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PROMOTING GREEN BUILDINGS: BARRIERS, SOLUTIONS, AND POLICIES

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Abstract

The building and construction sectors contribute about 38% of the greenhouse gas (GHG) emissions and account for 35% of the total energy consumption. With the growing population (especially in developing Asia) and increasing income, the demand for construction and building will continue to rise, which means that GHG emissions from the sector will also rise. Green buildings— encompassing the use of materials and processes which are environmentally friendly and minimizing the use of resources from the design, construction, and maintenance, to demolition stages—have been recognized as an important pathway to mitigate GHG emissions from the construction and building sectors. This paper makes a systematic review of the literature, standards, and policies, and provides a pathway for the implementation of green buildings, particularly in developing countries. The major challenges for green building implementation are access to construction materials and skilled laborers, followed by the high cost of low-carbon construction. Most existing policies provide for energy efficiency in buildings, rather than green buildings. Promoting energy efficiency is not an equal substitute for green building policies, as they do not support the manufacturing of low-carbon construction materials and activities. To reach net-zero carbon emissions and other nationally determined contributions, the construction and building sectors have a tremendous role, which calls for policy support for green buildings.

Keywords: GHG emission, green building, low-carbon construction, energy-efficiency, NDCs, green building standards

JEL Classification: Q28, Q42, Q43, Q53, G2, G3

Contents

1. INTRODUCTION

A number of countries from developing Asia, including Thailand, Kazakhstan, and Viet Nam, announced net-zero carbon emission targets by midcentury at COP26 in Glasgow on 31 October–12 November 2021. Along with the energy sector, other sectors such as construction, heavy industries, and transport will all need to decarbonize to reach these targets. This paper reviews the existing policy support for decarbonizing the building and construction sector, particularly those policies promoting green buildings.

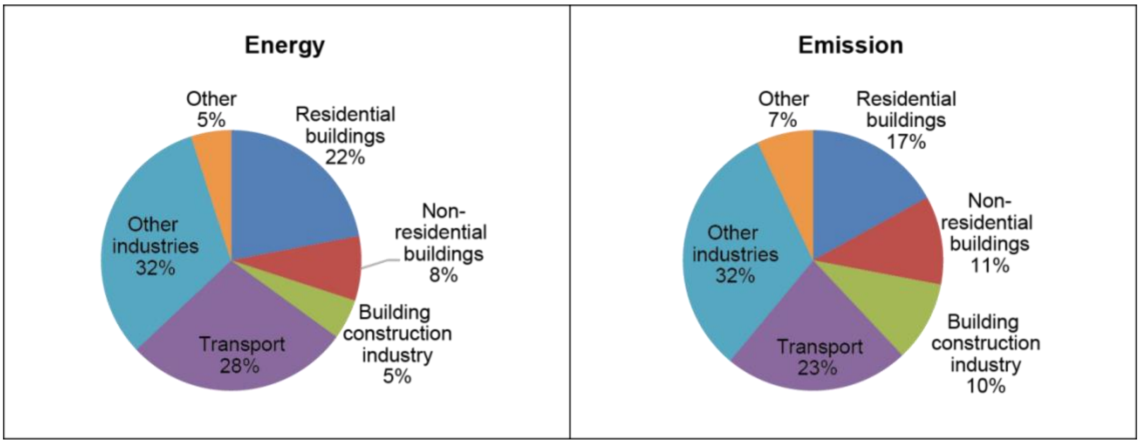
1.1 Greenhouse Gas Emissions

Greenhouse gas (GHG) emissions due to human consumption have been increasing over time, which is leading to major climatic changes (Strandsbjerg et al. 2021). Climate change is manifesting in the form of an increase in temperature, prolonged drought, variation in the rainfall pattern, glacial melting, flood, and salination resulting in the loss of life, assets, and livelihood (Aryal et al. 2020b). Compared to 1961, the global average temperature has increased by about 0.7°C in 2019, and during the same period, annual carbon dioxide (CO_2) increased from 9.36 billion tons to 36.45 billion tons (Ritchie and Roser 2020). However, the increase in temperature has varied across the regions. The adverse effect of GHG emissions and climate change is manifesting through prolonged drought (Le Houérou 1996; Easterling et al. 2000; Dai 2011; Leng et al. 2015), flooding and erratic rainfall (Aryal et al. 2020a), salination (Reid et al. 2009; Muir 2010; Colombani et al. 2016; Slama et al. 2020), desertification (Le Houérou 1996; Sivakumar 2007; Shukla et al. 2019), water stress (Gandure et al. 2013; Hejazi et al. 2015; Gosling and Arnell 2016), glacial lake outburst flooding (GLOF) (Bajracharya et al. 2007; Kaushik et al. 2020), and sinking of coastal land (Fuchs 2010; Erkens et al. 2015). Unchecked increase in GHG emissions could threaten the progress made thus far (Aaheim et al. 2012; Victor 2012; Estrada et al. 2015; Albert 2020) and would pose challenges to achieving global sustainable development goals (SDGs). It is thus of paramount importance for the global community to invest in technology and promote policies that could contribute to reducing GHG emissions.

1.2 GHG Emissions in the Building Sector

The Asia and the Pacific region is currently responsible for over 50% of global GHG emissions (Asakawa 2021). Decarbonizing the building sector is important not only for reaching nationally determined contributions (NDCs) and net-zero emissions targets, but also for making cities more livable. Many large cities in developing Asia (not only in India and the People's Republic of China [PRC]) suffer from high levels of air pollution, especially in winter, which has a negative impact on life expectancy, health, and quality of life. Buildings account for about 35% of the total energy consumption (22% from residential buildings, 8% from non-residential buildings, and 5% from manufacturing of construction material) and contribute to about 38% of GHG emissions (17% from residential buildings, 11% from non-residential buildings, and 10% from manufacturing of construction material) (United Nations Environment Programme 2020). Building construction industries also consume 5% of energy and contribute 10% of GHG emissions (Figure 1).

Figure 1: Global Share of Energy Consumption and Emissions in 2019



Source: United Nations Environment Programme (2020).

Concrete and steel are the top contributors to GHG emissions (two-thirds) among construction materials, followed by bricks (18%), and aluminum (8%), and Asia, particularly the PRC, is the largest contributor of GHG emissions from construction materials, and it is projected that India will overtake the PRC by 2053. It is alarming that building material–related emissions alone are projected to rise by 3.5 to 4.6 Gt CO2eq per year from 2020 to 2060, mostly coming from developing countries (Zhong et al. 2021).

1.3 Prospects

Energy usage in residential and non-residential buildings relates to cooking, lighting, heating (in cold countries), and cooling (in hot countries). Given growing populations, increasing income, and urbanization, the demand for energy in residential and residential buildings will continue to rise. Reducing the energy consumption in such buildings could thus contribute to reducing GHG emissions and mitigating climate change. Improving energy efficiency through controlling leakages and wastage and using gadgets that require less energy could help to minimize energy consumption. Numerous private and public benefits are also associated with the adoption of green building, such as a low life cycle cost (Arif et al. 2009; Abidin and Powmya 2014; Windapo 2014); energy savings (Manoliadis et al. 2006; Mulligan et al. 2014); water savings (Ahn et al. 2013; Devine and Kok 2015); comfort, satisfaction, and health benefits (Arif et al. 2009; Gou et al. 2013); reduction in the environmental impact of buildings (Manoliadis et al. 2006; Ahn et al. 2013); better indoor environmental quality (Bond 2010; Aktas and Ozorhon 2015); and good company image/reputation or marketing strategy (Zhang et al. 2011).

The demand for energy-efficient buildings is growing, but it has yet to gain momentum in developing countries. Governments around the world have recognized the importance of the building sector in decarbonization, as is evident from the fact that, from the countries who submitted NDCs, 136 countries stated *buildings*, 53 stated *energy efficient buildings*, and 38 stated *building energy code* (United Nations Environment Programme 2020). Recognizing the importance of green building in reducing environmental degradation (Yoon and Lee 2003), the governments in developing countries such as Viet Nam have initiated actions to promote green buildings, but the implementation has been slow and lacking in policy support (Nguyen and Gray 2016). Although the investment in energy-efficient buildings has been increasing, it is small compared to the total investment in the building and construction sector. For example, in 2019, the investment in energy-efficient buildings was US$152 billion, compared to US$5.8 trillion investment in the building and construction sector. Currently, the ratio between investment in energy efficient buildings to conventional construction is 1:37 (United Nations Environment Programme 2020).

In light of climate change and the increasing need to reduce GHG emissions to conserve scarce resources, the concept of green building is increasingly being recognized as an important way to reduce humanity's carbon footprint and provide a high quality, environmentally friendly future. Green buildings are complex and multifaceted and encompass several features, such as energy, water, and other resource efficiency; use of renewable energy; pollution and waste reduction measures; good indoor air quality; use of non-toxic material; environmentally friendly and adaptable to changing environment.

This paper therefore explores the opportunities and challenges associated with the adoption of green buildings, particularly in developing Asia. This paper reviews recent policies promoting the development in green buildings and provides recommendations to policy makers. The literature studying the effectiveness of policies promoting energy efficiency in buildings is more abundant than on policies promoting green buildings. A systematic review of the definition of green buildings, their environmental benefits, and the associated technological, life cycle assessment, managerial, and behavioral/cultural factors are provided in Zuo and Zhao (2014). A comparative assessment of green building policies is provided by Franco, Pawar, and Wu (2021). However, a review of green building policies is scarce. This paper aims to fill this gap.

This remainder of this paper is structured as follows. Section 2 provides a definition of green buildings. Sections 3 and 4 explain the need for policy support for green buildings by reviewing the barriers to green buildings, as well as the opportunities and solutions that green buildings provide. Section 5 reviews the most popular existing policies to promote green buildings. Section 6 concludes and provides policy recommendations.

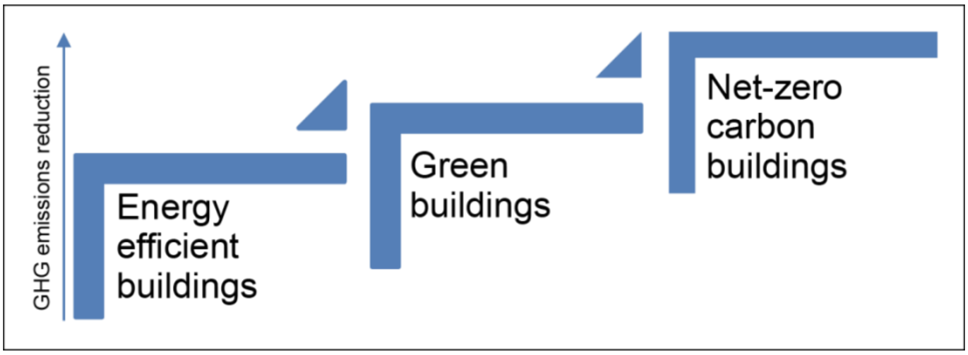
2. DEFINITION OF GREEN BUILDINGS

Green buildings usually refer to the use of environmentally friendly construction materials, processes, operation, and maintenance. The concept of a green building is driven by incentives to reduce the cost of energy and waste management in light of global warming and environmental degradation. It is a common approach among public buildings where energy use is high. Green buildings also have a higher social and environmental value, which cannot be quantified in monetary terms (Mohd et al. 2011). Given the high energy consumption by the construction sector, green and sustainable building practices have been implemented for years (Lorenzen 2012), and there is increasing demand to reduce energy consumption as well as to reduce environmental degradation (Azhar et al. 2011; Jalaei and Jrade 2015).

The green building concept has evolved over time. Initially, a green building was defined only in terms of environmental performance (Kua and Lee 2002; Yoshida and Sugiura 2010), but it has evolved to include sustainable and environmentally friendly construction methods and products (Hoffman and Henn 2008; Allwood et al. 2011; Hertwich et al. 2020), and further sustainable and environmentally friendly construction methods and products were added. In recent years, the efficient use of resources, the improvement of air quality, and reducing pollution have been added to the characteristics of a green or sustainable building (Haapio and Viitaniemi 2008; Kibert 2016; Li et al. 2016).

Unlike energy efficient buildings, green buildings include many other environmental aspects apart of energy efficiency, such as water efficiency, waste management, and the use of green materials in construction (Figure 2). Green buildings should not be confused with net-zero carbon buildings, which have achieved net-zero carbon emission by reducing energy consumption and are powered from on-site and/or off-site renewable energy sources (UK GBC 2019). Unlike green buildings, net-zero carbon buildings need to generate renewable energy, and are usually low rise buildings to produce a sufficient amount of renewable energy to satisfy building demand. Net-zero carbon buildings are less common than green and energy-efficient buildings.

Figure 2: Energy Efficient, Green, and Net-Zero Carbon Buildings



3. BARRIERS

Although green buildings are attractive, environmentally friendly, and have a major role to play in reducing GHG emissions and protecting the environment, there are several challenges to increasing the adoption of green buildings. Barriers to financing green buildings include (i) split incentives in the building market; (ii) developer hesitance to absorb the additional up-front costs of green building design, when the cost savings will only accrue for future owners; (iii) mismatch between building longevity and the relatively short holding periods for real estate assets in investment portfolios; (iv) minimal landlord incentives to invest in energy-efficient equipment because the tenant is paying the utility bill; and (v) subsidized or government-controlled energy prices (Kapoor et al. 2021).

The cost of implementing green buildings is the most important challenge in scaling their adoption. The high cost also leads to higher rental costs and makes it difficult to find both investors and tenants, thus, making green building less attractive to individuals with limited capital. There are also three other challenges: (i) lack of awareness, information, and education about the benefits of green building both private and public benefit; (ii) limited access to design, construction material, and skilled workers; and (iii) finally, the lack of guidelines and policies promoting green buildings.

A study in Malaysia has highlighted that lack of awareness is the major challenge for green building implementation in the country (Mohd et al. 2011), and this is also true in many developing countries around the world. Similarly, in Ghana, Chan et al. (2018) found higher costs, lack of financing, lack of skilled labor and market for green building (demand /supply), and lack of green building codes, regulation, promotion, leadership, and government incentives. Green certificates could be a vital tool to enhance sustainability by encompassing design, construction, operation, maintenance, and demolition, or building information modelling (BIM) (Muller et al. 2019). Leadership in energy and environmental design (LEED) is one of the most widely used certifications based on several encompassing features (Nguyen and Altan 2011; Dong et al. 2014; Suzer, 2015). Critical impediments to the adoption of green buildings in developing countries include high cost, lack of incentives (grants, tax reliefs), and lack of information; trained labor, material, and technology; and absence of lead organizations (DuBose et al. 2007; Potbhare et al. 2009). Developing countries should therefore invest in removing these barrier. As the rapidly growing population and increases in income, particularly in developing countries, will increase the need for buildings and associated housing timbers that could act as carbon sink and also reduce the production of construction material that emits carbon (Churkina et al. 2020).

4. OPPORTUNITIES AND SOLUTIONS

As the climate is changing rapidly and causing distress and destruction, there is an increasing need to reduce GHG emissions from buildings, including in those associated with the material and construction methods that contribute significantly to emissions (Li et al. 2017). It is of paramount importance to promote the concept of green and sustainable building at all levels—commercial, public, and residential. Failure to act now could pose a great threat to humanity in the coming decades. Green or sustainable buildings could contribute to decarbonization by reducing energy consumption in building use, as well as material and construction (Li et al. 2017; Zhong et al. 2021). Increases in population and income are resulting in an increase in demand for housing (Kc and Lutz 2017; GABC and UNEP 2019), which in turn increases demand for construction materials. There are thus opportunities to use materials that are environmentally friendly to build structures that are energy efficient (EA 2019; Hertwich et al. 2019).

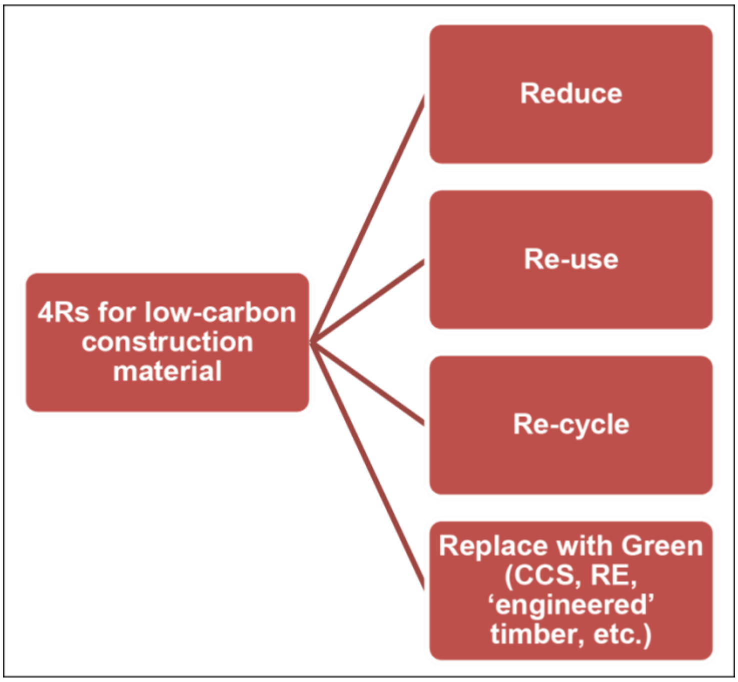
The construction industry is responsible for 11% of the world's man-made CO_2 emissions (the Economist 2022). Steel and cement are among the most carbon-intensive industrial materials on the planet, and their production accounts for 14%–16% of global energy-related CO_2 emissions (S&P 2021). If the cement industry were a country, it would be the third largest emitter of GHG (The Economist 2021). To meet a 2°C scenario, the cement industry needs to reduce its emissions by 24% by 2050, while meeting a demand forecast for an increase by 23% (BNEF 2021b). GHG emissions from construction materials can be reduced via the 4 Rs: reduce, re-use, re-cycle, and replace with low-carbon construction materials (Figure 3). Reducing the use of or greening construction materials such as concrete, steel, bricks, and aluminum would play an important role in reducing GHG emissions in the construction sector (Hertwich et al. 2020; Hansemann et al. 2021; Zhong et al. 2021). Replacing construction material with low-carbon materials such as engineered timber or other lightweight material could support decarbonization (Churkina et al. 2020; Arehart et al. 2021). Cement can also be replaced with industrial waste (The Economist 2022). Further, recycling and re-use of building reconstruction material, such as recycled concrete, would also contribute to emissions reduction (Dodoo et al. 2009; Liu et al. 2013; Oh et al. 2014).

Non-green buildings consume huge amount of energy for light, cooling, heating, and cooking purposes, so green buildings using equipment that is energy efficient could dramatically reduce energy consumption, particularly with the assistance of other technologies, such as artificial intelligence for automatically controlling lights, heating, and cooling systems.

The construction industries use natural resources and consume massive amounts of energy; they are thus responsible for large carbon emissions, environmental degradation, and global warming (Stadel et al. 2011; Wong et al. 2013; Wang 2014; Wong and Kuan 2014; Wong and Zhou 2015). There is a need to invest, within the construction industries, in reducing GHG emissions and environmental degradation, which could provide huge opportunities to producers of environmentally friendly materials and products. Given that the major challenges for green building are the cost, awareness, construction material, and skills, there is a strong need for government policies such as tax subsidies, credits, and interest rates to encourage the expansion of green building and awareness of its benefits. There are tremendous opportunities for construction industries to supply green building materials and for financial intermediates to finance its costs. For the consumer, green buildings are expected to reduce the cost of maintenance and energy, although they may be subject to higher rental fees as the cost of construction is high (Mohd et al. 2011).

Policy support for green buildings can incentivize demand for low-carbon construction materials, and investment in green construction could provide huge opportunities to producers of such construction materials. The UK, India, Germany, Canada, and UAE have committed to support new markets for low-carbon steel, cement, and concrete (S&P Global 2021).

Figure 3: Greening Construction



Note: CCS = Carbon capture and storage; RE = Renewable energy.

5. POLICIES

Because of the existing barriers for financing green buildings (as mentioned in Section 3) and their positive externalities for the environment and energy security (as mentioned in Section 4), policy support is provided for green buildings in many countries. The policy instruments to support green buildings can be structured as shown in Figure 4. Policy makers need to consider the differentiation of policy support for green buildings to ensure such policies are more cost effective (Table 1). Policies are usually differentiated by or limited to the following building types: commercial, industrial, residential, and public sector buildings. Policy incentives could be provided for energy efficiency improvements in general, green, and zero-carbon buildings; renewable energy installations in buildings; research, development, and demonstration; manufacturing of energy efficient technologies; and building energy audits. Policy incentives could be funded from the general public budget for a specified period or from a specified, limited fund. Such incentives would end after the specified period or when the fund is exhausted. Policy support could be provided at different stages: for construction of new green buildings or for retrofitting existing buildings to meet green building standards. The advantage of supporting new green building construction is that such a policy would also support demand for low-carbon construction materials such as steel, cement, and concrete, which would help to reduce emissions and waste at the construction stage and not only at the operation stage.

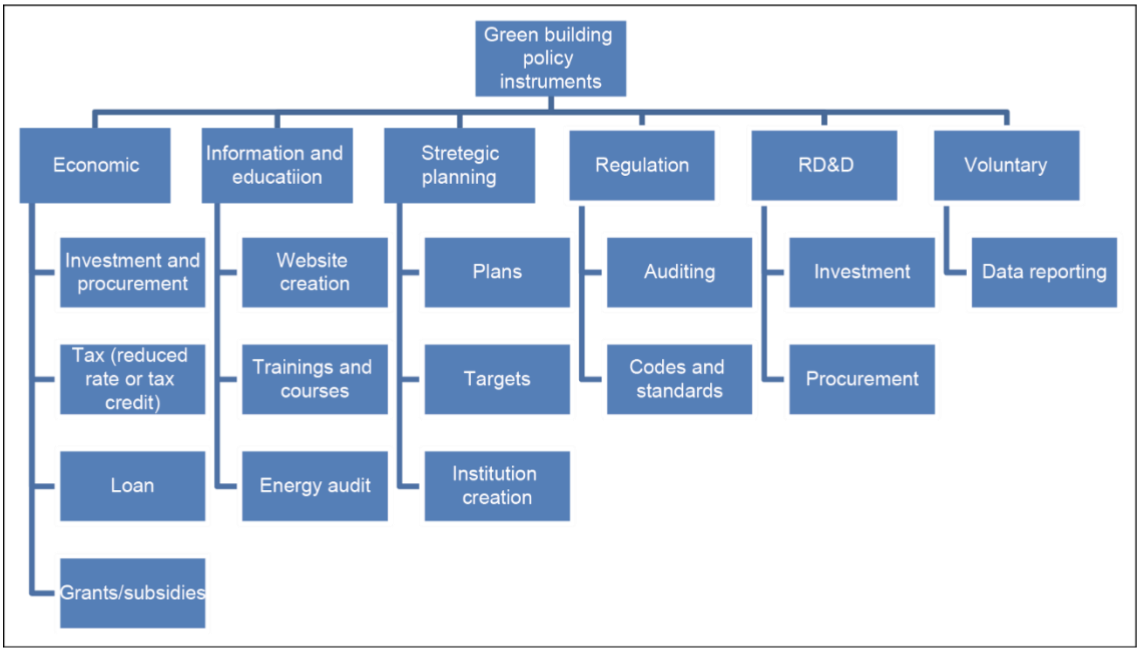
Mandatory green building regulations may be a more effective tool to promote energy efficiency improvements than voluntary instruments (Kim and Lim 2018). A review of green building standards and certifications has been provided by Franco, Pawar and Wu (2021), and only policies with mandatory requirements to obtain green building certification are effective in promoting green buildings (Fuerst, Kotokosta, and McAllister 2014). For example, a mandatory energy disclosure program contributed to the reduction in energy usage and carbon emissions from the affected building stocks in Australia (Kim and Lim 2018). Studies on developing Asia include evaluations of the effectiveness of green building policies in the PRC (Shi et al. 2014; Shen and Faure 2021), the determinants of green building adaptation in the PRC (Wang, Zhangm Su, and Deng 2018), and barriers to green building development in Malaysia (Samari et al. 2013).

Green building policies not only promote energy efficiency, but also benefit corporations, households, and governments by reducing energy bills. Green building policies could thus be considered a sustainable alternative to energy subsidies. A database of building policies has been provided by the IEA (2021) Policies and Measures database. Figure 4 illustrates the implementation of new (not accumulated) policies supporting energy efficiency in buildings. In addition to green building policies, other environmental policies, such as green subsidies, environmental taxes, and carbon emissions trading, can also promote green buildings. A combination of environmental taxes, green subsidies, and a carbon trading scheme is even better at promoting green buildings (Yang et al. 2021).

Any of policy instruments can be cost-effective if selected, designed, implemented, and enforced in a tailored way to local resources, capacities, and cultures (Boza-Kiss et al. 2013): ‘No single policy instrument in itself is optimal to promote green building’ (Shen and Faure 2021: 183), but rather an effective mix of policies need to be designed to promote green buildings (Rosenow, Fawcett, and Oikonomou 2016). Many studies have therefore focused on an efficient mix of policies (Lee and Yik 2004; Rosenow, Kerm, and Rogge 2017) rather than on individual policies. Theoretical and empirical contributions from the literature on energy efficiency policy mixes are provided in Rosenow et al. (2016). A comprehensive literature review of regulatory and voluntary policy instruments on building energy efficiency is provided in Lee and Yik (2004), but there is a lack of systematic reviews on literature studying the effectiveness of policies promoting green buildings.

The evaluation of effectiveness of energy efficiency policies is more abundant (e.g., Rosenow, Kerm, and Rogge 2017) than that for green building policies. Most studies have focused on building energy efficiency, and even papers on green buildings tend to refer to the benefits of green buildings in terms of improved energy efficiency and reduction of GHG emissions and waste. Use of green construction materials and the recycling, reuse, and reduction of construction materials have generally been overlooked.

Figure 4: Green Building Policies

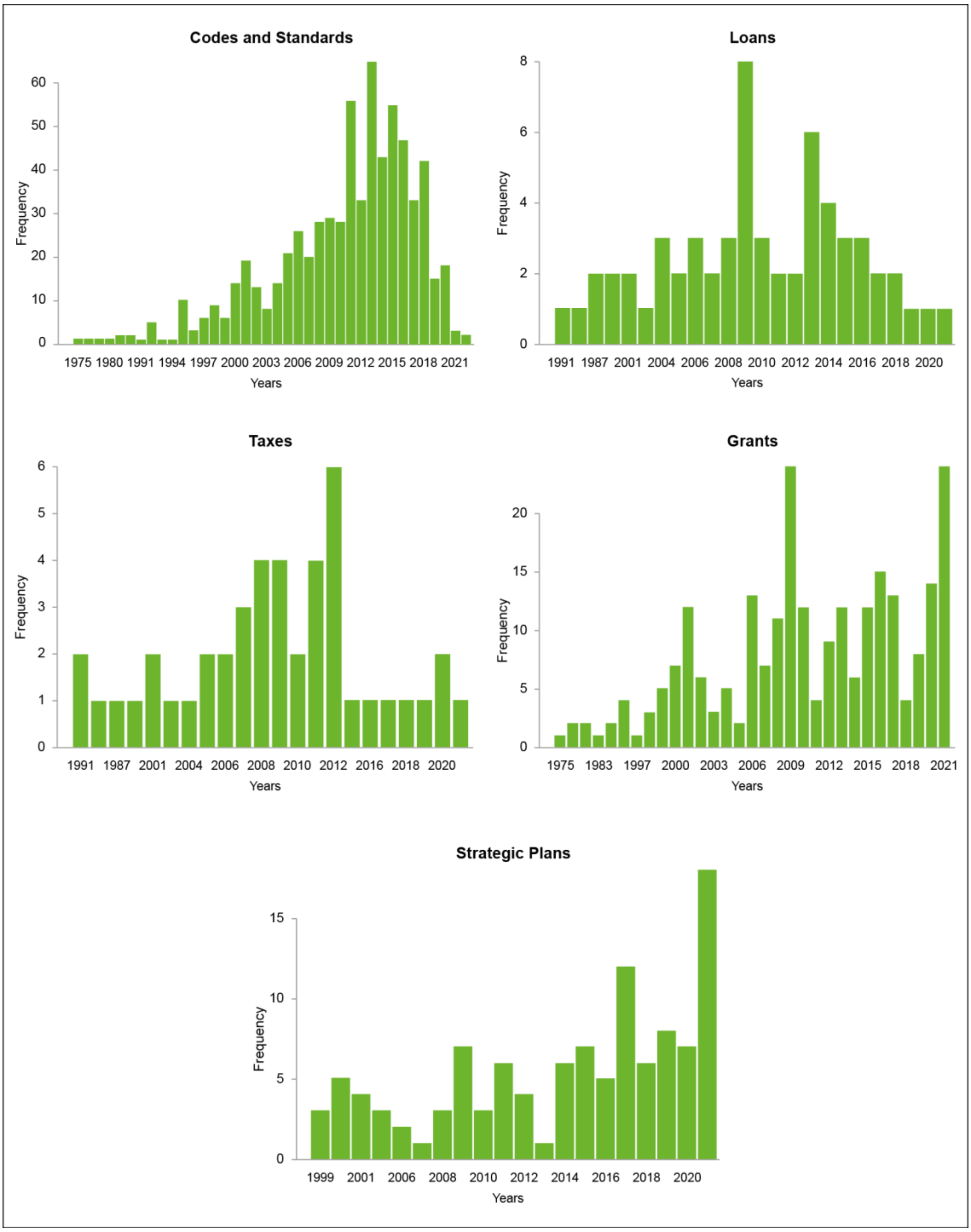


Source: Authors' own using IEA (2021).

Table 1: Considerations for Policies Supporting Green Buildings

Policy Target	Options
Buildings Types	Public sector, commercial, industrial, residential
Change	Green buildings or other (energy efficient, net-zero carbon, renewable energy installations in buildings, R&D, manufacturing of energy efficient technologies, energy audits)
Stage	New/existing buildings
Measure of results	Meeting specified building standards, technology installations, etc.
Policy instrument	Figure 4
Strictness	Voluntary or mandatory

Figure 5: Policies Supporting Energy Efficiency in Buildings



Sours: Authors own elaboration using data from IEA (2021).

Box 1: Green Building Policies in the PRC

This box is written by Nicolas Dei Castelli, Senior Transport Specialist, Asian Development Bank; Yixin Yao, Senior Research Fellow, Asian Development Bank Institute; and Ellen May Reynes, Climate Change and Technical Project Management consultant, ADB

The PRC has experienced unprecedented urbanization and socio-economic growth, which has driven the massive expansion of its building stock. The total building floor area had increased from 35 billion m^2 in 2000 to 64 billion m^2 in 2017. Residential buildings in urban areas increased by 188% from 2000 to 2017, while public, commercial, and office buildings increased by 161%. With 70% of the total population expected to live in cities by 2030, up from 56%[a] in 2020, the building stock is expected to further increase in the coming decade.

Growth in the building sector has been associated with significant resource and energy consumption, carbon emissions, and air pollution. In the PRC, buildings account for nearly one-third of total carbon emissions. There is a huge potential for energy saving and GHG emissions reduction if the energy performance of buildings is enhanced significantly, including the scaling up of green buildings. The Chinese government has promoted green buildings since 2006 and has developed measures to promote their development, ranging from information and capacity building to an overarching strategy with binding targets, technical standards, and guidelines; demonstrations, financial incentives, and rewards. The table below lists the key policies for promoting green buildings in the PRC.

Table: Key Policies of Green Buildings in the PRC

Year	Policies	Key Content
2006	Green building standard (1st version)	Defining green buildings, with six categories of criteria
2007	Measures for green building labeling	Defining different levels of green buildings, i.e., 1-, 2-, and 3-star (low to high)
2012	Implementation advice for accelerating green building development	A first-of-its-kind green building policy issued by the central government (rather than a ministry policy document): accelerating green building development and establishing the overall policy framework of green building development, especially, specifying financial incentives to promote green buildings.
2013	National action plan for green building development	Issued by the central government: Defining national targets of green building development, key tasks, and support mechanisms. The green building development target became an evaluation criterion for local government performance.
2014	Green building standard (2nd version)	Creating two types of labels for design and operation. The former is certified if the design of a specific building fulfills green building criteria, while the latter is certified after a building has been in use for a year. In addition, the Standard introduced detailed scores for different "green" categories.
2019	Green building standard (3rd version)	Redefining the key principles of green buildings: "human-centered and high quality of life" instead of an exclusive focus on environmental sustainability; creating new criteria based on this new principle; green buildings certified only after construction is complete; including a basic level as another level of green building label (four levels)

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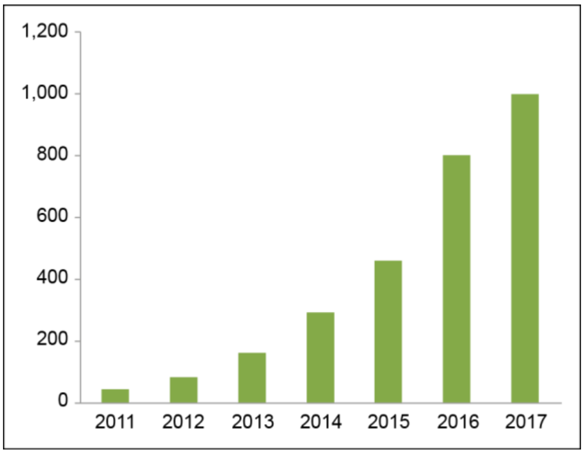
Box 1 *continued*

The PRC's national certification program to promote green buildings, the China Green Building Labelling (GBL), has the following criteria for evaluation: safety, durability, convenience, environment and livability, resource efficiency, health and comfort, and innovation. In its current design, GBL certification cannot be directly translated into carbon emissions reductions and other quantitative resource savings. Green buildings in the PRC have been scaled up from single pilot projects to new green building districts. The figure below shows the rapid growth of green buildings since 2011. However, most buildings only have designer instead of operational labels, which implies that buildings may only have been designed as green buildings but may not necessarily constructed accordingly.

Figure: Growth in Number of Green Buildings since 2011 in the PRC



[a] World Bank Database.

Box 2: Low-Carbon City: Xiangtan (PRC)

This box is written by Nicolas Dei Castelli, Senior Transport Specialist, Asian Development Bank; Yixin Yao, Senior Research Fellow, Asian Development Bank Institute; and Ellen May Reynes, Climate Change and Technical Project Management consultant, ADB

While all eyes are on the PRC's decarbonization policy, one climate-vulnerable and rapidly urbanizing city is paving the way toward the low-carbon cities of the future. Xiangtan, located in the south-central province of Hunan, has a semi-tropical climate and is prone to extreme precipitation events and floods from the surrounding rivers. Home to almost 3 million people, with an urbanization rate of 62%, it is an old industrial city undergoing rapid urbanization and industrial transformation. In 2018, Xiangtan became a low-carbon city under the Low Carbon City Initiative (LCCI) and has been striving to achieve carbon peaking by 2028 to contribute to the PRC's NDC target under the Paris Agreement. This target calls for great efforts to substantially reduce GHG emissions in a very limited time frame without hindering economic growth.

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Box 2 *continued*

Between 2005 and 2016, the GHG emissions from the building sector in Xiangtan grew by 330%, reflecting the massive growth and urbanization the city has experienced. As the total floor area of urban buildings is expected to grow further, substantial growth in GHG emissions is expected if green building interventions are not in place. Traditional construction practices have little focus on efficiency or low-carbon design. To reduce emissions from the built environment, Xiangtan is starting to retrofit existing buildings and implement measures for new buildings, adopting construction techniques and designs that require fewer natural resources and emit less GHG. Residents are expected to benefit from the energy and cost savings of buildings with better insulation and a more sustainable design.

As part of the effort to reduce GHG emissions in the building sector, the Xiangtan Municipal Government (XMG) is taking a two-pronged approach in the Xiangtan Low Carbon Transformation Sector Development Program[a]: through policies and certified green building projects showcasing green and low-carbon building techniques. The XMG has established the following policies to enhance low-carbon energy and buildings systems to bolster its vision for transformation:

- Xiangtan's 13th five-year plan and comprehensive work program for energy conservation and emissions reduction identified objectives and priority projects to promote clean and renewable energy technologies, specifically Energy Performance Contracts (EPC), Energy Service Companies (ESCO), and green buildings;
- Management rules on industrial zone autonomy will be set up in 2022 regarding the use of energy and resources to support each industrial zone in creating its own management schemes and rules, including mandatory connection to a smart energy/utility management system, if available in the area, to promote energy efficiency;
- An addendum in implementing regulations regarding green buildings has been approved to promote the use of EPC to enhance the energy efficiency of buildings for public institutions, support local banks in developing financing products for green buildings, and pilot building energy management systems for public buildings;
- Green building management rules have been passed to promote quantifiable green buildings certification, EPC, and ESCO for the energy efficiency, energy audits, and a more comprehensive statistics system for new and existing buildings.

At the same time, the XMG is set to demonstrate building transformation by integrating advanced technologies and resilience measures in both new construction and building retrofits. First, the XMG plans to construct a new hospital with integrated solutions, including a passive building design, water-saving features, and a trigeneration energy system to generate power, heating, and cooling that will be connected to an intelligent building energy (and utility) management system (BEMS) which will cover 200 public buildings in Xiangtan. The BEMS is a smart platform for energy management in buildings that will automatically regulate heating, cooling, and lighting, using weather predictions and sensors that will detect buildings' usage patterns, temperature, and air quality. The BEMS will facilitate operational efficiency, informed decision-making, and behavioral changes, thus lowering energy consumption in public buildings.

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Box 2 *continued*

Because the hospital is being built in a flood-prone area, extensive climate-resilience and nature-based measures such as rain gardens, rainwater detention ponds, green roofs with drainage delay, permeable pavement, and infiltration trenches will enhance the site's flood resilience compared to the PRC's sponge city technical standards.[b] These ecosystem-based measures will also improve the quality of green spaces for the patients and visitors while storing rainwater for water green spaces throughout the hospital campus during severe droughts. The plans also include establishing an off-grid energy system and critical infrastructure for the hospital above the ground floor to keep the hospital functional and ensure the continuation of operations during city-wide power outages and severe flooding events.

Xiangtan's new flood-resistant hospital, which will follow green building principles and have a trigeneration system for heating, cooling, and power. It will be able to withstand severe weather and flooding through ecosystem-based adaptation measures with large run-off areas and underground storage tanks *(photo by Xiangtan PMO/design institute).*

Second, the XMG will retrofit a currently unused government building to house the Asia Low-Carbon Training Center, showcasing green and low-carbon building techniques. The retrofit will include upgrading the 6,000 square meter building by installing external wall and roof insulation, triple/quadruple-glazed windows, water-saving faucets and toilets, an intelligent building energy monitoring system, and a combined heat pump and rooftop photovoltaic solar energy system. With support from the Hunan Provincial Government and the LCCI, the XMG plans to run the Asia Pacific Low-Carbon Training Center to share its experience on low-carbon transformation with the goal of replicating the city's low-carbon models in other cities in the PRC and other developing countries in Asia and the Pacific that share similar challenges.[c]

Third, Xiangtan aims to mainstream green buildings using a cost-efficient and quantifiable certification called the Excellence in Design for Greater Efficiencies (EDGE) certification that focuses on cutting energy consumption and carbon emissions from the building sector. Both buildings mentioned above, the hospital and the Asia Pacific Low-Carbon Training Center, will obtain EDGE certification, achieving more than 20% savings each in energy, water, and the energy embedded in the buildings' design and materials compared to the relevant PRC standards.[d] EDGE requires a reduction in emissions and resource use during construction as well as during operation.

Box 2 *continued*

XMG is also carrying out a holistic approach to becoming a low-carbon city by not only constructing greening buildings but also maintaining and upgrading older buildings. The XMG is set to transform 20 aging urban communities into modern, livable, and sustainable places using low-carbon solutions such as LED street lighting, photovoltaic solar panels, e-bicycle sharing, ecosystem-based adaptation measures at parking lots, drainage improvement, safer streets for walking and cycling, and installation of natural gas for cooking to show how any neighborhood can live with minimal environmental impact.

[a] ADB. People's Republic of China: Xiangtan Low-Carbon Transformation Sector Development Program. https://www.adb.org/projects/52230-001/main#project-pds-collapse.

[b] Ecosystem-based adaptation measures with green and blue assets are effective for flood control, drought mitigation, heat stress reduction, and carbon sinks, with co-benefits such as aesthetic quality, recreational capacity, better air quality, and improved health quality.

[c] Xiangtan is part of a network of cities participating in the LCCI that aims to decarbonize cities with historically high rates of carbon intensity and growth.

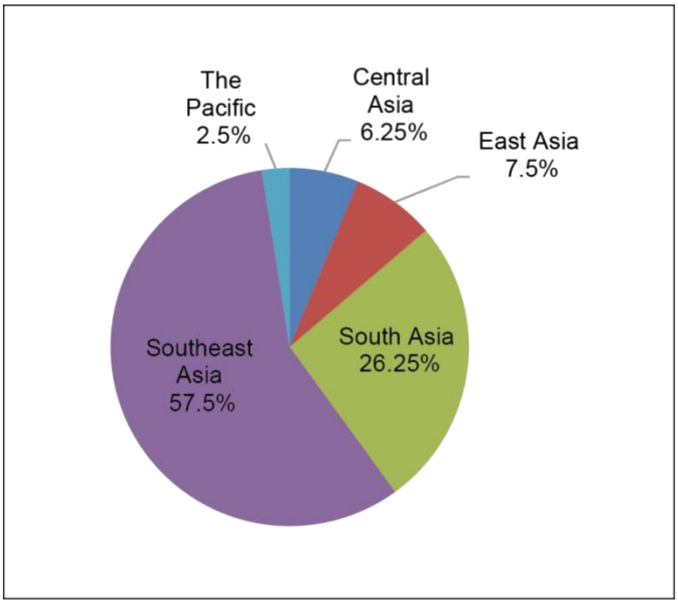
[d] The EDGE green buildings platform, which includes a green building standard, a software application, and a certification program for Homes, Hospitality, Retail, Offices, Hospitals, and Education buildings, helps users determine the most cost-effective options for designing green buildings within a local climate context to reduce operational expenses and environmental impact.

5.1 Codes and Standards

Codes and standards are the most popular policy instruments for supporting green buildings. This policy is particularly popular in South East Asia (Figure 6). Buildings can be certified as green buildings based on regional, national, and internationally recognized standards, which can also provide a certification level for building greenness, such as platinum, gold, silver, and bronze; number of stars; or score. A review of green building standards is provided in Franco, Pawar, and Wu (2021). Such standards are important for financing. For example, green bond proceeds could be used for green buildings that meet regional, national, or internationally recognized standards or certifications for environmental performance (ICMA 2021). Although some green building standards are internationally recognized and used around the world (e.g., LEED and BREAM), national green building standards have adapted them to reflect specific national or regional needs and circumstances (IRENA 2021). Green building standards are usually voluntary, but they could be compulsory for new buildings. For example, the UK Government announced that all new homes and businesses will have to meet rigorous new energy efficiency standards to lower energy consumption to achieve net-zero emissions by 2050 (Waterman 2021).

Most green building certification schemes are point-based rating systems. Points are given for each green building feature, which then determines the certification level. A building code could also be a voluntary or compulsory set of regulations for the construction, renovation, and repair of buildings, including energy use/efficiency targets for new buildings, specification of insulation standards, and stated building design choices to increase building energy efficiency (IRENA 2021). Building codes and standards are also important as a taxonomic and measurement tool for other policies promoting energy efficiency. Codes and standards can go beyond the whole building to include the appliances used in buildings, such as light bulbs and cooling and heating technologies. Examples of green building codes and standards are provided in Franco, Pawar, and Wu (2021).

Figure 6: Building Codes and Standards across Asia (2010–2020)



Sours: Authors own elaboration using data from IEA (2021).

Box 3: Singapore's Green Building Standard

Buildings account for over 20% of Singapore's emissions (NCCS[a]). Hence, greening buildings is a key strategy for meeting Singapore's NDCs.

The voluntary Green Mark Scheme was launched in 2005 to promote sustainable and environmentally friendly buildings in Singapore (BCA 2021).

In 2006, Singapore launched its first Green Building Masterplan, which encouraged, enabled and engaged industry stakeholders in adopting new green buildings (BCA[b]). Since then, the Green Building Masterplan has been continuously updated over the years. Updates included targeting new building owners to encourage sustainable design from the onset. This was later expanded to existing buildings, with BCA engaging building occupants to change their energy consumption behaviors.

The latest iteration of the Singapore Green Building Masterplan (SGBMP) was launched in 2021, capturing the collective commitment by the Built Environment to pursue even more ambitious sustainability targets. It aims to deliver 3 key targets of "80-80-80 in 2030".

i. 80% of buildings by gross floor area to be greened by 2030;

ii. 80% of new developments by gross floor area to be Super Low Energy[c] from 2030;

iii. 80% Energy Efficiency improvement (from 2005 levels) for best-in-class green buildings[d] by 2030.

During the development of the SGBMP, more than 80 industry stakeholders (architects, consultants, developers, engineers, contractors, suppliers, researchers and others) and 5,000 individuals from the community were engaged (BCA and SGBC 2021).

A public perception survey on green buildings noted that 91% of respondents agreed that Singapore needs to do more to green its buildings to tackle the impact of climate change (BCA and SGBC 2021).

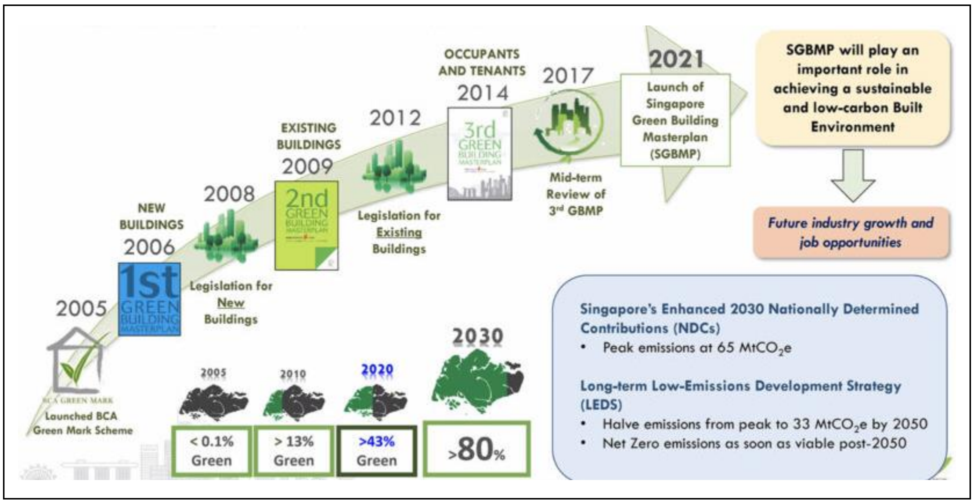
continued on next page

Box 3 *continued*

The survey also noted the top three challenges faced by industry practitioners for Super Low Energy buildings today were: 'lack of capital/funds/financial incentives', 'lack of leadership buy-in' and 'lack of consumer demand' (BCA and SGBC 2021). Since 2018, BCA has been working closely with firms through the Super Low Energy Building Programme, to encourage them to venture into the Super Low Energy building space (BCA[e]). To spur adoption of Super Low Energy buildings, the Government has taken the lead to drive demand by implementing the new **GreenGov.SG** requirements for public sector buildings in July 2021. All new and retrofitted public sector buildings will need to achieve Green Mark Platinum (Super Low Energy) standards or equivalent, where feasible. Other initiatives to encourage private building owners and developers to strive towards Super Low Energy buildings include the **Built Environment Transformation Gross Floor Area Incentive scheme** launched in November 2021, and the enhanced **Green Mark Incentive Scheme for Existing Buildings 2.0 scheme** available from 30 June 2022.

Other survey results can be viewed in BCA and SGBC (2021)'s Singapore Green Building Masterplan Public Engagement Report and infographic.[f]

Figure: Singapore's Green Building Journey



Source: Chin (2021).[g]

[a] National Climate Change Secretariat Singapore. Singapore's Emissions Profile. https://www.nccs.gov.sg/singapores-climate-action/singapore-emissions-profile/.

[b] Building and Construction Authority (BCA). Green Building Masterplans. https://www1.bca.gov.sg/buildsg/sustainability/green-building-masterplans.

[c] The best-in-class performing Green Mark Building that achieves at least 60% energy savings above 2005 building codes (https://www1.bca.gov.sg/buildsg/sustainability/super-low-energy-programme).

[d] As of March 2022, best-in-class buildings are able to achieve 65%–70% improvement in energy efficiency over 2005 levels.

[e] https://www1.bca.gov.sg/buildsg/sustainability/green-building-masterplans.

[f] BCA (2022) What Are People In Singapore Saying About The Future Of Green Buildings? https://www1.bca.gov.sg/docs/default-source/docs-corp-buildsg/sustainability/report-infographics.pdf?sfvrsn=c891f6d2_0.

[g] Excerpt from presentation of Noel Chin, Principal Manager, Green Building Technology, Building and Construction Authority of Singapore at IEA training program to promote low carbon buildings on 27 July and 28 July 2021. https://build4people.org/build4people-team-members-invited-as-speakers-at-iea-training-programme-to-promote-low-carbon-buildings/.

Box 4: Mainstreaming Green Building Development and Retrofitting with EDGE Certification

This box is written by Nicolas Dei Castelli, Senior Transport Specialist, Asian Development Bank; Yixin Yao, Senior Research Fellow, Asian Development Bank Institute; and Ellen May Reynes, Climate Change and Technical Project Management consultant, ADB

To ease the calculation of carbon emissions reduction, Xiangtan is promoting the new user-friendly EDGE certification system. The EDGE green buildings platform includes a green building standard, a software application, and a certification program for homes, hospitality, retail, offices, hospitals, and education buildings in more than 140 countries to help users determine the most cost-effective options for designing green buildings within a local climate context to reduce operational expenses and environmental impact. EDGE empowers emerging markets to scale up resource-efficient buildings in a fast, easy, and affordable way. EDGE certification can be achieved when a building uses at least 20% less energy, water, and carbon-intensive building materials compared to relevant PRC building standards. EDGE certifications can be granted to both new and old buildings with adequate retrofitting of sustainability technologies. The EDGE program also requires certification during both the design phase and post-construction to evaluate if the expected efficiencies were realized and if they resulted in actual reductions in GHG emissions.

Xiangtan's newest hospital is striving to become the first hospital in the PRC to achieve the EDGE certificate, which entails being energy and resource efficient right from the start. In addition to the efficiency gains through passive building design, water, and energy-saving features, the building will also rely on its own energy source—a combined cooling, heating, and power generation unit fueled by natural gas. This means that the unit can cool the building during the summer, heat the building during the winter, and supply energy throughout the year. Compared to other hospitals in Xiangtan, which rely on locally generated electricity that is 96% coal-based, the new hospital's energy source is more efficient and responsible for lower emissions.

An old, abandoned government building is also being transformed into a new sustainability training center, the Asia Pacific Low-Carbon Training Center, as outlined in Box 2. The building will become a place to train officials and other stakeholders from the PRC and other cities in Asia and the Pacific on low carbon transformation in cities by showcasing the low-carbon initiatives implemented in Xiangtan that they can use in their own projects.

Compared to building energy efficiency standards in the PRC, the new hospital has 28% energy savings, 48% water savings, and 50% less embodied energy in materials. The retrofitted government building will have 20.6% energy savings, almost 25% water savings, and more than 31% savings on embodied energy. Xiangtan hopes to make green buildings mainstream using this cost-efficient and quantifiable certification that focuses on cutting energy consumption and carbon emissions in the building sector.

Co-benefits

- *Economic: EDGE certification requires lower resource use during construction and operation, which enables allocation of more resources elsewhere.*
- *Environmental: EDGE certification has helped buildings reduce water consumption and waste production during construction and operation.*

5.2 Tax Incentives

Tax incentives for promoting energy efficiency improvements in buildings can be provided in a form of reduced tax rates, such as customs tariffs on energy efficient technologies, deductions for expenses, or a lump-sum tax credit (per square meter/foot) on energy efficiency improvements in buildings from the taxable base (e.g., income) of individuals and corporates (also called a tax credit) for income, production, or investment taxes. Tax credits and deduction of eligible expenses need not necessarily be 100%; they could be below, as in the United States, where 30% of qualified expenses are deductible, or they could be above, as in Italy, where 110% of qualified expenses are deductible.

Tax incentives can be also provided for renewable energy installations. This policy is particularly attractive in countries with a high income tax rate. The main drawback of this policy is that it is less attractive for low income groups, as their tax rate is usually low, or in countries with a low income tax rate (Figure 7). The cost of this policy for the government is lower and more predictable due to its short term nature, as tax incentives do not require long-term commitment from the government and could be ended at any time. If the tax credit exceeds the tax liability, the excess amount can be carried forward to the succeeding fiscal period. Example tax incentives for low-carbon buildings are provided in Table 2.

Figure 7: Pros and Cons of Tax Incentives

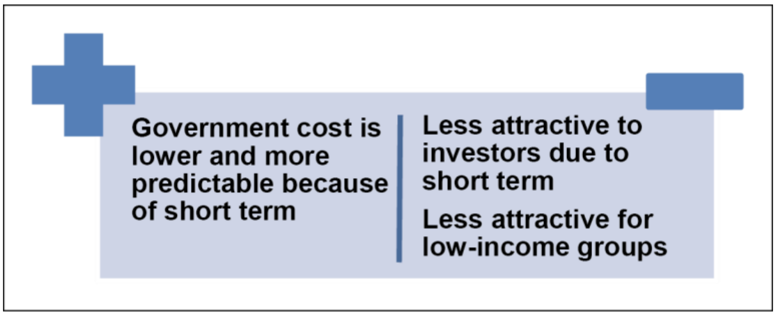


Table 2: Example of Tax Incentives to Promote Energy Efficiency Improvements in Buildings

Country	Policy	Tax	Year
Italy	Energy efficiency and renewable energy refurbishment tax reduction	Tax deduction, specified at 110% for thermal insulation refurbishments, as well as other energy efficiency measures	2020
Indonesia	Ministerial Regulation No. 2 on Green Building	Reduced land and building taxes	2015
Japan	Financial measures for houses	Tax scheme for businesses that acquire specified energy conservation equipment, which provides special depreciation rate applied for 30% of the acquisition cost	2002
Australia	Financial incentives for investment in residential renewable generation and residential efficiency	Expenses excluded from taxable income	2001
US	Tax incentives for energy-efficiency upgrades in commercial buildings	A tax deduction of up to $1.80 per square foot available for buildings that save at least 50% of the heating and cooling energy of a system or building; partial deductions of up to $.60 per square foot can be taken for measures affecting: the building envelope, lighting, or heating and cooling systems	
France	Tax credit for energy transition		2005

5.3 Grants and Subsidies

Grants and subsidies are usually provided for investments in energy efficiency technologies to reduce the upfront costs of introducing energy-efficient technologies in buildings, making buildings energy-efficient, green, or net-zero carbon (Table 4). Grants and subsidies could be provided as a lump sum or as a proportion of the cost, with a ceiling cap. Like taxes, grants and subsidies have a lower cost and are more predictable for governments. They could be closed at the end of a specified period, when the specified funds are exhausted, or at any time.

Box 5: Energy Efficiency Services Limited India

A government owned Energy Efficiency Services Limited (EESL)[a] was created by India's Ministry of Power to facilitate energy efficiency investments, including work designing, implementing, monitoring, and investing in energy-efficient projects. EESL has implemented projects in India by providing non-subsidized energy efficient appliances to the residential sector, businesses, and municipalities. Procurement of efficient bulbs has led to substantial cost reductions due to the large scale of this project, which may be the world's largest LED distribution project, and included street as well as building lighting. EESL plans to apply the same method to air conditioning appliances due to a fast growing demand for cooling in India. Projects have been executed in collaboration with financing organizations such as ADB, WB, UNEP, and USAID. ADB[b] provided a loan to EESL, guaranteed by the Government of India, to support demand-side energy efficiency investments in several Indian states. ADB's loan covered high-priority areas under EESL's ESCO business through the use of (i) more efficient LED municipal street lighting equipped with remote operating technology; (ii) more efficient domestic lighting through replacement of incandescent lights with LEDs; and (iii) more energy efficient agricultural water pumps. EESL estimates that energy savings of 80% can be achieved through the domestic lighting programs and 30% can be achieved with more efficient pumps.

[a] https://eeslindia.org/en/home/.

[b] https://www.adb.org/projects/48224-002/main.

Table 3: Example Grants for Energy Efficiency Improvements in Buildings

Jurisdiction	Policy	Grant	Year
Japan	Subsidies for commercial and residential building energy efficiency investments	i. Replacement of existing equipment with energy-efficient equipment at factories or other facilities: Between one half and one third of the project cost. ii. Introduction of net-zero energy houses (ZEH): Fixed amount per house. iii. Demonstration of net-zero energy buildings (ZEB): Up to two thirds of the project cost. iv. Retrofit of insulation in existing houses using energy-efficient building materials: Up to one third of the project cost.	2016
	Promotion of Home/Building Energy Management Systems (HEMS/BEMS) Promotion of Zero Energy Building/Houses (ZEB/ZEH)	Management systems for managing the energy consumption of appliances by using IT.	2001
Haryana, India	Scheme on promotion of energy audit in buildings	50% of the Energy Audit cost with the Maximum limit of Rs. 50,000/	2001
Denmark	Subsidy scheme to replace oil burners with heat pumps in buildings outside the district heating and gas grids	Heat pumps	2020
Estonia	Renovation of apartment buildings	30%–50% of total cost	2019
UK	Green Homes Grant		

5.4 Public Investment and Procurement

Energy efficiency in buildings could be incentivized for public buildings using grants, subsidies loans, public procurement, or public investments (Table 4). Examples of public buildings include schools, administrative buildings, and hospitals. This policy not only allows the promotion of energy efficiency in buildings, but also the reduction in public expenditure on energy bills. Public procurement of energy efficient technologies allows purchasing at competitive cost due to large-scale negotiations between the government and manufacturers, which allows companies, households, and public sector to purchase these technologies at a pre-determined price.

Table 4: Example Policies Promoting Energy Efficiency in Public Buildings

Jurisdiction	Policy	Buildings	Year
Canada	Community buildings retrofit initiative	Local governments and not-for-profit organizations to retrofit public buildings to improve energy performance, lower operating and maintenance costs, and transition to cleaner energy solutions	2021
Denmark	Subsidy scheme for energy savings in public buildings	Energy renovations in regional and municipal buildings with the lowest energy performance certificate standards (D-G) as well as buildings heated by oil burners and gas furnaces	2021
Portugal	Solar thermal incentive scheme	Purchase of a solar thermal kit, comprising panels and ancillary equipment, installation, yearly maintenance for six years, and a six-year guarantee. The kit is acquired at a competitive cost, firstly due to large-scale negotiations between the government and manufacturers. The government also provides an immediate rebate of EUR 1,641.70 for the purchase of a solar thermal kit, and four banks (Caixa Geral de Depositos, BES, Millenium bcp and BPI) have special preferential rate fixing programs for those wishing to take a credit to cover the remaining cost of the solar thermal system. In addition, the incentive scheme can be combined with existing tax credit provisions for the installation of such systems.	2009
Italy	Kyoto fund for energy efficiency of public buildings	Projects should guarantee an improvement for the building of at least 2 energy efficiency classes in public buildings.	2021
Denmark	Subsidy scheme for energy savings in public buildings	Energy renovations in regional and municipal buildings with the lowest energy performance certificate standards (D-G) as well as buildings that are heated by oil burners and gas furnaces.	2021
Portugal	Resource efficiency program in public administration 2030	Sets energy efficiency targets by 2030 for public administration buildings	2021
Spain	Modernization of public administration	Energy efficiency and renewable energy installations in public administrations buildings; forbids the purchase of boilers using fossil fuels.	2021
Greece	ELECTRA	To improve the energy efficiency of public buildings to be classified at energy efficiency level B	2020–2026

Box 6: Green Public Buildings in India and Indonesia

India and Indonesia have been burdened with low-quality housing, slums, and increasing demand for affordable housing for low-income households. As the main target of urbanization, big cities such as Mumbai and Surabaya have experienced high external and inner-city migration, leading to high demand for housing. Lack of available government land has led to a higher preference for developing multi-story public housing, including for lower income groups.

Efforts to improve sustainable public housing practices have been made in India and Indonesia. Green infrastructure features are present in recent housing projects, whether through built-in and/or add-on features. Common built-in features to reduce the energy required for servicing the building include passive cooling design and the building envelope. Popular add-on features include waste management and rainwater harvesting. As not all cities are equipped with a mandatory green building code, the features vary across cities and housing projects.

Many cities have created programs to provide affordable green public housing and improve living conditions with support from the national and local government. In Indonesia, low-income public housing is financed through the state (Ministry of Public Works and Housing) and local government budget. Financing through the Housing Finance Liquidity Facility program, a government-owned structure that funds 70% of the total mortgage at a 7.25% interest rate, has not been fully utilized. The government has recently introduced a financing scheme for housing built through public–private partnerships with a payment mechanism; this is a scheme previously used to finance infrastructure in Indonesia. For both public and private housing, there are tax exemptions and easier credit or bank loan provisions for sustainable housing that complies with the green rating standardization.

Sustainability outcomes in low income public housing are rarely measured, leading to a lack of understanding of the factors affecting social acceptance of green infrastructure features among low-income households. To address this gap, our study analyzed public housing that accommodated relocation from the slums and squatter settlements in Mumbai and Surabaya. Social acceptance was measured as household level acceptance of sustainable housing through residential satisfaction or quality of life (QoL). Variables to measure acceptance of green public housing were developed from sustainable housing indicators (Nair et al. 2005; Habitat for Humanity 2012), a model of housing quality determinants for affordable housing (Chohan et al. 2015; Wallbaum et al. 2012), and green building assessment tools (BREAM 2005; IISBE 2005; USGBC 2005). To identify the distribution of economic and social gains, the attribute of well-being, employment, affordability, and accessibility were included.

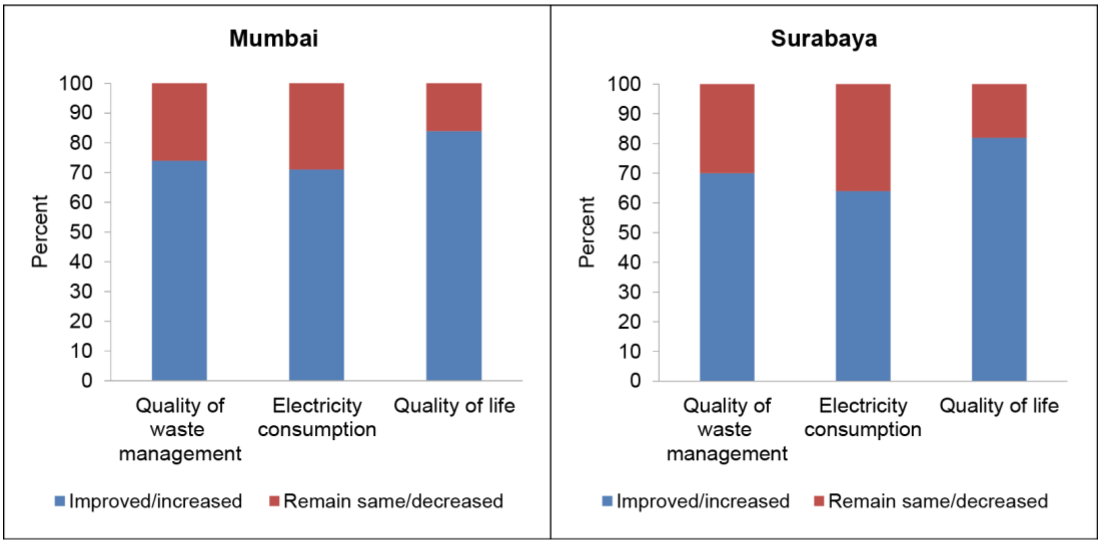
In Surabaya, three low income housing complexes of 2–5 buildings were selected: Rusun Penjaringan Sari, Urip Sumoharjo, and Grudo. Each tower consisted of 4–5 floors with a total of 60–80 units. Each housing unit measured 21–24 m^2. Resource efficiency measures for energy and water conservation installed were installed in the units, including renovation in some of the towers built before 2000. According to local regulations, waste management incorporating the tenets of reduce, reuse, and recycle and community management should be present as part of the community green and clean program. The survey was conducted between May and June 2018 with a target 300 respondents.

continued on next page

Box 6 *continued*

In Mumbai, three low income housing complexes were selected in Shivneri, Santacruz, and Bhoiwada. Like other more recent housing projects, eco-housing criteria were applied during the project implementation, including bio-diversity conservation methods during the site planning process; environmental architecture adopting climate responsive design practices to achieve thermal comfort, cross ventilation, and reduce glare; energy conservation and management with the use of fluorescent lamps; efficient building materials for finishing materials; water conservation; and waste segregation facilities. The survey was conducted between April and July 2019 with a target of 300 respondents (see figure below).

Figure: Perception of Housing Quality and Quality of Life in Green Low Income Public Housing



Public housing offered considerably improved social and environmental sustainability compared to life in the slums. The household perception of their overall well-being living in public housing was high in terms of the built environment and housing amenities. The analysis showed that green physical features greatly affected resident satisfaction with public housing. More than 70% of the surveyed households in both countries reported high satisfaction with the waste management in their residential complexes. More than 60% and 70% of the surveyed household reported higher consumption of electricity in Surabaya and Mumbai, respectively. This increase in consumption was due to an increase in their living area compared to their previous dwelling. Most households (more than 80%) reported an improvement in their overall quality of life living in their present residential complexes.

This box is authored by Ranjeeta Mishra and Mahesti Okitasari.

Box 7: Green Buildings for Hospitals

This box is written by Nicolas Dei Castelli, Senior Transport Specialist, Asian Development Bank; Yixin Yao, Senior Research Fellow, Asian Development Bank Institute; and Ellen May Reynes, Climate Change and Technical Project Management consultant, ADB

Independent All-in-one Heating, Cooling, and Power System in Xiangtan's New Hospital

Apart from passive building design and water-saving features, Xiangtan's newest hospital will install a new natural gas–powered combined cooling, heating, and power generation system alongside a solar PV power system. The system will be built according to the best international practices and will be able to provide the entire hospital with heating, cooling, and electricity—even during blackouts. The system consists of several unit types. One natural gas–powered electricity generation unit capable of powering the entire hospital, one heat recovery unit connected to the electricity generation unit that will provide heat (or power and an absorption unit for cooling), two chillers for warm summers, and two natural gas boilers for the winter. In the future, the natural gas could be replaced by biogas produced from organic waste.

A "DeNOx" system will also be installed on the natural gas-powered unit to ensure NOx air emissions live up to the highest international clean emissions standards. In addition, the heat recovery unit will maximize the energy usage of the natural gas–powered unit by recovering the waste heat and providing more than 15% of the total heating required. When cooling is needed, the recovery unit will power the absorption machine, which will provide upwards of 13% of the entire cooling capacity needed for the hospital. A BEMS will forecast the demand for energy during operations and intelligently manage the energy systems.

Co-benefits

- Economic: The tri-generation unit capable of providing cooling, heating, and power will be able to provide the hospital with cheaper energy.
- Climate: The natural gas–powered tri-generation unit will emit less GHG than the largely coal-powered main grid.

Key numbers

- 16.6 MW of cooling capacity can be provided by the two mechanical chillers included in the tri-generation unit
- 12.8 MW of heating capacity is the peak power that the two natural gas boilers in the tri-generation unit can provide.

Creating a climate-resilient low-carbon hospital

Hospitals need to be able to operate year-round without interruptions, so preventing interruptions due to flooding is critical. Climatic modelling and risk assessments showed that the new hospital in Xiangtan was being built in a particularly flood-prone area with higher than expected risks. To combat this, the hospital will make use of nature-based adaptation measures to increase the resilience against future flooding events. While the original design followed national sponge city standards, enhanced measures had to be implemented due to the increased risk. The sponge city standard, developed in 2014, mandated that the hospital have 740 m^3 of water storage capacity. However new assessments showed a total of 7,840 m^3 water storage capacity is needed to withstand once-in-30-years flooding events.

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Box 7 *continued*

The increase in capacity will be added through enhanced nature-based adaptation measures such as rain gardens, rainwater detention ponds, green roofs with drainage delay, permeable pavement, and infiltration trenches. While the rainwater ponds will primarily be used for flood drainage, they will also improve the quality of the green spaces for patients and visitors. The ponds will be used to grow medical plants and herbs while also providing water for green spaces throughout the hospital campus during severe droughts.

With the new flood prevention measures and an off-grid tri-generation energy system generator located on an upper ground floor to avoid flooding accidents, the hospital will be able to operate even during city-wide power outages and severe flooding events. The ground floor will also be lifted 0.5 to 1 m to limit damage to the equipment during floods, while an emergency plan for how to act when the building is flooded will provide guidelines for personnel.

Co-benefits

- *Social: The patients at the new hospital in Xiangtan will be able to enjoy enhanced green spaces providing medical plants and herbs while also securing the area in case of flooding events.*
- *Health: The hospital will be able to continuously provide healthcare regardless of blackout or flooding events.*

The newest Xiangtan hospital will be able to withstand severe flooding due to the presence of large run-off areas, underground storage tanks, and back-up generators in case the grid experiences a blackout (photo by Xiangtan PMO/design institute).

5.5 Strategic Plans

Strategic plans include policy signals demonstrating national plans for reaching energy efficiency, including national targets (such as NDCs and net-zero emissions), national strategic plans, and creation of institutions. Some countries have announced targets relevant to green buildings, such as net-zero targets, NDCs, and emissions intensity, while some countries have targets related specifically to green buildings or energy efficiency (Table 5). The advantages of targets, as a policy instrument, are that they are clear and measurable and can be used for long-term planning of other policies for meeting these targets.

Table 5: Green Building and Other Relevant Targets

Country	Target	Target Year	Document	Organization
	Net zero carbon target	Mid-century		
	GHG emissions reduction		National Determined Contributions	
	Energy intensity			
Netherlands	Energy label targets Voluntary agreement to bring building stock to an average of energy label B. Mandatory for all office buildings to have an energy label C. Energy label A will be the standard.	2020 From 2023 From 2030	Dutch national government	
India	(i) Reduce cooling demand across sectors by 20% to 25% by 2037–2038, (ii) Reduce refrigerant demand by 25% to 30% by 2037–2038, (iii) Reduce cooling energy requirements by 25% to 40% by 2037–2038, (iv) Recognize "cooling and related areas" as a key area of research under national Science and Technology Program, (v) Training and certification of 100,000 servicing sector technicians by 2022–2023		Cooling Action Plan	
PRC	Green buildings should account for over 50% of all newly constructed buildings in urban areas by 2020, and more than 60% of existing residential buildings in urban areas across the country should be retrofitted as energy-efficient buildings		13th FYP for the Development of Building Energy Efficiency and Green Building	
Singapore	80% of green buildings	2030	Singapore Green Building Masterplan (SGBMP)	BCA and the Singapore Green Building Council
	80% of new developments (by gross floor area) to be Super Low Energy (SLE) buildings	From 2030		
	80% improvement in energy efficient for best-in-class green buildings	2030		
International	To reduce (and compensate where necessary) all operational and embodied carbon emissions within their portfolios	2030	Net Zero Carbon Buildings Commitment	World Green Building Council
	All buildings to be net zero whole life carbon	2050		
Australia	Zero energy and carbon-ready commercial and residential buildings		Trajectory for Low Energy Buildings	
UK	600,000 heat pump installations per year by 2028		Ten Point Plan for a Green Industrial Revolution – Point 7: Greener Buildings	

5.6 Energy Audits

Although policies incentivizing building energy audits do not directly promote improvements to energy efficiency, audits can help to realize potential energy efficiency improvements and provide justification for investment. Energy audits include the inspection, verification, technical and economic analysis, and evaluation of energy use systems, equipment operation, management, and energy consumption, as well as recommendations for improvements. They are usually voluntary and incentivized using grants, subsidies, or tax incentives. Regular energy audits (usually every 4–5 years) could be compulsory for certain building categories, such as large energy consumers in Morocco, public organizations in the PRC, or large companies in Germany and Austria. Buildings with certified energy efficiency may be excluded from obligatory energy audits. Such policies require the availability of certified energy auditors, which also creates employment opportunities.

Box 8: Conserving Energy and Water with 200 Smart Buildings in Xiangtan (PRC)

This box is written by Nicolas Dei Castelli, Senior Transport Specialist, Asian Development Bank; Yixin Yao, Senior Research Fellow, Asian Development Bank Institute; and Ellen May Reynes, Climate Change and Technical Project Management consultant, ADB

To reduce energy consumption and water usage in public buildings, Xiangtan is installing a new intelligent BEMS. Data from sensors in more than 200 public government buildings will be sent to a central database. The resource management software will then be able to tap into that data to regulate lighting, temperature, humidity, and water consumption to optimize resource consumption.

One of the buildings which will be connected to the city-wide BEMS is the new Xiangtan hospital. Data collected from throughout the building using onsite sensors and meters, including cooling demand, heating demand, electricity demand, hot water demand, outside temperature, humidity, weather information, number of patients, and behavioral characteristics, will be consolidated and analyzed for trends and to prepare demand forecasts to allow for efficient and effective facility-wide insight and control. The insights from the BEMS can then be used to further optimize energy management strategies, which will also reduce operational costs. Smart controls in the BEMS will be able to adjust temperature and lighting in individual rooms according to real-time usage, as well as incorporating behavioral and weather forecasts. The BEMS can integrate actual efficiency performance and measure it against performance targets.

Connecting 900,000 m^2 in 200 public buildings to the city-wide BEMS will enable monitoring of building energy statistics, city-wide building energy saving efforts, and the resulting reduction in GHG emissions. As part of the Xiangtan government's commitment to reducing GHG emissions from the building sector, the local government issued the Implementation Rules for Green Buildings. The new rules are meant to incentivize new and existing buildings to become smarter using an intelligent BEMS, which in most cases enables energy performance contraction to accelerate effective energy conservation measures and reduce emissions from buildings.

Services from the Xiangtan Health Commission and Xiangtan Housing and Urban-Rural Construction Bureau will be improved with the data and demand-management capability of the BEMS at the hospital and in all other government buildings.

Co-benefits

- *Economic: The new monitoring systems are expected to improve energy efficiency in buildings by 10%, which translates to cost savings that can be invested elsewhere.*
- *Climate: The project will result in energy savings of almost 24,000 MWh per year, reducing the amount of coal needed to produce energy for the power grid.*

6. CONCLUSIONS AND POLICY IMPLICATIONS

Rapid changes in climatic condition, with the increase in the frequency of extreme weather events such as prolonged heat and drought, flooding, GLOF, erratic rainfall, salination, and sea inundation have raised concern for the future of the humanity. Global efforts encompassing all sectors are needed to check climate change through the reduction in GHG emissions. As the building and construction sectors account for one-third of total energy consumption and contribute one-third of GHG emissions, they have the potential to contribute significantly to the reduction in GHG emissions and reversing the trend of climate change. The rapidly growing population, which is expected to reach 9.7 billion by 2050, and increasing income will increase the demand for housing, so it is critical to bring about significant innovation in the sector to reduce GHG emissions, and green buildings could play a crucial role. Green building involves greening the entire process from the manufacturing of the construction materials to design, construction, maintenance, and demolition. Green buildings that are environmentally friendly involve the use of processes and materials that cause minimal damage to the environment and are energy and resource efficient, as well as providing attractive amenities such as better indoor air.

There are challenges to the implementation of green buildings, particularly in developing countries, where the necessary construction materials and skilled laborers are not readily available. The cost of constructing green buildings is also high. The lack of standards, policies, and support from the government also acts as a barrier to green buildings in developing countries, so policies should be developed to support skilled labor through training and increase access to green building materials. Popular policies that can help to promote green buildings include codes and standards, tax incentives, grants and subsidies, loans, and public investment and procurement, as well as strategic plans. Most policies are interlinked, so a combination of policies is required for better efficiency. This paper provides the following key messages for policy makers:

- Green buildings can help to meet NDCs, energy security, and reduce GHG emissions from the sectors of manufacturing building materials, building construction, and building operation.
- Popular policies to promote green buildings include codes and standards, tax incentives, grants and subsidies, loans, public investment and procurement, and strategic plans.
- Mixed policy instruments are recommended.
- Most existing policies are provided for energy efficiency, not green buildings.
- Promoting energy efficiency in buildings is not an equal substitute for green building policies, as they do not promote manufacturing of low-carbon construction materials and low-carbon building construction.

Policies develop over time, and long-term planning of support is recommended, starting from more voluntary and rewarding policies and then moving toward compulsory and punitive policies.

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