WORLD RESOURCES INSTITUTE

WORKING PAPER

ACCELERATING BUILDING DECARBONIZATION: EIGHT ATTAINABLE POLICY PATHWAYS TO NET ZERO CARBON BUILDINGS FOR ALL

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EXECUTIVE SUMMARY

Highlights

- Cities will lead the shift to net zero carbon buildings (ZCBs) and will therefore play a major role in achieving the goal of a decarbonized world.
- ZCBs are more achievable when the definition is expanded beyond the boundary of the individual building to allow the use of off-site clean energy or consideration across a portfolio of district or municipal buildings.
- This working paper lays out a menu of pathways to achieve ZCBs, with a focus on operational carbon emissions. Each pathway is a combination of up to five components: basic energy efficiency, advanced energy efficiency,[1] on-site carbon-free renewable energy, off-site carbon-free renewable energy, and carbon offsets only in cases where efficiency measures and renewables cannot meet 100 percent of energy demand.
- Policies shape a city's ability to achieve ZCB pathways. This working paper draws on reviews of current policy frameworks and consultations with stakeholders in four countries—India, China, Mexico, and Kenya—to determine how policies at the national and subnational level enable or disable the different ZCB components and pathways.
- Even within these different policy contexts, we find ZCB pathways that are feasible today, making a decarbonized building stock a target increasingly within reach for urban policymakers.

CONTENTS

Working Papers contain preliminary research, analysis, findings, and recommendations. They are circulated to stimulate timely discussion and critical feedback, and to influence ongoing debate on emerging issues. Working papers may eventually be published in another form and their content may be revised.

Suggested Citation: Becqué, R., D. Weyl, E. Stewart, E. Mackres, L. Jin, and X. Shen. 2019. "Accelerating Building Decarbonization: Eight Attainable Policy Pathways to Net Zero Carbon Buildings for All." Working Paper. Washington, DC: World Resources Institute. Available online at https://www.wri.org/publication/accelerating-building-decarbonization.

Box ES-1 | **A Note to Readers: Definitions and Scope of the Paper**

This paper uses the term *net zero carbon building* (ZCB) to define an energy efficient building, regardless of whether the building uses on-site renewables, off-site renewables, and/or credible offsets to achieve a (net) balance between energy demand and renewable energy supply or between the carbon emissions associated with annual energy demand and energy provision. The balance between building energy demand and the provision of carbon-free renewable energy can be achieved at the level of the individual building or at the district or municipal portfolio scale.

This definition of ZCBs was chosen to align closely with the thinking presented in the Zero Code standard by Architecture 2030, which itself consulted with key institutions like the World Green Building Council and the International Finance Corporation's EDGE program. The standard was published in spring 2018 as "a national and international building energy standard for new commercial, institutional, and mid- to high-rise residential buildings."[a]

In line with the thinking of the World Green Building Council and several of its member councils around the world, as well as Architecture 2030, we allow the use of carbon offsets as a last-resort option. Offsets may be purchased to close the gap in cases where on- or off-site carbon-free renewable energy cannot provide for 100 percent of energy demand. Such offsets are bound by a number of criteria, including additionality and their being used to invest in energy efficiency or renewable energy projects.

Commonly used terms today include *net zero energy*, *nearly zero energy*, *net zero carbon*, *zero net carbon*, or *zero carbon buildings*. These different concepts all refer to buildings that achieve or nearly achieve a balance between energy demand and renewable energy supply or the carbon emissions associated with energy demand and provision. We focus this working paper on buildings that achieve net zero carbon emissions at either the individual building or district/municipal portfolio level. Readers interested in a more in-depth consideration of effective building energy efficiency policies can consult the World Resources Institute's *Accelerating Building Efficiency: Eight Actions for Urban Leaders* report.[b]

The paper presents a menu of ZCB policy pathways and analyzes policy frameworks in four countries to test the hypothesis that no matter the current policy framework, a ZCB pathway is achievable today. We emphasize that the paper limits its consideration of pathway feasibility mainly to policies currently in place—their enabling or disabling effect—and policies that are lacking. The paper does not consider local markets or technical capabilities. However, financial and technical factors will play a major role in which ZCB pathways can be pursued by policymakers and by actors on the ground, particularly building developers and building owners and managers.

Sources: a. Zero Code, n.d.; b. Becqué et al. 2016.

Purpose of This Paper

This paper responds to the global discourse around the need to decarbonize the world's building stock by 2050 in order to meet global climate goals. It aims to provide clear, feasible policy pathways by which developing countries can achieve net ZCBs in their cities. We hope the paper will provide a starting point for urban decision-makers who are interested in understanding the wide range of policy options available to them. We do not consider the full spectrum of opportunities and barriers that affect planning for ZCBs, and this document alone does not provide a sufficient basis for policy actions.

An Introduction to ZCBs in Cities

To achieve the Paris Agreement's vision of a decarbonized world and the Sustainable Development Goals' vision of equitable climate action, reducing the carbon footprint of buildings will be at the center of actions to mitigate the impacts of climate change. The building sector today is responsible for a staggering one-third of global energy consumption and energy-related carbon emissions.[2] Zero carbon buildings can create significant equity benefits by reducing energy poverty, strengthening energy resilience, and improving energy access for all.

Cities must be lead actors in shifting the world toward a decarbonized building sector. With a higher percentage of the world's population now living in urban areas than ever before, cities largely determine the future of their countries. Urban decision-makers will have to lead on fostering and accelerating ambition on ZCBs. Actors at different government levels and in the public and private sectors will need to come together to overcome barriers and make net ZCBs a feasible and desirable goal.

Certain key national and subnational policies have direct enabling or disabling effects on the feasibility of achieving ZCBs. Mandatory requirements such as building codes and appliance standards, various incentives for voluntary action, and action plans influence whether and how much building owners will choose to incorporate EE or clean energy elements in their new building construction or existing building renovation plans. Although some policies are enacted mainly at the national level, regional and municipal authorities also have influence.

ZCBs are more achievable and accessible when they are broadly defined. Our definition of ZCBs allows cities to produce or procure clean renewable energy beyond the boundaries of the individual building site and achieve net zero carbon emissions across a group of buildings as well as at the level of the individual building.

Pathways to ZCBs

To accelerate policy ambition among urban decision-makers, this paper introduces a menu of eight pathways to decarbonize the building stock. We recognize that there are multiple ways to arrive at 100 percent reduction of a building's operational carbon emissions. Each pathway consists of a "package" of measures—some combination of basic energy efficiency (basic EE), exemplary energy performance (advanced EE),[3] on- or off-site carbon-free renewable energy (on-site RE and off-site RE), and—only in cases where efficiency measures and renewables cannot meet 100 percent of energy demand—the use of carbon offsets.[4] Embodied carbon emissions associated mainly with a building's construction can also be added as a component to these ZCB pathways. Illustrative examples of how the pathways can be constructed from constituent energy efficiency and renewable energy components are shown in Table ES-1.

Not all pathways to ZCBs are equally desirable. We develop a set of principles to guide the choice of components. Energy efficiency comes first because using no more energy than necessary often results in the least expensive pathways, along with significant additional benefits including health and comfort. Next in the hierarchy of preference is use of on-site RE, which adds to a city's total installed capacity of clean energy. Off-site RE is the next choice and may be especially suitable for portfolios of buildings seeking to achieve net zero carbon emissions across their combined energy use. Lastly, carbon offsets may be chosen to compensate for remaining carbon emissions that cannot be avoided through efficiency measures and carbon-free renewable energy supply.

Table ES-1 | **Cities Can Achieve Zero Carbon Buildings via Different Combinations of Energy Efficiency (EE) Measures, Use of Renewable Energy (RE), and—as a Last Resort—Carbon Offsets**

PATHWAY		COMPONENT				
		BASIC EE[a]	ADVANCED EE[b]	ON-SITE RE	OFF-SITE RE	CARBON OFFSETS[c]
Exemplary energy performance	1	◆	◆	◆		(if needed)
	2	◆	◆	◆	◆	(if needed)
	3	◆	◆		◆	(if needed)
	4	◆	◆			◆
Minimum energy efficiency	5	◆		◆		(if needed)
	6	◆		◆	◆	(if needed)
	7	◆			◆	(if needed)
	8	◆				◆

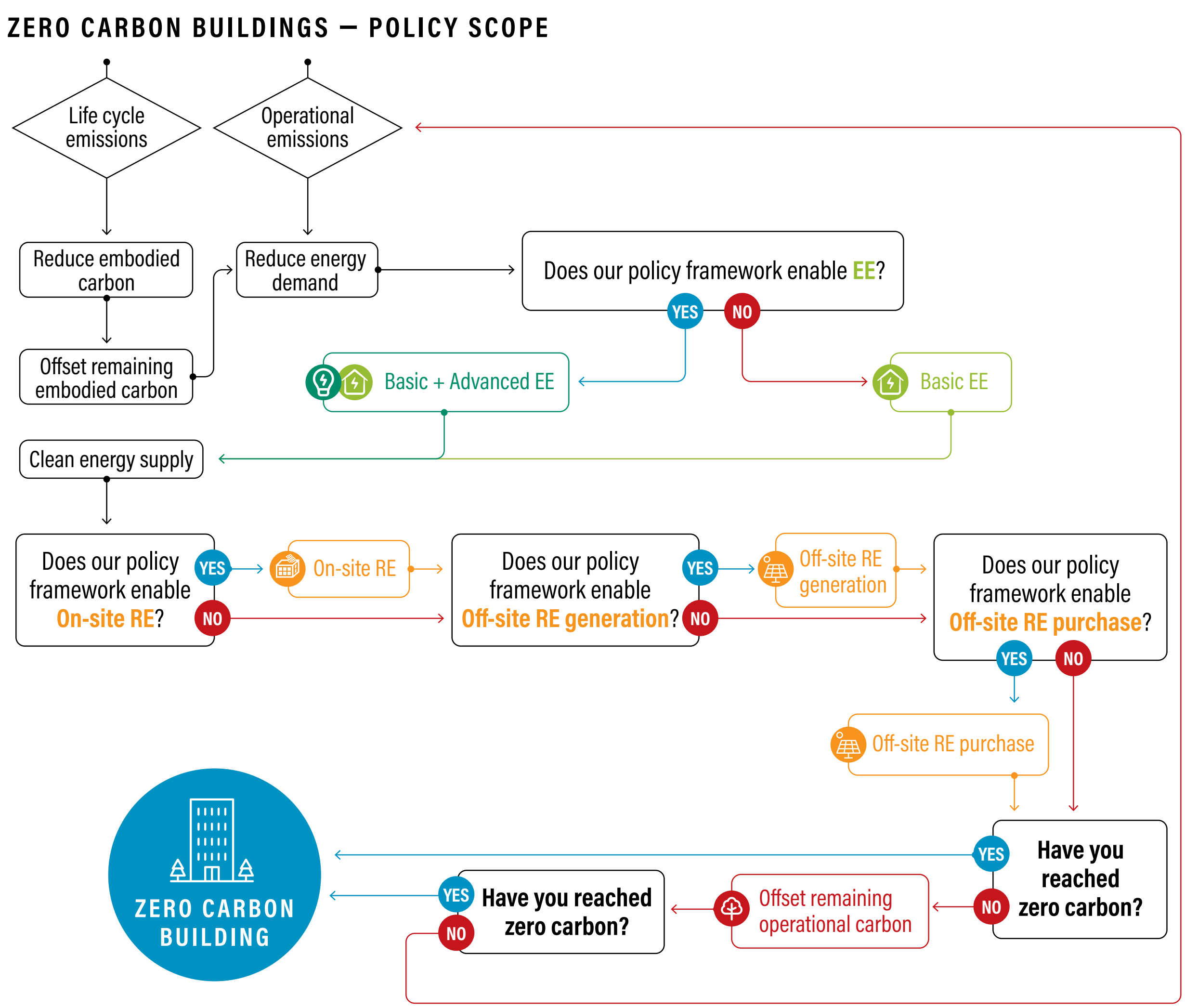
Notes:
[a] The minimum required level of energy efficiency achieved by complying with local codes and standards.
[b] More ambitious energy performance that goes beyond minimum regulatory requirements.
[c] Recommended only in cases where efficiency measures and renewables cannot meet 100 percent of energy demand.
Source: WRI.

Applying these principles allows us to develop a decision tree that can help urban decision-makers map out the best ZCB pathway, given their local policy framework. The decision tree (Figure ES-1) lays out the ZCB components in a recommended order of consideration. Some ZCB pathways will be easier to pursue than others, depending on the policies and programs currently in place and market readiness—that is, sectoral experience and the availability, quality, and cost of products, materials, designs, and labor.

Key Findings: ZCB Pathways and Enabling Policies

The research suggests that even within different policy frameworks, there is likely to be a ZCB pathway that is achievable today. In each of four countries that are influential in their regions—India, China, Mexico, and Kenya—examples of nearly ZCBs already exist or are under development.

Figure ES-1 | Decision Tree to Help Identify Suitable ZCB Policy Pathways, Combining Energy Efficiency (EE), Renewable Energy (RE), and/or Carbon Offsets as a Last Resort



Source: WRI.

Policy and economic considerations reinforce the hierarchy of desirable ZCB pathways. For example, it is often cheaper to meet energy demands through energy efficiency measures than through the provision of alternative, greener energy supplies. Creating on-site RE where feasible is preferable to off-site RE sources because it directly expands the total carbon-free renewable generation capacity and helps strengthen energy security. It should therefore be considered before purchasing off-site renewables where possible, though financial or site constraints may rule out this option. Generating or purchasing carbon-free renewable energy is preferable to purchasing carbon offsets, which can be hard to verify and, ultimately, cannot support a full transition to a decarbonized building stock.

Municipal governments can lead the achievement of ZCB pathways through several roles. On the policy side, municipal governments may be able to act as regulator, convener, and facilitator as well as act as complementary or strategic partner to state or national governments for policy design and implementation. In addition, municipal governments can lead by example as an owner/investor of a substantial portfolio of buildings.

Leadership from state- and national-level government is also critical to enable the success of local initiatives to achieve ZCB pathways. State and national governments often design essential policy components, such as building energy efficiency codes and standards, and renewable energy regulations that govern which options are available to energy consumers. These policymakers can also work in partnership with local governments to strengthen policy effectiveness.

The Need to Accelerate Ambition

Although all buildings must be net zero carbon by 2050 to meet the goals of the Paris Agreement, not even 1 percent of buildings are considered net zero carbon today. Estimates from 2017 noted 2,500 net zero energy buildings existed worldwide—500 commercial buildings and 2,000 housing units. This number refers only to buildings that are officially recognized to be net zero energy, for instance, through a green building certification or by having adhered to an official standard. It leaves out the many buildings that have reached net zero energy but are not recognized as such. Examples include noncertified buildings that use local passive design principles and on-site renewable energy to achieve net zero carbon, buildings in off-grid areas that are energy self-sufficient through on-site renewables, or buildings powered by 100 percent renewable energy from the local grid. Because there are so few recognized ZCBs, they are seen as one-off pilot projects rather than a scalable approach to buildings.

ZCBs are currently seen as the preserve of only the wealthiest economies. Buildings recognized as ZCBs today are clustered largely in the European Union and North America. The barriers to achieving ZCBs at scale in developing economies in the short term are therefore often seen as insurmountable—because it has not been done, it is often assumed that it cannot be done.

Rather than perceiving ZCBs as one-off projects to be scaled in the future in wealthy economies, our research asserts that ZCBs are possible in all economies, and we must start pursuing them today. Knowledge of a menu of pathways toward ZCBs can change urban decision-makers' perceptions of carbon-neutral buildings. Rather than far-off aspirations, they can be seen as targets within reach. The pathways can be applied at the individual building level or to a group of buildings, such as a municipal building portfolio or a city district. This should increase the feasibility and affordability of some of the pathways while simultaneously generating a variety of community-scale benefits.

Putting Theory into Practice: Next Steps

This paper limits its analysis to assessing the policy feasibility of the eight ZCB pathways by considering the enabling or disabling effects of policy frameworks in four countries. The paper does not consider technical, market, or economic conditions, although these factors will also influence which ZCB pathways are most feasible.

Additional research is needed into the technical, market, and economic conditions for ZCBs. In addition to the enabling or disabling influence of national and local policy pathways on ZCBs, success relies on critical factors that include technology availability, the first cost and overall cost-effectiveness of energy efficiency and renewable energy measures, and the availability of financing structures in the local context.

Further research is also needed into the implications of decarbonizing the building stock, rather than individual buildings, by addressing ZCBs at the district or portfolio scale. This may involve different (communal) drivers than an individual building approach—such as benefits from resilience and

ABBREVIATIONS

AC	air conditioner
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BEA	Building Efficiency Accelerator
CCER	China Certified Emission Reduction
CDM	Clean Development Mechanism
CEL	certificado de energia limpia (clean energy certificate)
ECBC	Energy Conservation Building Code
EDGE	Excellence in Design for Greater Efficiency
EE	energy efficiency
ESCO	energy service company
FAR	floor area ratio
FIT	feed-in tariff
GBC	green building council
GEC	Green Electricity Certificates
GRIHA	Green Rating for Integrated Habitat Assessment
HVAC	heating, ventilating, and air-conditioning
IECC	International Energy Conservation Code
IFC	International Finance Corporation
IGBC	Indian Green Building Council
INFONAVIT	Instituto del Fondo Nacional de la Vivienda para los Trabajadores (National Workers' Housing Fund Institute)
IPP	independent power producer
KGBS	Kenya Green Building Society
LEED	Leadership in Energy and Environmental Design
MAITREE	Market Integration and Transformation for Energy Efficiency
MEPS	minimum energy performance standards
MOF	Ministry of Finance
MOHURD	Ministry of Housing and Urban-Rural Development
NOM-ENER	Normas Oficiales Mexicanas de Energia (Mexican Official Standards of Energy)
PPA	power purchase agreement
PROCALSOL	Promoción de Calentadores Solares de Agua en México (Promotion of Solar Water Heaters in Mexico)
PV	photovoltaic
RE	renewable energy
REC	renewable energy certificates
REDD	Reduced Emissions from Deforestation and Forest Degradation
RPO	renewable purchase obligation
USGBC	U.S. Green Building Council
WorldGBC	World Green Building Council
WRI	World Resources Institute
ZCB	zero carbon building

improved air quality—and also incorporates a broader set of interventions that impact the carbon intensity of buildings, such as decarbonizing centralized electric grids.

The World Resources Institute (WRI) aims to raise ambition among cities on the depth and scale at which ZCBs are being rolled out across urban areas. This menu of ZCB pathways and analysis on policy impacts on pathway feasibility form the first step toward such a transition. This analysis shows that a decarbonized building stock is attainable through policy pathways and is politically feasible, even in jurisdictions that so far have gained less experience in or have had less of a focus on greening building energy demand and supply.

As a next step, WRI and partners are launching "Zero Carbon Buildings for All," a national-subnational and private sector consortium to support governments in taking the first steps toward ZCBs or enhancing their existing efforts and mobilizing the financing to convert policy into shovel-ready projects.

INTRODUCTION

The goal of the Paris Agreement on climate change is to keep average global temperature increase to well below 2°C, and preferably below 1.5°C. It requires the peaking of global emissions as soon as possible, followed by a rapid reduction, bringing greenhouse gas emissions effectively to zero in the second half of this century. The current climate targets of many countries and cities are largely inconsistent with this long-term vision.

Although action is becoming increasingly widespread in both the power and mobility sectors, progress toward zero carbon buildings (ZCBs) has been relatively slow, even though building decarbonization can greatly support national and subnational low carbon development goals. Technically the solutions, though not perfect, already exist. The costs of renewable energy generation are falling rapidly, making them increasingly competitive with conventional grid electricity while creating jobs and reducing pollution. The principal barriers faced are political, financial, and normative.

The Case for ZCBs

With a higher percentage of the world's population now living in urban areas than ever before, cities will lead much of the effort to shift to a low-carbon economy. Cities will largely determine the future of their countries, and actors in both the public and private sector will need to collaborate to overcome policy and market barriers and make ZCBs a feasible and desirable goal.

To help foster and accelerate policy ambition on ZCBs among urban decision-makers whose policies and leadership are impacting the development and prosperity of cities, this paper lays out a menu of pathways to effectively decarbonize the urban building stock. Each ZCB pathway consists of a combination of basic or advanced energy efficiency, on-site and/or off-site carbon-free renewable energy, and—only in cases where renewables cannot fully provide for 100 percent of remaining energy demand—the use of carbon offsets[5] to reduce or compensate for all of a building's operational carbon emissions. Stakeholders who wish to expand their definition of net zero carbon to include the embodied carbon emissions associated mainly with a building's construction can add this component to their set of ZCB pathways.

1.1.1. Pathways to ZCBs

It is our hope that the availability of a menu of ZCB pathways will help transform the aspiration of carbon-neutral city buildings into a practical target increasingly within reach. Building decarbonization can be pursued both at the individual building level or across a group of buildings, for example, a portfolio of buildings under the same local ownership or management or within a city district. Such an approach is expected to increase the feasibility and affordability of some ZCB pathways and generate a variety of community-scale benefits. Our research suggests that, even within different policy frameworks, one or more ZCB pathways are achievable today.

Not every pathway is considered equally desirable. It is generally good practice to consider opportunities for energy efficiency before greener energy supplies. Following contemporary thinking in the net zero buildings community, we introduce a set of core principles that allows us to differentiate between the ZCB pathways, creating a hierarchy of pathways from more to less desirable. We also discuss the roles and degree of influence of municipal, national, and/or state governments in achieving these pathways.

1.1.2. Four country case studies

We assess the policy frameworks relevant to ZCBs in four countries: India, China, Mexico, and Kenya. All are powerhouses in their own regions, but their diverse geographies and institutional structures present ideal case studies of how ZCB pathways may be pursued in different ways. We aim to identify not only pathway feasibility but also help pinpoint policy strengths and weaknesses relevant to building decarbonization. The methodology applied for the country analysis is provided in Appendix A, while each country's policy framework is presented in more detail in Appendix B. We include a set of suggested priority policy actions for each country that can help close the gap between existing and enhanced policy and bring preferable ZCB pathways within reach. The research demonstrates that ZCBs can become an attainable goal within each of these countries and their wider regions. Even local jurisdictions that currently have less experience with greening building energy demand and supply can aspire to this goal.

This paper can help interested urban decision-makers broaden their thinking around the options available to them for decarbonizing their local building stock. It does not, however, consider the full spectrum of opportunities and barriers that come into play when pursuing ZCB goals and does not provide a sufficient basis for policy actions.

As a next step, the World Resources Institute (WRI) aims to recruit a select number of Building Efficiency Accelerator (BEA) cities to take first or further steps in accelerating ZCBs. We will support them in the application of ZCB pathways thinking to accelerate the pace and scale of building decarbonization. Interested cities are welcome to get in touch.

The following sources, among many available, are recommended as further reading.

Building efficiency:

- WRI's *Accelerating Building Efficiency: Eight Actions for Urban Leaders* report, https://www.wri.org/publication/accelerating-building-efficiency-actions-city-leaders
- The Building Efficiency Accelerator, http://buildingefficiencyaccelerator.org/resources/
- The Building Efficiency Initiative, https://buildingefficiencyinitiative.org/
- The Global Buildings Performance Network, http://www.gbpn.org/

(Net) ZCBs:

- Architecture 2030's Zero Code, https://architecture2030.org/zero-code/
- The World Green Building Council, http://www.worldgbc.org/thecommitment
- The International Finance Corporation's global target of net zero carbon via EDGE tool: https://ifcextapps.ifc.org/ifcext%5Cpressroom%5Cifcpressroom.nsf%5C0%5C7B96214C03769DBE8525817700524A9C

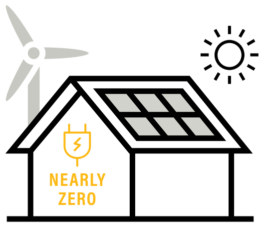
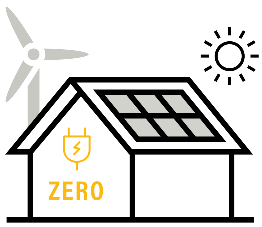
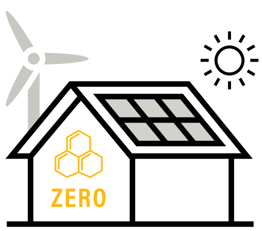
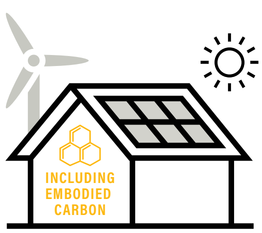
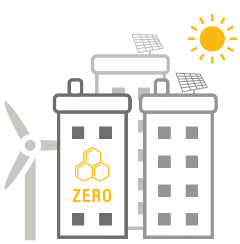
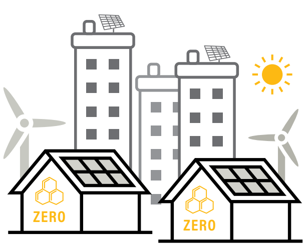
Aggregated renewable energy purchasing:

- The Renewable Energy Buyers Alliance, http://rebuyers.org/
- The Rocky Mountain Institute's Business Renewables Center, https://www.rmi.org/our-work/electricity/brc-business-renewables-center/

The Greenhouse Gas Protocol for Project Accounting:

- Project Protocol, https://ghgprotocol.org/standards/project-protocol

Table 1 | **Overview of Commonly Applied Zero Building Concepts and What They Entail**

	**Nearly zero energy building**	An energy efficient building that supplies most (but not all) of its annual energy use through on- or near-site renewable energy sources.
	**Net zero energy building**	An energy efficient building that produces enough on-site or nearby renewable energy to meet building operations' energy consumption annually on a net basis (the building delivers at least the same amount of renewable energy to the grid than is used from the grid over the course of a year). Note: Not all renewable energy is considered to be carbon-free in its generation.
	**(Net) zero carbon building (ZCB)**	An energy efficient building that produces on-site, or procures, enough carbon-free renewable energy to meet building operations' energy consumption annually. Note: Zero carbon is often used interchangeably with net zero carbon, whether or not the building uses potentially fossil fuel–derived grid electricity to make up for temporary gaps in on-site renewable energy generation to meet demand or uses carbon offsets. If it does, it is usually called a "net" zero building.
	**(Net) zero carbon building, including embodied carbon**	An energy efficient building that produces on-site, or procures, enough carbon-free renewable energy to meet building operations' energy consumption annually and also over its life cycle, compensating for the carbon embodied in the building's construction. Note: An emerging goal is to also include embodied carbon arising from the materials, machinery, and equipment used in building construction, maintenance, and repair into the net zero definition. Preferably, these embodied emissions are reduced during the design and construction phase rather than compensated during the operational building phase.
	**(Net) zero carbon building portfolio**	A group of energy efficient buildings sharing a similar characteristic and usually under the same ownership or management, with carbon-free renewable energy demands mainly provided for within the boundaries of the portfolio rather than at the level of individual buildings.
	**(Net) zero carbon district**	A group of energy efficient buildings within a geographically defined urban area, with carbon-free renewable energy mainly supplied through nearby off-site sources, generating clean energy at the district level.

Source: WRI.

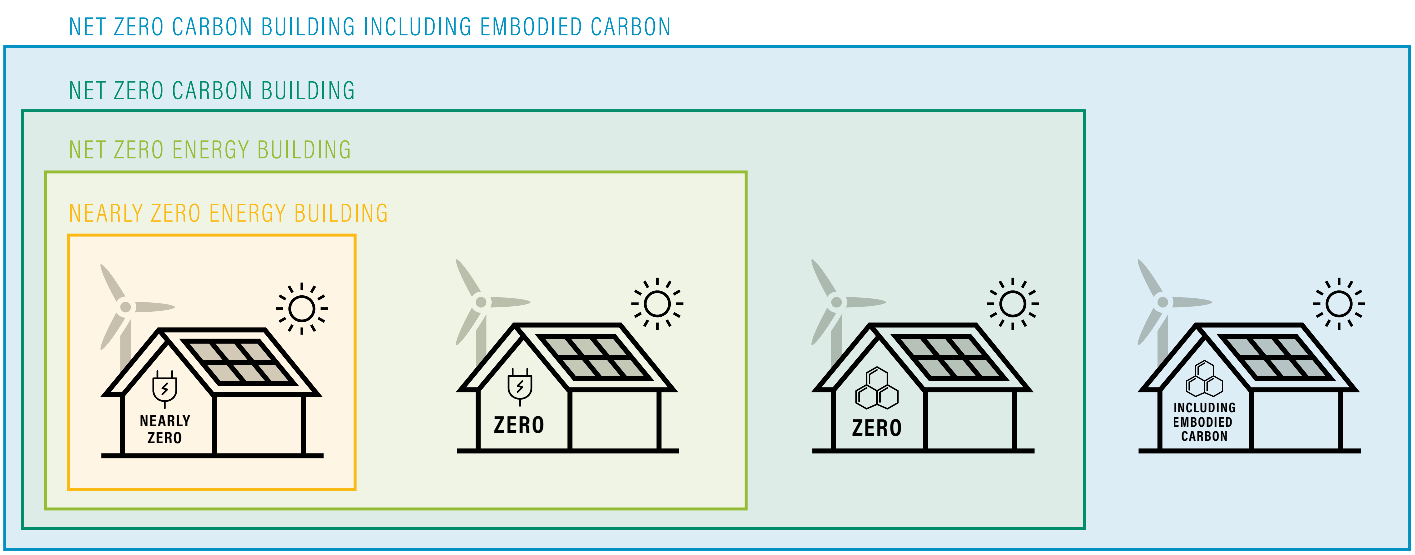
A Short Primer on Zero Building Concepts

Various concepts are commonly used in the literature and discussions of building decarbonization. They all concern buildings that achieve a net zero or nearly zero balance between energy demand and renewable energy supply or between the carbon emissions associated with energy demand and energy provision. To clarify the relationship between these concepts, we provide concise definitions and boundaries for those most commonly used (Table 1).[6] The concepts can be seen as nested, each one slightly more ambitious or all-encompassing than the last (Figure 1).

All these concepts offset carbon-based energy consumption with improved energy efficiency and new renewable energy capacity. However, the nearly and net zero energy definitions represent a narrower path, focusing on on-site or near-site renewable energy production. This limits their application to mostly low-density, low-rise, suburban, or rural building applications (Architecture 2030 et al. 2016).

The focus of this paper is mostly on *net* zero carbon buildings. For simplicity, we refer to these throughout this paper as ZCBs. We provide additional explanation of the various concepts for achieving building energy and/or carbon neutrality, as well as concise definitions for a few commonly used terms, in Appendix C.

Figure 1 | **ZCB Concepts Can Be Seen as Nested, from Less to More Encompassing, in Terms of Their Ability to Achieve Carbon Neutrality**



GETTING TO ZERO CARBON: A STRUCTURED APPROACH

Framing ZCBs

Recent years have seen rapidly growing interest in ZCBs. This has resulted in at least 2,500 verified net zero energy buildings around the world today, ranging from single- and multifamily housing to schools and commercial office buildings.

Zero carbon buildings can be thought of in terms of measures taken within a building or group of buildings, measures taken outside the building(s), and measures appropriate to specific characteristics of the building(s). There are generally trade-offs to be made between the costs, desirability, and practicality of all these measures.

For a ZCB, energy efficiency is generally considered a first priority before meeting the building's (remaining) energy needs with carbon-free renewables. In practice, however, the cost and effort of ensuring deep energy savings against business as usual,[7] in particular for existing building stock, may not always weigh up against spending these same resources on other decarbonization efforts, such as greening the electricity grid or promoting on-site renewable power generation. And, depending on the building type and local conditions, renewable energy can sometimes be more (cost-) effectively developed at the system level, such as at the scale of districts, cities, or entire regions, rather than at the level of individual buildings. An example is a high-rise building with small floor plates in a high-density city.

Trade-offs may also exist between building vintages—such as whether to focus more on new buildings by implementing and enforcing strong codes and standards or on existing building stock through retrofits—and between segments of the market, such as commercial, residential, or municipal buildings (e.g., schools, hospitals, etc.). The optimal combination of measures to arrive at ZCBs, as well as the optimum scale (individual buildings versus a district, municipal, or portfolio approach), is likely to differ by region and is equally dependent on market conditions and the policy framework in place. Identifying the best approach will be a critical first step for urban decision-makers aiming to develop a ZCB policy road map.

This section discusses the main components of ZCBs: basic and advanced energy efficiency, on- and off-site renewable energy, and carbon offsets. These components are described in more detail in Appendix D. The section also introduces a set of principles that help guide the choice and prioritization of components to achieve ZCBs. The section concludes with some examples of ZCB certification tracks that recently have been developed by national green building councils (GBCs) around the world.

Key Components of ZCBs

Buildings are major end users of energy, mainly for space heating and cooling, lighting, and running equipment. The most common energy source is usually electricity, and electricity generated from fossil fuel sources releases carbon dioxide emissions to the atmosphere. In many buildings, natural gas also plays an important role for energy provision, and in some countries unreliable grids have resulted in considerable use of diesel-powered backup generators. The carbon emissions associated with a building's energy use are called *operational carbon emissions* because they are caused by the building's operation.

The construction of buildings is also associated with carbon emissions, resulting from both the construction materials (their extraction, manufacture, and transport to site) and the machinery and equipment used on- and near-site (fuel). These emissions are known as *embodied carbon emissions*.

On average, embodied carbon emissions represent about one-quarter of a building's total life cycle emissions. The global average is based on a relatively inefficient building stock supplied by electricity from a heavily fossil fuel–based grid. However, in the case of low-energy buildings or buildings supplied by a low-carbon-intensity grid, embodied emissions can represent as much as 40–60 percent of the life cycle carbon emissions (Karimpour et al. 2014). In Kenya, one of our four case study countries, 70 percent of grid electricity is derived from renewable energy sources, giving greater weight to embodied carbon in a building's total carbon footprint. Many developing countries are rapidly adding new buildings to their building stock, and the aggregated carbon emissions associated with materials such as steel and cement can be considerable.

Despite the importance of embodied carbon, current ZCB approaches most commonly target operational carbon emissions. Three main components, related to energy demand and energy supply (Table 2), can reduce a building's (or a group of buildings') operational emissions to zero:

- **Energy efficiency (EE):** A building's energy consumption may be reduced in many ways, starting with passive design measures. What we call *basic EE* involves pursuing the minimum required level of energy efficiency by ensuring that the building complies with local codes and standards. In many countries, such codes and standards still have considerable untapped potential for higher performance. *Advanced EE* involves more ambitious energy performance that goes beyond minimum regulatory requirements.
- **Renewable energy (RE):** Further reductions in building emissions can be achieved by using carbon-free renewable energy sources. The options include on-site RE generation, off-site RE purchase, or off-site RE generation. The cost of renewable energy technologies for generation and storage have fallen considerably in recent years, and renewables are increasingly able to compete economically with conventional grid energy, making renewable energy a more attractive option.
- **Carbon offsets:** Sometimes a combination of energy efficiency and generating or purchasing renewable energy does not eliminate 100 percent of a building's operational carbon emissions. This leads to a nearly (net) zero carbon building. For existing buildings using fossil fuels such as gas for cooking or hot water heating, it may not always be feasible to fully eliminate carbon emissions. In such a case, carbon offsets may be used to compensate for the balance of emissions. Such offsets should preferably be able to prove additionality[8] and should be used to invest in energy efficiency or carbon-free renewable energy projects elsewhere, although preferably within the boundaries of the city. The emissions reduction benefits must be claimed through a credible mechanism such as carbon credits or a local carbon credit fund.[9]

Table 2 | **Emissions-Reduction Components of Zero Carbon Buildings (ZCBs)**

ZCB COMPONENTS		EXAMPLES OF MEASURES	PREFERRED HIERARCHY
EE +	Basic EE: minimum energy efficiency (EE) in line with local codes & standards	■ Building EE codes/standards ■ Appliance MEPS[a]	(Baseline)
	Advanced EE: exemplary EE performance	■ Incentives that encourage beyond-code/standard performance	Energy efficiency first
RE +/or	+ On-site renewable energy (RE)	■ On-site RE generation through solar panels or solar hot water systems	On-site RE generation first
	+ Off-site RE (purchase)	■ Green retail tariffs ■ Power purchase agreement (PPA)[b] ■ Renewable energy credit (REC)[c]	Remainder that cannot be provided by EE or on-site RE
	+ Off-site RE (generation)	■ Direct ownership of off-site RE assets	
CO_2	+ Carbon offsets	■ Carbon credits purchased through investment in EE or RE reduction projects elsewhere	Only if on- or off-site RE are not viable options or if embodied carbon is included in ZCB scope

Notes:
[a] *MEPS* refers to "minimum energy performance standards" for appliances.
[b] PPAs represent a contract signed directly between a buyer and a nonutility RE provider to let the buyer purchase RE from a project at a long-term fixed price.
[c] RECs show proof that renewable energy has been generated. The energy is fed into the grid, and the carbon emission reduction benefits are traded through a certificate. See Appendix D for more information.
Source: WRI.

Stakeholders may decide to expand their definition of ZCB to include embodied carbon. To the extent that these embedded emissions cannot be reduced or avoided, credible carbon offsets may be used to compensate for them.

These components can be combined in various ways to achieve a full 100 percent (net) reduction of a building's operational carbon emissions.

All combinations start with basic energy efficiency measures (basic EE) and other components are added in different proportions to achieve full carbon emissions reduction. In all cases, credible carbon offsets are applied only when all other options have been fully utilized—or are not available. We define any effective combination of components as a *ZCB pathway*. Section 3 of this paper explores pathways in more detail.

Principles to Guide Choice of Components

Not every combination of measures is considered equally desirable. Financial costs and broader social and environmental factors dictate a hierarchy of preference among different components. For example, the avoidance of energy use in the first place (efficiency) is preferable to constant energy use supplied even from clean renewable resources. Some technologies will be more cost-effective than others for large-scale building decarbonization and/or will provide greater carbon reduction and other environmental or social benefits. However, the choice of specific ZCB pathways will be based on the judgment of building developers, owners, and managers and will depend heavily on local circumstances. As an example, in jurisdictions with high energy subsidies, the cost of renewable energy may outcompete the savings achievable from additional energy efficiency measures.

The following core principles can help decision-makers identify the most or more preferable approaches to achieving ZCBs, and they align with accepted thinking in the building community. For ZCBs to reduce their fossil fuel–generated energy consumption, they first apply building design strategies and energy efficiency measures to reduce consumption, then incorporate (carbon-free) on-site renewable energy systems, then use off-site (carbon-free) renewable energy to meet the balance of its energy needs, and lastly use credibly carbon offsets in case a gap remains in net carbon balance (Architecture 2030 et al. 2016).

- **Efficiency first.** The aim is always to use no more energy than necessary. Energy-efficient building design and energy-efficient building equipment and appliances should be implemented before meeting remaining energy demand with renewable sources of energy. This does not mean pursuing energy efficiency at any cost: the optimal combination of energy efficiency and renewable energy is likely to differ by region, depending on local policy and market conditions. Nonetheless, it is preferable that energy efficient design measures are used to achieve energy efficiency that exceeds local codes and standards, which often do not tap into the full energy reduction potential of a building.

EE before **RE**

- **On-site energy generation first.** Having achieved energy savings through efficiency measures, the aim is to use carbon-free renewable energy.[10] On-site generation is preferable to off-site options because on-site generation increases the total installed capacity of clean renewable energy within a city or district. In addition, on-site generations help enhance the building's energy security and energy resilience in case of disruptions to the grid. Where on-site generation for individual buildings is not a viable option due to technical, financial, and/or legislative barriers, off-site energy options can be explored.
- It may already be possible to purchase renewable energy locally. If not, interested stakeholders can explore the option of generating renewable energy at the district scale to serve a group of buildings within that area. Distributed generation models of this kind help enhance local energy security and resilience in case of grid power outages. High-density urban areas, however, may not have sufficient suitable space for on-site or local off-site generation, and may have to rely on clean energy generated well beyond the district or even city boundaries.

ON-SITE before **OFF-SITE RE**

- **Renewable energy generation/purchase before carbon offsets.** Any ZCB approach should first exploit the options for on- and/or off-site renewable energy provision. This encourages building owners/ managers to first tap into opportunities where they can exert a greater degree of direct influence and that reduce emissions close to the source. If neither on-site nor off-site generation or purchase are viable options—due to technical, financial, and/or legislative barriers—then carbon offset options can be explored next. They should be used only to compensate for the carbon generated by remaining consumption of non-carbon-free energy.

RE before CARBON OFFSET

- **Embodied carbon reduction before carbon offsets to achieve life cycle carbon neutrality.** The entire life cycle of a building involves construction, maintenance and repair, renovation and retrofit, and eventually demolition, and all stages produce carbon emissions from materials, machinery, and fuel. These emissions are known as embodied carbon.
- Increasingly, governments are likely to encourage the inclusion of embodied carbon in ZCB approaches to account for all carbon emissions across the building's full life cycle. The reduction of embodied carbon should be considered before compensating for remaining emissions with carbon offset solutions, such as carbon credits. For example, building managers can choose low-carbon materials and cleaner fuels.

CARBON REDUCTION before CARBON OFFSET

Applying these four principles allows us to compile a decision tree (Figure 2), laying out the ZCB components in a recommended order of consideration. Together, they help users create a road map for different segments of a city's building stock by "navigating" the decision tree and determining suitable combinations of ZCB components. These combinations constitute the pathways toward ZCBs.

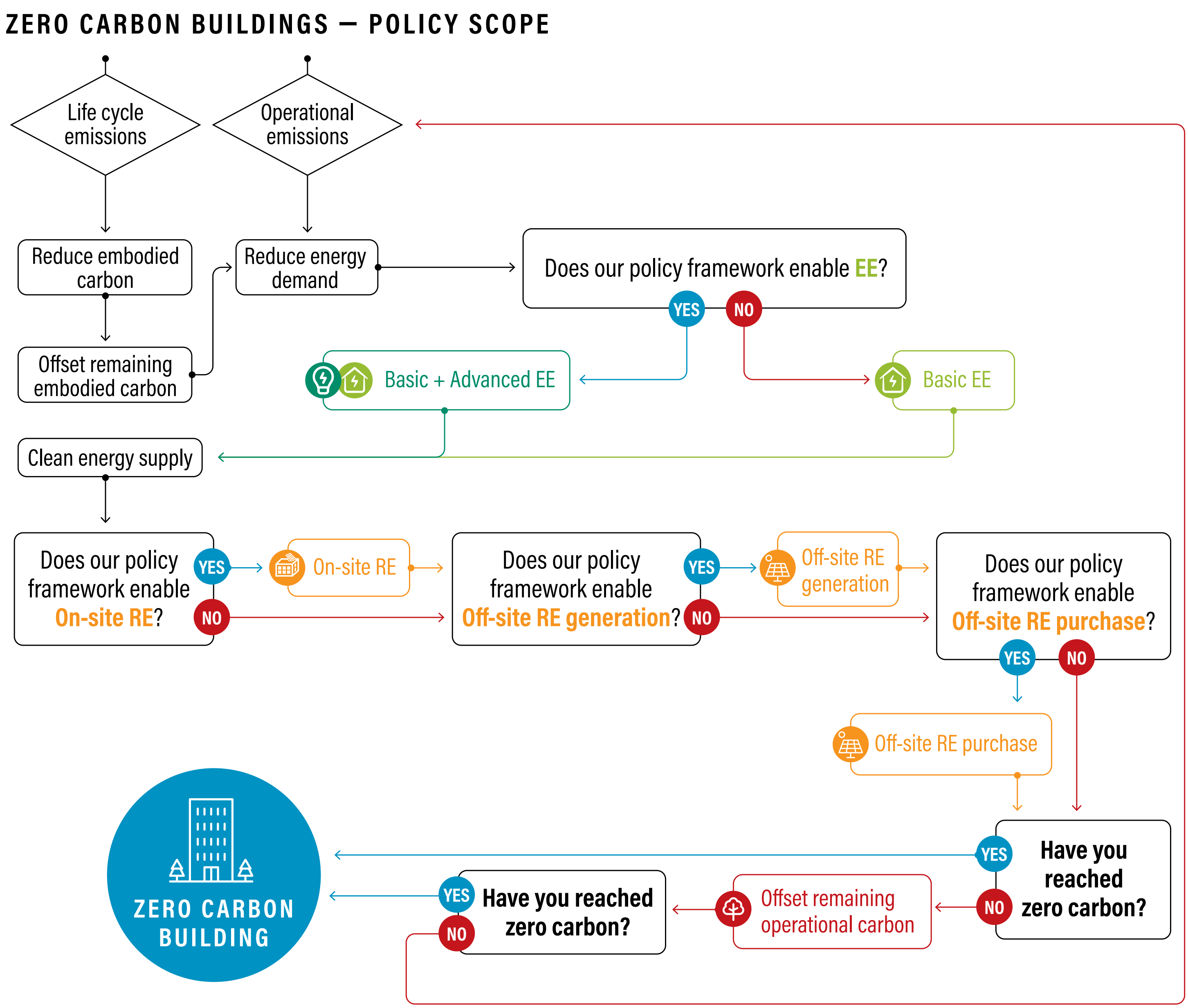
Each component in the decision tree must be considered within the enabling policy framework currently in place, the availability of suitable technologies and skilled labor, and the cost-effectiveness of pursuing various options. This paper considers only the policy framework in determining the feasibility of different ZCB pathways. However, urban decision-makers are advised to incorporate not only policy but also additional market and other considerations to help inform the local appropriateness of different building decarbonization pathways. In addition, although a jurisdiction may have supportive policies in place, it is not unlikely that practitioners on the ground run into conflicting existing policies that can pose a hurdle and may need active involvement from policymakers to help clear them.

ZCB Certification Tracks

ZCBs are not simply an idea. Multiple independent certification initiatives have sprung up to help building owners and managers gain recognition in the market for their efforts. The International Living Future Institute in the United States was one of the first organizations to develop stringent certification for net zero energy buildings, which must exemplify deep energy efficiency and meet all energy demands through on-site renewables only. Recently, it has also launched a net zero carbon certification track,[11] which allows the use of on- and off-site renewables (Liljequist 2018).

In 2016 the World Green Building Council (WorldGBC), the overarching organization for national GBCs, has been working with a group of member councils through its Advancing Net Zero project. The aim is to accelerate uptake of ZCBs to 100 percent by 2050 through the introduction of tools, resources, and programs such as certification schemes. Participating in this project are the GBCs of Australia, Brazil, Canada, China, Croatia, Finland, France, Germany, India, Ireland, Italy, Jordan, New Zealand, the Netherlands, Norway, Singapore, Spain, South Africa, Sweden, the United Arab Emirates, the United Kingdom, and the United States (WorldGBC, n.d.).

Figure 2 | **Decision Tree to Help Identify Suitable ZCB Policy Pathways, Combining Energy Efficiency (EE), Renewable Energy (RE), and/or Carbon Offsets as a Last Resort**



Source: WRI.

Certification tracks are usually not initiated by government policy but instead are developed by independent nonprofit organizations and are voluntarily pursued by building developers, owners, and managers who desire third-party verification in order to market their sustainability credentials, including enhanced energy efficiency performance.

Table 3 provides a snapshot of eligible ZCB certification tracks and their requirements developed by GBCs in four countries. These voluntary ZCB certification tracks demonstrate the diversity of approaches to building decarbonization. Collectively, the member GBCs have certified over 400 buildings as net zero carbon since 2017, based on verified performance data (WorldGBC 2018).

A MENU OF ZCB PATHWAYS

Overview of ZCB Pathways

In Section 2 we showed how ZCB components—energy efficiency, a noncarbon renewable energy supply, and carbon offsets—can be assembled in different combinations to form ZCB pathways. In total, we identify eight ZCB pathways that can be pursued to fully reduce a building's operational carbon emissions. The preferred hierarchy of components is that energy efficiency and renewable energy should be implemented before carbon offsets, which should only be used when other options are fully utilized, impractical, or unavailable. Thus, pathway 1 is preferable to pathway 2 and so on. However, each of the ZCB pathways leads to the equivalent of 100 percent

Table 3 | **Zero Carbon Building Certification Schemes in Four Countries, as of 2017**

REQUIREMENTS		GREEN BUILDING COUNCIL			
		AUSTRALIA	BRAZIL	CANADA	SOUTH AFRICA
Overall performance requirements		Annual verified consumption data	Annual verified net zero energy balance	Annual verified zero carbon operational emissions balance	Zero carbon operational emissions balance; recertification every 3 years
EE +	Basic energy efficiency (EE)		If using on-site renewable energy (RE): no additional EE requirements		
	Advanced EE	30% more EE than usual	If using off-site RE: EE requirements beyond ASHRAE[a]	Heating EE targets set for each climate zone	Min. 80% demand reduction over code by using EE and/or on-site RE
RE +	+ On-site RE	Allowed	Allowed	At least 5% of energy demand met by on-site RE	-
	+ Off-site RE	Allowed	Commercial buildings can use RECs for max. 10% of energy demand	Allowed if procured via RECs or bundled green power (green retail tariff + associated RECs)	Off-site RE only allowed if demand reduction requirements met
CO_2	+ Carbon offsets	Any remaining, nonelectricity operational CO_2 emissions to be offset annually	-	Report on embodied CO_2 of structural & envelope building materials	CO_2 offsets allowed if demand reduction requirements met

Notes: For more information, see the World Green Building Council's advancing net zero snapshots for these four countries, available at https://worldgbc.org/news-media/worldgbc-snapshots-detail-net-zero-carbon-standards-developed-green-building-councils.

[a] ASHRAE = American Society of Heating, Refrigerating and Air-Conditioning Engineers. ASHRAE issues a building energy efficiency standard, ASHRAE 90.1, which is updated every few years. The original standard, ASHRAE 90, was published in 1975.

Source: WRI.

carbon reduction, meaning that all operational carbon emissions have been reduced or compensated for in a building. Any pathway that is feasible within a given jurisdiction could be pursued.

Table 4 presents the menu of eight ZCB pathways. The first four involve "exemplary energy performance," meaning energy efficiency measures that go beyond what is required by local codes and standards. The second four involve only "minimum energy efficiency," meaning energy efficiency measures that meet required standards but no more.

Although we include a ninth pathway that illustrates how to achieve 100 percent decarbonization by including a building's embodied carbon emissions, this paper focuses mainly on the first eight pathways, which are designed to fully reduce operational carbon emissions.

As a working example, we will use pathway 6 to illustrate how, by applying the principles, we can proceed step-by-step to avoid 100 percent of the carbon emissions associated with the operational energy use of a building (Figure 3). With the principle of "efficiency first" in mind, we first aim for building energy performance in line with local energy efficiency codes and standards (basic EE). Compliance with existing codes and standards cannot be assumed because, in many countries, such codes and standards are either voluntary, mandatory but poorly enforced, or waiting to become mandatory through a cumbersome process that transfers responsibility from the national to the local level.

Next, we consider the options for meeting remaining energy demand through a combination of on- and off-site renewables. We begin with on-site RE generation. If

Table 4 | **Zero Carbon Building Pathways and Their Component Parts**

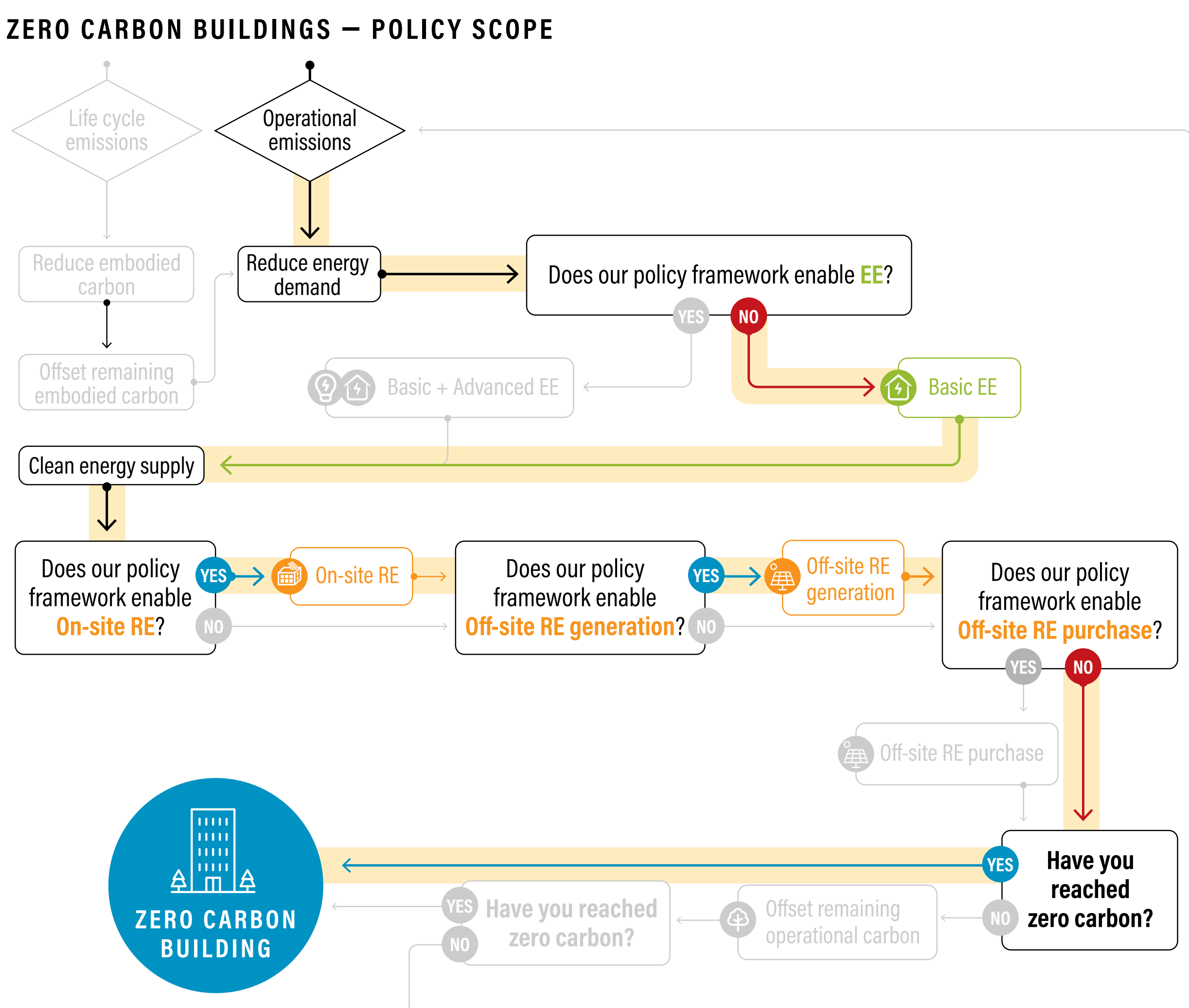
PATHWAY		COMPONENT				
		BASIC EE[a]	ADVANCED EE[b]	ON-SITE RE	OFF-SITE RE	CARBON OFFSETS[c]
Exemplary energy performance	1	◆	◆	◆		(if needed)
	2	◆	◆	◆	◆	(if needed)
	3	◆	◆		◆	(if needed)
	4	◆	◆			◆
Minimum energy efficiency	5	◆		◆		(if needed)
	6	◆		◆	◆	(if needed)
	7	◆			◆	(if needed)
	8	◆				◆
Embodied carbon emissions	9	◆	◆	◆	◆	◆

Notes:
[a] The minimum required level of energy efficiency (EE) achieved by complying with local codes and standards.
[b] More ambitious energy performance that goes beyond minimum regulatory requirements.
[c] Recommended only in cases where efficiency measures and renewable energy (RE) sources cannot meet 100 percent of energy demand.
Source: WRI.

it turns out that we can meet only part of the building's energy demand through on-site options, we subsequently add an off-site RE supply, if locally available. If this still does not achieve 100 percent reduction of the building's operational carbon emissions, we may decide to use carbon offsetting as a last resort to make up for the gap between nearly and net zero carbon.

Although a jurisdiction's current policy framework and market conditions will influence the feasibility of different pathways, building owners and managers should be aware that the "state of play" changes constantly as policies and markets develop. For example, a city might provide high electricity subsidies and lack a net metering policy, which would make the installation of on-site solar photovoltaic (PV) panels an unattractive proposition. A building developer could, in such a case, begin by pursuing a pathway that uses off-site RE while ensuring the building is "on-site RE ready" and able to switch to an on-site RE pathway once policy and market factors make on-site solar panels sufficiently attractive.

Figure 3 | **How to Achieve Zero Carbon Emissions by Following Pathway 6**



Source: WRI.

Real-World Buildings Illustrate the ZCB Pathways

From the 2,500 ZCBs in the world, we have selected a few examples to illustrate how their approaches fit within our ZCB pathways (Table 5.) These buildings show that despite a wide range of climates and different governance systems, they were all able to achieve decarbonized status. Each uses its own unique mix of energy efficiency, renewable energy, and/or carbon offsets to arrive at building carbon neutrality. The important takeaway message from these examples is that even in jurisdictions with less well-developed or less ambitious policy frameworks and perhaps limited local experience with ZCB, energy efficiency, or renewable energy concepts, **a feasible ZCB pathway is still likely to be available.**

Note that we did not analyze the broader market and technological conditions prevailing in the cities where these buildings are located.

Table 5 | **Illustrative Examples of Zero Carbon Buildings for Each Pathway Option**

PATHWAY		COMPONENT				
		BASIC EE	ADVANCED EE	ON-SITE RE	OFF-SITE RE	CARBON OFFSETS
1	**Indira Paryavaran Bhawan** New Delhi, Delhi, India Building type: Public office & education Climate type: Hot and humid / temperate climate More information: Net Zero Energy Buildings (NZEB) platform, http://www.nzeb.in/case-studies/detailed-case-studies-2/ipb-case-study/	Compliant with local codes and standards	Natural light, shading, landscaping; EE active building systems: 70% less energy than conventional	Photovoltaic (PV) panels	—	—
	Passive energy apartments (18 floors) Qinhuangdao, Hebei, China Building type: Residential building Climate type: Cold climate More information: E&E News, https://www.eenews.net/stories/1060012314	Compliant with local codes and standards	Passive design; super insulating homes; heat recovery: >90% less energy than conventional	—	—	—
	EcoCasa Max homes Hermosillo, Sonora, Mexico Building type: Residential building Climate type: Hot and dry climate More information: EcoCasa, https://www.gob.mx/shf/documentos/ecocasa	Compliant with local codes and standards	Passive house features: 87% energy reduction	PV panels	—	—
PATHWAY		BASIC + ADVANCED EE		ON-SITE RE + OFF-SITE RE (PURCHASE OR GENERATION)		CARBON OFFSETS
2	**Pearl River Tower (71 floors)** Guangzhou, Guangdong, China Building type: Commercial office Climate type: Warm and humid climate More information: "Pearl River Tower," https://en.wikipedia.org/wiki/Pearl_River_Tower	Radiant heating and cooling; double-skin façade; underfloor ventilation; daylight harvesting; building orientation to optimize breeze/solar potential		PV panels; solar collectors; wind turbines—nearly zero energy building (ZEB): local power company does not allow selling back excess RE to grid		—
	PCNTDA building Pune, Maharashtra, India Building type: Public office Climate type: Warm and humid climate More information: BigEE, "PCNTDA," http://www.bigee.net/en/buildings/guide/services/examples/building/30/#energy-consumption	Natural ventilation; daylighting; LED lighting; 95% non-air-conditioned (AC)		PV panels—nearly ZEB		—

Table 5 | **Illustrative Examples of Zero Carbon Buildings for Each Pathway Option (Cont'd)**

	PATHWAY	BASIC + ADVANCED EE	ON-SITE RE + OFF-SITE RE (PURCHASE OR GENERATION)	CARBON OFFSETS
2	**Infosys campuses (portfolio)** Various locations, India Building type: Commercial offices Climate type: Variety of climates—all rather warm More information: CleanTechnica, https://cleantechnica.com/2015/12/07/how-indian-it-giant-infosys-is-going-carbon-neutral/	LEED Platinum[a] buildings	PV panels; RE grid electricity; off-site RE plant	—
	Olas Verdes hotel Playa Guiones, Nossara, Costa Rica Building type: Hotel Climate type: Warm and humid climate More information: USGBC, https://www.usgbc.org/projects/olas-verdes-hotel?view=overview	Almost 50% more energy efficient than conventional	PV panels; solar hot water; almost 100% RE grid electricity	—
	PATHWAY	**BASIC + ADVANCED EE**	**OFF-SITE RE (PURCHASE OR GENERATION)**	**CARBON OFFSETS**
3	**TZED homes (80 apartments; 15 homes)** Bangalore, Karnataka, India Building type: Residential building Climate type: Warm and dry climate More information: Architecture & Developpement, http://www.archidev.org/spip.php?article1151	LED lighting; light sensors; green roofs; natural ventilation; daylighting	District cooling for refrigeration and AC	Project earns carbon credits
	PATHWAY	**BASIC + ADVANCED EE**	**—**	**CARBON OFFSETS**
4	**Tampines Concourse** Singapore Building type: Commercial office Climate type: Hot and humid climate More information: City Developments Limited, http://cdlcommercial.com.sg/property/11-tampines-concourse	Building envelope; natural daylighting; noncompressor air cooling	—	Construction and operational carbon is offset
	PATHWAY	**BASIC EE ONLY**	**ON-SITE RE**	**CARBON OFFSETS**
5	**Malankara Tea Plantation** Kottayam, Kerala, India Building type: Office and packaging plant Climate type: Warm and humid climate More information: OutBack Power, http://www.outbackpower.com/downloads/case_studies/pdf/malankara.pdf	—	PV panels provides 100% of energy needs	—
	URBN Hotel Shanghai, China Building type: Hotel Climate type: Warm/temperate and humid climate More information: TemptingPlaces, https://www.temptingplaces.com/en/	Efficient lighting; double pane windows	PV panels	Remaining CO_2 emissions from energy offset

Table 5 | **Illustrative Examples of Zero Carbon Buildings for Each Pathway Option (Cont'd)**

	PATHWAY	BASIC EE ONLY	ON-SITE RE + OFF-SITE RE (PURCHASE OR GENERATION)	CARBON OFFSETS
6	**Essent headquarters** Den Bosch, Noord Brabant, The Netherlands Building type: Commercial office Climate type: Temperate climate More information: Essent, https://www.essent.nl/content/overessent/actueel/ index.html/zonnepanelen-op-dak-van-kantoor-essent/	Compliant with local code	PV panels; biogas for heating; 100% wind energy for grid electricity	—
	PATHWAY	**BASIC EE ONLY**	**OFF-SITE RE (PURCHASE OR GENERATION)**	**CARBON OFFSETS**
7	**Bombay House (TATA headquarters)** Mumbai, Maharashtra, India Building type: Commercial office Climate type: Warm and humid climate More information: Construction World, https://www.constructionworld.in/articles/special-project/Green-House-/12418	Range of EE measures to bring existing building up to current standards	Renewable energy credits purchased for 75% of energy use	—
	Adobe office Bangalore, Karnataka, India Building type: Commercial office Climate type: Warm and dry climate More information: Adobe Blog, https://theblog.adobe.com/adobes-bangalore-office-among-first-in-india-to-be-powered-100-by-renewable-energy/	—	Solar PPA to cover 100% of energy demand	—
	PATHWAY	**BASIC EE ONLY**	**—**	**CARBON OFFSETS**
8	**Barclays Bank** (portfolio) UK, Europe, and beyond with strong Africa presence Building type: Commercial offices Climate type: Variety of climates More information: Environmental Finance, https://www.environmental-finance.com/content/market-insight/carbon-offsetters-look-beyond-climate-change.html	Compliant with local code; sometimes beyond	—	Buys voluntary carbon offsets in Kenya (avoided deforestation), India, and China (RE)
	PATHWAY	**BASIC + ADVANCED EE**	**ON-SITE RE AND/OR OFF-SITE RE (PURCHASE OR GENERATION)**	**CARBON OFFSETS FOR EMBODIED CARBON**
9	**Pixel Building** Melbourne, Victoria, Australia Building type: Commercial office Climate type: Temperate climate More information: Inhabitat, https://inhabitat.com/ pixel-building-australias-first-carbon-neutral-building-is-now-complete/	Building envelope; natural daylighting and shading; LED light; superefficient heating, ventilating, and air-conditioning; "Perfect" score under local green building certification	PV panels and micro wind turbines provide 100% of energy needs	Construction emissions fully offset

Notes: EE = energy efficiency; RE = renewable energy.

[a] LEED (Leadership in Energy and Environmental Design) is a green building rating and certification scheme from the U.S. Green Building Council with different certification levels, of which "Platinum" represents the highest level.

Source: WRI.

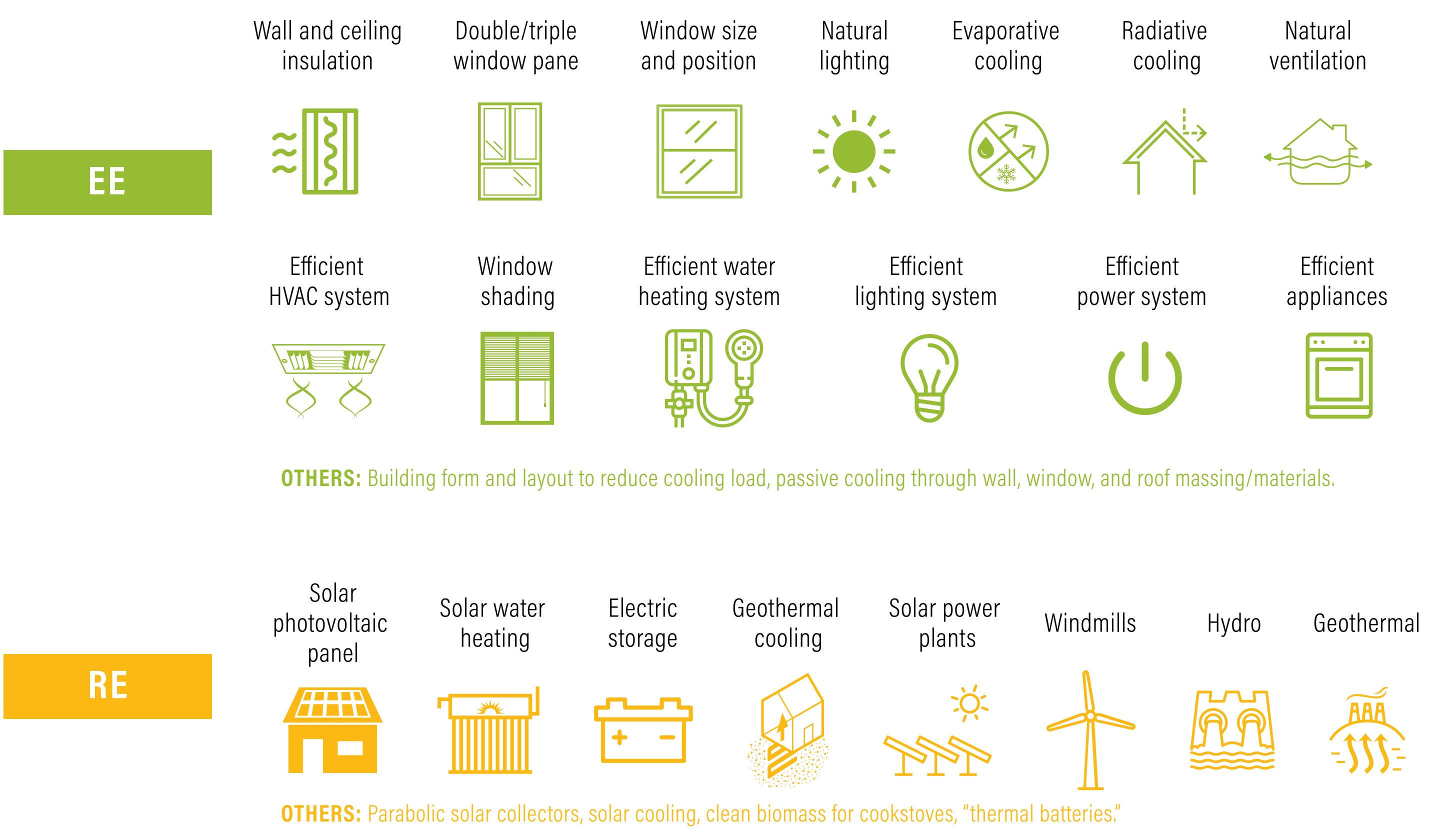
Technologies to Support the ZCB Pathways

Many technologies necessary to support ZCB pathways are already available in the global market and increasingly in most local markets. These technologies cater to different climates, budgets, and existing levels of expertise (Figure 4).

Energy efficiency options range from the use of passive measures—such as smart use of natural daylight, natural ventilation, insulation, and evaporative cooling—to active measures like installation of high-efficiency heating, ventilation, and air-conditioning (HVAC) systems, LED lighting, and efficient appliances.

Common renewable energy technologies include on-site PV panels and solar water heaters and off-site renewable energy systems such as solar power plants, wind turbines, and hydropower plants.

Figure 4 | **Widely Available Energy Efficiency (EE) and Renewable Energy (RE) Technologies That Support Zero Carbon Buildings**



Source: WRI.

ZCB PATHWAYS AND THE DIFFERENT ROLES OF GOVERNMENT

Decisions affecting the feasibility of ZCB pathways are governed by a mix of public and private actors. Around the world, the degree of influence over buildings held by the public sector versus the private sector varies widely, as does the relative level of authority vested in each sphere of government. The specific authority and capacity for action held by local (including city or municipal), regional, and national levels of government (or by the private sector) is known as *capacity to act*. Capacity to act must be an important consideration for ZCB stakeholders as they prioritize their actions (Hammer 2009).

The Role of City Governments in Enabling ZCB Pathways

Local governments generally hold the authority to adopt and/or implement a range of policies influencing building efficiency. However, their approach is heavily influenced by guidance or requirements from provincial, state, or national governments. Building energy efficiency codes and standards, for instance, are usually designed and issued at the national level.

Policies that affect the availability and attractiveness of off-site RE options, in particular, are often designed and implemented at higher levels of government. The regulation of energy utilities is also usually handled by national or regional government, although some larger cities and city states have the capacity to act in this area. In some urban areas, governments take little role in shaping building efficiency and renewable energy development, leaving action primarily to the private sector.

City-level policymaking and implementation

Depending on a country's urban and wider governance system, each government level has a different capacity to take on specific roles in the development, implementation, and enforcement of policy. In spite of these differences, local governments typically play the following roles (Becqué et al. 2016):

Regulator: Local government is responsible for the design, implementation, and/or enforcement of regulations related to a policy or program. Often these take the shape of mandates or incentives.

Convener and facilitator: Local government can help enable voluntary private action by convening actors, launching or facilitating public-private partnerships, or creating programs that address barriers to action.

Owner/investor: Local governments are often owners of and/or investors in a city's public buildings, such as public offices, schools, museums, and hospitals. City governments can lead by example, thereby helping to prove the case for ZCBs and create market demand.

Complementary or strategic partner: Local governments may undertake complementary or strategic actions that contribute to the introduction, uptake, or success of a policy or program led by higher levels of government, such as state or national government.

Table 6 summarizes the most common roles played by local governments in developing or implementing policies or programs that support the components of ZCB pathways.

Table 6 | **“Capacity to Act” and the Different Roles Played by Local Governments**

ZCB PATHWAY COMPONENTS		CITY GOVERNMENT ROLE			
		REGULATOR	CONVENER/ FACILITATOR	OWNER/INVESTOR	PARTNER
EE +	Basic energy efficiency (EE)	■ (Adapt), incorporate, and enforce code ■ Enforce mandatory energy performance standards	■ Engage/educate building stakeholders ■ Train/inform market	■ Ensure code compliance for public buildings	■ Inform central government code design
	Advanced EE	■ Set local EE targets ■ Design/implement EE incentives ■ Design/implement EE challenge programs ■ Design/implement EE audits and benchmarking	■ Support central government EE targets ■ Engage /educate stakeholders ■ Support green building certification	■ Lead by example for public buildings ■ Mandate green certification of public buildings ■ Facilitate EE performance information ■ Facilitate EE finance solutions	■ Work with utilities to implement EE programs
RE +	+ On-site renewable energy (RE)	■ Set local RE targets ■ Design/implement rooftop RE incentives ■ Design/implement rooftop RE support programs	■ Support central government RE targets ■ Engage/educate building stakeholders ■ Inform/train market	■ Lead by example for public buildings ■ Facilitate rooftop RE finance solutions	■ Inform central government photovoltaic policy design ■ Work with utilities to implement rooftop RE programs
	+ Off-site RE		■ Support aggregating private sector demand for off-site RE purchase	■ Lead by example by aggregating RE demand from public buildings	■ Work with utilities to reduce nonutility RE purchase resistance
CO_2	+ Carbon offsets		■ Educate stakeholders on voluntary market to create demand and awareness	■ Lead by example by offsetting public sector’s carbon footprint	

Source: WRI.

Local government influence on enabling policies

Given the wide choice of available policies, local governments should seek to prioritize those policy actions over which they have more direct influence and which provide greater environmental and social benefits. Local governments will want to consider the contribution of a proposed policy or program to achieving citywide goals, such as reducing the city's carbon footprint; addressing energy poverty, energy access, or energy security; or curbing air pollution.

In general, local governments tend to have the highest level of control over energy efficiency measures (Figure 5). Although local governments are not usually the actual designers of building energy efficiency codes and standards, they are often crucial for their incorporation in local bylaws and subsequent enforcement. In addition, local governments can encourage stakeholders to pursue energy efficiency through incentives and support programs.

Local governments still have some influence over policies that affect the attractiveness and feasibility of on-site RE, such as by providing incentives. They often rely heavily on state and/or national government action to facilitate off-site RE purchasing. Nonetheless, once such policies are in place, local governments may be able to use their convening and buying power, for example, to aggregate demand for renewable energy purchasing via power purchasing agreements (PPAs) or pressure their local utility to introduce more renewables into the energy mix.

Using Policy to Facilitate a ZCB District or Portfolio Approach

The menu of ZCB pathways gives cities the opportunity to pursue or encourage ZCB approaches not only for individual buildings but also across a district or portfolio of buildings. By *district* we mean a defined area within a city, such as a neighborhood; *portfolio* refers to a set of buildings within the boundaries of the city that share at least one characteristic and are often under the same ownership or management. Examples might be a portfolio of city-owned public buildings, a portfolio of commercial offices all located within the city, or a portfolio of affordable housing stock.

Defining ZCBs in this way allows for more flexible approaches that achieve 100 percent reduction of operational (or embodied) emissions across a group of buildings rather than striving for full decarbonization of each building.[12] Some buildings, particularly existing ones, are unlikely ever to become fully decarbonized at the individual building level because of poor initial design that makes energy efficiency measures challenging and costly, insufficient roof space for on-site renewables, or insufficient energy demand to engage on their own in off-site renewable purchase options. However, under a portfolio approach, even such buildings can contribute carbon reductions and are thus encouraged to be included in taking actions that might otherwise have been ignored.

Figure 5 | **Relative Level of Local Government Influence on Policies Affecting Energy Efficiency, On- and Off-Site Renewable Energy (RE)**

Source: WRI.

Examples of policy approaches that target a district or (municipal) portfolio approach include the following:

- Local governments issue citywide energy efficiency or on-site RE challenges. These schemes challenge building owners—for example, in the commercial office segment—to voluntarily reduce their energy use or install on-site renewables to meet a predefined target.
- Local governments help to aggregate energy demand from a group of public and/or private buildings in order to engage in a PPA for off-site RE. This approach is becoming increasingly popular because it allows building owners with smaller energy loads to benefit from PPA options and generally lowers the cost of energy provision for the participants.
- Local governments engage with their utility to request a proposal for renewable energy delivery. When a large city sets ambitious renewable energy goals and asks its utility for cleaner energy, the utility may be interested in collaborating rather than getting cut out of the deal by third-party renewable energy suppliers.
- Local governments facilitate district-level renewable energy solutions, such as distributed energy generation.[13] Besides grid-connected rooftop solar systems, communal examples are a district heating and/or cooling plant or a local smart grid network.
- Local governments incentivize buildings with rooftop space—such as warehouses, factories, and parking garages—to install rooftop renewables and become net energy producers. By feeding the excess generated energy into the grid, they can provide for part of the renewable energy demand of nearby buildings with limited on-site generation opportunities.
- Local governments establish local cap and trade systems, under which they set a cap on total carbon emissions and encourage eligible parties to trade emissions among themselves. Parties are allocated an emissions allowance; facilities with high energy consumption need to purchase emissions allowances from highly efficient or net positive buildings[14] in order to stay within their allowance.

The Role of National and State Governments in Enabling ZCB Pathways

National and state government are critical actors when it comes to designing and implementing policies that affect the uptake of energy efficiency and renewable energy options by building owners and managers. Although cities are the centers of focus and action when it comes to decarbonizing the building stock, local governments often rely heavily on higher levels of government to provide them with a suitable enabling policy environment.

The different roles of national/state governments in policymaking and implementation

Higher government levels typically design critical policy pieces (regulator role), such as building energy efficiency codes and standards and renewable energy regulations that govern which options are available to energy consumers. Examples of the latter are net metering, feed-in tariffs (FITs), and the ability to engage in PPAs, purchase green energy tariffs, or buy renewable energy credits (RECs). Most of these options are associated with expanding consumers' choices on how they access energy, including nonutility purchase or self-generation. Policies formulated by national and state governments can also impede effective action at the local level. For example, a city incentivizing rooftop PV panels or energy efficiency may have difficulty convincing building owners/managers to invest in these technologies if electricity rates are heavily subsidized.

National and/or state governments can also be key to implementation (regulator role), especially if local governments require their active involvement before they themselves can act. In many jurisdictions, building codes and standards are issued by national government, and they may even need to be adopted (and, where relevant, adapted) by every state before local governments incorporate them in their regulations and subsequently enforce them. State governments can also help prioritize cities— with higher capacity or with higher expected growth in their building energy demand—to demonstrate the potential success and benefits of various policies, helping encourage smaller cities to follow.

National and state governments can also work in partnership (facilitator/strategic partner roles) with local governments. Higher government levels can provide guidance and support to local governments on how to effectively implement or enforce policies coming from the national or state level. Local governments can support national or state targets on energy efficiency or renewable energy and lead by example through the public building stock under their direct control. Local governments can also act as a strategic partner to higher government levels in designing, trialing, and tracking policy approaches (Broekhoff et al. 2015).

The influence of national and state governments on enabling policies

Although national and state governments have relatively firm control over energy efficiency measures such as the introduction of codes and standards, they often rely heavily—particularly in decentralized governance systems—on local governments to implement and enforce them. For example, national or state governments may decide to open up the electricity market and provide consumers with a wider range of renewable energy options. They typically set tariffs and decide the level of consumer subsidies for grid electricity. Local governments play a secondary but important role through local incentives, market and consumer facilitation, and leading by example through their public building stock (Figure 6).

COMPARING THE FEASIBILITY OF ZCB PATHWAYS

We tested the practical value of the ZCB pathways by analyzing the current policy framework in four countries—India, China, Mexico, and Kenya—and assessing the degree to which they enable progress toward decarbonizing their building stock. Our analysis shows that, regardless of policy differences, **one or more ZCB pathways is likely already within reach today** in each country. However, although the policy environment is maturing in many jurisdictions, the local market may still need to catch up to provide a suitable enabling environment for ZCBs. Our country research focused mainly on current policies and programs. It did not consider the state of local market factors, such as the cost and availability of specific energy efficiency– or renewable energy–related products and services, financing options, and the skilled labor to install and maintain them. Technical, market, and/or financial barriers are likely to further influence which ZCB pathways building owners/managers can most feasibly pursue.

Figure 6 | **Relative Level of National and State Influence on Policies Affecting Energy Efficiency, On- and Off-Site Renewable Energy (RE)**

Source: WRI.

Pathways at a Glance

Tables 7 and 8 provide an overview of the feasibility of each of the eight ZCB pathways in the four countries under consideration. A detailed explanation of how these assessments of feasibility were derived, together with recommended actions for governments at city, state, and national level, is provided in the country analyses in Appendix B.

Table 7 | **Feasibility of Each Zero Carbon Building Pathway under Current Policies and Programs in Study Countries**

PATHWAY		COMPONENT					COUNTRY			
		BASIC EE[A]	ADVANCED EE[B]	ON-SITE RE	OFF-SITE RE	CARBON OFFSETS[C]	INDIA	CHINA	MEXICO	KENYA
Exemplary energy performance	1	◆	◆	◆		(if needed)	X	O	O	X
	2	◆	◆	◆	◆	(if needed)	O	✓	O	O
	3	◆	◆		◆	(if needed)	O	O	O	X
	4	◆	◆			◆	O	✓	O	O
Minimum energy efficiency	5	◆		◆		(if needed)	X	O	✓	O
	6	◆		◆	◆	(if needed)	✓	✓	✓	O
	7	◆			◆	(if needed)	O	O	✓	X
	8	◆				◆	✓	✓	✓	✓

X = pathway is not sufficiently supported by the current policy framework.

O = the pathway is feasible under current policy but with limited application—either for specific segments of the building market and/or critical policy elements are insufficiently developed to make the pathway attractive.

✓ = the pathway is sufficiently facilitated through current policy.

Notes: [a] The minimum required level of energy efficiency (EE) achieved by complying with local codes and standards.
[b] More ambitious energy performance that goes beyond minimum regulatory requirements.
[c] Recommended only in cases where efficiency measures and renewable energy (RE) sources cannot meet 100 percent of energy demand.
Source: WRI.

Table 8 | **Feasibility of Each Zero Carbon Building Component under Current Policies and Programs in Study Countries**

COUNTRY	BASIC EE[a]	ADVANCED EE[b]	ON-SITE RE	OFF-SITE RE	CARBON OFFSETS[c] AS A LAST RESORT
India	✓	O	X	X	✓
China	✓	✓	O	O	✓
Mexico	✓	O	✓	✓	✓
Kenya	✓	O	O	X	✓

X = pathway is not sufficiently supported by the current policy framework.

O = the pathway is feasible under current policy but with limited application—either for specific segments of the building market and/or critical policy elements are insufficiently developed to make the pathway attractive.

✓ = the pathway is sufficiently facilitated through current policy.

Notes: [a] The minimum required level of energy efficiency (EE) achieved by complying with local codes and standards.
[b] More ambitious energy performance that goes beyond minimum regulatory requirements.
[c] Recommended only in cases where efficiency measures and renewable energy (RE) sources cannot meet 100 percent of energy demand.
Source: WRI.

Pathway feasibility under the current policy and program framework

When we examine ZCB pathway feasibility by building segment, it becomes clear that commercial buildings are best catered for under current policies and programs (Table 9). Only a few of the pathways across the four countries are considered feasible for residential buildings, although large residential complexes under one owner may fare better than individual households. Smaller commercial buildings appear limited in their opportunities as well. Nonetheless, the overview provides a generic indication of pathway feasibility. It should not be viewed as a predictor of pathway feasibility for specific categories of buildings.

Pathways are considered most feasible for commercial buildings for a variety of reasons. Off-site RE purchasing may require a high minimum energy demand (e.g., one megawatt, or MW). Likewise, incentives and support programs tend to focus on larger commercial building owners, and residential building owners may even be ineligible for certain policy benefits.

In addition, pathways that emphasize energy efficiency first are often not well supported by current policy. And, in some of the study countries, the presence of "perverse incentives," such as high electricity subsidies or the lack of critical policy pieces, make on- or off-site RE a challenging proposition. In spite of these obstacles, Table 5 indicates that **ZCB pathways can be considered a politically feasible goal in all four study countries.**

Table 9 | **Feasibility of Zero Carbon Building Pathways under Current Policy Framework**

PATHWAY		COUNTRY			
		INDIA	CHINA	MEXICO	KENYA
Exemplary energy performance (basic & advanced EE) plus...					
1	On-site RE		Commercial	Commercial	
2	On-site and off-site RE	Commercial (>1 MW energy demand)	Commercial and residential	Commercial (>1 MW energy demand)	Commercial
3	Off-site RE	Commercial (1 MW energy demand)	Commercial	Commercial (1 MW energy demand)	
4	Carbon offsets in place of RE	Commercial	Commercial and residential	Commercial & residential	Commercial
Minimum energy efficiency (basic EE) plus...					
5	On-site RE		Commercial	Commercial	Off-grid (residential)
6	On-site and off-site RE	Commercial (>1 MW energy demand)	Commercial and residential	Commercial (>1 MW energy demand)	Commercial and residential
7	Off-site RE	Commercial (1 MW energy demand)	Commercial	Commercial (1 MW energy demand)	
8	Carbon offsets in place of RE	Commercial	Commercial and residential	Commercial and residential	Commercial

Notes: EE = energy efficiency; RE = renewable energy. Red shading color indicates that the pathway is not sufficiently supported by the current policy framework. Light green shading indicates that the pathway is reasonably feasible under current policy, but either only for specific segments of the building market and/or critical policy elements are not well enough developed to make this very attractive. Bright green shading indicates that the pathway is sufficiently facilitated through current policy.
Source: WRI.

Pathway feasibility under an enhanced policy and program framework

Targeted policy actions can enhance the feasibility of pathways and expand the number of pathways that can be considered attainable. Policymakers can gradually shift over time from targeting mainly "low-hanging fruit" to more challenging goals that can bring more preferable pathways within reach.

Table 10 provides an indicative overview of which ZCB pathways could become more feasible if the priority actions that we recommend for the four study countries (detailed in Appendix B) were to be implemented. Although local and national governments may not be capable of or interested in pursuing all of the policy recommendations, it becomes clear that almost all of the eight ZCB pathways can be brought within reach through targeted enhancements of policies and programs currently in place in the four study countries.

Key Enabling and Disabling or Lacking Policies

In each of the four study countries, we were able to identify current key policies that appear to either enable or disable (impede) ZCBs or policies that, while known to be effective elsewhere, are lacking in one or more of the study countries. This section provides an overview of key policies relating to four core components of the ZCB pathways: basic and advanced EE and on- and off-site RE. We hope that highlighting specific policies in this way will allow urban decision-makers to better understand the ingredients of a successful policy package to accelerate building decarbonization. More detailed analyses for each country are provided in Appendix B.

This section is structured as follows. First, a schematic table shows which ZCB pathways incorporate the core component in question. A table then summarizes key enabling, disabling, or lacking policies with specific examples from the four study countries. The table also indicates the nature of the role played by central or local

Table 10 | **Feasibility of Each Zero Carbon Building Pathway under Enhanced Policies and Programs in Study Countries**

PATHWAY		COMPONENT					COUNTRY			
		BASIC EE[A]	ADVANCED EE[B]	ON-SITE RE	OFF-SITE RE	CARBON OFFSETS[C]	INDIA	CHINA	MEXICO	KENYA
Exemplary energy performance	1	◆	◆	◆		(if needed)	✓	✓	✓	○
	2	◆	◆	◆	◆	(if needed)	✓	✓	✓	○
	3	◆	◆		◆	(if needed)	✓	✓	✓	○
	4	◆	◆			◆	✓	✓	✓	○
Minimum energy efficiency	5	◆		◆		(if needed)	✓	✓	✓	✓
	6	◆		◆	◆	(if needed)	✓	✓	✓	✓
	7	◆			◆	(if needed)	✓	✓	✓	✓
	8	◆				◆	✓	✓	✓	✓

○ = the pathway is feasible under current policy but with limited application—either for specific segments of the building market and/or critical policy elements are insufficiently developed to make the pathway attractive.

✓ = the pathway is sufficiently facilitated through current policy.

Notes: [a] The minimum required level of energy efficiency (EE) achieved by complying with local codes and standards.
[b] More ambitious energy performance that goes beyond minimum regulatory requirements.
[c] Recommended only in cases where efficiency measures and renewable energy (RE) sources cannot meet 100 percent of energy demand.
Source: WRI.

government in developing and/or implementing that policy. We refer to *central government* meaning national, federal, state, and/or provincial government levels, and *local government* refers to municipal- or county-level governments. The lists of policies are not meant to be exhaustive. Other countries may have policies in place that are not included here but that are equally enabling or disabling.

These policy findings can help inform readers' thinking, but they do not suffice on their own as a basis for policymaking. Urban decision-makers should preferably strengthen their policy framework in line with the four principles set out in Section 2.3 of this paper.

Minimum energy efficiency (basic EE)

All eight ZCB pathways incorporate minimum energy efficiency (basic EE), which means ensuring that a building performs in line with local energy efficiency codes and standards. Basic EE is therefore the baseline requirement for a ZCB (Table 11).

Our analysis of current policies and programs in India, China, Mexico, and Kenya indicates that the presence of mandatory energy efficiency building codes and standards, which are reasonably simple to implement and enforce, is critical for ZCBs.

Table 11 | **Basic Energy Efficiency Is a Baseline Requirement for All Zero Carbon Building Pathways**

PATHWAY		COMPONENT				
		BASIC EE	ADVANCED EE	ON-SITE RE	OFF-SITE RE	CARBON OFFSETS
Exemplary energy performance	1	◆	◆	◆		(if needed)
	2	◆	◆	◆	◆	(if needed)
	3	◆	◆		◆	(if needed)
	4	◆	◆			◆
Minimum energy efficiency	5	◆		◆		(if needed)
	6	◆		◆	◆	(if needed)
	7	◆			◆	(if needed)
	8	◆				◆

Note: Basic EE is the minimum required level of energy efficiency (EE) achieved by complying with local codes and standards.
Source: WRI.

Table 12 | **Enabling, Disabling, and Lacking Policies for Basic Energy Efficiency**

KEY ENABLING POLICIES	GOVERNMENT LEVEL	ROLE
■ Mandatory building energy efficiency codes or standards are regularly updated, implementable, and well enforced	■ Central ■ Local	■ Regulator ■ Regulator/ facilitator
■ Local jurisdictions amend the code to require better performance than the average; in China, Beijing's building code is more stringent than the central code	■ Central ■ Local	■ Regulator ■ Regulator
■ Government provides technical guidance documents, such as in China and Mexico, on code implementation and enforcement	■ Central ■ Local	■ Facilitator ■ Facilitator
■ Minimum energy performance standards (MEPS) for appliances with high energy comsumption, such as air conditioners and fridges, that are enforced and regularly updated as more efficient appliances become widely available in the market	■ Central ■ Local	■ Regulator ■ Regulator/ facilitator

KEY DISABLING/LACKING POLICIES	GOVERNMENT LEVEL	ROLE
■ Mandatory building codes or standards that are not updated to increase their stringency; Kenya introduced a building code in 1968 that was not updated until 2016[a]	■ Central ■ Local	■ Regulator ■ Regulator
■ Voluntary building energy efficiency codes or standards, such as in India, are unlikely to see much uptake unless tied, for instance, to building approvals or combined with extensive support and incentive schemes	■ Central ■ Local	■ Regulator/ facilitator ■ Regulator/ facilitator
■ Mandatory building energy efficiency codes or standards that are cumbersome to implement; in Mexico, states first need to adopt and adapt the code before each municipality can incorporate it in local regulations	■ Central ■ Local	■ Regulator ■ Regulator
■ No penalties in place for noncompliance with mandatory codes and standards	■ Central ■ Local	■ Regulator ■ Regulator

Note:
[a] Kenya's 2016 and 2017 building code updates are still awaiting parliamentary assent.
Source: WRI.

Exemplary energy performance (advanced EE)

In addition to basic EE, ZCB pathways 1–4 incorporate exemplary energy efficiency (advanced EE)—that is, energy efficiency performance that exceeds what is required by local codes and standards (Table 13).

Our analysis identified a number of enabling and disabling or lacking policies relevant to exemplary energy efficiency in India, China, Mexico, and Kenya (Table 10). They highlight the positive effects of government in its role as convener and/or facilitator of, for example, incentives, rating and certification schemes, knowledge sharing, and energy challenges. Governments are also important in their role as building owners/investors who can lead by example. On the other hand, high energy subsidies resulting in energy tariffs that do not reflect the real cost of generating energy are a major impediment to pursuing greater energy efficiency.

Table 13 | **Advanced Energy Efficiency Is a Component of Zero Carbon Building Pathways 1-4**

PATHWAY		COMPONENT				
		BASIC EE	ADVANCED EE	ON-SITE RE	OFF-SITE RE	CARBON OFFSETS
Exemplary energy performance	1	◆	◆	◆		(if needed)
	2	◆	◆	◆	◆	(if needed)
	3	◆	◆		◆	(if needed)
	4	◆	◆			◆
Minimum energy efficiency	5	◆		◆		(if needed)
	6	◆		◆	◆	(if needed)
	7	◆			◆	(if needed)
	8	◆				◆

Note: Advanced energy efficiency (EE) involves more ambitious energy performance that goes beyond minimum regulatory requirements.
Source: WRI.

Table 14 | **Enabling, Disabling, and Lacking Policies for Advanced Energy Efficiency**

KEY ENABLING POLICIES	GOVERNMENT LEVEL	ROLE
■ Nonfinancial incentives to promote energy efficient/green buildings, such as allowing developers an increase in floor area ratio (FAR); in India, many states give developers extra FAR if they can prove a certain performance level	■ Central ■ Local	■ Facilitator ■ Facilitator
■ Financial incentives to promote energy efficient or green buildings; India and China provide subsidies, such as for certified green buildings, ultra-low-energy buildings, and building retrofits	■ Central ■ Local	■ Facilitator ■ Facilitator
■ Energy audit and benchmarking schemes for public or certain private buildings, as in China and Kenya, that help identify improvement opportunities while also collecting valuable data on energy performance	■ Central ■ Local	■ Regulator ■ Regulator
■ Programs that support, facilitate, and challenge public and/or private building owners to improve energy efficiency; Mexico City challenges building owners to achieve at least a certain percentage reduction in energy use	■ Central ■ Local	■ Convener/ facilitator ■ Convener/ facilitator
■ Development of or support for green building rating and certification schemes, such as China's Three Star or India's Green Rating for Integrated Habitat Assessment (GRIHA) and Indian Green Building Council	■ Central ■ Local	■ Facilitator ■ Facilitator
■ Government leading by example by requiring new public buildings and major retrofits to comply with a suitable (green building) rating and certification system, such as the minimum level of China's Three Star or India's GRIHA	■ Central ■ Local	■ Owner/ investor ■ Owner/ investor
■ Programs that address both affordable housing and energy efficiency, like Mexico's green mortgage program by INFONAVIT[a] and the EcoCasa program, supporting developers to build more efficient, affordable homes	■ Central ■ Local	■ Facilitator ■ Facilitator

KEY DISABLING/LACKING POLICIES	GOVERNMENT LEVEL	ROLE
■ High grid electricity subsidies for households, such as in India and Mexico, which reduce the economic case for energy efficiency measures	■ Central	■ Regulator
■ Lack of awareness in many jurisdictions as a result of limited communication and outreach about the benefits of energy efficiency as well as potential incentives available	■ Central ■ Local	■ Facilitator ■ Facilitator
■ Relative absence of incentives and energy performance information for building buyers that could encourage them to opt for a more energy efficient building	■ Central ■ Local	■ Facilitator ■ Facilitator
■ Relative absence in many jurisdictions of facilitating programs that educate and inform building stakeholders and support them in pursuing energy efficiency measures	■ Central ■ Local	■ Convener/ facilitator ■ Convener/ facilitator
■ Few or no programs in many jurisdictions that show governments leading by example on energy efficiency in their public building stock	■ Central ■ Local	■ Owner/ investor ■ Owner/ investor
■ Barriers to the growth of the energy service company (ESCO) industry. In China, ESCOs rely heavily on subsidies and find it difficult to obtain working capital	■ Central ■ Local	■ Facilitator ■ Facilitator

Note:
[a] INFONAVIT stands for the Instituto del Fondo Nacional de la Vivienda para los Trabajadores (National Workers' Housing Fund Institute).
Source: WRI.

On-site RE

ZCB pathways 1 ,2, 5, and 6 incorporate on-site RE as either the sole means of supplying the building with clean energy (pathways 1 and 5) or in combination with off-site renewables (2 and 6) (Table 15). Our assessment of policy frameworks in the four study countries points to the importance of an attractive and stable net-metering scheme and financial incentives to overcome the up-front capital cost of installation. High energy subsidies, on the other hand, disincentivize the use of on-site renewables because they greatly increase the length of payback times (Table 10).

Table 15 | **On-Site Renewable Energy (RE) Is a Component of Zero Carbon Building Pathways 1, 2, 5, and 6**

PATHWAY		COMPONENT				
		BASIC EE	ADVANCED EE	ON-SITE RE	OFF-SITE RE	CARBON OFFSETS
Exemplary energy performance	1	◆	◆	◆		(if needed)
	2	◆	◆	◆	◆	(if needed)
	3	◆	◆		◆	(if needed)
	4	◆	◆			◆
Minimum energy efficiency	5	◆		◆		(if needed)
	6	◆		◆	◆	(if needed)
	7	◆			◆	(if needed)
	8	◆				◆

Source: WRI.

Table 16 | **Enabling, Disabling, and Lacking Policies for On-Site Renewable Energy (RE)**

KEY ENABLING POLICIES	GOVERNMENT LEVEL	ROLE
■ Renewable energy targets, including rooftop photovoltaic (PV) panels, such as those set by India's national government	■ Central ■ Local	■ Regulator/ faciltator ■ Regulator/ facilitator
■ Introduction of net metering, as in Mexico and India, that provides consumers with like-for-like credits or an attractive and stable feed-in tariff for supplying on-site RE to the grid	■ Central ■ Local	■ Regulator ■ Facilitator
■ Incentives that promote on-site RE, like tax depreciation on the cost of on-site RE systems in Mexico and India; Mexico City offers a reduction in property taxes for buildings that install solar hot water systems	■ Central ■ Local	■ Facilitator ■ Facilitator

KEY DISABLING/LACKING POLICIES	GOVERNMENT LEVEL	ROLE
■ High grid electricity subsidies for households, such as in India and Mexico, that reduce the economic case for on-site PV systems	■ Central	■ Regulator
■ Incentives that frequently change, such as subsidies or feed-in tariffs that are reduced after a relatively short period of time, creating an unstable investment climate	■ Central ■ Local	■ Facilitator ■ Facilitator
■ Lack of awareness in many jurisdictions, as a result of limited communication and outreach about the benefits and possibilities for on-site RE as well as available incentives.	■ Central ■ Local	■ Facilitator ■ Facilitator
■ Limited programs that show government leading by example by requiring new public buildings and major retrofits to install rooftop renewables where feasible	■ Central ■ Local	■ Owner/ investor ■ Owner/ investor

Source: WRI.

Off-site RE

ZCB pathways 2, 3, 6, and 7 incorporate off-site RE as either the sole means of supplying the building with clean energy (pathways 3 and 7) or in combination with off-site renewables (2 and 6) (Table 17). Our analysis indicates that, in addition to greening the grid and introducing green tariffs at an attractive price point, opening up electricity markets to nonutility actors and allowing them to engage in PPAs directly and/or offer RECs to consumers is an important policy move to enable off-site renewables. On the other hand, uptake of off-site RE is inhibited by minimum eligibility conditions, such as requiring prospective buyers to have at least 1 MW of energy demand, or renewable energy options that come at a high cost premium without being paired with incentives to soften the price hurdle (Table 18).

Table 17 | **Off-Site Renewable Energy (RE) Is a Component of Zero Carbon Building Pathways 2, 3, 6, and 7**

PATHWAY		COMPONENT				
		BASIC EE	ADVANCED EE	ON-SITE RE	OFF-SITE RE	CARBON OFFSETS
Exemplary energy performance	1	◇	◇	◇		(if needed)
	2	◇	◇	◇	◆	(if needed)
	3	◇	◇		◆	(if needed)
	4	◇	◇			◇
Minimum energy efficiency	5	◇		◇		(if needed)
	6	◇		◇	◆	(if needed)
	7	◇			◆	(if needed)
	8	◇				◇

Source: WRI.

Table 18 | **Enabling, Disabling, and Lacking Policies for Off-Site Renewable Energy**

KEY ENABLING POLICIES	GOVERNMENT LEVEL	ROLE
■ Opening up the electricity market to nonutility actors, allowing users to engage directly in power purchase agreements (PPAs) as well as to purchase renewable energy credits (RECs); both Mexico and India have opened their markets to provide consumers with more choices	■ Central	■ Regulator
■ Government promotion of development of RE to supply energy to the grid; in Kenya, the grid is 70% powered by renewables	■ Central ■ Local	■ Facilitator ■ Facilitator
■ Introduction of green tariffs, as in Mexico, at an attractive price point that enables customers to buy renew-able energy (RE) from the grid	■ Central	■ Regulator/ facilitator
■ Government aggregation of energy demand from public buildings in order to engage in off-site RE purchase (PPA or RECs)	■ Central ■ Local	■ Owner/ investor ■ Owner/ investor

Table 18 | **Enabling, Disabling, and Lacking Policies for Off-Site Renewable Energy (Cont'd)**

KEY DISABLING/LACKING POLICIES	GOVERNMENT LEVEL	ROLE
■ High minimum energy demand requirements on consumers interested in participating in a PPA or buying RECs; in India and Mexico, parties need at least 1 MW energy demand to be able to use PPAs or RECs as an off-site RE solution	■ Central	■ Regulator
■ Utilities, such as in India, take an uncooperative stance in allowing consumers to purchase nonutility RE via PPAs	■ Central ■ Local	■ Regulator/ facilitator ■ Facilitator
■ Green tariffs, such as in Karnataka, India, that come with a high cost premium, making them unattractive to consumers	■ Central	■ Facilitator
■ Governments fail to actively enforce renewable purchase obligations (RPOs), as in India; RPOs help increase demand and thus develop the market for RECs	■ Central	■ Regulator
■ Certain off-site RE options, such as green energy tariffs, are only available to qualified registered users, as in Mexico, thereby excluding most households	■ Central	■ Regulator

Source: WRI.

CONCLUSIONS AND NEXT STEPS

Buildings are major energy users, responsible for roughly one-third of global energy consumption. To achieve global and national climate and energy goals, the building sector needs to decarbonize by 2050.

Cities, where most buildings are located, will have to be at the forefront of the movement to decarbonize the building sector. Actors at different governance levels need to come together to overcome barriers and make ZCBs a feasible and desirable goal on which to set their sights. With a maturing policy environment and rapidly falling technology costs, policies that support ZCBs can also greatly support national and subnational low-carbon development goals while creating a range of economic and environmental benefits.

To accelerate the speed and scale of uptake, we have laid out a menu of eight pathways to arrive at net zero carbon buildings. Each pathway consists of a combination of basic or advanced EE, on- and/or off-site RE, and—when renewables cannot provide for 100 percent of remaining energy demand—carbon offsets to compensate for the balance of carbon emissions. Not every ZCB pathway can be considered equally desirable in terms of the costs and benefits, even when broader environmental and social benefits are taken into account. For this reason, we use a set of four core principles to determine a hierarchy of action, which ranks pathways from more to less recommended.

Using four countries as study cases, our research shows that, regardless of the current policy framework, at least one ZCB pathway—and usually more—is feasible today. This implies that the target of a decarbonized building stock is coming within reach. This is the case even in jurisdictions with less experience of ZCBs and that have focused less on greening building energy demand and supply.

Our policy analysis also highlights key enabling and disabling policies that play an important role in determining the feasibility of the different pathways. Critical enabling policies include mandatory energy efficiency codes and standards that are easy to implement and enforce by the responsible government levels; governments acting as conveners and/or facilitators through their use of incentives, rating and certification schemes, knowledge sharing, and challenges; and governments leading by example in their roles as owners of or investors in public buildings. Attractive and stable net-metering schemes for on-site renewables and, where needed, financial incentives to overcome up-front capital costs of installation are important supports for clean energy buildings. Some deregulation of electricity markets to allow nonutility actors to engage in PPAs directly and/or offer RECs to consumers looking to purchase off-site RE can also increase the feasibility of the ZCB pathways.

On the other hand, disabling policies—such as high energy subsidies that result in energy tariffs that do not reflect the real cost of generating energy—are a major impediment to pursuing both greater energy efficiency and the uptake of renewables. Restrictive conditions, such as minimum energy demand thresholds that prevent prospective buyers from entering the off-site RE market, are a major disincentive. High-cost renewable energy options that are not paired with incentives to reduce the price hurdle also decrease the feasibility and attractiveness of many ZCB pathways.

With this knowledge, urban decision-makers can map out potentially feasible ZCB pathways that are appropriate for segments of their cities' building stock, whether at the individual building or district/portfolio level, working with the policies currently in place. We hope this paper will help them better understand how their policy framework impacts their goals to reduce building carbon and identify the gaps and obstacles that may need addressing. This can empower them to increase their ambition on building decarbonization and transform ZCBs into a politically attainable goal.

In coming months and years, WRI aims to raise ambition amongst the BEA network and other cities regarding the depth and scale at which ZCBs are being rolled out in urban areas. This paper serves as the first step toward such a transition. In the next phase, WRI is looking to recruit a select number of cities that are committed to take the first or further steps in accelerating ZCBs. WRI anticipates providing them with technical support to apply ZCB pathways thinking to accelerate both the pace and scale of building decarbonization.

APPENDIX A. METHODOLOGY

A.1. Introduction

In this paper we present a menu of ZCB pathways, inspired by the thinking presented in the Zero Code standard of Architecture 2030 and by other parties exploring pathways to zero carbon, such as the ZCB certification tracks developed under the WorldGBC's Advancing Net Zero project. The Zero Code standard by Architecture 2030 was published in spring 2018 as "a national and international building energy standard for new commercial, institutional, and mid- to high-rise residential buildings" (Zero Code n.d.). The novelty of this paper lies in structuring this thinking into a framework of distinct pathways that policymakers can use to determine suitable ZCB policy approaches for core segments of their building stock.

Because ZCBs are more achievable and affordable when broadly defined, we also use this menu of pathways approach to adopt a scope that allows buildings to produce or procure clean renewable energy beyond the building site's boundaries, and/or achieve net zero carbon emissions either at the level of individual buildings or across a group of buildings within a district or municipal portfolio. Finally, we test these approaches by using four countries in three different continents as case studies.

This section lays out our methodology for analyzing how pathways are being enabled or disabled by local policy so that others interested in performing this same analysis for their jurisdiction can follow the same approach.

A.2. Country Selection

We selected four countries, each of which is a major economic powerhouse in its region. China and India are expected to see the largest absolute volume of new buildings being built in the coming decades. Mexico has a track record of developing green, affordable housing and a particularly vibrant renewable energy market. Kenya has made great strides in providing a suitable enabling framework for solar energy access.

A.3. Policy Framework

We analyzed current policies and programs at the national and subnational levels in each of the four countries to test this paper's hypothesis that there can be an achievable ZCB pathway within any existing policy framework. After reviewing and analyzing the body of literature for each ZCB component—basic and advanced EE, on- and off-site RE, and carbon offsets—we developed a framework of 56 policy types grouped into 16 categories that, taken together, can enable or impede the uptake of ZCBs. The policies we considered are listed in Table A1.

Table A1 | Policies Considered to Determine the Feasibility of a Zero Carbon Building Pathway in Four Countries

ENERGY PLANNING	
1	Legislation or action plan, aiming to increase building energy efficiency (EE)
2	Legislation or action plan, aiming to develop or increase renewable energy (RE) generation
ZCB POLICIES AND PROGRAMS	
3	Policy to *mandate* uptake of zero carbon buildings (ZCBs)
4	Policy to *incentivize* uptake of ZCBs
5	ZCB trainings, workshops, other knowledge/communications activities, pilots
6	ZCB design specifications or standards for key building types/climate zones
7	ZCB research and development, demonstration buildings
8	Incorporation of ZC/green/EE/RE measures in (affordable) housing programs
ZCB CERTIFICATION	
9	ZCB certification schemes
BUILDING ENERGY EFFICIENCY CODES AND STANDARDS	
10	Building EE code or standard
EXISTING BUILDING STANDARDS	
11	Performance requirements for existing buildings to get up to code when undertaking major renovations
12	Retro-commissioning
13	Mandatory lighting upgrades
DATA COLLECTION—BUILDING ENERGY CONSUMPTION	
14	Energy audit policy or program
15	Energy benchmarking policy or program
16	Energy “challenge,” encouraging participants to reduce energy and track it
APPLIANCE STANDARDS AND INCENTIVES—AIR CONDITIONERS	
17	Minimum energy performance standards (MEPS) for air conditioners (ACs)
18	Energy performance label for ACs
19	Incentive programs to encourage greater uptake of efficient ACs, including replacement programs

Table A1 | **Policies Considered to Determine the Feasibility of a Zero Carbon Building Pathway in Four Countries (Cont'd)**

ENERGY EFFICIENCY INCENTIVES—FINANCIAL	
20	Tax credits/reductions
21	Rebates
22	On-bill financing for residents
23	Tax-lien financing/property assessed clean energy financing for residents
24	Credit lines or partial risk guarantees for developers
25	Green mortgage program for residents
26	Energy service company/Energy Performance Contracting programs
ENERGY EFFICIENCY INCENTIVES—NONFINANCIAL	
27	Fast-track permitting
28	Density bonus for developers
29	Gross floor area concessions for developers
ENERGY EFFICIENCY INCENTIVES—FACILITATING PRIVATE SECTOR ACTION	
30	Local public-private partnerships; knowledge/exchange platforms, training
31	Green leases
32	Better access to finance
33	Certification schemes—voluntary or mandatory
UTILITY/GRID ELECTRICITY	
34	Government regulating and governing grid electricity provision and demand management
35	Individual metering of building properties
36	Consumer electricity charging
37	Grid electricity subsidies for certain customer groups
38	Utilities (mandated to) carry out EE activities to help customers reduce energy usage
39	Utility customers receiving overview of individual energy usage through their bill

Table A1 | **Policies Considered to Determine the Feasibility of a Zero Carbon Building Pathway in Four Countries (Cont'd)**

ENABLING ON-SITE RENEWABLE ENERGY—GRID CONNECTED	
40	Incentives to purchase on-site RE (rebates, tax breaks, subsidies)
41	Mandatory installation of photovoltaic (PV) panels on new homes, or requiring homes to be "PV ready"
42	Net metering
43	Feed-in tariffs
44	Charging of on-site RE producers for their connection to the grid
45	Policies *prohibiting/impeding* on-site RE
ENABLING ON-SITE RENEWABLE ENERGY—OFF-GRID ENERGY ACCESS	
46	Energy access programs/initiatives providing off-grid solar to households with no or poor grid connections
47	Low-income housing improvement programs
ENABLING OFF-SITE RENEWABLE ENERGY PURCHASING	
48	Green energy tariffs
49	RE purchasing from third party/nonutility (e.g., physical or virtual power purchase agreements)
50	Trading of renewable energy certificates
51	Policies *prohibiting/impeding* off-site RE purchasing
ENABLING OFF-SITE RENEWABLE ENERGY GENERATION	
52	Incentives for nonutility RE generation
53	Policies *prohibiting/impeding* off-site RE generation
CARBON OFFSETS	
54	Building carbon offset standard
55	Access to (voluntary) local markets for purchasing carbon credits
56	Labels to ensure the quality of offsets

A.4. Policy Impact on ZCB Components

We mapped how these policies would impact the implementation of each ZCB component (basic and advanced EE, on- and off-site RE, and carbon offsets). We considered which policies have the greatest positive and negative impact on implementing each ZCB component (Table A2).

With the advice of local experts (WRI offices in China, India, and Mexico, and the Kenya Green Building Society), we then systematically considered the availability and applicability of these policies in each country, taking into account key attributes and considerations impacting their likely influence on ZCBs. This analysis yielded a map of which ZCB components were feasible in each country given the current policy framework.

Table A2 | **Key Policies Considered to Enable or Impede Zero Carbon Building Components**

KEY POLICIES ENABLING ZERO CARBON BUILDINGS	KEY POLICIES IMPEDING ZERO CARBON BUILDINGS
Basic EE	
■ Mandatory building energy efficiency (EE) codes or standards that are regularly updated, implementable, and well enforced	■ Mandatory building energy efficiency codes or standards without updates to increase their stringency
■ Local adaptation of national code or standard that is more stringent	■ Mandatory building energy efficiency codes or standards that are cumbersome to implement
■ National government technical guidance on code or standard implementation and enforcement	■ Mandatory codes or standards without penalties for noncompliance
■ Minimum energy performance standards for appliances with high energy consumption that are regularly updated and well enforced	■ Voluntary building energy efficiency codes or standards lacking measure to incentivize uptake
Advanced EE	
■ Nonfinancial incentives to promote energy efficient/green buildings	■ High grid electricity subsidies for households
■ Financial incentives to promote energy efficient/green buildings	■ Lack of awareness about energy efficiency benefits and available incentives
■ Energy audit and benchmarking schemes for public or private buildings	■ Absence of energy performance information and efficiency incentives for building buyers
■ Programs that support, facilitate, and challenge building owners to improve energy efficiency	■ Absence of information supporting building owners to pursue energy efficiency measures
■ Development of or support for green building rating and certification schemes	■ Absence of government leadership by example on building energy efficiency
■ Government leadership by example through requirements, certifications, or targets	■ Barriers to the growth of the energy service companies industry
■ Programs that address both affordable housing and energy efficiency	
On-site RE	
■ Renewable energy (RE) targets	■ High grid electricity subsidies for households
■ Net metering or a stable feed-in tariff	■ Incentives that frequently change
■ Incentives promoting on-site RE	■ Lack of awareness about on-site RE benefits and available incentives
	■ Lack of government leadership by example
Off-site RE	
■ Opening electricity markets to nonutility actors to partake in power purchase agreements (PPAs) or purchase renewable energy credits (RECs)	■ High minimum energy demand requirements to partake in PPAs or buying RECs
■ Promoting the development of RE for the provision of grid energy	■ Utility barriers to consumers purchasing nonutility RE via PPAs
■ Cost-competitive green tariffs	■ Green tariffs with a very high markup
■ Aggregating energy demand from public buildings for off-site RE purchase (PPA or RECs)	■ Lack of government enforcement of renewable purchase obligations to support the market for RECs
	■ Limiting availability of off-site RE options to qualified registered users

Source: WRI.

A.5. Pathway Feasibility Based on ZCB Components

To subsequently determine the feasibility of complete pathways in each country, we examined the feasibility of its component parts. If one or more components of the pathway is poorly enabled in a country, then that pathway would be considered somewhat feasible or unfeasible from a current policy perspective. A broad comparative overview of pathway feasibility in the four countries is included in Section 5 of this paper, and further details can be found in the subsequent Appendix B.

Having distilled the core enabling and disabling policies that were identified as having the most influence on pathway feasibility, this information was used to inform a number of country-specific recommendations for enhancing the local policy framework for energy efficiency and renewable energy at the national and subnational levels to bring more ZCB pathways within reach.

In addition, we considered the different roles and levels of influence of city, national, and state governments. We also focus on a number of policy options that allow cities to facilitate a district or municipal portfolio approach to building decarbonization.

APPENDIX B. CURRENT POLICIES AND PROGRAMS ENABLING ZCBS

Four countries were selected for a deeper analysis of their current policies and programs to illustrate how countries and cities can help enable or even inadvertently disable ZCB pathways through their framework of policies and programs. The four case studies show that even in the absence of comprehensive sets of policies, and despite a very diverse set of contexts, there are *almost always one or more ZCB pathways already within reach.* Targeted priority actions can help further increase the relative ease and desirability of achieving these pathways.

Nonetheless, the actual feasibility and attractiveness of a pathway for a building owner/manager depends on a variety of factors, including market readiness, awareness of the benefits, and the availability of capital finance, of which this analysis has mainly considered the policy and program state of play.

B.1. India

B.1.1. Overview

In India, buildings account for over a third of total electricity consumption, with consumption still increasing due to rapid urbanization. The country also regularly faces acute electricity shortages, amounting to about 10 percent annually, which can increase to more than 15 percent during peak demand periods (NRDC and ASCI 2012). A move to energy efficient, ZCBs has enormous potential to provide India with clean, secure, and reliable energy for all well into the future.

Although India has developed building energy efficiency policies for more than 15 years, it has yet to implement mandatory requirements. Its national Energy Conservation Building Code (ECBC) still has a mostly voluntary character and relies on the willingness of states and municipalities to adopt and incorporate the code. The cumbersome process has resulted in only 10 states taking the effort to adopt the ECBC between 2007 and 2018.

The absence of mandatory energy efficiency policies results not only in low uptake of building energy efficiency, but it also stunts the market for such products and services. It also slows down the pace at which economies of scale can be reached, which would lead to more capital being allocated to and more competitive pricing emerging for this segment of the market.

At the same time, India has shown leadership in the green building market, with multiple successful rating and certification schemes on offer that jointly have certified several thousands of buildings, including about a dozen buildings than can be considered (net) zero or nearly (net) zero carbon.

India's electricity market reform in 2003 has also opened up more options for renewable energy generation and purchasing. Nonetheless, limited incentives for rooftop PV panels; highly subsidized electricity rates for certain customer groups, such as households; caps on net-metering capacity; and no stable long-term price signal for FITs hamper the growth of on-site RE generation.

Current regulations for off-site RE purchasing cater to large energy consumers, requiring a minimum of 1 MW of energy demand to purchase from non-utility actors. Coupled with utilities resisting the loss of their customers, the market for renewable energy purchasing has yet to reach its full potential. At the same time, India is a major global force when it comes to generating local carbon credits, and the relatively low-cost supply of credits in the voluntary market provides options for offsetting operational building energy emissions in case on- and/or off-site RE does not provide feasible options (CDP 2017; Sengupta 2017).

Altogether, India's current policy framework already puts **multiple ZCB pathways within reach of Indian building owners/managers**, although this is mainly true for commercial buildings and in particular those that have a considerable energy demand. In addition, although the Indian national and state policy environment is increasingly favorable to ZCBs, the local market may still need to catch up to enable nonpolicy elements of various ZCB pathways.

B.1.2. Pathways at a glance

ZCB PATHWAYS ENABLED THROUGH THE CURRENT FRAMEWORK OF POLICIES AND PROGRAMS

India's policy and program framework for basic and advanced EE, on- and off-site RE, and carbon offsetting makes a number of ZCB pathways already within reach today. The feasibility of each available ZCB pathway that government may encourage building owners/managers to pursue is shown in Table B1.

Table B1 | **Indicative Overview of the Feasibility of Each Pathway in India under the Current Policy and Program Framework**

PATHWAY		COMPONENT					INDIA
		BASIC EE	ADVANCED EE	ON-SITE RE	OFF-SITE RE	CARBON OFFSETS	
Exemplary energy performance	1	◆	◆	◆		(if needed)	X
	2	◆	◆	◆	◆	(if needed)	O
	3	◆	◆		◆	(if needed)	O
	4	◆	◆			◇	O
Minimum energy efficiency	5	◆		◆		(if needed)	X
	6	◆		◆	◆	(if needed)	✓
	7	◆			◆	(if needed)	O
	8	◆				◇	✓

X = pathway is not sufficiently supported by the current policy framework.

O = the pathway is feasible under current policy but with limited application—either for specific segments of the building market and/or critical policy elements are insufficiently developed to make the pathway attractive.

✓ = the pathway is sufficiently facilitated through current policy.

Notes: [a] The minimum required level of energy efficiency (EE) achieved by complying with local codes and standards.
[b] More ambitious energy performance that goes beyond minimum regulatory requirements.
[c] Recommended only in cases where efficiency measures and renewable energy (RE) sources cannot meet 100 percent of energy demand.
Source: WRI.

For India, many ZCB pathways are increasingly within reach. Nonetheless, those pathways considered to be somewhat or very feasible[15] under the current policy state of play are mostly or only attainable for owners/managers of commercial buildings or public buildings, for which government can lead by example.

For owners/managers of residential buildings, most pathways are considered either too challenging or are not even viable due to a lack of enabling policies. Thus, low uptake can be expected unless dedicated policies also help faciliate this part of the market.

Table B2 provides a concise overview of the enabling or disabling policies for each ZCB component. It indicates the most likely building types that would be considered feasible as well as potential caveats for pursuing the component. Those pathway components that are relatively easy to achieve—meaning they are the most feasible under the current framework of policies and programs—are not necessarily the most preferable ones, keeping in mind the core principles and hierarchy of pathways (Section 2.3).

Table B2 | **Overview of Most Feasible/Likely ZCB Components to Pursue in India under the Current Policy and Program Framework**

COMPONENT	FEASIBILITY	DETAILS
Basic EE	Dependent on the national building energy code having been adopted by the local state Most suitable for (large) commercial buildings, which are the main subject of the voluntary building energy code; a code for residential buildings is only just emerging	■ Building energy efficiency (EE) code: Energy Conservation Building Code (ECBC) for commercial and residential (coming), voluntary ■ Minimum energy performance standards for air conditioners
Advanced EE	Most suitable for commercial buildings, which can afford to pursue green building certification to which many incentives are tied; however, limited EE experience in the market will mainly see front-runners take this path.	■ Exemplary building EE code performance: ECBC+ and ECBC++ ■ Star-rating program: 1–5 star rating based on energy performance index ■ Green building certification schemes: IGBC,[a] GRIHA,[b] SVAGRIHA,[c] LEED,[d] EDGE[e] ■ Financial incentives for GRIHA- or IGBC-rated buildings ■ Nonfinancial incentives for IGBC-rated buildings ■ Market Integration and Transformation for Energy Efficiency ("MAITREE") program: public building EE retrofits
On-site RE	Policies do not sufficiently facilitate this component Most suitable for commercial buildings, which face higher electricity rates, making on-site renewable energy (RE) more attractive	■ High electricity subsidies for residential discourage photovoltaic (PV) panels ■ PV: residential—national/state subsidies, majority expired; commercial—40% depreciation in first year ■ Net metering: widespread at state level, often like-for-like credits, energy bill adjusted, or (low) feed-in tariff
Off-site RE (purchase or generation)	Dependent on the local state providing RE open access Most suitable for commercial buildings, which may have enough remaining energy demand (minimum 1 MW) to engage in a power purchase agreements (PPAs) or buy renewable energy credits (RECS)	■ PPA: for users with minimum of 1 MW; emerging market ■ Green tariff: none or limited ■ RECs: sold once/month, representing 1 MW each
Carbon offsets	Only if EE and RE cannot reach 100 percent Most suitable for commercial buildings since there is a dearth of local programs that target individual consumers to offset their carbon footprint, making this a less attractive option for residential buildings	■ Voluntary carbon credit market present, selling carbon credits from local accredited projects

Notes:
[a] India Green Building Council Rating Systems.
[b] Green Rating for Integrated Habitat Assessment.
[c] Simple Versatile Affordable Green Rating for Integrated Habitat Assessment.
[d] Leadership in Energy and Environmental Design.
[e] Excellence in Design for Greater Efficiency.
Source: WRI.

B.1.3. The impact of policies on pathway feasibility

From the analysis, it has become clear that a select number of policies/programs—or their absence—are responsible for enabling or disabling local players to pursue energy efficiency and renewable energy solutions, which together can be used to arrive at a (net) zero or nearly (net) zero carbon building.[16]

Key current policies and programs that help **enable the feasibility of ZCB pathways** include the following. They are accompanied by the relevant government levels (national, state, and/or municipal) that are currently responsible for aspects of the policy as well as the type of responsibility they take on. In general, the listed actions all relate to the government's role as regulator.

Energy Efficiency

ENABLING POLICIES	GOVERNMENT LEVEL & RESPONSIBILITY	
■ The ECBC includes exemplary performance levels, known as ECBC+ and ECBC++ (minimum of 35 percent and 50 percent energy efficiency, respectively, versus conventional).	■ National ■ State ■ Municipal	■ Design & issue ■ Adopt (& adapt) ■ Implement & enforce
■ Multiple successful green building rating and certification schemes are actively being promoted and provide education and training support to interested parties.	■ National ■ State ■ Private sector	■ Incentivize ■ Incentivize ■ Implement
■ A range of national or state incentives that, through financial or nonfinancial rewards (such as increased floor area ratio), encourage green design, although the majority are tied to obtaining green building certification.	■ National ■ State	■ Design & implement ■ Design & implement

Renewable Energy

ENABLING POLICIES	GOVERNMENT LEVEL & RESPONSIBILITY	
■ Renewable energy targets set by the national government, which include rooftop PV panels	■ National ■ State	■ Issue & implement ■ Implement
■ The widespread availability across Indian states of net-metering schemes	■ National ■ State	■ Design & issue ■ Design & implement
■ The opening up of the electricity market, allowing users to engage in nonutility PPAs as well as to purchase RECs	■ National ■ State	■ Design & issue ■ Implement

Key policies and programs—or the lack thereof—that (in part) **disable the feasibility of ZCB pathways** include the following. They are accompanied by the relevant government levels (national, state, and/or municipal) currently responsible for aspects of the policy and their specific responsibilities. In general, the listed actions all relate to a government's role as regulator, except where it concerns supporting the market (convener/facilitator role) and leading by example (owner/investor role).

Energy Efficiency

DISABLING/LACKING POLICIES	GOVERNMENT LEVEL & RESPONSIBILITY	
■ The voluntary nature of the ECBC and the cumbersome process for states and municipalities to adopt and incorporate it in their local regulations, which results in many local jurisdictions having no energy efficiency regulations to follow	■ National ■ State ■ Municipal	■ Design & issue ■ Adopt (& adapt) ■ Implement & enforce
■ The absence (until recently) of an ECBC for residential buildings, which is now gradually being introduced in phases and is still as a voluntary code	■ National ■ State ■ Municipal	■ Design & issue ■ Adopt (& adapt) ■ Implement & enforce
■ High grid electricity subsidies for households, which reduce the economic case for both energy efficiency measures and on-site PV systems	■ State	■ Design & implement
■ Many financial and nonfinancial incentives being tied to being green building certified (GRIHA or IGBC), which may put them out of reach for smaller building developers lacking the means to pursue such certification	■ National ■ State	■ Design & implement ■ Design & implement
■ The relative absence of facilitating programs that educate and inform building stakeholders and support them in pursuing energy efficiency measures	■ National ■ State ■ Municipal	■ Design & implement
■ The relatively limited number of programs that show government leading by example on energy efficiency for their public building stock	■ National ■ State ■ Municipal	■ Design & implement

Renewable Energy

DISABLING/LACKING POLICIES	GOVERNMENT LEVEL & RESPONSIBILITY	
■ The expiration of most national or state subsidies for households to install PV panels as well as the halving of the percentage depreciation allowed for commercial buildings installing PV systems	■ National ■ ■ State	■ Design & implement ■ Design & implement
■ The requirement to have at least 1 MW in energy demand to engage in a PPA for off-site RE or buy RECs	■ State ■ Utilities	■ Design & issue ■ Implement
■ The lack of green energy tariffs; the state of Karnataka is an exception because such electricity comes with a 50 percent markup, which reduces its attractiveness	■ State ■ Utilities	■ Design & issue ■ Implement
■ RECs only being sold once/month at India's national exchange, providing interested parties with limited opportunities for their purchase	■ National	■ Design & issue
■ The uncooperative stance of many utilities to allow their customers open access to renewable energy per the 2003 Electricity Act	■ State ■ Utilities	■ Oversight ■ Implement

B.1.4. Priority actions for better enabling the ZCB pathways

With enhanced policy, several of the ZCB pathways that are currently considered to be insufficiently or only somewhat facilitated by the current policy framework in India will become increasingly attainable and desirable, putting India firmly on the track toward building decarbonization.

A short list of priority policy actions is provided for city governments,[17] followed by a similar list for national and state governments, that can facilitate progress in cities. The recommended actions acknowledge that decisive action at higher government levels is often a prerequisite to enable urban stakeholders to most effectively act on policies that can help enable the ZCB pathways.

Energy Efficiency—City Governments

POLICY PRIORITY ACTIONS	ROLE
■ Large and major cities to incorporate the ECBC into their local regulations and tie it to building approval forms and processes (for example, Hyderabad), effectively making the ECBC mandatory for new buildings	■ Regulator
■ Cities to introduce (nonfinancial) incentives for buildings that can prove compliance with ECBC+ and ECBC++, which are voluntary exemplary performance levels of the ECBC	■ Regulator
■ Cities to develop communication and outreach materials that help educate the market on how to achieve compliance with the ECBC	■ Convener/ facilitator
■ Cities to lead by example by requiring new public buildings and major retrofits of public buildings to comply with at least the minimum level of a suitable green building rating and certification system, such as IGBC or GRIHA	■ Owner/ investor

Renewable Energy—City Governments

POLICY PRIORITY ACTIONS	ROLE
■ Large and major cities to introduce or alternatively lobby their states to introduce/reinstate incentives for rooftop renewables (PV, solar hot water)	■ Regulator/ partner
■ Cities to lead by example by requiring new public buildings and major retrofits of public buildings to install rooftop renewables where feasible	■ Owner/ investor
■ Cities to aggregate energy demand from (existing) public buildings to engage in off-site RE purchase (PPA or RECs)	■ Owner/ investor

Energy Efficiency—National/State Governments

POLICY PRIORITY ACTIONS	ROLE
■ National government to develop a process to turn the ECBC into a mandatory code, for instance, by tying it to building approvals; the current introduction of the ECBC for residential buildings provides such an opportunity	■ Regulator
■ States to rapidly adopt (and, if necessary, adapt) the ECBC, if they have not done so yet	■ Regulator
■ National government to more proactively phase out electricity subsidies for specific groups to increase the attractiveness of energy efficiency (or on-site RE) measures, ensuring that the increase in energy bills can be mitigated by a drop in energy consumption through affordable and readily available energy efficiency measures	■ Regulator
■ National/state government to reconsider if incentives would be best tied to green building certification and/or also to the ECBC to put them in reach of more building developers	■ Regulator
■ State governments to develop communication and outreach materials that help educate the market on how to achieve compliance with the ECBC	■ Convener/ facilitator
■ National and state government to lead by example by requiring new public buildings and major retrofits of public buildings to comply with at least the minimum level of a suitable green building rating and certification system, such as IGBC or GRIHA	■ Owner/ investor

Renewable Energy—National/State Governments

POLICY PRIORITY ACTIONS	ROLE
■ National/state government to introduce or reinstate attractive incentives for rooftop renewables (PV, solar hot water)	■ Regulator
■ States to introduce green energy tariffs with a limited markup to increase their attractiveness	■ Regulator
■ States to work with their local utilities to develop alternative business models that help cushion the loss in revenue from customers seeking nonutility renewable energy options, thereby reducing the stumbling blocks for off-site RE purchasing put in place by utilities	■ Convener/ facilitator
■ States to enforce RPOs to increase the demand for and thus help develop the market for RECs	■ Regulator

These actions will help better facilitate pathways 3 and 7, which are currently only somewhat feasible, while also supporting the enhanced feasibility of other pathways.

Section 5 of this paper provides a comparative overview of all four countries considered in this analysis. It shows the feasibility of each pathway under the current policies as well as under an enhanced policy framework if the priority actions were to be implemented. Importantly, it points to how targeted policy enhancement can put every ZCB pathway well within India's reach.

B.1.5. Current policies for facilitating ZCB pathways

ENERGY EFFICIENCY

In 2002 India enacted the Energy Conservation Act, marking the start of building EE policies. In 2007 an important next step was taken by launching the ECBC, which so far has mainly applied to large commercial buildings. Data suggest that ECBC-compliant buildings may be 25–60 percent more efficient than standard buildings in India (NRDC and ASCI 2014), with the ECBC providing additional exemplary performance levels known as ECBC+ and ECBC++. The ECBC is mostly a voluntary code, however; as such, it generally bears no penalties for noncompliance.

To be applicable, the ECBC also has to be adopted by states first, then implemented by Urban Local Bodies, and finally embedded in the bylaws of municipalities, which has proven to be a very slow and cumbersome process. This is further impeded by the shortage of building professionals with sufficient knowledge of EE and the rather complex permit application process (IPEEC 2015). As a result, it was estimated that in 2013 no more than 10 percent of applicable new buildings complied with the ECBC, with only 7 states having adopted the ECBC at that time, up to 10 states in 2017. States can make modifications to the ECBC to make the code better suit local circumstances.

A success story of implementation is the Greater Hyderabad Municipal Corporation. Not only has it incorporated the ECBC into its local regulations, but it has also made it mandatory through integration with building approval forms and processes and has been actively enforcing the code (NRDC 2016).

In 2017 an ECBC for residential buildings was being introduced. This new ECBC will launch in stages, having first released Part 1 for the building envelope, to gradually familiarize the market. Similar to the ECBC for commercial buildings, its implementation depends largely on states and municipalities adopting and incentivizing the code because the national government cannot mandate states to implement the ECBC (BEEP 2018).

For existing buildings, a star-rating program (one to five stars) was introduced in 2009 by the national government. The ratings are based on an energy performance index (kilowatt-hour per square meter, kWh/m^2) determined for three climate zones and involving energy audits. By late 2014, around 125 buildings had taken part in the program, pointing toward low uptake.

The incremental costs and payback time for EE projects (in the absence of binding regulations) deter many in the private sector building community. Although anecdotal evidence points toward a drop in the cost premium for an energy efficient building of 16–17 percent in 2000 to only 4 percent in 2013, high interest rates at banks can still double the payback time due to the cost of (extended) interest payments for energy efficient equipment (EIU 2013).

In the residential market, price sensitivity is high among homes bought by lower-middle-class families, which represent up to 90 percent of the housing market. Combined with relatively low electricity fees, subsidized for residential consumers by commercial and industrial energy users, the economic argument is currently not in favor of energy efficiency (Khosla 2016).

Several green building rating and certification schemes have been introduced into the Indian market that have been quite successful so far in garnering the industry's interest. In addition to Leadership in Energy and Environmental Design (LEED), a scheme originally from the United States, that has more than 2,300 buildings certified in India, the Indian Green Building Council (IGBC) has introduced its IGBC green building certification scheme.

The IGBC has about 1,000 buildings certified and more than 4,000 registered. Eleven of these certified buildings can be considered to be nearly zero energy. The IGBC is also working on a "net zero" certification scheme as part of the WorldGBC's Advancing Net Zero project, which helps GBCs to offer a certification track for ZCBs (WorldGBC 2018).

Another popular scheme is the Green Rating for Integrated Habitat Assessment (GRIHA), introduced in 2005 by the national government. GRIHA has standards for all Indian climate zones and can result in 40–60 percent energy savings compared to conventional. A three-star GRIHA rating has now become mandatory for new public buildings owned by the national government (NRDC and ASCI 2012).

Incentives for building developers are mostly linked to obtaining certification under GRIHA or the IGBC. Many states and municipal corporations have financial incentives in place, providing partial rebates on property taxes, permit fees, or the registration fees for the actual green building rating schemes. Other incentives give developers rights to a greater built-up area than those currently sanctioned, known as the floor area ratio (FAR). Several states provide FAR incentives, which do not cost the government anything but are being perceived as valuable by developers.[18] Smaller building developers who lack the means to pursue green building certification do not benefit from incentives for energy efficiency (NRDC and ASCI 2014).

For the most part, the government does not appear to tap into the potential to lead by example. For instance, a 2016 announcement by the state of Maharashtra that required an IGBC rating for all new/renovated government buildings appears to have had no follow-up.

Role of cities: *Cities*[19] *can extend incentives or lobby their states to introduce or reinstate incentives for rooftop PV panels as well as lobby or collaborate with their state government to develop attractive long-term (price) signals toward the market for net metering and FITs.*

ON-SITE RE GENERATION

Utilities in India are generally regulated by the states, which leaves very little room for cities to influence electricity access, pricing, and subsidies for certain consumer groups in light of their impact on the economic attractiveness of both basic and advanced EE measures and on-site RE systems. Nonetheless, since the reform of India's electricity market in 2003, which created open access for renewable energy, producers, buyers, and sellers of renewable energy have been provided with more opportunities, even though awareness is still relatively low. In addition, central government targets for renewable energy (175 gigawatts, or GW, by 2022) include a target for rooftop PV panels equivalent to 40 GW, and most states have introduced net-metering or similar regulations (Climatescope 2018).

At the same time, many incentives to facilitate rooftop PV panels have expired or have been reduced. The central government, for instance, used to offer a 30 percent subsidy on the capital cost of PV panels or even solar lanterns for households, with some states adding an extra percentage or a certain cash amount. For commercial rooftop PV panels, a tax incentive is available, initially allowing 80 percent tax depreciation in the first year; in April 2017 it was capped at 40 percent, and it is only available if the project is commissioned in the first six months of a financial year.

For on-site producers of renewable energy, a number of states offer FITs. Although rates were initially quite attractive, they have dropped multiple times since. The lower FITs thereby hamper the longer-term investment decisions for rooftop solar systems. In some states, utilities only provide customers who are most expensive to serve the option to feed energy into the grid and be compensated for as an incentive to generate their own on-site energy. Many states also cap their net-metering options to a maximum aggregated annual amount of megawatts across the state on a first-come, first-served basis and to a maximum percentage of local transformer capacity to protect their fragile grids (Climatescope 2018).

Role of cities: *Cities can extend incentives or lobby their states to introduce or reinstate incentives for rooftop PV panels as well as lobby or collaborate with their state government to develop attractive long-term (price) signals toward the market for net metering and FITs.*

OFF-SITE RE PURCHASE

The option to purchase off-site RE from nonutility actors is available to those who have at least 1 MW in energy demand. Several state governments have considered lowering the 1 MW limit; however, they face challenges from the utilities about losing customers and thus revenue. As an example, the state of Tamil Nadu dropped the minimum requirement to 500 kW and subsequently to 50 kW. It then raised the limit to 1 MW again due to utility concerns. In some states, customers also require permission from the local utility if interested in purchasing nonutility renewable energy, with the utility maintaining the right to refuse the request.

Although the PPA market is very new in India, it is reasonably vibrant despite many awaiting the outcomes of the courts, with some large customers having challenged the utilities for their stance. Green energy tariffs, however, are mostly still nonexistent, with the state of Karnataka providing the option with a roughly 50 percent markup on the regular price of grid electricity; as a result, the policy has not seen much uptake yet. For small private sector and residential consumers, purchasing green energy is currently not a viable option because of the absence of green tariffs, the low cost premium, and the high bar set for purchasing nonutility renewable energy.

Since 2010, India has offered solar and nonsolar RECs, each representing 1 MW. The RECs are sold in India's national exchange on the last Wednesday of every month. Although the RECs are verified, buyers do not know which project generated them. The REC price is low due to limited demand compared with the generation of RECs, resulting in RECs trading at the floor price. Although utilities are bound by RPOs, which should fuel demand in the REC market, not all have fulfilled their obligations. The resulting low price provides opportunities for building owners/managers with at least 1 MW in energy demand to purchase RECs at an attractive price (Shrimali 2013).

Role of cities: *Cities can work with their local utilities to develop alternative business models that help cushion the loss in revenue from customers seeking nonutility renewable energy options, thereby reducing the stumbling blocks for off-site RE purchasing fueled by utilities.*

CARBON OFFSETTING

Since 2005, India became one of the largest producers of carbon credits under the Clean Development Mechanism (CDM), at some point claiming almost a third of the market (CDP 2017). Since 2012, however, new carbon reduction projects are no longer eligible to register under the CDM. One challenge faced by Indian carbon credits generated under the CDM was the question of additionality, with many arguing that a considerable part of the credits did not fulfill this criterion.[20] With CDM no longer an option, India has become an important source for carbon credits in the voluntary market, leading many developers to sell to voluntary buyers instead.

A considerable crash in the price of carbon credits has made registering for and generating carbon credits less attractive for Indian developers, many of whom now operate in the renewable energy industry. For the time being, however, this provides buyers with a relatively low-cost supply of credits for locally offsetting their emissions (Sengupta 2017). These carbon credits should be vetted to ensure they are of high quality and meet additionality criteria.

Role of cities: *Cities can educate stakeholders on the options for offsetting their carbon footprint through the voluntary carbon offset market, thereby fueling greater demand and awareness, although ensuring that they first consider energy efficiency and renewable energy options and that they thoroughly consider the quality of these credits in their analysis of suitable options.*

B.2. China

B.2.1. Overview

China has the largest construction market in the world. In 2010 it surpassed the size of the U.S. construction market (EU MSE Centre 2015). In the five years from 2011 to 2016, the building and construction industry grew at an average rate of 8.5 percent annually as a result of rapid urbanization (IBISWorld 2017). This strong urbanization trend, combined with an increasing demand for better indoor thermal comfort, is expected to lead to a significant increase in building energy use if no mitigating measures are being taken.

Building energy efficiency has been on the government agenda since 1986, although the first two decades saw limited interest from both the private and the public sector. In 2005, according to official inspection data, the compliance rate with local mandatory energy efficiency codes and standards stood at 53 percent for the design stage and at 21 percent for the construction stage. As implementation and enforcement have significantly improved, compliance rates in urban areas reached nearly 100 percent in 2010. Rural areas, however, are not subject to compliance inspection (Bin and Nadel 2012).

To support a move to a more sustainable building market, China has also introduced a wide range of incentive policies and has developed green building rating systems and labels, the most well-known being China's Three Star rating, along with financial incentives for certified projects. For its 13th Five-Year Plan (2016–20), the national government has set a goal of 50 percent of new construction being certified (MOHURD 2017b). In addition, passive house and ultra-low-energy passive building concepts have been introduced to the Chinese market through a range of pilots, and the Passive Ultra-low Energy Building Standard Guideline for Residential Buildings was issued in 2015. The national government is currently taking this a step further through pilots and draft guidelines for nearly and net zero energy buildings, which also incorporate renewable energy provision.

To facilitate the uptake of alternative energy sources, the national government has been financially supporting the building of integrated PV panels, shallow geothermal energy, sewage waste heat recovery, wind energy, and biomass since 2006. In addition, the recently introduced Renewable Portfolio Standards require each Chinese province to achieve a certain percentage of renewable electricity generation as part of its overall energy portfolio, with noncompliance being subject to penalties (NEA 2018). Ongoing power market reform also aims to deregulate the power system and reduce China's wind and solar curtailment.

For on-site renewables, China's national government has (previously) been offering subsidies for building-integrated PV systems, and many provinces and municipalities have done so for household solar PV systems (NEA 2017). China is the world's largest market for solar hot water systems, with the national government previously providing consumers with rebates. The country has also adopted FITs in 2013 for both large-scale and distributed generation (Fuller and Guo 2016).

To provide consumers with more options to purchase renewable electricity, the Green Electricity Certificates (GECs) initiative was released in July 2017 (NEA 2017). It provides a platform for all, including building owners/managers and households, to directly purchase RECs from renewable energy suppliers. Uptake so far has been low, with a shrinking public subsidy fund for renewable energy dependent on fee collections from customers (Miao et al. 2017).

Even though some of China's policies are still in their infancy, the country's policy framework is increasingly paving the way for (net) ZCBs to be implemented at scale. This means that **all ZCB pathways are already somewhat or well within reach of Chinese building owners/managers**. Although the Chinese policy environment is increasingly favorable to ZCBs, the local market may still need to catch up to enable the nonpolicy elements of various ZCB pathways.

B.2.2. Pathways at a glance

ZCB PATHWAYS ENABLED THROUGH THE CURRENT FRAMEWORK OF POLICIES AND PROGRAMS

China's policy and program framework for basic and advanced EE, on- and off-site RE, and carbon offsetting makes all the ZCB pathways somewhat or fully within reach today. The feasibility of each available ZCB pathway that the government may encourage building owners/managers to pursue is shown in Table B3.

In theory, all of the ZCB pathways can be achieved in China today,[21] with a range of supporting policies in place for each of the ZCB pathways. Nonetheless, as a result of gaps in the policy framework as well as some policies not yet being well established, not all pathways are equally within reach. In addition, several of the ZCB pathways are considered mostly or only attainable for owners/managers of commercial buildings and of public buildings, for which the government can lead by example.

Table B4 provides a concise overview of the enabling or disabling policies for each ZCB component, indicates the most likely building types for which the component is considered feasible, and potential caveats for pursuing the component. Those pathway components that are relatively easy to achieve—meaning they are the most feasible under the current framework of policies and programs—are not necessarily the most preferable ones, keeping in mind the core principles and hierarchy of pathways (Section 2.3).

Table B3 | **Indicative Overview of the Feasibility of Each Pathway in China under the Current Policy and Program Framework**

PATHWAY		COMPONENT					CHINA
		BASIC EE	ADVANCED EE	ON-SITE RE	OFF-SITE RE	CARBON OFFSETS	
Exemplary energy performance	1	◆	◆	◆		(if needed)	○
	2	◆	◆	◆	◆	(if needed)	✓
	3	◆	◆		◆	(if needed)	○
	4	◆	◆			◆	✓
Minimum energy efficiency	5	◆		◆		(if needed)	○
	6	◆		◆	◆	(if needed)	✓
	7	◆			◆	(if needed)	○
	8	◆				◆	✓

○ = the pathway is feasible under current policy but with limited application—either for specific segments of the building market and/or critical policy elements are insufficiently developed to make the pathway attractive.

✓ = the pathway is sufficiently facilitated through current policy.

Notes: [a] The minimum required level of energy efficiency (EE) achieved by complying with local codes and standards.
[b] More ambitious energy performance that goes beyond minimum regulatory requirements.
[c] Recommended only in cases where efficiency measures and renewable energy (RE) sources cannot meet 100 percent of energy demand.
Source: WRI.

Table B4 | **Overview of Most Feasible Zero Carbon Building Components to Pursue in China under the Current Policy and Program Framework**

COMPONENT	FEASIBILITY	DETAILS
Basic EE	■ High penetration of energy efficiency (EE) techniques ■ Building energy codes and standards have been improving over time to reflect technology progress according to different types of buildings and climate zones.	■ More strict building energy codes ■ Ambitious national targets of energy efficient buildings
Advanced EE	■ High penetration of EE techniques ■ Most suitable for commercial/public buildings: Financial incentives are provided for above-code practices (i.e., green building label, passive house certificate, demonstration projects), with many targeting commercial buildings and/or more likely to be within reach of larger building developers or owners/managers.	■ National, subnational, and local government incentives ■ Green building rating and certification schemes ■ International collaboration
On-site RE	■ On-site photovoltaic (PV) systems are very popular. ■ Most suitable for commercial/public buildings: While building-integrated renewable energy (RE) and distributed energy have been promoted by national and subnational governments, rooftop PV panels for residential buildings in urban areas are often challenging due to limited rooftop space.	■ Building code: solar water heating, integrated PV panels, PV lighting system; ■ Feed-in tariffs (FITs) provided and net metering allowed
Off-site RE (purchase or generation)	■ Green tariffs are available for renewable power, but RE purchase is difficult in a regulated market. ■ Most suitable for commercial/public buildings: Off-site renewables can be purchased directly from solar/wind power producers, but this option is limited to only a few eligible buyers.	■ Ongoing power market reform—possible to buy RE ■ Green tariffs available for RE providers ■ No green power purchase, but possible in the future (if the power market is deregulated ■ Renewable energy credits (RECs) are weakly enforced ■ RECs are available through a national trading platform, but the market is rather inactive because of the following: □ The cost for buyers comes in addition to their electricity bills □ Price is similar to that of FITs, which the RE supplier has to forgo to create RECs
Carbon offsets	■ Only if EE and RE cannot reach 100 percent ■ Available option but not practiced in building sector yet ■ Most suitable for commercial/public buildings: Mainly the commercial sector is familiar with the voluntary market.	■ Voluntary carbon credits are available for trading through the China Certified Emission Reduction (CCER) system

Source: WRI.

B.2.3. The impact of policies on pathway feasibility

An analysis of China's policy framework points to a number of core policies/programs responsible for enabling and disabling local players to pursue energy efficiency and renewable energy solutions, which together can lead one to a (net) zero or nearly (net) zero carbon building.[22]

Key current policies and programs that help **enable the feasibility of ZCB pathways** include the following. They are accompanied by the relevant government levels (national, state, and/or municipal) that are currently responsible for aspects of the policy as well as the type of responsibility they take on. In general, the listed actions relate to the government's role as regulator or as convener/facilitator in the market.

Energy Efficiency

ENABLING POLICIES	GOVERNMENT LEVEL & RESPONSIBILITY	
National mandatory building energy efficiency codes or standards set minimum requirements for different building types and climate zones and are well enforced in medium to large cities.	■ National ■ Province/ municipal	■ Design & issue ■ Implement & enforce
The Ministry of Housing and Urban-Rural Development (MOHURD) provides technical guidelines on building energy efficiency code implementation and compliance and technical codes or standards for certain energy efficient technologies.	■ National ■ Province ■ Municipal	■ Design & issue ■ Implement ■ Implement & enforce
A variety of standards, benchmarking, and certificate systems have been put in place, such as China's Three Star, Green Building Material Certificate, China Energy Label for energy efficient appliances and equipment, and MEPS for air conditioners.	■ National ■ ■ Province/ municipal	■ Design & implement ■ Implement
Financial and some nonfinancial incentives are available for those pursuing above-code practices. These include subsidies for certified green buildings, ultra-low-energy passive buildings, pilot and demonstration projects, and retrofits as well as some provinces and cities offering tax credits, or extra FAR.	■ National/ province/ municipal	■ Design & implement
Banks are required by government to provide low-interest loans for energy efficiency improvements, thereby overcoming hurdles around (the high cost of) access to capital.	■ National	■ Design & implement
MOHURD has established a voluntary energy auditing program for public buildings requiring provincial governments and major cities to submit annual energy audit reports. Some cities, such as Beijing and Shanghai, are taking the lead, going beyond what is required at the national level.	National Province/ municipal	Design & issue Implement
MOHURD has issued a technical guideline for ultra-low-energy buildings (similar to passive houses) and is working on a similar guideline for nearly zero energy buildings. It has also issued a five-year target for uptake of such buildings, with several local governments issuing additional policies.	■ National ■ Province/ municipal	■ Design & issue ■ Implement

Renewable Energy

ENABLING POLICIES	GOVERNMENT LEVEL & RESPONSIBILITY	
China's Renewable Portfolio Standards (currently under consultation) set renewable energy quotas for each province.	■ National ■ Province	■ Design & implement ■ Implement
Financial incentives for building-integrated renewables and distributed renewable energy generation are provided, including FITs and some subsidies.	■ National/ province/ municipal	■ Design & implement
A GEC trading platform was established in 2017, allowing consumers to buy RECs from renewable energy suppliers.	■ National	■ Design & implement

Key policies and programs—or the lack thereof—that (in part) **disable the feasibility of ZCB pathways** include the following. They are accompanied by the relevant government levels (national, state, and/or municipal) currently responsible for aspects of the policy and their specific responsibilities. In general, the listed actions relate to a government's role as regulator, except where it concerns supporting the market (convener/facilitator role).

Energy Efficiency

DISABLING/LACKING POLICIES	GOVERNMENT LEVEL & RESPONSIBILITY	
China's building codes/standards are currently not being reviewed or evaluated at regular, predictable intervals, and many of them have not been updated since 2010, which may hinder the further uptake of energy efficiency in buildings.	■ National ■ Province ■ Municipal	■ Design & issue ■ Implement ■ Implement & enforce
Many of China's market facilitation efforts to increase energy efficiency depend strongly on public funding and mandates/targets, with only certain building owners being affected and progress made being at risk if strong government intervention were to be discontinued.	■ National/ province/ municipal	■ Design & implement
Voluntary building energy efficiency audit programs are unlikely to lead to considerable uptake in the market.	■ National ■ Province/ municipal	■ Design & implement ■ Implement
Overall, there are few incentives for building buyers to purchase more energy efficient houses and apartments; currently, incentives are mainly available for developers and investors.	■ National ■ Province/ municipal	■ Design & implement ■ Implement

Renewable Energy

DISABLING/LACKING POLICIES	GOVERNMENT LEVEL & RESPONSIBILITY	
Frequent changes, limited durations, insufficient funds ("oversubscribed"), and/or accelerated phaseouts for subsidy schemes for FITs for distributed renewable energy do not support the creation of a stable, predictable investment climate.	■ National ■ Province/ municipal	■ Design & implement ■ Implement
No green energy tariffs and no PPA options are available as off-site RE purchase options to building owners/ managers.	■ National ■ Province/ municipal	■ Design & implement ■ Implement
As RECs sold via the pilot GEC trading platform present a cost premium to buyers, with no incentives provided to offset the extra cost, the market currently remains mostly inactive.	■ National ■ Province/ municipal	■ Design & implement ■ Implement

B.2.4. Priority actions for better enabling the ZCB pathways

With enhanced policy, several of the ZCB pathways that are currently considered to be only somewhat facilitated by the current policy framework in China will become increasingly attainable and desirable, allowing China to become a global leader in building decarbonization.

A short list of priority policy actions is provided for city governments, followed by a similar list for national and provincial governments, that can facilitate progress in cities. The recommended actions acknowledge that decisive action at higher government levels is often a prerequisite to enable urban stakeholders to most effectively act on policies that can help enable the ZCB pathways.

Energy Efficiency—City Governments

POLICY PRIORITY ACTIONS	ROLE
With mandatory national codes or standards usually setting the baseline for energy performance, provincial and municipal governments should actively use the options when/where available to them to set more ambitious requirements based on their development needs, local resources, and climate zones.	■ Regulator
Local government can proactively take the lead by incentivizing above-code practices; currently, only a select number of Tier 1 cities do so.	■ Regulator
Interdepartmental collaboration should be enhanced and incorporate energy efficiency improvement goals with other environmental goals, such as air quality improvement, renewable energy purchase goals, and carbon emission reduction.	■ Regulator
Local governments should make use of the option to run pilot and demonstration projects for retrofitting, energy management systems, and building-integrated renewables.	■ Owner/ investor

Renewable Energy—City Governments

POLICY PRIORITY ACTIONS	ROLE
Facilitate the power market reform at the local level; coordinate the negotiation among stakeholders (state grid enterprises, dealers, renewable investors) so that renewable energy can be sold to building owners directly through PPAs	■ Regulator/ facilitator
Set a mandatory target for energy sourced from renewables for public buildings and large-scale industrial and commercial buildings, which can be fulfilled by buying RECs, PPAs, or investing in on-site renewables	■ Regulator
Establish a stable, predictable subsidy/tariff regime for net metering with FITs and for the encouragement of building-integrated renewables to encourage the uptake of on-site RE	■ Regulator

Energy Efficiency—National/Provincial Governments

POLICY PRIORITY ACTIONS	ROLE
Review and update the mandatory building energy codes/standards regularly to enable the uptake of new energy efficiency technologies by introducing a five-year code review cycle	■ Regulator
Develop national building challenge and training programs for different stakeholder groups, such as building developers, architects, and architecture students to increase awareness and uptake of building energy efficiency	■ Facilitator
Decouple savings on energy bills from energy improvements of public buildings and municipal budget allocations, as this leads to perverse incentives to keep energy bills high;[23] instead, properly incentivize reductions in energy bills for public buildings	■ Regulator
Local governments to proactively design communication and outreach programs to encourage learning and knowledge exchange among key stakeholder groups	■ Regulator

Renewable Energy—National/Provincial Governments

POLICY PRIORITY ACTIONS	ROLE
Work closely with stakeholders in the power market to design an implementable regulation that allows non-utility PPAs; current policy allows renewable energy providers only to sell electricity directly to consumers if given the approval of the local provincial grid company	■ Regulator
Incentivize building owners/managers to purchase RECs, with the market currently remaining fairly inactive due to the cost premium	■ Regulator

These actions will help enable pathways 1 and 5, which are not considered feasible under the current policy framework, and better facilitate pathways 2, 3, and 7, which are currently only somewhat feasible.

Section 5 of this paper provides a comparative overview of all four countries considered in this analysis. It shows the feasibility of each pathway under the current policies as well as under an enhanced policy framework if the priority actions were to be implemented. Importantly, it points to how targeted policy enhancement can put every ZCB pathway well within China's reach.

B.2.5. Current policies for facilitating ZCB pathways

ENERGY EFFICIENCY

The first building energy efficiency code introduced in China was the Design Standard for Energy Efficiency of Residential Buildings, adopted in 1986 (JGJ 26-1986) and updated in 1995 (JGJ 26-1995). It initially only covered the "severe cold" and "cold" climate zones of northern China, where heating demand is very high. This code was again updated in 2010 and was renamed the Design Standard for Energy Efficiency of Residential Buildings in Severe Cold and Cold Zones (JGJ 26-2010). It sets specifications for building envelope thermal performance (such as window/wall ratio, heat transfer coefficients, shading coefficient, airtight level, etc.) and HVAC system performance (boiler efficiency for central heating, heating pump electricity/heat ratio, and coefficient of performance for heaters, etc.). The 1986 version required a 30 percent reduction of heating energy consumption versus a baseline building, the 1995 version required a 50 percent reduction in heating energy consumption, and the 2010 version required a 65 percent reduction of heating energy consumption (Feng et al. 2017).

In 2001, MOHURD issued the Design Standard for Energy Efficiency of Residential Buildings in Hot Summer and Cold Winter Zone (JGJ 134-2001) and the Design Standard for Energy Efficiency of Residential Buildings in Hot Summer and Warm Winter Zone in 2003 (JGJ 75-2003). Both codes were updated, in 2010 and 2012, respectively. The current version for the hot summer/cold winter climate zone (JGJ 134-2010) requires a 50 percent reduction in heating and cooling energy consumption relative to a baseline building. For the hot summer/warm winter climate zone (JGJ 75-2012), a 50 percent energy efficiency improvement of the building envelope and HVAC system is required versus the baseline.

Building energy efficiency specifications for major building renovations have followed a similar path. The first technical specification (JGJ 29-2000) focused primarily on the energy efficiency for heating (i.e., boilers for central heating and indoor heating system) and building envelop energy performance. The updated version (JGJ 29-2010) covers other climate zones and requires a minimum 20 percent energy efficiency improvement after renovation (Bin and Jun 2012).

Over time, both national and local governments have issued a number of mainly financial incentives to facilitate policy uptake. In 2012, for instance, MOHURD and the Ministry of Finance (MOF) allocated subsidies based on floor area and region for retrofitting existing residential buildings in the hot summer/cold winter climate zone (MOHURD 2012a). In the same year, a subsidy was provided for any 2- or 3-star certified building under the China Green Building Label based on the total floor space and the energy efficient technologies applied (MOHURD 2012b). Many cities now require new construction to meet at least the 1-star requirements, and some cities also provide rebates for the application fees of the Three Star green building scheme. Besides national subsidies established by MOHURD and MOF, many provincial and local governments provide additional subsidies to encourage more ambitious action, such as Guangdong Province providing subsidies for the China Green Building Label (Guangdong PDHURD 2016).

Since 2007, MOHURD, in collaboration with the German government, has organized technical workshops and trainings to introduce the German passive house (*passivhaus*) concept, referring to ultra-low-energy buildings. After establishing passive house pilot projects in various provinces, especially in China's colder northern regions, and the issuance of the Passive Ultra-low Energy Building Technical Guideline for Residential Buildings in 2015 (MOHURD 2015), the 13th Five-Year-Plan introduced a goal to add 10 million m^2 of ultra-low-energy buildings during the 2016–20 period (MOHURD 2017b).

The 2015 technical guideline set the highest energy efficiency benchmark in the market, requiring a 90 percent improvement in energy efficiency compared to current building energy codes and an 85 percent improvement for heating. It does not, however, specify the use of on-site renewables or the purchase of off-site renewables. Built on the passive house technical guideline, MOHURD has released the Technical Standard for Nearly Zero Energy Building (draft), which will redefine the required energy performance for ultra-low-energy buildings (passive house standard), nearly zero energy and zero energy buildings, and will include renewable energy provision requirements.

Many local governments are supporting the national goal to promote ultra-low-energy and nearly zero energy buildings by issuing additional policies. Beijing, for example, issued the Action Plan for Promoting Ultra-Low Energy Building (2016–20), which committed financial incentives for 300,000 m^2 of certified ultra-low-energy buildings until 2018 (Beijing MHURDC 2016). Hebei Province, on the other hand, has committed to build 1 million m^2 of ultra-low-energy buildings by 2020 (Mo 2016).

ON-SITE RE GENERATION

The national Golden Sun Projects policy, initiated in 2009 to promote solar power generation, provided 50 percent of the up-front capital costs for regular PV projects and 70 percent for remote/off-grid PV projects (IEA/IRENA 2016). This generous subsidy stimulated the uptake of PV panels, although many applicants used loopholes to make unfair use of the policy (Urban and Geall 2014). Noticing the loophole, the policy was replaced by FITs in 2013 (Liang 2014). The net-metering subsidy and FITs are set at fixed prices, differing by regions, and are reevaluated annually according to the actual capital cost of PV systems. This has resulted in gradually lower rates per kWh being set for renewable electricity fed into the grid through FITs, although the reduced rates only apply to new generation capacity.

FITs are available at different rates for large-scale wind and solar projects; on-site PV systems, which upload all of their generated energy to the grid; and on-site PV systems up to 6 MW capacity that feed a maximum of 50 percent of their generated energy onto the grid. In addition, subsidies are available from the national government and some local governments for every kWh of generated on-site RE, including energy used on-site (Hall 2019).

China is the world's largest market for solar water heater systems, producing about 1 million systems annually (Urban et al. 2016), although rebates have now been phased out in most regions. Many of the rebates were driven by subnational governments where the RE industry provides important local economic benefits. For example, 99 percent of households in the city of Rizhao in Shandong Province have purchased solar hot water systems through a combination of local mandatory and incentive policies (C40 2011). Uptake of solar hot water systems has been higher in rural areas, where households often have more rooftop space available.

Furthermore, a special fund for building-integrated renewables was created in 2006 that covers solar energy, shallow geothermal energy, heat recovery technology, wind energy, and biomass (MOF 2006). Many provincial and municipal governments have been providing matching subsidies to achieve their five-year plan goals. A program was also put in place in 2015 to support solar systems in poor regions, attracting investors through long-term public-private partnerships and putting in place 20-year net-metering or FIT agreements, with the revenue from selling electricity to the grid shared between the households and investors (CPAD 2016).

OFF-SITE RE PURCHASE

Off-site renewables have been encouraged in a variety of ways, including the use of FITs for large-scale wind farms and solar power plants. Recently, China has been developing the Renewable Portfolio Standards, which require each province to achieve a certain percentage of renewables in its grid electricity generation mix (NEA 2018). Noncompliance is subject to penalties. If implemented, this may also help alleviate the frequent occurrence of wind and solar curtailment.

More of interest for building owners/managers is the GEC pilot program, which allows them to buy RECs directly from independent wind and solar energy providers (Miao et al. 2017). So far, the market is quite inactive, with the transaction volume representing less than 1 percent of total certificates available in the market since its commencement in July 2017 (CNREC n.d.). A key reason is likely that RECs present an additional cost for consumers; they continue to pay their normal electricity bills, but there are no mandates or financial incentives in place that encourage energy users to purchase RECs. The suppliers, on the other hand, no longer qualify for FITs once they sell their RE as credits, and they want to receive a price per kWh at least equal to or higher than the FIT.

Building owners/managers in China are currently unable to engage directly in a PPA or select a green energy tariff because China's state grid solely controls the power market. Discussions are taking place in China to reform the power market, charging transmission fees to RE suppliers who opt to feed their energy into the grid for sale to consumers via virtual PPAs (An et al. 2015).

CARBON OFFSETTING

In 2017 China launched a national carbon emission trading scheme after having piloted seven subnational trading systems since 2011, making it the world's largest carbon emission trading scheme (EDF and ERI 2017).[24] The first phase of China's scheme has seen 1,700 energy-producing enterprises participating, covering a total of 3 billion tons of CO_2 emissions. Even though only the power sector is included under the scheme, it is expecting to cover the petrochemical industry, building material manufacturing industry, chemical industry, paper industry, and other energy-intensive industries in the future (UNFCCC 2017). With the anticipated expansion of the scheme, parties covered under it are provided with direct access to a carbon credit market, and their coverage in the scheme will help push them in the direction of zero carbon.

The CCER program enables voluntary carbon emission reduction projects to sell their offsets. The CCER Trading Platform subsequently issues a Carbon Credits Exchange Certificate for any carbon credit transactions (CCER n.d.). Projects are validated by third parties to ensure accuracy, quality, and additionality (Qing 2018). Consumers can purchase these credits to offset emissions.

B.3. Mexico

B.3.1. Overview

In Mexico, (net) ZCBs are part of a nascent market. The country's first net zero energy building is under development in the city of Monterrey (Gerencia de Edificios 2015), and through the EcoCasa program for sustainable, affordable housing, a number of passive homes (EcoCasa Max) with ultra-low-energy use have been built in recent years. At the same time, green building is rapidly gaining ground. LEED, the green building rating and certification scheme, has over 200 certified and 500 registered projects in Mexico (USGBC 2016).

Building energy efficiency is slowly gaining ground with the introduction of a national building code in 2014, the International Energy Conservation Code–Mexico (IECC-Mexico), which, however, only becomes mandatory once adopted by and incorporated into local legislation by states and their municipalities. A variety of energy efficiency support programs and incentives targeting new or existing buildings have also been introduced by the national and subnational governments, some more successful than others. A good example is the green mortgage program of the National Workers' Housing Fund Institute (Instituto del Fondo Nacional de la Vivienda para los Trabajadores; INFONAVIT), which, as of 2012, accounts for 70 percent of all new mortgages and provides prospective homeowners with additional credit to implement water- and energy-saving measures (INFONAVIT 2012). Nonetheless, high electricity subsidies, particularly for residential consumers, reduce the economic case for both energy efficiency and the installation of on-site RE.

With the Mexican Energy Reform introduced in 2013, the electricity market has opened up to welcome a whole suite of new on- and off-site RE generation and purchase opportunities. These include a menu of net-metering options for on-site RE producers as well as the possibility to engage in PPAs, buy RECs, and purchase green grid electricity. At the same time, the requirement to become a qualified registered user to partake in some of these options and/or to have at least 1 MW of aggregated energy demand exclude the participation of households and other small energy consumers (SENER 2018).

Nonetheless, the positive policy developments in Mexico in recent years on both the energy efficiency and renewable energy fronts, combined with a large domestic market for the generation of carbon credits, puts **all eight ZCB pathways already more or less within reach of Mexican building owners/managers**. At the same time, the majority of the pathways under the current policy framework are mostly or only suitable for commercial and public buildings rather than residential ones. In addition, although the Mexican policy environment is increasingly favorable to ZCBs, the local market may still need to catch up to enable nonpolicy elements of various ZCB pathways.

B.3.2. Pathways at a glance

ZCB PATHWAYS ENABLED THROUGH THE CURRENT FRAMEWORK OF POLICIES AND PROGRAMS

Mexico's policy and program framework for basic and advanced EE, on- and off-site RE, and carbon offsetting makes a number of ZCB pathways already within reach today. The feasibility of each available ZCB pathway that the government may encourage building owners/managers to pursue is shown in Table B5.

Table B5 | **Indicative Overview of the Feasibility of Each Pathway in Mexico under the Current Policy and Program Framework**

PATHWAY		COMPONENT					MEXICO
		BASIC EE	ADVANCED EE	ON-SITE RE	OFF-SITE RE	CARBON OFFSETS	
Exemplary energy performance	1	◆	◆	◆		(if needed)	○
	2	◆	◆	◆	◆	(if needed)	○
	3	◆	◆		◆	(if needed)	○
	4	◆	◆			◆	○
Minimum energy efficiency	5	◆		◆		(if needed)	✓
	6	◆		◆	◆	(if needed)	✓
	7	◆			◆	(if needed)	✓
	8	◆				◆	✓

○ = the pathway is feasible under current policy but with limited application—either for specific segments of the building market and/or critical policy elements are insufficiently developed to make the pathway attractive.

✓ = the pathway is sufficiently facilitated through current policy.

Notes: [a] The minimum required level of energy efficiency (EE) achieved by complying with local codes and standards.
[b] More ambitious energy performance that goes beyond minimum regulatory requirements.
[c] Recommended only in cases where efficiency measures and renewable energy (RE) sources cannot meet 100 percent of energy demand.
Source: WRI.

For Mexico, all of the identified ZCB pathways are already within reach.[25] At the same time, the slow adoption of energy efficiency makes pathways pursuing exemplary energy performance less likely to see major uptake, and the current policies favor commercial buildings and public buildings, for which the government holds the reins.

For owners/managers of residential buildings, the majority of pathways will remain beyond reach unless dedicated policies—of which Mexico already has multiple good examples—are further tailored and refined to help faciliate this part of the market.

Table B6 provides a concise overview of the enabling or disabling policies for each ZCB component and indicates the most likely building types for which the component is considered feasible and the potential caveats for pursuing the component. Those pathway elements that are easiest to achieve under the current framework of policies and programs are not necessarily the most preferable ones, although Mexico is in a good position to gradually increase the feasibility of the more preferable pathways.

Table B6 | Overview of Most Feasible/Likely Zero Carbon Building Components to Pursue in Mexico under the Current Policy and Program Framework

COMPONENT	FEASIBILITY	DETAILS
Basic EE	Dependent on national building energy code being adopted by local state and municipality Most suitable for commercial buildings	■ Energy efficiency (EE) standards: NOM-ENER[a] for nonresidential ■ Building EE code: IECC-Mexico[b] for commercial and residential with fewer than three floors ■ Mexico City, Merida, Veracruz: local EE regulations ■ MEPS[c] for air conditioners
Advanced EE	Pursuing exemplary EE performance still not common Mainly suitable for commercial buildings: Advanced EE programs primarily focus on public and commercial buildings. Financial incentives are available in residential market for self-build affordable housing, but this pathway is not attractive for residential buildings due to high electricity subsidies.	■ Mexico City: energy audits for select public buildings; Sustainable Buildings Certification Program; Building Challenge Program (EE retrofit) ■ Energy performance rating system: public and commercial ■ Green mortgage program ■ EcoCasa program: financial incentives for EE in residential affordable housing ■ Lighting and appliance replacement programs
On-site RE	Mainly suitable for commercial buildings: Tax depreciation and net metering facilitate on-site renewable energy (RE) for businesses, but there are limited or no on-site RE incentives for residential buildings.	■ High electricity subsidies for residential discourage photovoltaic (PV) systems ■ Solar hot water: in Mexico City for hospitals and large commercial (30% of demand); PROCALSOL,[d] Nationally Appropriate Mitigation Actions ■ Merida: land tax reduction for households installing PV ■ Companies can depreciate 100% of cost of PV ■ Net metering and net billing for residential and commercial small producers ■ No feed-in tariffs
Off-site RE (purchase or generation)	Suitable for commercial buildings, which may have enough remaining energy demand (minimum 1 MW) to qualify for power purchase agreements (PPAs), green tariffs, and renewable energy credits (RECs). Residential homeowners cannot purchase off-site RE.	■ PPAs for qualified users with minimum 1 MW demand ■ Green tariffs for qualified users with no (public) or minimum 1 MW demand (commercial) ■ RECs for clean energy certificates that each represent 1 MW of RE
Carbon offsets	Commercial and residential building owners have options for purchasing locally generated carbon credits.	■ Voluntary carbon credit market present, selling carbon credits from local accredited projects

Notes:
[a] Mexican Official Standards (Normas Oficiales Mexicanas de Energía).
[b] International Energy Conservation Code–Mexico.
[c] Minimum energy performance standards.
[d] Promotion of Solar Water Heaters in Mexico (Promoción de Calentadores Solares de Agua en México).
Source: WRI.

B.3.3. The impact of policies on pathway feasibility

An analysis of Mexico's policy framework points to a number of core policies/programs responsible for enabling and disabling local players to pursue energy efficiency and renewable energy solutions, which together can lead one to a (net) zero or nearly (net) zero carbon building.[26]

Key current policies and programs that help **enable the feasibility of ZCB pathways** include the following. They are accompanied by the relevant government levels (national, state, and/or municipal) that are currently responsible for aspects of the policy as well as the type of responsibility they take on. In general, the listed actions relate to the government's role as regulator or as convener/facilitator in the market.

Energy Efficiency

ENABLING POLICIES	GOVERNMENT LEVEL & RESPONSIBILITY	
■ In 2014 Mexico introduced a building energy efficiency code, the IECC-Mexico, which sets requirements for commercial buildings and residential buildings with fewer than three floors.	■ National ■ State ■ Municipal	■ Design & issue ■ Adopt (& adapt) ■ Implement & enforce
■ A range of programs to support or facilitate energy efficiency have been introduced, in particular in Mexico City, focusing foremost on the public and commercial sectors.	■ National ■ Municipal	■ Design & implement ■ Design & implement
■ Mexico has had success with several programs tackling both affordable housing and energy efficiency, including INFONAVIT's green mortgage program and the EcoCasa program.	■ National	■ Design & implement

Renewable Energy

ENABLING POLICIES	GOVERNMENT LEVEL & RESPONSIBILITY	
■ Mexico's energy market reform in 2013 has opened up the market for nonutility RE options, including on-site PV systems with net metering, PPAs, green energy tariffs, and RECs.	■ National	■ Design & issue
■ Mexico City, in particular, is promoting or mandating (for part of demand) solar hot water systems for various building types, using incentives such as a reduction in property duties.	■ Municipal	■ Design & implement/ enforce
■ Net metering and multiple variations of it, such as net billing, are widely available for both residential and commercial building owners.	■ National ■ State	■ Design & implement ■ Facilitate
■ Companies are provided a 100 percent tax depreciation on the cost of installing on-site PV systems and other renewable energy equipment.	■ National	■ Design & issue

Key policies and programs—or the lack thereof—that (in part) **disable the feasibility of ZCB pathways** include the following. They are accompanied by the relevant government levels (national, state, and/or municipal) currently responsible for aspects of the policy and their specific responsibilities. In general, the listed actions relate to the government's role as regulator or as convener/facilitator in the market.

Energy Efficiency

DISABLING/LACKING POLICIES	GOVERNMENT LEVEL & RESPONSIBILITY	
■ The national IECC-Mexico building code only becomes mandatory once it has been incorporated in local legislation. In most local jurisdictions the code does not yet apply due to limited capacity and limited experience with energy efficiency.	■ National ■ State ■ Municipal	■ Design & issue ■ Adopt (& adapt) ■ Implement & enforce
■ Many of Mexico's market facilitation efforts to increase energy efficiency depend almost entirely on public and/or international funding, meaning progress made is at risk once funding runs out.	■ National/ state/ municipal	■ Design & implement
■ Some of these efforts have only been able to impact a very small portion of the market, an example being the Sustainable Buildings Certification Program, which saw 65 buildings or tenanted portions becoming certified between 2009 and late 2016.	■ National/ state/ municipal	■ Design & implement
■ High subsidies for household electricity fees reduce the economic case for both energy efficiency and on-site RE.	■ National ■ Utilities	■ Design & issue ■ Implement

Renewable Energy

DISABLING/LACKING POLICIES	GOVERNMENT LEVEL & RESPONSIBILITY	
■ High electricity subsidies for households make on-site PV systems only attractive for high-consuming, high-income households or for business, both of which pay higher electricity fees.	■ National ■ Utilities	■ Design & issue ■ Implement
■ There is a lack of incentives for households to install on-site PV systems.	■ National ■ State ■ Municipal	■ Design & implement
■ Commercial buildings are required to have at least 1 MW in energy demand (within the same economic group of interest) to engage in a PPA, register for a green energy tariff, or buy RECs.	■ National ■ State	■ Design & issue ■ Facilitate
■ In addition, PPAs and green energy tariffs are only available to qualified users, which can be public or commercial parties. Households cannot register for green energy tariffs.	■ National ■ State	■ Design & issue ■ Facilitate & lead by example

B.3.4. Priority actions for better enabling the ZCB pathways

With enhanced policy, several of the ZCB pathways that are currently considered to be only somewhat facilitated by the current policy framework in Mexico will become increasingly attainable and desirable, putting Mexico in a good place to become a leader in Latin America on ZCBs.

A short list of priority policy actions is provided for city governments, followed by a similar list for national and state governments, that can facilitate progress in cities. The recommended actions acknowledge that decisive action at higher government levels is often a prerequisite to enable urban stakeholders to most effectively act on policies that can help enable the ZCB pathways.

Energy Efficiency—City Governments

POLICY PRIORITY ACTIONS	ROLE
■ Large and major cities to incorporate the IECC-Mexico into their local regulations, thereby making the code mandatory for new buildings	■ Regulator
■ Cities to introduce (nonfinancial) incentives, an example being to give developers extra FAR for buildings that can prove exemplary energy performance in excess of IECC-Mexico	■ Regulator
■ Cities to develop communication and outreach materials that help educate the market on how to achieve compliance with IECC-Mexico in light of low compliance rates as exemplified by a 2016 sample from Mexico City	■ Convener/ facilitator
■ Cities to introduce challenge programs (for example, Mexico City) that encourage building owners/managers to meet or exceed an energy reduction goal	■ Convener/ facilitator
■ Cities to lead by example by requiring new public buildings and major retrofits of public buildings to comply with at least the IECC-Mexico, if not yet mandatory locally, and preferably beyond	■ Owner/ investor

Renewable Energy—City Governments

POLICY PRIORITY ACTIONS	ROLE
■ Large and major cities to introduce incentives for households to install rooftop renewables (PV, solar hot water)	■ Regulator/ partner
■ Cities to lead by example by requiring new public buildings and major retrofits of public buildings to install rooftop renewables where feasible	■ Owner/ investor
■ Cities to aggregate energy demand from (existing) public buildings in order to engage in off-site RE purchase (PPA or RECs)	■ Owner/ investor

Energy Efficiency—National/State Governments

POLICY PRIORITY ACTIONS	ROLE
■ National and state governments to further advance their (already existing) support to cities for incorporating IECC-Mexico into local regulations and how to subsequently enforce it	■ Regulator
■ States to rapidly adopt (and, if necessary, adapt) the IECC-Mexico, if they have not done so yet	■ Regulator
■ National government to reconsider electricity subsidies for specific groups to increase the attractiveness of energy efficiency (or on-site RE) measures, ensuring that the increase in energy bills can be mitigated by a drop in energy use through affordable and readily available energy efficiency measures and/or accompanying this with measures that protect the affordability of electricity for low-income households	■ Regulator
■ National government to increase the energy efficiency requirements under successful programs, such as INFONAVIT's green mortgage	■ Regulator
■ National and state governments to further build on existing or expired efforts (for example, EcoCasa) to help educate and support the market on energy efficiency	■ Convener/ facilitator
■ National and state government to lead by example by requiring new public buildings and major retrofits of public buildings to comply with a suitable (green building) rating and certification system, such as LEED or the recently introduced E4 Energy Performance Rating System	■ Owner/ investor

Renewable Energy—National/State Governments

POLICY PRIORITY ACTIONS	ROLE
■ National/subnational government to introduce incentives for households to install rooftop renewables (PV panels, solar hot water)	■ Regulator
■ National government to consider introducing a green energy tariff for households, with a minimal markup to increase its attractiveness	■ Regulator
■ National government to consider relaxing the rules around qualified users, allowing a group of buildings (in a district) with at least 1 MW in energy demand to register and thus be able to jointly engage in a PPA	■ Convener/ facilitator

These actions will help enable pathways 1, 2, 3, and 4, considered only somewhat feasible under the current policies.

Section 5 of this paper provides a comparative overview of all four countries considered in this analysis. It shows the feasibility of each pathway under the current policies as well as under an enhanced policy framework if the priority actions were to be implemented. Importantly, it points to how targeted policy enhancement can put every ZCB pathway well within Mexico's reach.

B.3.5. Current policies for facilitating ZCB pathways

ENERGY EFFICIENCY

The federal government of Mexico has established a range of voluntary and mandatory energy efficiency standards for buildings and their components. In 1995 it introduced the Mexican Official Standards (Normas Oficiales Mexicanas de Energia, or NOM-ENER), intended to be updated every five years and applicable to nonresidential, new buildings, and major renovations. Before the introduction of a national building code in 2014, it acted as the country's only official standards on building energy efficiency and was mandatory only if included in local state and municipal regulations, which only a few states and municipalities did (IPEEC 2015).

In 2014, however, Mexico launched the IECC-Mexico. The building energy efficiency code applies to new commercial buildings as well as residential buildings with fewer than three floors, and it acts as a model for local authorities. The code allows for the use of prescriptive and performance-based approaches, identifying six climate zones and introducing requirements in line with NOM-ENER (ICC 2016).

Limited resources and capabilities mean that, similar to the NOM-ENER, only a limited number of local governments, including Mexico City, have so far adopted the IECC-Mexico, thereby making the code mandatory and the governments responsible for its enforcement. The national government aims for a mandatory code for all buildings by 2030, with the transition from voluntary to mandatory pending its adoption by state and local legislations. In general, however, enforcement of building codes and regulations is very weak. Of a 2016 sample of buildings in Mexico City, for instance, 71 percent failed to meet compliance thresholds.

Nonetheless, several cities, including Mexico City, Merida, and Veracruz, are actively introducing (stricter) building energy efficiency requirements. Also, the energy consumption of existing buildings receives attention through various lighting replacement programs and others run by the federal government. In Mexico City, existing buildings have been the target of multiple programs, including energy audits for selected public buildings, mainly hospitals; the Sustainable Buildings Certification Program, which has seen limited uptake; and the soon-to-be launched Building Challenge program, which encourages public/private building owners or managers of existing buildings to commit to retrofitting projects that will save at least 10 percent in energy demand (C40 2017).

An energy performance rating system, E4, is also being created by the national government for public and commercial buildings (AES 2017). The high level of dependence on public funding, the low awareness of energy efficiency, and the limited energy service company (ESCO) market capacity,[27] however, hinder growth in the existing building segment of the market (Sustainia 2018).

Limited financial incentives are available to stimulate interest in the new building market beyond residential buildings. Since 2007, Mexico has pioneered two innovative affordable housing programs. Of these, INFONAVIT's green mortgage program, Hipoteca Verde, is well-known. It now accounts for 70 percent of all mortgages in the country. It gives families an additional credit on top of the actual mortgage to cover the cost of several green measures, which is paid back through the savings on their bills (INFONAVIT 2012).

In addition, the EcoCasa program launched in 2013 in collaboration with international partners. It provides housing developers with attractive loans if they offer affordable homes with a design that results in at least 20 percent or 40 percent carbon emission reductions (EcoCasa 1 and 2, respectively) compared to a determined baseline while trialing passive homes[28] (EcoCasa Max) as well (Rebolledo 2015).

Nonetheless, as a result of high subsidies for household grid electricity fees—with residential rates covering only 43 percent of actual cost in 2011—energy efficiency does not always make economic sense. For instance, a recent energy efficiency pilot for new affordable housing units in León, a hot and dry area, led to 26 percent lower energy consumption. However, due to the subsidized electricity rates, the cost savings on a household's energy bill were too low to compensate for the very modest additional cost of the measures (Davis et al. 2018). Mexico is considering phasing out residential electricity subsidies by 2035.

Role of cities: *Cities can adopt the national building code to make its requirements locally mandatory, enforce the code, and offer incentives and support to the public and private market for incorporating energy efficiency measures in existing and new buildings.*

ON-SITE RE GENERATION

With private sector commercial and industrial building owners paying higher electricity rates than residential ones, they have a greater incentive to look for alternatives to grid electricity, such as by installing on-site RE capacity. Companies can depreciate in a single year 100 percent of the cost of PV panels and other RE equipment that will operate for at least five years from their tax return, resulting in about a 30 percent reduction on the capital cost (Climatescope 2017c).

For residential customers, the city of Merida offers a financial incentive for installing PV panels through a reduction in the land right tax. The incentive, however, has not seen much uptake due to the heavily subsidized grid electricity fees, in combination with the way the incentive was designed, a general lack of awareness, and an inability to finance the panels with bank interest rates as high as 16 percent for a loan (Schierenbeck 2014). More support is available for those interested in installing solar hot water heaters. In particular, Mexico City supports or requires solar hot water systems for a range of new and existing buildings.

In 2013 Mexico also introduced net metering at the time of its Mexican energy market reform. Net metering is available for residential users with systems less than 10 kW capacity and for commercial users with systems less than 30 kW capacity, with credits accruing in the following month's bill. Any surplus energy fed into the grid, beyond what the user needs on an annual basis, is paid out after one year at a price equal to the variable cost of generating energy, which, in most parts of Mexico, is not very attractive cost wise.

Several additional options were introduced in 2013, including a net billing system under which all energy purchased from the grid is charged at the regular price. A third option concerns the total sale of on-site RE generation, whereby all energy generated is sold to the grid at a price reflecting the local marginal cost of generation. The fourth option of isolated supply and local generation allows for local RE generation and distribution within a private local "grid," without being connected to the public grid. As a result, the producer does not have to pay transmission and distribution charges (SENER 2018).

Role of cities: *Cities can provide incentives, regulations, and support to facilitate or mandate the uptake of on-site RE for certain building types, both for rooftop PV panels and solar hot water systems.*

OFF-SITE RE PURCHASE

As a result of the Mexican Energy Reform introduced in 2013, the options for off-site RE generation and purchase have greatly increased. With the introduction of the remote generation option, for instance, qualified registered users can now engage in PPAs for the supply of remotely generated RE. There are no minimum requirements for public sector users to become qualified. Private sector users, however, must have a minimum of 1 MW aggregated energy demand within the same economic group of interest as a threshold. It is allowed to have multiple registries of at least 1 MW each. Households cannot become qualified users (SENER 2018).

Only qualified users can purchase green power, which puts this option out of reach of households. Green energy contracts are entered into through bilateral negotiation with a qualified supplier, which can be a utility or another provider with energy generation contracts within an area.

In 2013 clean energy certificates (certificados de energia limpia; CELs) were introduced as well. CELs act like RECs and represent 1 megawatt-hour (MWh) of renewable energy. The CEL price fluctuates pending supply and demand, with certain high-energy consumers obligated to purchase a certain percentage of CELs. Mandatory or voluntary CEL buyers are not provided with financial incentives such as tax breaks to soften the cost premium. The bidding price of CELs has dropped more than 50 percent, however, since their introduction. To purchase CELs voluntarily, a party first has to register as a "voluntary entity." Furthermore, it is not possible to buy a part of a CEL, or less than 1 MWh (CRE 2016).

Role of cities: *Cities can educate public and private sector actors on the opportunities for off-site RE purchase and generation.*

OFF-SITE RE GENERATION

Mexico's self-supply scheme has been allowing parties to either purchase or commission the generation of off-site RE by using the electricity grid. The purchaser of the RE has to hold a share in the generation assets. The cost for using the grid is subsidized for self-supply, with the transmission charge being independent of the actual distance between generation and consumption assets. Due to lower generation costs, the supply scheme is dominated by wind power plants (Schierenbeck 2014). After 2019, however, the scheme will be discontinued and is currently limited to the amount of permits issued before the energy reform.

Role of cities: *Not applicable.*

CARBON OFFSETTING

Mexico is an active participant in the CDM for generating carbon credits and hosts hundreds of CDM projects. A number of carbon offset projects have also been implemented under voluntary carbon offset schemes.[29] Organizations such as Plan Vivo, the Verified Carbon Standard, the Gold Standard, and the Climate Action Reserve all have registered and issued voluntary carbon offsets to projects in Mexico implemented under each program's respective standards (Climate Action Reserve 2015).

In addition, local programs exist for consumers and companies to offset their carbon footprint. A major one is the Neutralizate program by ProNatura, which was created in 2008. It supports Mexican indigenous communities to develop forestry projects that sell certified offsets in the voluntary carbon market (Climate Action Reserve 2017).

Role of cities: *Cities can educate stakeholders on the options for offsetting their carbon footprint through the voluntary carbon offset market, thereby fueling greater demand and awareness, although ensuring that they first consider energy efficiency and renewable energy options and that they thoroughly consider the quality of these credits in their analysis of suitable options.*

B.4. Kenya

B.4.1. Overview

In Kenya, green buildings are a nascent segment of the market, although organizations such as the Kenya Green Building Society (KGBS) are actively trying to accelerate their uptake. No dedicated (net) ZCBs have been built to date, but multiple green building certification schemes have been introduced. Several advanced buildings throughout the nation, including in the capital city, Nairobi, now incorporate a range of green features. Examples include the regional United Nations Environment Programme and UN headquarters, the regional Coca-Cola headquarters, Strathmore University, and the Learning Resource Center of the Catholic University of East Africa.[30]

Building energy efficiency is an emerging topic, supported by Kenya's revised building code for new buildings (2016)[31] as well its Energy Management Regulations for high-consuming existing buildings. At the same time, 70 percent of Kenya's installed electricity capacity is already supplied by renewable energy sources, mainly hydro- and geothermal power and, to a lesser extent, solar and wind power. Additional regulations (Energy Regulatory Commission 2012) also require many (new and existing) buildings to install solar water heating systems, although the noncompliance penalty for existing buildings was annulled in summer 2018, likely undermining its effectiveness. Furthermore, the country focuses on rapid expansion of grid connectivity for those already living near existing grid infrastructure (World Bank 2015a).

Nonetheless, many households are not yet connected to the grid, with Kenya witnessing major growth in recent years in the off-grid solar market, facilitated by pay-as-you-go payment models and financial transfer systems like mobile phone-based M-Pesa (Power Africa 2016). There is also quite a push for cleaner cookstoves, with close to 70 percent of the population relying on biomass or fossil fuels such as kerosene for their cooking needs (Hivos 2012).

Together, this could mean that a large number of Kenya's poorer households currently can be considered to live in zero or nearly zero carbon homes through on-site solar or green grid electricity—albeit not always reliable or available around the clock—in combination with clean cookstoves. This household energy consumption may increase in the future as poorer households become less poor over time. For grid-connected buildings, particularly commercial ones, the combination of energy efficiency and the installation of solar hot water systems with an increasingly green grid puts a number of **zero carbon building pathways within close reach**. At the same time, although the Kenyan policy environment is increasingly favorable to ZCBs, the local market may still need to catch up to enable nonpolicy elements of various ZCB pathways.

B.4.2. Pathways at a glance

ZCB PATHWAYS ENABLED THROUGH CURRENT FRAMEWORK OF POLICIES AND PROGRAMS

Kenya's policy and program framework for basic and advanced EE, on- and off-site RE, and carbon offsetting makes a number of ZCB pathways already within reach today. The feasibility of each available ZCB pathway that the government may encourage building owners/managers to pursue is shown in Table B7.

For Kenya, several of the identified ZCB pathways are already within reach.[32] At the same time, the very limited experience with energy efficiency will only see limited uptake of those pathways pursuing exemplary energy performance. In addition, the current absence of net metering—although a net-metering scheme has been proposed—makes installing on-site RE to meet 100 percent of demand most attractive for off-grid buildings.

Together with the lack of options for purchasing off-site RE, the feasibility of multiple pathways is hampered by the limited policy framework that enables grid-connected consumers to tap into RE options. Although Kenya's grid is already majority powered by RE, building owners/managers may require carbon offsetting to make up for the shortfall in reducing operational emissions by 100 percent.

The result of this is reflected in Table B8, which shows that only a few pathway components are relatively easy to pursue. It provides a concise overview of the enabling or disabling policies for each ZCB component and indicates the most likely building types for which the component is considered feasible as well as potential caveats for pursuing the component.

Table B7 | Indicative Overview of the Feasibility of Each Pathway in Kenya under the Current Policy and Program Framework

PATHWAY		COMPONENT					KENYA
		BASIC EE	ADVANCED EE	ON-SITE RE	OFF-SITE RE	CARBON OFFSETS	
Exemplary energy performance	1	◆	◆	◆		(if needed)	X
	2	◆	◆	◆	◆	(if needed)	O
	3	◆	◆		◆	(if needed)	X
	4	◆	◆			◆	O
Minimum energy efficiency	5	◆		◆		(if needed)	O
	6	◆		◆	◆	(if needed)	O
	7	◆			◆	(if needed)	X
	8	◆				◆	✓

X = pathway is not sufficiently supported by the current policy framework.

O = the pathway is feasible under current policy but with limited application—either for specific segments of the building market and/or critical policy elements are insufficiently developed to make the pathway attractive.

✓ = the pathway is sufficiently facilitated through current policy.

Notes: [a] The minimum required level of energy efficiency (EE) achieved by complying with local codes and standards.
[b] More ambitious energy performance that goes beyond minimum regulatory requirements.
[c] Recommended only in cases where efficiency measures and renewable energy (RE) sources cannot meet 100 percent of energy demand.
Source: WRI.

Table B8 | Overview of Most Feasible/Likely Zero Carbon Building Components to Pursue in Kenya under the Current Policy and Program Framework

COMPONENT	FEASIBILITY	DETAILS
Basic EE	Basic energy efficiency (EE) is feasible if enforced.	■ Building EE code: new buildings ■ Energy Management Regulations: existing buildings with more than 180,000 kWh annually ■ MEPS[a] for air conditioners (emerging)
Advanced EE	Only front-runners are likely to use advanced EE due to limited market experience with EE and a lack of EE incentives.	■ No government incentives ■ Green building rating and certification schemes ■ KGBS[b] training and support ■ EE finance
On-site RE	100% on-site renewable energy (RE) is most attractive for off-grid buildings due to current lack of net-metering policy (though it is in the pipeline). New residential buildings require on-site solar hot water.	■ Building code: solar hot water for residential; all to consider photovoltaic/wind power ■ Solar water heating regulations for existing buildings with more than 100 L/day ■ Net metering coming (62% credit for every 1 MWh) ■ Off-grid pay-as-you-go solar market ■ Clean cookstove tax breaks
Off-site RE (purchase or generation)	Policies do not sufficiently facilitate this component. The exception is that in some regions, 100% of local grid RE is already supplied through RE, though this may be difficult to verify.	■ No green energy tariffs, but grid electricity 70% RE ■ No power purchase agreement option ■ No renewable energy credits ■ Off-site generation maybe possible
Carbon offsets	Building owners have options for purchasing locally generated carbon credits.	■ Voluntary carbon credit market present, selling carbon credits from local accredited projects

Notes:
[a] Minimum energy performance standards.
[b] Kenya Green Building Society.
Source: WRI.

B.4.3. The impact of policies on pathway feasibility

Kenya's policy framework points to a number of core policies responsible for enabling and disabling local players to pursue energy efficiency and renewable energy solutions, which together can lead one to a (net) zero or nearly (net) zero carbon building.[33]

Key current policies and programs that help **enable the feasibility of ZCB pathways** include the following. They are accompanied by the relevant government levels (national, state, and/or municipal) that are currently responsible for aspects of the policy as well as the type of responsibility they take on. In general, the listed actions relate to the government's role as regulator as well as market facilitator. In Kenya, we even see the opposite situation, whereby a private sector initiative helps educate and train the public sector.

Energy Efficiency

ENABLING POLICIES	GOVERNMENT LEVEL & RESPONSIBILITY	
■ A new building code was adopted in 2016, replacing the previous 1968 code and incorporating various energy efficiency measures or considerations.[34]	■ National ■ Counties	■ Design & issue ■ Implement & enforce
■ The KGBS actively promotes the principles and benefits of green buildings to both private and public sector actors.	■ Private sector	■ Implement

Renewable Energy

DISABLING/LACKING POLICIES	GOVERNMENT LEVEL & RESPONSIBILITY	
■ Kenya's grid is already over 70 percent supplied by renewable energy sources, and the government is intent on further increasing the volume of renewable energy generation.	■ National ■ Counties	■ Design & implement ■ Implement
■ An active enabling environment is allowing many off-grid households to use solar systems for their energy needs.	■ National	■ Design & implement
■ Government is actively expanding access to grid electricity for those living near existing grid infrastructure.	■ National	■ Design & implement
■ The new building code of 2016 and the solar water heating regulations of 2012 require certain (new) buildings to install solar hot water systems.	■ National	■ Design & enforce

Key policies and programs—or the lack thereof—that (in part) **disable the feasibility of ZCB pathways** include the following. They are accompanied by the relevant government levels (national, state, and/or municipal) currently responsible for aspects of the policy and their specific responsibilities. In general, the listed actions relate to a government's role as regulator, as market convener/facilitator, and as owner/investor of public building stock.

Energy Efficiency

DISABLING/LACKING POLICIES	GOVERNMENT LEVEL & RESPONSIBILITY	
■ Kenya's 47 counties are responsible for building code enforcement. Considering their limited exposure to energy efficiency, this may prove challenging.	■ National ■ Counties	■ Design & issue ■ Implement & enforce
■ No incentives or facilitating policies are in place to support building energy efficiency.	■ National ■ Counties	■ Design & implement ■ Design & implement
■ There is an absence of programs that show government leading by example on energy efficiency for their public building stock.	■ National ■ Counties	■ Design & implement ■ Design & implement

Renewable Energy

DISABLING/LACKING POLICIES	GOVERNMENT LEVEL & RESPONSIBILITY	
■ Limited incentives or facilitating policies are in place to support on-site RE beyond the off-grid market.	■ National ■ Counties	■ Design & implement ■ Design & implement
■ No net-metering policy is currently in place. A proposed policy would see on-site RE producers receive a 62 percent credit for every 1 MWh exported to the grid.	■ National ■ Utilities	■ Design & issue ■ Implement
■ No green energy tariffs, limited PPA options, and no RECs are available as off-site RE purchase options. This makes meeting a building's energy demand by 100 percent off-site RE only possible in regions where 100 percent of local grid electricity is already supplied through renewable energy; the latter may be difficult to verify.	■ National	■ Design & issue
■ The penalty for noncompliance with the solar water heating regulations of 2012 was publicly annulled in summer 2018 for existing buildings, after providing them with a five-year grace period for installation, making high uptake among existing buildings quite unlikely.	■ National	■ Design & enforce

B.4.4. Priority actions for better enabling the ZCB pathways

With enhanced policy, Kenya can become an emerging leader not only in the off-grid solar market but also in the grid-connected building energy market in Africa. This is due to the country's strong position in both the off-grid solar energy market and the off-site RE market. Although some of the ZCB pathways are currently already somewhat in reach as a result of the current policy framework, implementing the priority actions will make these pathways increasingly attainable and desirable.

A short list of priority policy actions is provided for city governments, followed by a similar list for national and state governments, that can facilitate progress in cities. The recommended actions acknowledge that decisive action at higher government levels is often a prerequisite to enable urban stakeholders to most effectively act on policies that can help enable the ZCB pathways.

Energy Efficiency—County Governments

POLICY PRIORITY ACTIONS	ROLE
■ Urban counties to tie compliance with the new code to building approval forms and processes, thereby facilitating its mandatory character	■ Regulator
■ Urban counties to introduce (nonfinancial) incentives, an example being to give developers extra FAR for buildings that can prove exemplary energy performance in excess of the new building code	■ Regulator
■ Urban counties to lead by example by requiring new public buildings and major retrofits of public buildings to comply with at least the minimum level of a suitable green building rating and certification system, such as KGBS's ratified Green Star, the Green Africa Building Standards and Certification, LEED by the U.S. Green Building Council (USGBC), or the Excellence in Design for Greater Efficiency (EDGE) by the International Finance Corporation (IFC)	■ Owner/ investor

Renewable Energy—County Governments

POLICY PRIORITY ACTIONS	ROLE
■ Urban counties to introduce incentives for rooftop renewables (PV panels, solar hot water systems), building on the successful examples of the off-grid solar market	■ Regulator
■ Urban counties to lead by example by requiring new public buildings and major retrofits of public buildings to install rooftop renewables where feasible	■ Owner/ investor

Energy Efficiency—National Government

POLICY PRIORITY ACTIONS	ROLE
■ National government to provide support and training to counties (for instance, in collaboration with the KGBS) on energy efficiency and how to implement and help enforce the new building code	■ Convener/ facilitator
■ National governments to develop communication and outreach materials (potentially in collaboration with the KGBS) that counties can use to educate the market on energy efficiency and how to achieve compliance with the new building code	■ Convener/ facilitator
■ National government to lead by example by requiring new public buildings and major retrofits of public buildings to comply with at least the minimum level of a suitable green building rating and certification system, such as KGBS's Green Star or the Green Africa Building Standards and Certification	■ Owner/ investor

Renewable Energy—National Government

POLICY PRIORITY ACTIONS	ROLE
■ National government to reconsider the proposed net-metering policy to ensure that the proposed net-metering credit is aligned with its goals	■ Regulator
■ National government to consider opening up the current PPA route between independent power producers (IPP) and the national grid to nongrid energy purchasers interested in purchasing directly from IPPs, such as building owners/managers with a large energy demand	■ Regulator
■ National government to lead by example by requiring new public buildings and major retrofits of public buildings to install rooftop renewables where feasible	■ Owner/ investor

These actions will support the feasibility of pathways 1, 3, and 7, which are not considered feasible under the current policy framework. It will also help better facilitate pathways 5 and 6, which are currently only somewhat feasible.

Section 5 of this paper provides a comparative overview of all four countries considered in this analysis. It shows the feasibility of each pathway under the current policies as well as under an enhanced policy framework if the priority actions were to be implemented. Importantly, it points to how targeted policy enhancements can put many ZCB pathways well within Kenya's reach.

B.4.5. Current policies for facilitating ZCB pathways

ENERGY EFFICIENCY

In 2009 Kenya started a review of its building code, which was still based on British standards introduced in 1968. The new 2016 mandatory building code, based in part on the Eurocode,[35] incorporates energy efficiency through a number of passive and active design measures or considerations (NPBA 2009). The new building code also introduces penalties for noncompliance; however, policy enforcement is seen as a challenge and is regularly lacking at both national and local government levels (Were et al. 2015). Kenya has 47 counties that have to adopt, adapt, and enforce the code, but many of them have had limited exposure to green building and building energy efficiency, and they may grapple with limited capacity.

Preceding the adoption of the new code, the Energy Management Regulations were introduced in 2012, requiring certain commercial, industrial, and institutional buildings with high energy consumption to develop an energy management plan. These facilities have to undertake an energy audit at least every three years, prepare an energy investment plan, submit annual implementation papers, and prove that at least 50 percent of the identified and recommended savings are being realized. These regulations are also expected to provide government with valuable data on energy consumption for benchmarking purposes (Climatescope 2017a). However, enforcement of the regulations thus far has been limited.

At the same time, no financial or nonfinancial incentives are in place to encourage more energy efficient buildings. Building owner/manager action beyond the current regulations, if enforced, is mainly fueled by the efforts of nonprofit or private organizations and initiatives, such as by the KGBS. The KGBS has been licensed to use the (originally Australian) Green Star building certification scheme;[36] supports the IFC in promoting its green building rating tool, EDGE; and also offers USGBC's LEED scheme. Besides supporting and educating professionals in the private sector, the KGBS also trains government officials from a number of Kenyan counties, including Nairobi City County, and works alongside several development finance institutions and the Kenya Green Bond program to unlock foreign and local currency green finance for buildings targeting green certification.[37]

In 2016 another green building certification scheme, the Green Africa Building Standards and Certification, was introduced in Kenya by the Green Africa Foundation (Wahinya 2016). Across all of these schemes, including LEED,[38] around 24 green buildings have been registered in Kenya so far, although not all have pursued actual certification (IFC 2017).

Together, these measures provide a good start to make Kenya's building stock more energy efficient, although capacity building at private and public level, proper enforcement by local counties, and a sufficiently attractive enabling environment that facilitates and encourages action will help determine to what extent Kenya will see real uptake of building energy efficiency in the near future.

Role of cities*: Cities can encourage local counties to enforce existing EE regulations; support local green building schemes, for instance, by setting an example through publicly owned building stock and/or by incentivizing certification under these schemes; and introduce (nonfinancial) incentives for developers to incorporate energy efficiency.*

ON-SITE RE GENERATION

The new building code, introduced in 2016, requires new housing developments to have solar hot water for bathroom use and promotes the use of on-site PV systems and wind power. Solar water heating regulations introduced in 2012 make it mandatory also for existing buildings with hot water requirements exceeding 100 liters per day to install and use solar water heaters. Nonetheless, in summer 2018 the penalty for noncompliance was publicly annulled because it was considered to threaten the affordability of low-income housing, making enforcement officers powerless to ensure implementation of the regulations (Karume 2018).

Net metering is currently being considered for on-site RE systems of 1 MW or less, although owners of such systems would only receive a 62 percent credit for every 1 MWh exported to the local grid (Climatescope 2018). FITs, on the other hand, are already in place for utility-, commercial-, and industrial-scale generation of renewable energy, with rates set for a 20-year period for producers. For systems with a capacity over 10 MW, this may be replaced with an auction system. A backlog of FIT applications, however, results in few projects actually moving forward. In addition, most building owners are unlikely to generate renewable energy at a sufficient scale to qualify (Climatescope 2017b).

For off-grid areas, 15–20 percent of Kenyan households already use solar systems, and other energy-access solutions are taking off, including green minigrids, biodigesters, and microhydropower systems. This leads to reduced consumption and expenditure on kerosene and diesel for many off-grid households. One of the success factors has been privatization of the energy market, attracting investment into decentralized renewables and fueling both innovation and competition. The government has also exempted several of these off-grid products from taxes and tariffs, while having no kerosene or diesel subsidies that can negatively impact the financial attractiveness of cleaner alternatives (SEforAll 2017).

Besides a lack of grid electricity, 70 percent of Kenyan households lack clean fuel options for cooking. Kenya now has one of the highest availabilities of improved cookstoves in the region, with local production and a healthy market in both urban and peri-urban areas (Hivos 2012). In 2016 the national government removed a 16 percent value-added tax on liquefied petroleum gas, which hindered the uptake of cleaner cooking fuels and stoves, while it simultaneously announced an increase in the cost of kerosene. It also lowered import duties on energy efficient cookstoves, although the latter does not benefit the affordability of the many clean cookstoves being manufactured locally (Clean Cooking Alliance 2016).

Role of cities*: Cities can enforce solar hot water regulations, facilitate local expansion of on-site RE generation, and facilitate and incentivize off-grid clean energy solutions.*

OFF-SITE RE PURCHASE

Kenya's energy generation and distribution planning is undertaken on the basis of a 20-year rolling Least Cost Power Development Plan. The new Energy Bill, written in 2017 and signed into law in March 2019, aims to liberalize both power distribution and retail; therefore, it is expected to provide enhanced opportunities for renewable energy producers.

Currently, Kenya has about 10 licensed IPPs, which have PPAs in place to supply energy to Kenya's grid. With consumers not having a choice of third-party suppliers via PPAs, the current situation does little to encourage renewable energy choice for building owners.

Nonetheless, in 2015 already 70 percent of grid electricity was being supplied by renewable energy sources, with this amount still expected to increase; this was due to an increase in geothermal energy, followed by hydropower (currently the dominant source) and wind power. This means that even without active options for renewable energy purchases, such as by choosing a green energy tariff or by engaging in a PPA with an independent producer, grid-connected building owners may already have most of their energy being supplied by renewable energy.

With a low official electrification rate of around 36 percent in 2014, Kenya is also actively expanding access to safe and legal grid electricity through its Last Mile Connectivity Project. This initiative particularly targets "under grid" connections for households that already live "under the grid" or basically near existing grid infrastructure (World Bank 2015a).

Role of cities*: Cities can support local expansion of renewable energy generation and Last Mile Connectivity efforts.*

CARBON OFFSETTING

Kenya has a variety of carbon reduction projects available through the CDM and the Reduced Emissions from Deforestation and Forest Degradation (REDD) scheme, and companies can buy carbon credits through official channels.[39] Kenya Airways, for instance, has a voluntary carbon offsetting scheme for travelers that has been investing in a REDD project protecting dryland forests in southeastern Kenya (Wildlife Works 2013).

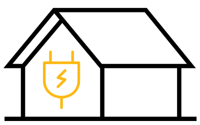
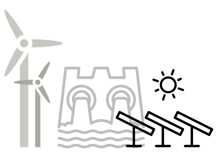
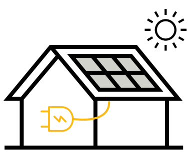
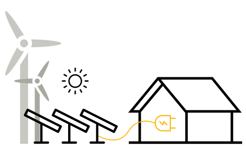
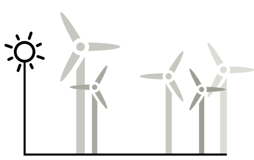
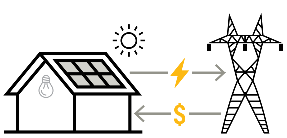
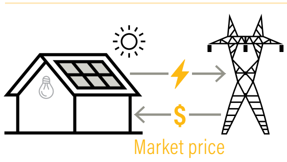
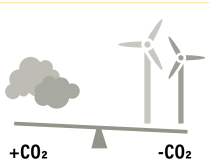
Carbon offsetting of operational energy or embodied (construction-related) carbon emissions is therefore a viable option, particularly for commercial or public sector building owners, and it can be used to support projects and reduce emissions within Kenya.

Role of cities*: Cities can facilitate and support local carbon reduction projects that generate carbon credits and lead by example by offsetting public sector emissions, although ensuring that they first consider energy efficiency and renewable energy options and thoroughly consider the quality of these credits in their analysis of suitable options.*

APPENDIX C. DEFINITIONS AND CONCEPTS

In this appendix, Table C1 provides short definitions[40] of a number of commonly used terms throughout the paper. It is followed by Table C2, which presents a concise overview of a number of different energy and carbon-neutral building concepts that readers may come across in literature or in discussions of the topic. It provides definitions (similar to those provided in Section 1.2) complemented by a short summary of the key principles of each concept as well as their boundaries and delineations.

Table C1 | Relevant Definitions

	Building energy use	Energy consumed at the building site as measured at the site boundary. Note: At a minimum, this includes heating, cooling, ventilation, domestic hot water, indoor and outdoor lighting, plug loads, process energy, elevators and conveying systems, and intrabuilding transportation systems. Contributions from on- or off-site renewable energy systems are not included in building energy use.
	Renewable energy	Energy generated from a source that is not depleted when used. Note: The most common forms of renewable energy are photovoltaic systems, solar thermal power plants, (off-site) wind turbines, hydroelectric plants, geothermal power plants, and geothermal heat pumps.
	On-site renewable energy	Renewable energy generated by systems within the site boundaries of the building.
	Off-site renewable energy	Renewable energy generated by systems not located within the building site boundaries.
	Additionality	Additional energy efficiency savings or renewable energy generating capacity are generated as a result of and in proportion to the energy demand of the zero carbon building.[a]
	Net metering	A system through which excess on-site generated renewable energy can be transferred to the electricity grid and the producer is compensated for it, often by the amount provided being credited against the retail price.
	Feed-in tariff	A system through which (excess) on-site generated renewable energy is transferred to the electricity grid, receiving payment for every unit delivered.
	Carbon offset	A reduction in emissions of greenhouse gases that would not otherwise have occurred, made in order to compensate for or to offset greenhouse gas emissions occurring elsewhere.

Note:
[a] Definition inspired by Architecture 2030's Zero Code.
Source: WRI.

Table C2 | **Zero Carbon and Energy-Related Terms, Defined**

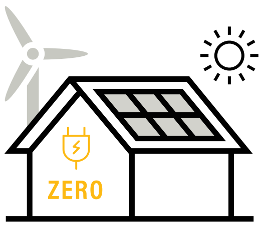
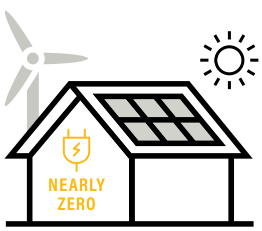
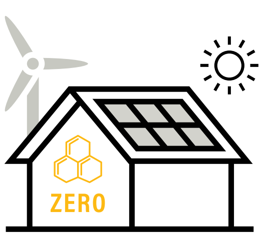
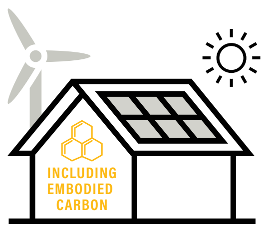
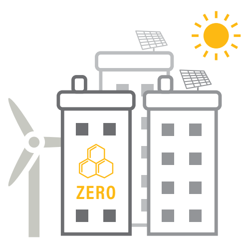
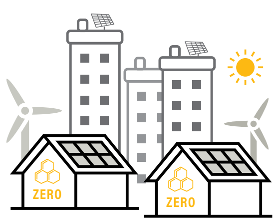
CONCEPT	DEFINITION	
	KEY PRINCIPLES	CONSIDERATIONS/LIMITATIONS
	**NET ZERO ENERGY** An energy efficient building that produces enough on-site or nearby renewable energy (RE) to meet building operations' energy consumption annually on a net basis (meaning the building delivers at least the same amount of renewable energy to the grid as the grid uses over the course of a year). Note: Not all RE is considered to be carbon-free in its generation.	
	■ Efficiency considered first before meeting its (remaining) energy demands with RE ■ Generates as much RE on-site or nearby as it uses on an annual basis ■ For new buildings, does not use on-site combustion (fossil fuels) ■ For existing buildings, may use on-site combustion from existing sources, such as gas for cooking	■ Not all buildings have sufficient (roof) space for installing on-site renewables, particularly in the case of mid- to high-rise buildings ■ Daily on-site generation and demand profiles may not match one-on-one, requiring grid electricity—often from power plants that burn fossil fuels—to meet demand during those times ■ May use renewable but potentially carbon-intensive energy sources, such as biomass
	**NEARLY NET ZERO ENERGY** An energy efficient building that supplies most (but not all) of its annual energy use through on- or near-site RE sources.	
	■ Deep efficiency considered first before meeting part of its remaining energy demands through RE ■ Generates some but not all of its RE demand on-site or nearby ■ May become net zero energy if adding (more) on-site or nearby RE or purchasing off-site RE ■ For new buildings, does not use on-site combustion (fossil fuels) ■ For existing buildings, may use on-site combustion from existing sources, such as gas for cooking	■ Not all buildings have sufficient (roof) space for installing on-site renewables, particularly in the case of mid- to high-rise buildings ■ Installing on-site RE may not always be cost-effective, and purchasing RE may not be an option ■ May use renewable but potentially carbon-intensive energy sources, such as biomass
Net zero energy ready	■ Similar to net zero energy except that no on-site RE is being generated ■ Instead, buildings have the **provisions in place** to install photovoltaic (PV) panels in the future	■ Without the actual installation of PV panels, this simply represents an energy efficient building ■ Only suitable for buildings that have sufficient space to become net zero energy by installing PV panels
	**NET ZERO CARBON** An energy efficient building that produces on-site, or procures, enough carbon-free RE to meet building operations' energy consumption annually. Note: *Zero carbon* is often used interchangeably with *net zero carbon*, whether or not the building uses potentially fossil fuel–derived grid electricity to make up for temporary gaps in on-site RE generation to meet demand or uses carbon offsets. If it does, it is usually called a *"net" zero building*.	
	■ Efficiency considered first before meeting (remaining) energy demands with carbon-free RE ■ Generates on-site or nearby or procures as much carbon-free RE—or carbon offsets—as it uses on an annual basis ■ For existing buildings, may use on-site combustion from existing sources, such as gas for cooking, offset by the purchase or generation of carbon-free RE or RE credits	■ Daily on-site generation and demand profiles may not match one-on-one, requiring the use of grid electricity—often from power plants that burn fossil fuels—to meet demand during those times ■ Does not usually include embodied carbon ■ Does not use renewable but potentially carbon-intensive energy sources, such as biomass

Table C2 | Zero Carbon and Energy-Related Terms, Defined (Cont'd)

CONCEPT	DEFINITION	
	KEY PRINCIPLES	CONSIDERATIONS/LIMITATIONS
	**(NET) ZERO CARBON, INCL. EMBODIED CARBON** An energy efficient building that produces on-site, or procures, enough carbon-free RE to meet building operations' energy consumption annually and also over its life cycle, compensating for the carbon embodied in the building's construction; an emerging goal is to also include embodied carbon arising from the materials, machinery, and equipment used in building construction, maintenance, and repair, into the *net zero* definition.	
	■ Same as (net) zero carbon, plus ■ embodied carbon emissions (e.g., from construction) are reduced or offset	■ As buildings become more energy efficient and electricity grids greener, embodied carbon will represent a larger share of a building's footprint
	**(NET) ZERO CARBON PORTFOLIO** Refers to a group of energy efficient buildings, sharing a similar characteristic and usually under the same ownership or management, with carbon-free RE demands mainly provided for within the boundaries of the portfolio rather than at the level of individual buildings.	
	■ Same as (net) zero carbon, but ■ carbon-free RE is generated and exchanged within the boundaries of the building portfolio	■ Mid- to high-rise buildings may not have much space for on-site renewables; instead, total RE demand is provided for within the portfolio of buildings
	**(NET) ZERO CARBON DISTRICT** Refers to a group of energy efficient buildings within a geographically defined urban area, with carbon-free RE mainly supplied through nearby off-site sources, generating clean energy at the district level.	
	■ Same as (net) zero carbon, but ■ carbon-free RE is mainly supplied through nearby off-site sources, generating clean energy at the district level	■ Mid- to high-rise buildings may not have much space for on-site renewables; instead, their RE demand is provided for at the district level

Source: WRI.

APPENDIX D. ZCB COMPONENTS

Section 2.2 of this paper discusses the different components available to us for reducing a building's operational carbon emissions to zero. These components, being basic and advanced EE, on- and off-site RE, and carbon offsets, are explained further in this appendix.

D.1. Energy Efficiency

D.1.1. Minimum energy efficiency (basic EE)

The simplest way for a government to accelerate the uptake of (net) ZCB would be to require buildings to demonstrate compliance or alignment with locally applicable energy efficiency codes and standards in combination with on- or off-site RE for meeting remaining energy demand or even the use of carbon offsets. Minimum energy efficiency is therefore the baseline or prerequisite for any (net) zero carbon building.

Nonetheless, making sure that a building adheres to local regulatory policies on energy efficiency is not a given. In many countries, codes and standards are voluntary, mandatory but poorly or not enforced, or waiting to become mandatory through a cumbersome process that transfers responsibility from the national to the local level.

Building efficiency codes and standards. The minimum energy efficiency level required for a building is usually laid down in a mandatory or voluntary code, sometimes also called a standard.[41] Building energy codes are most commonly focused on new buildings, but they can also be applied to existing buildings, usually during renovations. There is no single energy code or set of requirements that will suit all types of buildings, economies, and climates.

Typically, building energy codes set different energy performance and compliance requirements for residential and nonresidential buildings while tailoring them to existing best practices for the area's climate as well as locally available resources and technologies. Codes are usually tightened over time—for example, through three yearly code upgrade cycles. Two-thirds of countries, however, still do not have mandatory energy codes in place for all relevant building segments (GBPN 2015).

Appliance standards. MEPS specify the performance requirements for an energy-using device, effectively limiting the maximum amount of energy that may be consumed by that product in performing a specified task. Examples are MEPS for air conditioners (ACs), which are commonly applied in buildings to cool internal spaces. Despite the rapid worldwide growth in AC use, in many countries MEPS are still nonexistent, outdated, under development, or have significant room for improvement based on the best AC models already available in the global market (CLASP 2011). In India, for instance, the average AC sold in 2016 had an energy performance equivalent to a three-star rating, on a scale of one to five stars as introduced by the Indian government for rating ACs (Emerson Climate Technologies 2012).

D.1.2. Exemplary energy performance (advanced EE)

Many countries do not have mandatory building efficiency codes and/or MEPS for building appliances in place, and where they do exist, there is often considerable untapped scope for greater energy efficiency performance (CLASP 2017). At the same time, many studies have shown that efficiency is often (one of) the cheapest energy resources a country has available when accounting for all costs of energy generation and provision.

The "efficiency first" principle thus means first considering the potential for energy efficiency before converting conventional building or appliance energy supplies to renewable energy sources and prioritizing those efficiency improvements when they are more cost-effective than energy generation. Increasingly, governments are starting to recognize the importance of encouraging building owners/managers to go beyond local codes and standards in terms of their energy efficiency efforts.

An example is the city of Beijing, China, which not only has a local building code more stringent than the national one but also requires new developments to conform with the minimum level (one star) of China's Three-Star green building rating program and hands out subsidies per square meter of floor area for those pursuing higher (i.e., two- or three-star performance levels) (Yu et al. 2014).

D.2. Renewable Energy

D.2.1. On-site RE and storage

Depending on the building type and the locally available solar energy potential, buildings can meet all or part of their demand with on-site generated renewables. Usually, these involve rooftop PV panels or solar hot water systems. In many countries, subsidies or tax credits are available for the purchase of PV panels to overcome high up-front capital costs, although the cost of PV panels has rapidly come down in recent years. Net metering and FITs also help to further boost uptake. This has allowed Germany, for instance, to now generate around 7 percent of the country's total energy demand from rooftop PV panels.

Although on-site RE generation is preferable as a ZCB pathway over sourcing off-site renewables, certain building types, such as mid- to high-rise buildings, may have limited opportunities for on-site generation under currently available technologies. In addition, the solar energy potential varies depending on climate, with sunnier climates generally having greater potential.

D.2.2. Off-site RE purchase

A variety of options may be available, pending local circumstances, for the purchase of off-grid RE, either for all of a ZCB's energy needs or for the portion that cannot be supplied through on-site RE. Ideally, a building can prove that it has a long-term commitment in place for purchasing renewable energy. In addition, it would be preferable if the purchased energy meets the additionality criterion, thus ensuring that a building's purchase of renewable energy contributes to the generation of new, "additional" renewable energy, thereby expanding the total pool of renewable energy supply (Architecture 2030 2018).

Green energy tariffs. Some energy retailers, such as local utilities, offer their customers the option to purchase 100 percent renewable energy from the grid for all or part of their energy needs. Often this green energy comes at a cost premium versus "gray" energy. Currently, green energy tariffs are mostly confined to North America, the European Union, Australia, and New Zealand.

In 2015, for example, 58 percent of households in the Netherlands had a green power contract with their utility, generally at a very low cost premium. One reason for this high uptake has been the introduction of an "ecotax" in 1996, which increased energy prices for all consumers except those purchasing green electricity (MacDonald 2016).

Power purchase agreements. Beyond the grid, there is an increasing range of options to purchase renewable energy directly from solar or wind energy projects. For example, buyers may unite in a syndicate or collaborative to aggregate their energy demand and strike an attractive deal with a renewable energy project developer. Developers may also offer small chunks of renewable energy from their off-site RE project for sale to individual buyers.

For the actual PPA signed between a buyer and the renewable energy project developer, we can distinguish between physical and virtual PPAs. *Physical* PPAs on-sell excess power from a purchasing party's own renewable energy investments (e.g., a large company invests in a wind farm and on-sells the excess it does not need), which is only possible in markets that are not tightly regulated, such as competitive access or direct retail markets that allow "retail electricity choice," giving energy consumers the ability to buy power competitively from an entity other than the local utility. *Virtual* PPAs, which make up the majority of PPAs, let a party buy clean energy from a project at a long-term fixed price without technically being the owner of the purchased power—for instance, a company continues powering its operations with grid electricity but strikes a long-term cost deal on renewable energy with a project developer who feeds its energy into the grid (BRC 2016).

An example of renewable energy buyers uniting is provided by India's Green Power Market Development Group, which brings together local governments, utilities, regulators, companies, and energy developers in various Indian states, including Karnataka and Tamil Nadu, to bulk purchase renewable energy through virtual PPAs with renewable energy project developers (WRI 2017).

Renewable energy certificates. RECs are known under a variety of names in different countries. They show proof that energy has been generated from renewable sources, with each REC representing the environmental benefits of a certain unit (such as 1 MWh) of renewable energy generation. The generated energy is fed into the grid, and the environmental benefits are traded through a certificate that can be sold and bought. This allows a building developer/owner to purchase RECs equivalent to the amount of energy used by the building.

Mexico, for instance, allows certain renewable energy projects to issue "clean energy certificates" that can be bought by others looking to fulfill their renewable energy commitments (Sustainability Roundtable 2012). RECs often get confused with carbon offsets. Purchasers of the RECs, however, buy the legal right to the renewable attributes they represent, somewhat similar to what happens with a virtual PPA. In both cases the generated clean energy is fed into the grid, where it is indistinguishable from nonrenewable energy, but the mechanisms put in place ensure that buyers can claim the benefits.

D.2.3. Off-site RE generation

Instead of purchasing renewable energy, building developers/owners may also generate their own renewable energy at an off-site location. They can do so by purchasing or leasing a separate parcel of land and constructing a renewable energy system on it. While the actual building continues to draw power from the grid, the off-site renewable energy system delivers power to the grid, such as through a FIT (Architecture 2030 2018). Increasingly, large corporations, including Apple, Google, and Facebook, are investing in off-site RE facilities to cover part or all of the energy needs of their facilities.

D.3. Carbon Offsets

A more uncommon means of getting to a ZCB would be to use carbon offset solutions, equivalent to the carbon footprint generated by using nonrenewable energy for part or all of the building's energy needs. This gap could be referring to only grid-purchased energy, however in some countries power cuts are so common that buildings commonly have diesel backup generators, which can also generate considerable emissions.

To compensate for these carbon emissions, a similar amount of carbon offsets would be purchased or generated. The types of carbon offsets range from planting trees to those resulting from investments in clean energy or energy efficiency projects elsewhere to generate carbon savings. The resulting emission reductions are often sold as so-called carbon credits. A variety of quality standards are available for carbon credits to ensure aspects such as additionality and lasting carbon reductions (World Bank 2015b).

In jurisdictions where on-site RE may come with an unfavorable policy framework leading to long payback times and off-site RE or REC purchases are limited or not available to segments of the market (such as residential) due to local legislative frameworks, carbon offsets may be considered as a permissible pathway toward achieving ZCB. However, for the purpose of the ZCB pathways set out in this paper, **only carbon offsets that can prove additionality, and are used to invest in energy efficiency or renewable energy projects off-site, are considered eligible to offset emissions from operational energy use.**

A good example of such an approach is the city of London. Its zero carbon homes policy requires new residential buildings to achieve at least a 35 percent reduction in carbon emissions on-site through energy efficiency and renewable energy. Any remaining on-site emissions have to be offset through a cash-in-lieu contribution to the relevant borough. The resulting carbon offset funds provide a source of funds for carbon reduction projects across London and, in particular, play a role in funding emission reduction measures for existing buildings where achieving carbon savings can be more challenging and expensive.[42]

In addition, stakeholders are increasingly interested in the embodied carbon footprint of buildings. To compensate for these embodied emissions, the use of carbon offsets could be encouraged to the extent that they cannot be first reduced or avoided.

ENDNOTES

1. *Basic EE* involves pursuing the minimum required level of energy efficiency by ensuring that the building complies with local codes and standards. In most countries, such codes and standards still have considerable untapped potential for higher performance. *Advanced EE* involves more ambitious energy performance that goes beyond minimum regulatory requirements.

2. For more information, please see the United Nations Environment Programme's *Global Status Report 2016: Towards Zero-Emission Efficient and Resilient Buildings*, available at https://wedocs.unep.org/handle/20.500.11822/10618, and *Global Status Report 2017: Towards a Zero-Emission, Efficient, and Resilient Buildings and Construction Sector*, available on the World Green Building Council website, https://www.worldgbc.org/sites/default/files/UNEP%20188_GABC_en%20%28web%29.pdf.

3. *Basic EE* involves pursuing the minimum required level of energy efficiency by ensuring that the building complies with local codes and standards. In most countries, such codes and standards still have considerable untapped potential for higher performance. *Advanced EE* involves more ambitious energy performance that goes beyond minimum regulatory requirements.

4. Carbon offsets should be able to prove additionality and should be primarily used to invest in energy efficiency or renewable energy projects elsewhere.

5. Carbon offsets should be able to prove additionality and should be primarily used to invest in energy efficiency or renewable energy projects elsewhere.

6. Definitions provided in this section are based on a synthesis of credible definitions available in recent literature, together with expert judgment by the WRI team.

7. The "business as usual" situation, in this case a typical building without energy efficiency measures.

8. Additionality requires proof that a mitigation measure would not have occurred without payment of the mitigation credit (i.e., would not have been economically feasible or customary). In this case, additional energy efficiency savings or renewable energy generating capacity are generated as a result of and in proportion to the energy demand of the ZCB.

9. *Carbon credit* is a generic term for any tradable certificate or permit representing a reduction of one metric ton of carbon dioxide emissions or the equivalent of another greenhouse gas.

10. Not all renewable energy is considered carbon free. Certain types of biomass, for instance, may come with a high carbon footprint as well as other adverse environmental and/or social impacts.

11. For more information about net zero carbon certification, see the International Living Future Institute at https://living-future.org/zero-carbon-certification/.

12. The approach is analogous to a car manufacturer achieving a required level of fuel efficiency by averaging the efficiencies of all vehicles in the fleet.

13. *Distributed generation* refers to electrical generation and storage performed by a variety of small, grid-connected devices at or near where the energy will be used.

14. *Net positive* refers to a building, facility, or operation that reduces more (operational) carbon than it generates, in essence becoming "net positive." An example could be a highly energy-efficient building producing more on-site RE than it needs to fulfill remaining energy demands.

15. The analysis has not considered the state of the market, including the (local) cost and availability of specific energy efficiency– or renewable energy–related products and services and the skilled labor to install and maintain them.

16. Carbon offsets would typically be used to make up for the gap between nearly and 100 percent ZCB.

17. In India, the city government may consist of a municipal corporation (for areas with more than 1 million inhabitants) or a municipality (for smaller urban areas).

18. There is some evidence that points to FAR limits regularly being flouted by developers in some states, which would undermine the effectiveness of a FAR-based incentive.

19. For instance, municipal corporations.

20. Carbon offsets used as part of ZCB pathways should be able to prove additionality and should be used primarily to invest in energy efficiency or renewable energy projects elsewhere.

21. The analysis has not considered the state of the market, including the (local) cost and availability of specific energy efficiency– or renewable energy–related products and services, and the skilled labor to install and maintain them.

22. Carbon offsets would typically be used to make up for the gap between nearly and 100 percent ZCB.

23. If a municipality reduces its energy bill as a result of energy efficiency improvement measures, it risks receiving less budget in the next fiscal year from state or national governments, a perverse outcome.

24. Carbon offsets used as part of ZCB pathways should be able to prove additionality and should be used primarily to invest in energy efficiency or renewable energy projects elsewhere.

25. The analysis has not considered the state of the market, including the (local) cost and availability of specific energy efficiency– or renewable energy–related products and services, and the skilled labor to install and maintain them.

26. Carbon offsets would typically be used to make up for the gap between nearly and 100 percent ZCB.

27. ESCOs enable the procurement of energy efficiency technologies or services by taking on the first costs and often the risk of these investments, then being paid back by a building owner through the energy savings via an energy performance contract or similar mechanism.

28. Passive house standards result in extremely energy-efficient homes; in general, they use at least 80 percent less energy than a conventional home.

29. Carbon offsets used as part of ZCB pathways should be able to prove additionality and should be used primarily to invest in energy efficiency or renewable energy projects elsewhere.

30. Not all of the mentioned examples have obtained green building certifications.

31. Since 2010, Kenya's implementation of the building code has devolved to the counties; however, many of the country's 47 counties lack sufficient capacity and knowledge to implement it.

32. The analysis has not considered the state of the market, including the (local) cost and availability of specific energy efficiency– or renewable energy–related products and services, and the skilled labor to install and maintain them.

33. Carbon offsets would typically be used to make up for the gap between nearly and 100 percent ZCB.

34. Although Kenya's 2016 and 2017 building code updates are still awaiting parliamentary assent, implementation has devolved to Kenya's 47 counties.

35. *Eurocode* refers to European standards specifying how structural design should be conducted within the European Union.

36. Known as Greenstar Africa.

37. Based on conversation between the authors and Madhur Ramrakha, Board Treasurer and Chair of Finance Committee for the KGBS, March 2019.

38. LEED is a green building rating and certification scheme from the United States and the most widely used scheme worldwide. LEED buildings can be found in dozens of countries.

39. Carbon offsets used as part of ZCB pathways should be able to prove additionality and should be used primarily to invest in energy efficiency– or renewable energy–related projects elsewhere.

40. Definitions provided in this section are based on a synthesis of credible definitions available in recent literature, together with expert judgment by the WRI team.

41. Building energy efficiency codes, which are termed ***standards*** in some countries, lay down mandatory or (sometimes) voluntary energy performance requirements for a building. Building certification programs provide (verified) recognition for a building's energy performance and potentially other green building features, are usually voluntary, and are often driven by the private sector.

42. For more information, see the Mayor of London's report entitled *Carbon Offset Funds: Greater London Authority Guidance for London's Local Planning Authorities on Establishing Carbon Offset Funds*, available at https://www.london.gov.uk/sites/default/files/carbon_offsett_funds_guidance_2018.pdf.

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ACKNOWLEDGMENTS

The authors would like to thank the following people for their peer review and helpful insights and comments during the development of this paper: Murefu Barasa (EED Advisory Limited), Christie Baumel (USDN), Victoria Burrows (World Green Building Council), Paul Cartwright (C40), Elizabeth Chege (Kenya Green Building Society), Joelle Chen (formerly World Green Building Council), Wei Feng (Lawrence Berkeley National Laboratory), Bianca Gichangi (EED Advisory Limited), Andreas Gruner (GIZ), Deepak Krishnan (WRI India), Jonathan Laski (formerly World Green Building Council), Andrew Lee (formerly Architecture 2030), Mark Lyles (New Buildings Institute), Anne Maassen (WRI Ross Center for Sustainable Cities), Sumedha Malaviya (WRI India), Vincent Martinez (Architecture 2030), Edward Mazria (Architecture 2030), Hong Miao (WRI China), Octavio Molina (WRI Mexico), Clay Nesler (Johnson Controls), Alex Perera (WRI), Madhur Ramrakha (Kenya Green Building Society), Heidi Bishop Ratz (WRI), David Rich (WRI), Inder Rivera (WRI Mexico), Carolyn Szum (Lawrence Berkeley National Laboratory), Laura Malaguzzi Valeri (WRI), Marco Villalobos (formerly WRI Mexico), Yaki Wo (Architecture 2030), Min Yuan (WRI China), and Mofan Zhang (WRI China).

Thanks also to Laura Malaguzzi Valeri, Emilia Suarez, Emily Matthews, Romain Warnault, Billie Kanfer, Lauri Scherer and Carni Klirs for their assistance with editing and producing this paper.

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