Improving Energy Efficiency for All: Lessons on sustainable building retrofits from Shanghai, China

Oates, L.E.; Yu, Zhongjue; Sudmant, Andrew; He, Qi; Gouldson, Andy; Lee, Adam

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IMPROVING ENERGY EFFICIENCY FOR ALL: LESSONS ON SUSTAINABLE BUILDING RETROFITS FROM SHANGHAI, CHINA

Lucy Oates, Zhongjue Yu, Andrew Sudmant, Qi He, Andy Gouldson and Alan David Lee

Summary

Worldwide, urban areas consume between 60% and 70% of total primary energy,[1] of which buildings account for close to half. With trillions of tonnes of carbon-intensive concrete already poured, and many of the buildings that will be operational for decades to come already built, improving the energy efficiency of existing buildings through retrofit is often a priority for climate action.

In Shanghai, China, one district has emerged as an example of leadership in China's green buildings sector. Changning District established a dedicated entity – the Changning Low Carbon Office – to coordinate energy efficiency retrofitting efforts. Additionally, the District created China's first online platform for monitoring the energy performance of buildings and is working with municipal and national government to offer subsidies to incentivise investments in retrofitting. Thanks to effective collaboration between all tiers of government, retrofits have been rolled out across almost half of the district's public and commercial floor space, with energy reductions of between 20% and 30% per building. This reduction is preventing the emission of around 190,000 tonnes of carbon dioxide (CO_2) annually – the equivalent of removing 65,000 cars from Shanghai's streets.

CONTENTS

Coalition for Urban Transitions
c/o World Resources Institute
10 G St NE
Suite 800
Washington, DC 20002, USA

C40 Cities Climate Leadership Group
3 Queen Victoria Street
London EC4N 4TQ
United Kingdom

WRI Ross Center for Sustainable Cities
10 G St NE
Suite 800
Washington, DC 20002, USA

ABOUT THIS POLICY BRIEF

This policy brief was prepared by the University of Leeds. It was developed in partnership with the Coalition for Urban Transitions, which is a major international initiative to support decision makers to meet the objective of unlocking the power of cities for enhanced national economic, social, and environmental performance, including reducing the risk of climate change. The research presented here was conducted in support of the Coalition's Economics workstream, and builds on previous University of Leeds and Coalition research on the economic and social benefits of low-carbon cities. The opinions expressed and arguments employed are those of the authors.

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Apartment buildings in Shanghai.
Credit: Humannet / Shutterstock

Scaling up the actions from Changning would contribute significantly to China's low-carbon urban development agenda. Analysis shows that extending the programme across commercial buildings in Shanghai could save nearly 9 megatonnes of carbon dioxide equivalent (CO_2e) annually compared with the business-as-usual pathway. This would be equivalent to removing 3 million cars from the road in China or eliminating all the emissions of a medium-sized US city like Atlanta. Moreover, the payback period on the upfront costs for such a programme may be as little as eight years.

The Chinese national government has played a crucial role in shaping the retrofitting programme in Changning. It could further promote improvements in building energy efficiency by adopting a comprehensive political, legislative and fiscal framework that offers or enables access to finance, sets stringent energy performance targets, establishes incentives to engage in ambitious improvements and provides transparency on progress. It could continue to offer financial incentives to stimulate market development for retrofitting, such as access to public subsidies for ambitious renovation projects, and could develop energy efficiency benchmarks and standards for existing and new buildings. The Chinese national government could also require all buildings to disclose their energy performance. Finally, it could encourage city governments to set building energy efficiency targets that exceed the national ones.

This policy brief is one of a series on frontrunning climate actions in cities around the world. The objective of this series is to strengthen the evidence on the economic and social implications of low-carbon, climate-resilient urban development. The series focuses on providing robust data on ex post outcomes of climate action, ranging from better public health to job creation to greater equity. Each case study explores some of the preconditions for the successful design and delivery of urban climate action and provides national policy recommendations that could enhance their effectiveness and the scale of their benefits.

Highlights

- Improving the energy efficiency of and reducing energy use in buildings could contribute significantly to the achievement of the Paris Agreement and a number of the Sustainable Development Goals (SDGs). It is an area with huge potential for carbon saving: more than half of urban abatement potential (not including industry) is attributable to the buildings sector.
- Many of the buildings that will shape future energy use already exist. Replacing older, less efficient buildings with newer, more efficient ones can have significant carbon implications. Retrofitting is therefore crucial for reducing current energy consumption and its associated emissions; improving the quality of the existing building stock; and preventing further emissions generated by the demolition of old buildings and construction of new buildings.

- Retrofitting is especially relevant in a Chinese context given the sheer scale of the development that has already taken place. It has been claimed that between 2011 and 2013 China used more cement than the US used in the entire 20th century.[2] Moreover, the average lifespan of a Chinese building is 35 years, extremely short compared to the 74-year average lifespan of US buildings and the 132-year average lifespan of buildings in the UK.[3] Even simply extending a building's lifespan before it has to be rebuilt can contribute to preventing substantial emissions – and improving the building's efficiency and comfort at the same time.
- Changning District in Shanghai has emerged as a leader on retrofitting in China. It has led or participated in several major interventions to improve building energy efficiency. It has formed a dedicated entity – the Changning Low Carbon Office – to coordinate its efforts in energy efficiency retrofitting, has worked with municipal and national government to incentivise retrofit investments and has rolled out a retrofitting programme across almost half of the district's public commercial floor space.
- In 2007, Changning District created China's first online platform for monitoring the energy performance of buildings. The platform has since been replicated in each of Shanghai's 17 districts and at the city level to monitor the public buildings of its respective jurisdictions. The Shanghai State Office Building and Large Public Building Energy Monitoring Center now monitors the energy consumption of 1,687 commercial and public buildings, accounting for 78 million square metres (m^2) of floor space in Shanghai.
- There is a strong financial, environmental and social case for retrofitting. Analysis of 67 energy efficiency sub-projects in Shanghai finds that for older buildings retrofitting can have a payback period as low as four years, shortened to three years when taking into account government subsidies. Retrofitting actions substantially reduce operational greenhouse gas emissions by between 20% and 30%, and can also generate a host of co-benefits – including improved indoor conditions for building inhabitants; the creation of new, green jobs; an increase in real estate value; and improved local air quality.
- Scaling up these projects across commercial buildings in Shanghai could save nearly 9 megatonnes of CO_2e annually compared with the business-as-usual pathway, reducing emissions from the commercial sector by one-quarter. This would be equivalent to removing 3 million cars from the city's roads or eliminating the entire emissions of a medium-sized US city such as Atlanta. Not only would such a programme cover its costs but would even start to generate financial returns after just seven years.
- To support retrofitting programmes, the national government should create a national action plan for a zero-carbon building stock. It should also maintain and update subsidies for energy efficiency retrofitting and stimulate further investment by creating a revolving retrofit fund; develop and publish energy efficiency performance ratings for buildings; and, ultimately, mandate a certain standard of energy performance for all buildings.

1. Background

THE GLOBAL CHALLENGE

Worldwide, urban areas consume 80% of energy, of which buildings account for an estimated 30 to 40%.[4] In total, energy use in buildings in urban areas accounts for roughly one-third of all global energy use.[5]

The urban built environment is an area in which intensive climate action could yield significant benefits for the economy, society and the environment, including contributing substantially to achieving many of the SDGs (see Box 1).[6] Similarly, the New Urban Agenda recognises that promoting green construction methods and energy efficient buildings could contribute to the reduction of greenhouse gases; the creation of new decent jobs; improvements in public health and reduced energy bills.[7]

BOX 1 Green buildings and the SDGs

In 2015, all United Nations Member States adopted 17 Sustainable Development Goals as part of the 2030 Agenda for Sustainable Development. These interconnected goals seek to address critical global challenges "including those related to poverty, inequality, climate change, environmental degradation, peace and justice".[8] Green buildings can contribute to the achievement of these goals in the following ways:

- **Goal 3 (good health and well-being):** green buildings enhance the health and well-being of their occupants
- **Goal 7 (affordable and clean energy):** green buildings improve energy efficiency
- **Goal 8 (decent work and economic growth):** designing and building green buildings creates new, green jobs
- **Goal 9 (industry, innovation and infrastructure):** the design of green buildings spurs innovation
- **Goal 11 (sustainable cities and communities):** green buildings will reduce the environmental impact of urbanisation
- **Goal 12 (responsible consumption and production):** green buildings reduce energy demand and improve the efficiency of resource use
- **Goal 13 (climate action):** green buildings produce fewer emissions and help to combat climate change

There is huge potential to improve the efficiency of buildings: 58% of the urban abatement potential outside of the industrial sector is attributable to the buildings sector.[9] More than half of this abatement potential comes from decarbonising the electricity grid, meaning wider energy system decarbonisation (and the electrification of energy systems that currently rely on fossil fuels) is critical for decarbonising buildings.[10] The remaining reduction could be achieved through efficiency improvements, by retrofitting existing buildings, installing appliances and promoting user behaviours that lead to significant reductions in energy use without accompanying reductions in comfort (as well as constructing very low or zero-emission new buildings).

Buildings require energy for lighting, cooling and heating of space and water, ventilation, and appliances such as computing and electronic equipment, among other things. These are all areas in which substantial technological improvements have been proven but not yet widely implemented across the world's building stock.[11] Implementing energy efficiency measures in these areas – for example by replacing lightbulbs with light-emitting diodes (LEDs); insulating walls and heating systems; improving monitoring and installing energy-efficient appliances – has the potential to generate a two- to tenfold reduction in energy requirements in a cost-effective way.[12]

Improving energy efficiency in existing buildings can be more challenging than constructing new energy-efficient structures. Older buildings often adhere to outdated and inefficient standards – if they adhere to any standards at all – and tend to have higher energy intensities than those of buildings constructed today.[13] Barriers to improving building energy efficiency 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, inadequate access to financing and the physical limitations imposed by the building's form.

To replace the entirety of the building stock, however, is more than simply impractical. In addition to being relatively expensive and time consuming, new-builds require new materials, leading to substantial greenhouse gas emissions. Emissions incurred during the construction phase – so-called 'embodied emissions' – typically account for 10–20% of a building's lifetime emissions.[14] These include, for example, emissions associated with the extraction, processing, manufacturing and transportation of raw materials. To avoid the catastrophic social, economic and environmental impacts of demolishing and rebuilding entire neighbourhoods, significant, coordinated and sustained policy interventions supporting the development of finance and business models to achieve the high rates of building retrofits are needed.[15]

THE CHALLENGE IN CHINA

In recent years, China has experienced dramatic economic and population growth, accompanied by rapid urbanisation, and has surpassed the US to become the world's largest energy consumer and greenhouse gas emitter.[16] Buildings have contributed significantly to this growth, with the total consumption for which the buildings sector is responsible more than tripling from 300 million tons of coal equivalent (Mtce) in 2001 to 906 Mtce in 2016.[17] They account for a fifth of the country's total primary energy consumption[18] and a quarter of greenhouse gas emissions,[19] of which commercial and public buildings contribute around one-third.[20]

Based on projected urbanisation in China over the next 20 years, energy demand for buildings and appliances will triple again based on business-as-usual construction[21] – and the climatic impacts of this would be felt globally.[22] Driven by rising emissions and worsening air pollution, China intends to transition to a more sustainable mode of urban development, exemplified by the country's 2015 commitment to peak its carbon emissions by 2030 or sooner.[23] The Chinese government, aided by a growing body of academic research, is beginning to explore the opportunities that energy efficiency retrofitting offer for low-carbon urban growth.

> **Based on projected urbanisation in China over the next 20 years, energy demand for buildings and appliances will triple again based on business-as-usual construction – and the climatic impacts of this would be felt globally.**

China consumed 6.6 gigatons of cement between 2011 and 2013 – more than the US used in the entire 20th century[24] – and the average lifespan of a Chinese building is only 35 years, extremely short compared to the 74 year average lifespan of US buildings and 132 year average lifespan of buildings in the UK.[25] This is important because 10 to 20% of the emissions footprint of a building that is expected to last between 50 and 75 years will typically be embodied in its construction without a major shift to low-carbon construction materials.[26] This implies that rebuilding China's buildings after only 35 years would double the share of embodied construction emissions. Even a building retrofit that does nothing more than simply extend the lifetime of a building before it has to be rebuilt can therefore contribute to preventing substantial emissions, even without affecting a building's operational energy use.

Electricity use accounts for 30% of total energy consumption in urban buildings in China.[27] Of this, 72% is generated by coal.[28] Coal is also the source of around 80% of heating in urban buildings, including that generated from coal-powered electricity.[29] Coal-fired thermal power plants contribute significantly to China's worsening particulate air pollution and increasing greenhouse gas emissions,[30] with greater affluence and its associated lifestyle changes further contributing to these trends.[31] Achieving the change necessary to transform the buildings sector will therefore rely on decarbonising China's electricity grid and reducing its coal dependency.

Retrofitting can contribute to reducing a building's reliance on coal-based heat and energy, for example by reducing heating and cooling requirements, and can generate a host of co-benefits, including improved air quality, and greater comfort and thus productivity of building users. Building energy efficiency is a key objective for the Chinese government to meet its broader energy efficiency and emissions reduction targets.[32]

2. Methodology

This policy brief is based on work undertaken by researchers from University of Leeds, Shanghai Jiao Tong University and the University of International Business and Economics.

The research presented is based on an analysis of data from the Shanghai State Office Building and Large Public Building Energy Monitoring Center,[a] and the World Bank's Implementation Completion and Results Report of the project "Green Energy for Low-Carbon City in Shanghai".[33]

To evaluate the cost effectiveness for energy efficiency measures in the buildings sector of Shanghai, an integrated building/sub-project-based cost and benefit assessment was carried out. Analysis involved aggregating potential economic savings from energy reductions by two types of energy (namely electricity and natural gas), allowing for analysis of the overall investment needs and paybacks from energy efficiency measures adopted in the buildings. For the purposes of this assessment, we assumed that the energy savings of sub-projects were 100% electricity (except for hotel energy savings, which were 70% electricity and 30% natural gas). The proportion of energy types used is in line with the annual building energy consumption monitoring report from the Shanghai State Office Building and Large Public Building Energy Monitoring Center.[34]

The analysis was supported by discussions with project workers, academics, key non-governmental organisations, members of government and firms working in the retrofitted buildings, and by extensive document analysis of public policies, project documents, academic publications and media reports.

[a] Data available at: http://www.shjzjn.org

Table 1: List of interviewees

STAKEHOLDERS	METHODS
Academia	3 interviews
International agencies	2 interviews
Non-governmental organisations	1 interview
District government	1 interview
Private sector	1 interview

3. The policy context

THE NATIONAL CONTEXT

China has been pursuing building energy-saving for many years and recently has done so in the wider context of efforts to mitigate climate change and improve energy efficiency.

China's Five Year Plans (FYP) have mapped development strategies and set targets for decades. Table 2 summarises the relevant national targets, as well as municipal targets. Targets from broad perspectives such as energy saving and carbon emission reduction come from the FYP for greenhouse gas reduction and the FYP for Energy Conservation and Emission Reduction. Targets for public buildings come from the FYP Special Plan for Building Energy Conservation. These targets were achieved by a number of approaches, namely energy-saving retrofits of existing residential buildings, improving building energy efficiency, expanding the energy monitoring system of large public buildings, expanding the implementation of renewable energy, applying the latest green building standards, promoting advanced wall materials, and improving the relevant legislation system.

Table 2: Targets for energy saving and public building retrofit in China's recent FYPs

	12TH FYP	13TH FYP
National targets		
Reduce energy consumption (tce) per unit of GDP[i]	16%	15%
Reduce CO_2 emissions per unit of GDP[i]	17%	18%
The proportion of non-fossil energy in primary energy consumption	11%	15%
Energy consumption savings[ii]	670 mtce	NA
Cap of total energy consumption per year	NA	5 billion tce
Energy saving retrofit of public buildings	60 million m^2	100 million m^2
Reduce energy consumption per m^2 in public buildings	10%	NA
Shanghai targets		
Reduce energy consumption (tce) per unit of GDP[i]	18%[iii]	17%[iii]
Reduce CO2 emissions per unit of GDP[i]	19%[iii]	20.5%[iii]
The proportion of non-fossil energy in primary energy consumption	12%	14%
Cap of total energy consumption per year	NA	123.57 mtce
Energy saving retrofit of public buildings	10 million m^2	10 million m^2

tce = ton coal equivalent; GDP = gross domestic product

i The percentages are based on the results of the previous FYP.
ii During the whole FYP period.
iii Instructed by the state council in national FYPs.

In addition to the regular plans and targets set every five years, the National Development and Reform Commission in collaboration with the Ministry of Housing and Urban-Rural Development proposed the Plan for Green Building Act in 2013. This plan not only came with public building retrofit targets that are in line with the FYPs but also suggested specific technologies for achieving the targets, such as energy saving retrofits of heating, ventilation and air conditioning, LED lighting, hot water supply systems, implementation of solar power and real-time monitoring of energy consumption.

THE MUNICIPAL CONTEXT

Cities are major players in the national government's climate action strategy. As a municipality, Shanghai takes direct instructions from the national government on the targets of energy intensity and carbon intensity, while also being empowered to set its own targets to tailor the national FYPs (Table 2). In recent years, Shanghai – and districts within it – have engaged in a range of complementary energy efficiency retrofitting projects, the most relevant of which are outlined below.

Shanghai Subsidy for Building Energy Efficiency

In 2009, the Special Subsidy for Building Energy Efficiency Projects in Shanghai (No. 816) was established to incentivise actors to improve building energy-efficiency. Funded equally by the central and the municipal government, the Special Subsidy is regularly updated to adapt to improvements in the sector (Figure 1). Update No. 311, issued in 2013, supported retrofit projects that reduced energy consumption per m^2 by more than 20%. Qualifying projects received CNY 40.00 (US$5.70)[b] per m^2 if they applied Energy Performance Contracting, wherein an external energy savings company implements a project and recovers the costs from the savings, or CNY 35.00 (US$4.99) per m^2 otherwise. The total amount of subsidy should not exceed 50% of the total investment of the project. Qualifying projects – known as "demonstration projects" – are shared widely to raise awareness about the potential of energy efficiency retrofitting.

Changning District Green Growth Strategy

In 2013, as part of its Green Growth Strategy, the Changning District government established its own district-level subsidy for energy-saving building retrofits. The aim was to signal to investors and project developers that the district government would guarantee strong support for retrofitting and to encourage early participation in the programme. Changning District offered building retrofit projects that saved at least 50 tce each year a subsidy of CNY 1,000 (US$143) per ton of coal equivalent avoided or CNY 450 (US$63) per ton of CO_2 equivalent (tCO_2e) annual emissions reduction. Changning District also provided 30% compensation for any losses incurred during a renovation project that interrupted normal business operations for six months or more. The total amount received would not exceed CNY 1 million (US$142,000).

At the same time as it created its own district-level subsidy, Changning District also attracted international support from the World Bank, who pledged more than US$100 million to provide technical assistance and capacity building to support low-carbon investments that reduced the need for grid-supplied electricity in buildings. The Shanghai and Changning subsidies remain operational; the World Bank-supported project was completed in 2018 (Figure 1).

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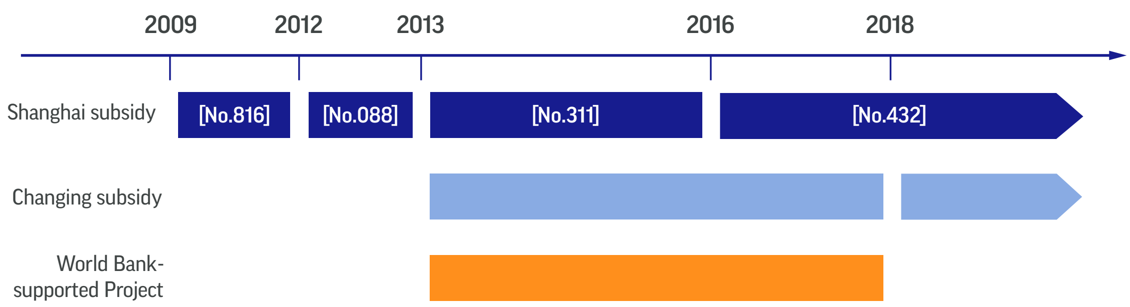
[b] 1 CNY = 0.142690 USD (xe.com, 27 February 2020).

Figure 1: Timeline of support to energy-saving retrofitting, 2009 to present



4. The case study: energy efficiency retrofits in Shanghai

With a population of more than 26 million, Shanghai is China's second largest city. Although the city has reduced the energy intensity of its GDP in recent years, absolute energy use and the associated levels of greenhouse gas emissions continue to be driven upwards by an increasing population and economic growth.[35] Like the country's capital, Beijing, Shanghai's per capita carbon emissions are more than double the national average, and three times the national average when the upstream and downstream emissions of the goods and services consumed in Shanghai are taken into consideration.[36] Driven by the social and environmental costs of this rapid growth, Shanghai has become a pioneer among Chinese cities, implementing programmes to shift the economy onto a lower-carbon path.

Changning District has emerged as a leader in China's green buildings sector and has led or participated in several major interventions to improve building efficiency since the district government identified green growth as a core objective for economic development. These include: establishing the country's first online platform for monitoring the energy performance of buildings; forming a dedicated governance entity to coordinate its efforts in energy efficiency retrofitting; working with municipal and national government to offer subsidies; and rolling out a retrofitting programme across almost half of the district's public commercial floor space. These efforts have since been replicated or implemented beyond Changning's borders into wider Shanghai.

SUCCESSES

In 2007, Changning District pioneered China's first online platform for monitoring the energy performance of public buildings, strengthening data collection and evaluation capacities. The monitoring platform collects and analyses real-time energy use data at the building level, allowing inefficiencies and opportunities for targeted interventions to be identified. The platform was used as a model for the entire city in 2012 when, as part of the 12th FYP, the city government mandated that every district should have a similar programme. The Shanghai State Office Building and Large Public Building Energy Monitoring Center now monitors the energy consumption of 1,687 commercial and public buildings, accounting for 78 million m^2 of floor space in Shanghai (see Box 1 for an example of how this has been used).[37]

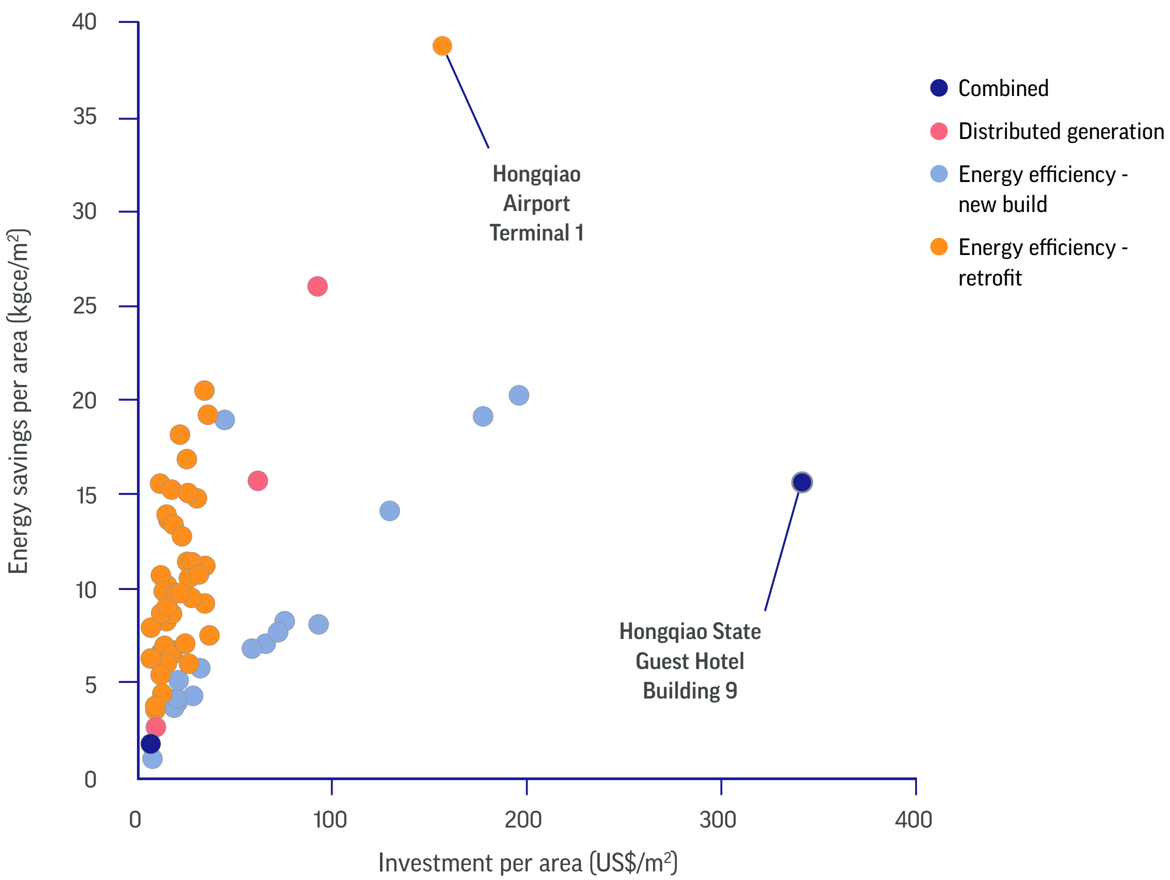
BOX 2 Energy monitoring platform in Huangpu District[38]

The Shanghai State Office Building and Large Public Building Energy Monitoring Center, based on the energy monitoring platform pioneered in Changning, is now used across the whole city. Each of Shanghai's 17 districts has also established a version in their own jurisdiction. In Huangpu District, the use of a district-level energy monitoring platform has enabled the government to overcome the challenge of a distribution grid that is plagued by insufficient capacity in hot weather. Since the launch of the online building energy monitoring platform, the service provider has been able to identify opportunities for large buildings to voluntarily reduce energy demand at the request of the State Grid Corporation of China. The impact on building users is marginal, but when aggregated it helps to balance supply and demand. In return for reducing their consumption the buildings receive discounts on their next energy bill.

Changning District has also formed an office dedicated to low-carbon management – the Changning Low Carbon Office – to coordinate its energy efficiency retrofitting efforts. With strong representation from local government leaders, the Changning Low Carbon Office 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. The Office is now called upon to support projects in other districts, serving as a key conduit for knowledge transfer. Data collected by the Shanghai State Office Building and Large Public Building Energy Monitoring Center shows that the Changning Low Carbon Office coordinated the retrofit of 45% of the 4 million m^2 of public and commercial floor area in Changning District between 2013 and 2018.[39]

With a successful pilot model in place in Changning, the district and municipal government, with financial and technical support from the World Bank,[40] rolled out a retrofit programme across the metropolitan area. A further 67 sub-projects have been supported by the Changning Low Carbon Office across wider Shanghai since 2016. Of these 67 sub-projects, 47 were retrofits and 20 were related forms of energy efficiency interventions that involved measures such as improvements to lighting, heating, ventilation and air conditioning systems, insulation, energy management systems, and low-carbon distributed generation systems (see Figure 2). The sub-projects cover 5.87 million m² of floor area (including outside of Changning District) and prevent 189,944 tonnes of CO_2 emissions annually.[41] This reduction in emissions is equivalent to removing more than 65,000 cars from the road. Supported by improvements in the national electricity grid's emissions intensity, these interventions could lead to emissions reductions of well over 50% by 2030, ahead
of national targets.[42]

Figure 2: The efficiency of low-carbon investment across 67 sub-projects

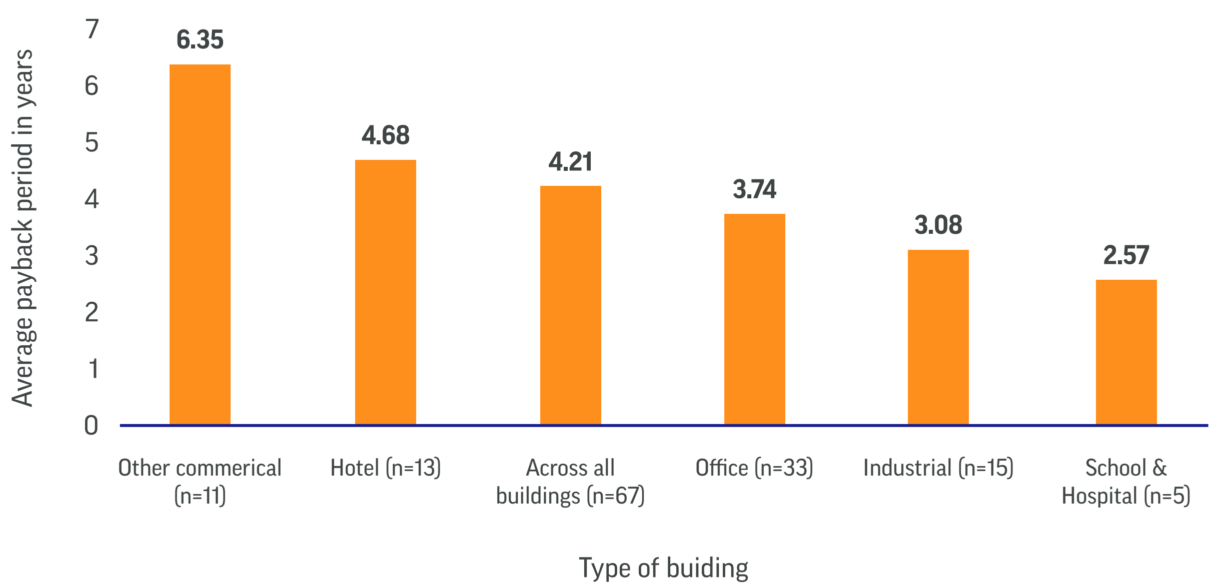


Notes: Hongqiao Airport Terminal 1 achieved annual energy savings of 38.69 kilograms of coal equivalent per m² (kgce/m²) from US$157.51/m² of investment. The average investment in new buildings ("EE new") was US$67.10/m², and the average annual energy saving was 8.51 kgce/m². Hongqiao State Guest Hotel is a demonstration project of a near-zero emission building.

While forward-looking analyses that assess the economic opportunity for low-carbon interventions in the buildings sector and other areas of the economy are relatively common,[43] retrospective analyses that assess interventions after they have taken place are less so. This is particularly the case in the commercial buildings sector, where private entities have neither the incentive nor inclination to make energy-use data public.

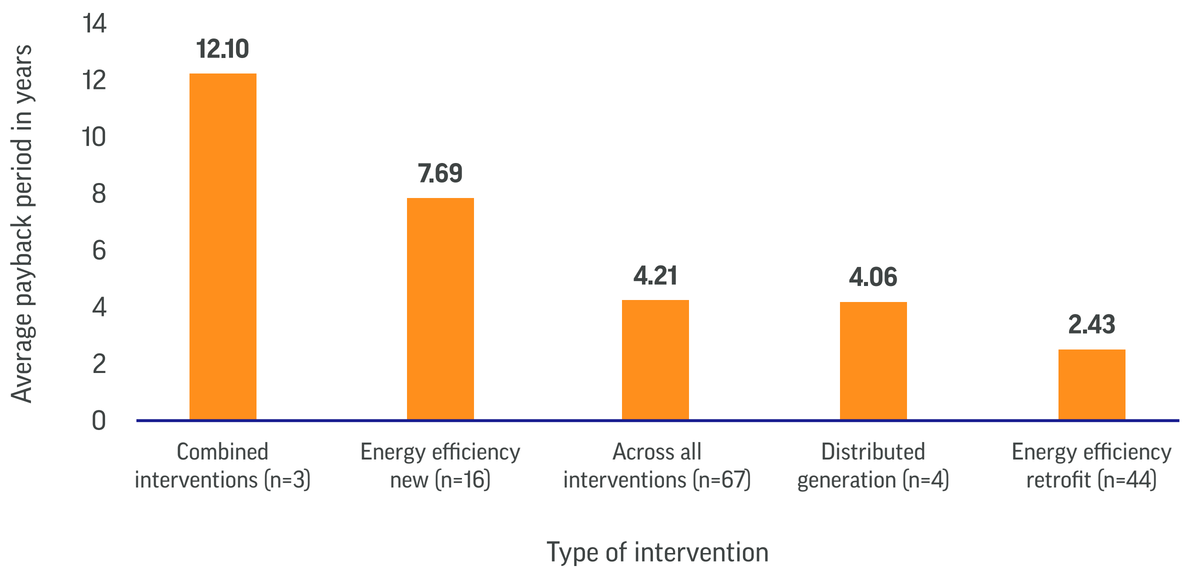
Data on the cost, energy intensity and emissions reductions from the 67 sub-projects in Shanghai reveal a strong financial case for retrofitting. As Figures 3 and 4 show, payback periods for some buildings may be as little as four years – or three years when taking into account government subsidies. Assessing the interventions according to their location, the strongest argument for retrofitting is presented by industrial properties, schools and hospitals (Figure 3). 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 aggressive retrofit options.

Figure 3: Payback periods for interventions by building type (years)



Assessing interventions by type, the strongest financial case for action is for retrofitting older buildings. This is illustrated by Figure 4, wherein "energy efficiency retrofit" refers to existing buildings and "energy efficiency new" considers buildings that are to be built or recently finished. This finding may reflect the relatively high energy efficiency standard of newer buildings and provides a strong case for deep retrofits in place of knocking down and replacing older buildings. New buildings may be built to a higher standard, but the energy efficiency benefits will come at the cost of substantial emissions from new materials used in construction.[44]

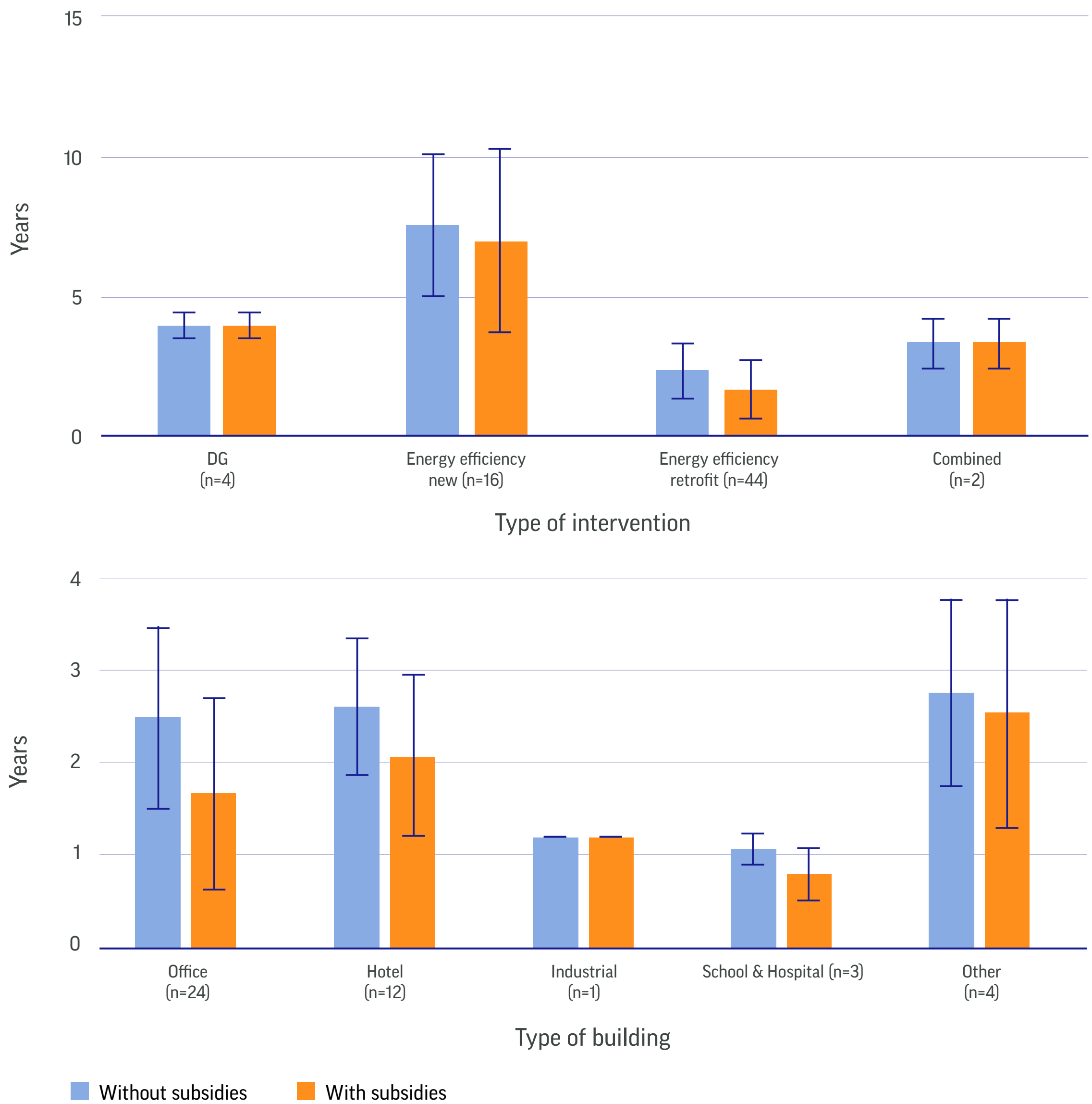
Figure 4. Payback periods for interventions by intervention type (years)



Across all interventions – whether assessed by type or location – a strong financial case for low-carbon action is revealed. Assuming a 15-year lifespan, measures in this analysis would have a rate of return ranging from 3% to 18%. Extend that lifespan to 25 years (which would be much more typical) and rates of return increase to between 13% and 20%, exceeding typical borrowing costs. This evidence is consistent with forward-looking modelling analysis of the commercial sector in Shanghai[45] and makes the case that investments can be made with confidence.

Assessing the post hoc retrofit data also provides an opportunity to assess the role of government subsidies in supporting retrofit investments.[46] Results show that subsidies have had a substantial effect on making the financial case for low-carbon investment in offices and hotels, and in supporting actions in recently completed, or soon to be constructed, commercial buildings (Figure 5). These findings suggest that subsidies have had the greatest impact on investments with relatively higher payback periods, and potentially a lower incentive to focus on energy bills: for example, hotels and offices may both see energy efficiency as a secondary concern to the comfort of their guests and employees.

Figure 5: Payback period with and without subsidies, by intervention and building type



Beyond offering a cost-effective way to reduce emissions, energy efficiency retrofitting can generate a host of social, economic and environmental co-benefits.[47] Retrofitting has been proven to improve conditions for building inhabitants by making buildings more comfortable and functional: the people living and working in efficient buildings enjoy cleaner indoor air, more natural light and more comfortable temperatures.[48] For office buildings, these improved conditions lead to an increase in workers' productivity.[49] Further economic advantages include the creation of new, green jobs and an increase in the value of real estate.[50] Reducing emissions and energy use could even impact regional air quality – a serious concern in Chinese cities – by limiting the emission pollutants and particulate matter generated from burning coal.[51]

OVERCOMING CHALLENGES AND SCALING UP THE BENEFITS

Changning District has experimented with innovative new policies, built on successes and shown willingness to go beyond the energy efficiency efforts of other regions of Shanghai, and of China. In doing so, it has demonstrated that large-scale retrofitting programmes can achieve success, despite numerous challenges.[52]

Scaling up the actions from Changning to Shanghai would contribute significantly to China's agendas of low-carbon urban development, green growth and climate change mitigation efforts. Indeed, these actions would be notable on a global scale. Applying results from this analysis and the most recent data from the Shanghai Statistical Yearbook to a model of the commercial sector in Shanghai shows that a programme across the city's entire commercial building stock could save nearly 9 megatonnes of CO_2e annually compared with the business-as-usual pathway (Figure 6).[53,] This represents approximately one-quarter of emissions from the commercial sector – equivalent to removing 3 million cars from the road or the entire emissions of a medium-sized US city such as Atlanta.[54] Such a programme would cost US$7.7 billion, and have a payback period of approximately eight years.

Figure 6: Emissions in Shanghai's commercial building stock with and without retrofit

Note: This figure is based on a model of Shanghai's emissions by sector, from which results from the residential sector are published.[55]

This level of action would both meet China's targets for peaking greenhouse gas emissions by 2030 and a wider need to halve emissions in the same period. With support from decarbonising the electricity grid – which is the source of approximately three-quarters of emissions from the commercial sector[56] – emissions from the commercial sector in Shanghai could decline dramatically further. Beyond the impact on emissions and energy use, scaling up Changning's retrofitting programme citywide could generate substantial employment. Using established figures for the number of jobs created per million of investment, more than 110,000 job years of green employment could be created in skilled positions. Realising this opportunity will require concerted action from urban and national policy-makers. While the overall financial case appears to be strong, many buildings will face individual challenges in raising funding as a result of particular issues – for example bespoke architectural features or business-specific challenges. In addition, many building owners may continue to see retrofitting as a lower priority than other uses of their time and resources. Subsidies to encourage retrofitting will therefore be critical. Meanwhile, the government can also consider the implicit role that subsidies for fossil fuels (including oil, natural gas and coal) play in discouraging retrofitting while contributing significantly to greenhouse gas emissions and poor air quality in cities.[57]

Governments will need to work more closely with the private sector to raise the levels of finance that will be required to achieve the necessary transformation of the building stock. Public-private partnerships are one well-established approach for this.[58] Such partnerships will need to be designed carefully to maximise public benefits for which there may not be an explicit monetary return and to ensure retrofits are sufficiently "deep" and do not only "cherry-pick" the lower-cost, higher-return options, locking buildings or even entire cities into a mildly, rather than a deeply, decarbonised future.[59]

Making data more timely

Scaling the interventions implemented in Changning will require better information on the energy performance of the building stock. At the city level, statistical yearbooks lack data on energy efficiency and there is usually at least a two-year gap between data collection and release. This means that private, academic and public actors have an incomplete and already out-of-date picture of the opportunity for action. Improved data sets would not only make for more targeted interventions – and better, more reliable modelling – but would also enable planners to design interventions across entire neighbourhoods rather than single homes or offices, vastly improving the financial case for retrofitting by bundling actions together. Continuing to make energy performance data widely available by establishing city- and nationwide platforms for energy performance reporting – like the

Shanghai State Office Building and Large Public Building Energy Monitoring Centre – would significantly increase transparency and could in turn help to stimulate both investment and access to finance by demonstrating the viability of energy efficiency improvements.

Developing more stringent building standards

Better data would form the basis for more stringent building standards, which are needed for both existing and new buildings. Existing initiatives, such as the Three Star System for energy performance, are purely voluntary, which creates gaps in energy efficiency data sets and potentially discourages the participation of building owners who know that their properties would have poor results.

Similarly, it will be vital to ensure that standards are user, rather than technology, focused,[60] and account for the ways in which people live and work in buildings in order to maximise the benefits to public health, economic productivity and well-being that can come with retrofits.[61] A "whole building" approach that takes into account the construction, management and use of buildings when both designing and assessing energy efficiency interventions, and that focuses on the energy efficiency outcomes rather than particular technologies, should form the basis of these improved standards. In this area, the approach China has taken in other areas of policy – namely target-setting at a national level, and support for experimentation and competition at the urban level – may yield benefits.[62]

Supporting coordination within and between districts

National governments have a critical role to play in supporting coordination between the many and overlapping interests and needs of local governments, private actors and building owners, users and managers. Improving coordination not just within, but also between, districts would help to aggregate citywide opportunities for building owners and managers to participate in energy efficiency retrofitting schemes. This would help to reduce the high transaction costs involved for individual buildings and help to address concerns about competitiveness – two major barriers that remain in Changning.[63] One way in which national governments could improve coordination would be to help cities establish dedicated umbrella agencies – like Changning's Low Carbon Office, but at city- rather than district-level – that would manage the roles, responsibilities and expectations of all actors. An office like this could also facilitate research and knowledge transfer by identifying and communicating best practices; raise awareness and education about green design; and build technical and institutional capacity to design and implement energy efficiency programmes.

5. Policy recommendations

Five main policy recommendations emerge from this study:

1. **Create a national action plan for zero-carbon building stock, demonstrating the potential of energy efficiency retrofitting through public buildings**

   At the national level a comprehensive political, legislative and fiscal framework is needed which offers or enables access to finance, sets stringent building standards, establishes incentives to engage in ambitious improvements and provides transparency on progress. Energy market reform should also be a key objective of any national plan for zero-carbon building stock, given that decarbonisation of electricity grids is crucial for achieving transformative change in the commercial buildings sector and for building low-carbon cities more generally. As well as taking specific actions as part of a plan-zero carbon building stock (such as those outlined in the following recommendations), national governments can put in place a broader supporting governance framework. For example, national governments should help cities to establish dedicated coordination bodies – like Changning's Low Carbon Office – through which agencies can engage across sectors and share best practices, and they should build capacity by educating built environment professionals on energy efficiency, for example by offering accreditation in green design.[64] National governments should also lead by example, ensuring that all public buildings adhere to or exceed stringent building standards and disclosing publicly their energy performance (see recommendations 3, 4 and 5).

2. **Maintain subsidies for energy efficiency retrofitting while stimulating market investment**

   As well as legislative support, the national government should offer financial incentives to stimulate market development, such as access to public subsidies for ambitious renovation projects that reduce energy consumption by more than half. Central subsidies can drive local matching funds and thus stimulate market investments.[65] Linking the subsidy level to the savings achieved may encourage energy companies and building owners to undertake bolder renovations than they may otherwise pursue. Establishing a revolving fund, wherein savings from investments in energy efficiency are captured and reinvested, can reduce the cost of the subsidies to the government.[66] Such investments can benefit the national government since energy-efficient buildings can also improve conditions for, and the productivity of, inhabitants. Accounting ccounting for such positive effects in cost-benefit analyses could increase the feasibility of deeper renovations and ensure the full range of energy and non-energy related benefits can be captured.[67]

3. **Develop energy efficiency benchmarks for existing buildings and require all buildings to publicly disclose their energy performance**

China's Three Star System for labelling the energy performance of new buildings is relatively new and still voluntary. The national government can put in place and enforce legislation that requires all buildings – new and existing – to publicly disclose their energy performance. This will help to identify and target savings opportunities, as well as serve to monitor the effectiveness of building retrofitting and identify best practices. A ranking system recognising buildings that significantly and cost-effectively reduce their energy consumption may encourage greater participation in the pursuit of energy efficiency. Such a system should be supported by reliable and accessible data. A nationwide secure online monitoring platform – like the one launched in Changning and rolled out across Shanghai – could clarify for financiers the economic rationale of retrofitting while also helping governments, energy companies and building owners to identify savings opportunities and target interventions more precisely. Centralising such a platform could allow the national government to rank municipalities based on their energy performance and would remove the possibility of local data manipulation.[68]

4. **Make energy efficiency retrofitting mandatory for buildings that do not meet energy performance requirements**

The national government should adopt more stringent green building standards and appliance-based energy efficiency standards that track whole building energy consumption rather than energy savings brought about by specific renovations. Specific actions in the shorter term could include mandating that all government agencies reduce their energy consumption through retrofitting and making retrofitting compulsory for any building that does not meet designated performance standards. Revenue generated through fines for non-compliance could in turn finance compliance measures. Voluntary targets for exceeding minimum standards may help to incentivise private actors.[69] Legislation can be introduced to work towards this goal, for example mandating that all planning applications for renovations must meet a certain standard (like in Toronto, Canada) or that buildings must be improved to a certain standard before a (new) lease or deed of sale is issued. This must be accompanied by access to finance (see recommendation 1); other opportunities include providing favourable loan conditions for potential buyers who intend to retrofit to higher standards.

5. **Encourage city governments to set ambitious building energy efficiency targets that exceed those of national targets**

Changning has demonstrated the potential for testing innovative and bold approaches to retrofitting, gaining recognition for its efforts and encouraging other parts of Shanghai to follow suit. Other cities looking to show leadership in energy efficiency should be allowed and encouraged to set ambitious targets that go beyond those set at national level, as Beijing in China, Vancouver in

Canada and Houston in the US, for example, have done.[70] Worldwide, many urban authorities are constrained by national construction regulations, where standard building codes and energy performance targets are applied. National governments should instead put in place flexible retrofitting guidelines that can be adapted to suit local circumstances, including *minimum* energy performance targets that cities can increase to match their own ambitions. Demonstration projects help to highlight successful interventions, while citywide performance ranking systems can help to spur competition.

6. Conclusions

Reducing energy use in buildings – and particularly in China's buildings – can significantly contribute to global progress towards the Paris Agreement objectives and the SDGs. The buildings sector in China is responsible for a fifth of the country's energy consumption and a quarter of greenhouse gas emissions.[71] Aggressive action in this area could be transformative on a global scale.

The district of Changning in Shanghai is a pioneer in China's green buildings sector, having established the country's first online platform for monitoring the energy performance of buildings, formed a dedicated governance entity to coordinate its efforts in energy efficiency retrofitting, and worked with national and international actors to roll out a successful retrofitting programme across almost half of the district's public commercial floor space.

These efforts have since been expanded beyond Changning's borders into wider Shanghai and are reducing the city's emissions by 190,000 tCO_2e every year. Scaling these actions even further, across all commercial buildings in Shanghai, could save nearly 9 megatonnes of CO_2e annually compared with the business-as-usual pathway, reducing emissions from the commercial sector by one quarter. Not only would doing this cover its costs, but it would even start to generate financial returns after just eight years.

There are also additional incentives for national governments to foster such programmes: retrofitting comes with a host of co-benefits generated by improved energy efficiency in buildings. These co-benefits include better indoor conditions, which means healthier and more productive workers, and more sought-after premises, which can be sold or rented for a higher price.

Accelerating energy efficiency initiatives for buildings, both in China and elsewhere, will require strong support from national governments in terms of providing resources, offering incentives, and identifying and correcting inadequacies.
A national action plan for zero-carbon building stock with an accompanying fiscal and governance framework – drawing on successes demonstrated in Changning – would be a major first step towards healthier and more sustainable cities, with significant benefits for the economy, society and the environment.

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ABOUT THE COALITION FOR URBAN TRANSITIONS

The Coalition for Urban Transitions is the foremost initiative supporting national governments to secure economic prosperity and reduce the risk of climate change by transforming cities. The Coalition equips national governments with the evidence and policy options they need to foster more compact, connected and clean urban development. The Coalition's country programmes in China, Ghana, Mexico and Tanzania provide models for other countries on how to effectively develop national urban policies and infrastructure investment strategies.

A special initiative of the New Climate Economy (NCE), the Coalition for Urban Transitions is jointly managed by C40 Cities Climate Leadership Group and the World Resources Institute Ross Center. A partnership of 35+ diverse stakeholders across five continents drives the Coalition, including leading urban-focused institutions and their practice leaders from major think-tanks, research institutions, city networks, international organisations, major investors, infrastructure providers, and strategic advisory companies.

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