency levels, leading to biased datasets emerging from the program. Expanding the coverage of the building energy performance monitoring system, specifically in public and commercial buildings, would require more mandatory measures than economic incentives (Liu et al., 2020). The improved data sets would not only make for more targeted interventions, improved modelling, and would enable planners to design interventions across entire neighbourhoods rather than single homes or offices, vastly improving the financial case, and also support improvements in the level of achievable impact.

(4) Raising building standards

Building standards also need to be raised for both existing and new buildings. Mandatory standards are usually considered inefficient measures, but will be a strong force to promote building retrofits (Huang et al., 2016). The currently in force mandatory standard in terms of energy performance of buildings regulates the design and construction phase (GB 50189-2015), while the standard that regulates the energy consumptions of the operation phase is voluntary (GB/T 51161-2016). The Chinese government chose to mandate the former because it is easier to implement and verify on new buildings (Interview 1). The national government should consider making retrofitting compulsory for old buildings that do not meet the energy performance standards. Furthermore, China has been developing the “Three Star” system for energy performance assessment and certification, which is currently voluntary. (Geng et al., 2012). Expanding this kind of certification can be combined with density bonus initiatives to generate interest for developers to promote building retrofits (Schmitt et al., 2007).

(5) Promoting research and development on deep retrofits

The “shallow” retrofits implemented in the Changning Project may not be a sufficient response to climate change in the long run. The NZE building in this project seemed to achieve the expected “deep” retrofit but with a significantly higher cost. Governments will have to continue to support research and development on deep retrofit technologies and innovations and avoid “cherry-picking” the lower-cost, higher-return options, locking buildings or even entire cities into a mildly rather than a deeply decarbonised future (IEA, 2017) and should not overlook the need for a smart adaptation to the impacts of climate change simultaneously.

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