Financing Net Zero Carbon Buildings

A background and scoping paper

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CITIES CLIMATE FINANCE LEADERSHIP ALLIANCE

AUTHORS

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ABOUT CPI

CPI is an analysis and advisory organization with deep expertise in finance and policy. Our mission is to help governments, businesses, and financial institutions drive economic growth while addressing climate change. CPI has five offices around the world in Brazil, India, Indonesia, the United Kingdom, and the United States.

ABOUT THE CITIES CLIMATE FINANCE LEADERSHIP ALLIANCE

The Cities Climate Finance Leadership Alliance is a coalition of leaders committed to deploying finance for city-level climate action at scale by 2030. Trillions of dollars will be required to help cities build the low-emissions, resilient infrastructure necessary to combat and react to climate change. The Cities Climate Finance Leadership Alliance is the only multi-level and multi-stakeholder coalition aimed at closing the investment gap for urban subnational climate projects and infrastructure worldwide.

DESCRIPTORS

SECTOR

Buildings

REGION

Global

KEYWORDS

Buildings, Construction, Zero Carbon Buildings, Subnational

RELATED CPI WORKS

Tracking incremental energy efficiency investments in certified green buildings

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EXECUTIVE SUMMARY

This paper is the output of an exercise that aims to build the foundation for future work by the Cities Climate Finance Leadership Alliance (the Alliance) through a structured approach to analyze the challenges and priorities relevant to cities in decarbonizing the buildings sector. It is not an exhaustive study of zero carbon buildings, but rather a guide for future alliance work and exercise to build in-house knowledge.

Buildings contribute 37% of global energy-related CO_2 emissions. Nine percent of emissions are from on-site energy generation, 18% are from grid electricity, and 10% are from materials and construction (UNEP, 2021).

The IEA estimates that total investment in the global buildings sector must increase from USD 4.9 trillion in 2017 to approximately USD 5.4 trillion in 2050 to limit global warming to well below 2°C. China, India, the European Union, and the United States will receive 60% of investments. New construction will account for 67%, with heating and cooling in existing buildings accounting for another 18% (IEA 2019).

New building construction, driven by population growth, urbanization, and rising incomes, will be concentrated in low and middle-income countries in Africa and Asia that will experience 93% of urban population growth between 2020 and 2050 (UN DESA 2018). Cooking and heating are currently the largest energy end-uses, but cooling is the fastest-growing energy end-use, with new demand concentrated in emerging markets.

Achieving net zero carbon buildings at scale will require changes to every building element, including materials, thermal envelopes, passive heating and cooling design, active heating and cooling (HVAC), appliances, lighting, and electricity generation. The greatest opportunities lie in reducing embodied carbon in construction materials and cleaner and more efficient heating and cooling, including through passive design. Clean cooking will also play a major role in reducing emissions and air pollution from cooking, which is responsible for 0.5 $GtCO_2e$ of emissions annually (Ritchie, 2021). Financial instruments that can support net zero carbon building include traditional instruments used for all buildings, such as equipment leases, mortgages, and bonds, as well as specialized mechanisms that utilize the cost savings energy efficiency such as on-bill repayment, energy service contracts, and property assessed clean energy loans. Traditional instruments like bonds and commercial debt have already demonstrated they work at scale, but on their own will not help shift the market to lower carbon buildings, while specialized instruments explicitly targeting net zero buildings have had difficulty scaling and reaching lower-income households.

Several policies to support net zero carbon buildings exist, such as green building labeling, energy efficiency buildings codes, and equipment performance standards. However, those policies are not widespread, especially in low and middle-income countries with the greatest building stock growth, and often lack ambition. The success of policies is dependent on capacity to implement and enforce them, and a construction sector that can deliver low carbon buildings.

Each country and region have unique challenges and opportunities for net zero carbon buildings, and to this end this work also includes two deep dives on Nigeria and Indonesia to explore country-specific dynamics.

In Nigeria, the use of fossil fuel generators to address power shortages, expected heat waves, poor quality of building materials are key challenges. Addressing cooling and building-level electricity generation are high impact areas for intervention in Nigeria but building the enabling framework for private investment in zero carbon buildings must be strengthened to enable investment in net zero buildings at scale.

In Indonesia, the new green buildings regulation set national standards for buildings and is set to greatly expand the low carbon buildings market. However, implementation of this regulation will be left to municipalities. The success of the new regulations will depend on ensuring cities and the construction industry have sufficient implementation capacity. The growing demand for cooling will be the focal point as the largest energy end-use.

Future Alliance work in 2022 on net zero carbon buildings will focus on city-level policies and financing modalities that facilitate private investment in low-carbon buildings. These will be supplemented by country deep dives on Nigeria's regulatory framework and policy and blended finance support for cooling in Indonesia.

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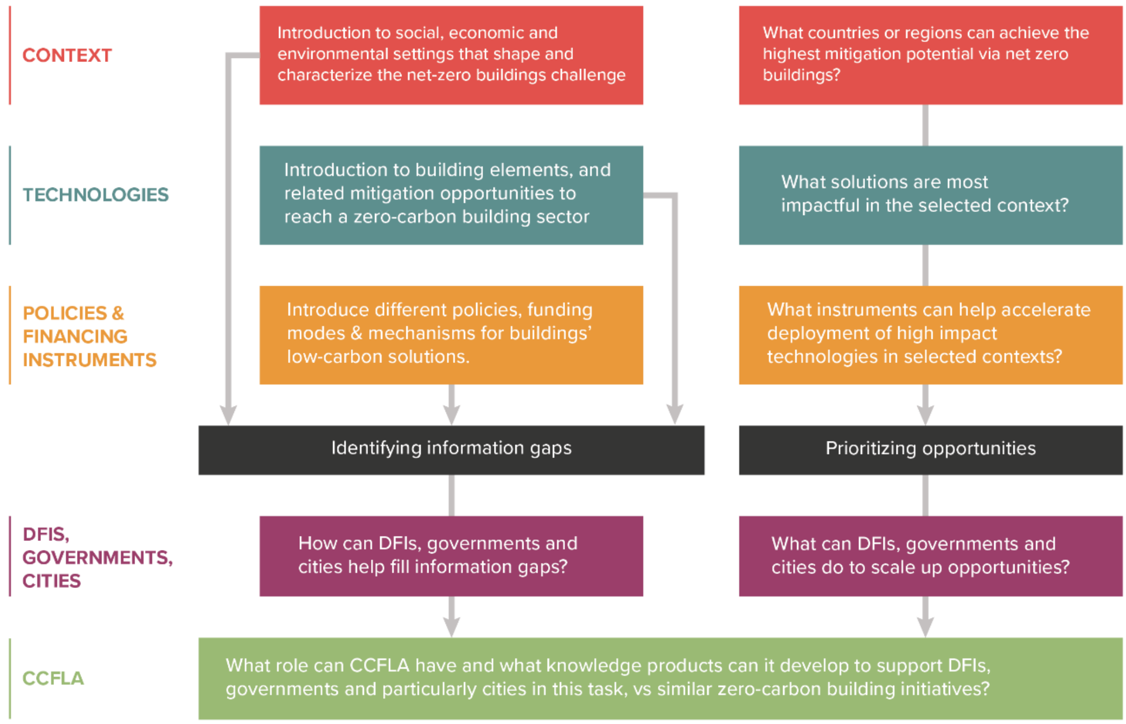
1. OBJECTIVES

This paper is the result of an internal exercise undertaken to build knowledge on net zero buildings definitions, barriers, investment needs, and actors; and to identify and prioritize opportunities for the Cities Climate Finance Leadership Alliance (the Alliance) to support the decarbonization of the buildings sector. This exercise was intended to build a foundation for future work through a structured approach to analyze the challenges and priorities relevant to cities in decarbonizing the buildings sector. It is not intended to be comprehensive.

Figure 1. Analytical approach



The paper is structured in five parts:

1. The context and building stock characteristics that shape the decarbonization challenge,
2. The building elements and technologies that are responsible for GHG emissions and offer mitigation opportunities, and
3. The financial instruments and policies that can scale technologies and drive the production of net zero buildings in cities.

4. The paper is global in scope but includes deep dives on Indonesia and Nigeria to explore the unique challenges for net zero buildings in those countries and how those influence opportunities for subnational governments.[1]
5. Finally, priorities for future work by the Alliance are identified.

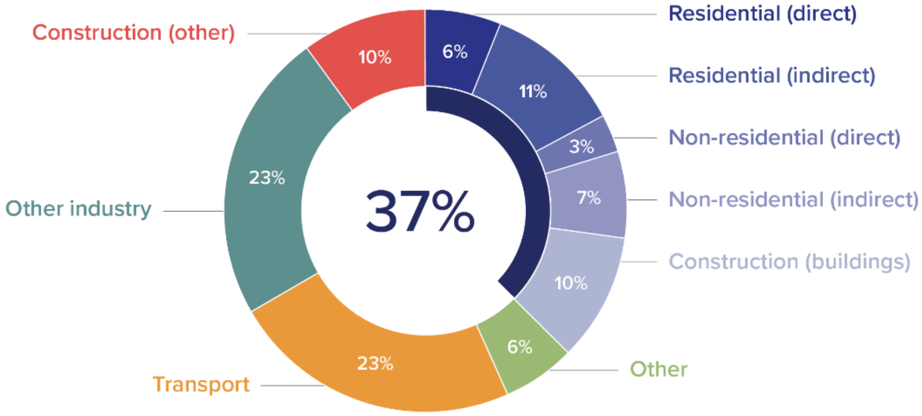
[1] Given that this paper is global in scope, the term sub-national governments is used, rather than city or municipal governments, to acknowledge the variety of intergovernmental architectures, powers, and mandates given to subnational governments. Nonetheless, the focus is on urban areas where the majority of people and buildings reside, and city governments play a key role. The term city-level is used to acknowledge that buildings and construction markets often operate at the level of functional urban areas.

2. INTRODUCTION

2.1 THE BUILDINGS SECTOR HAS A FUNDAMENTAL ROLE IN GLOBAL GHG EMISSIONS

Buildings contribute to greenhouse gas (GHG) emissions throughout their lifecycles through direct emissions from onsite energy generation, indirect emissions from off-site energy generation, and embodied carbon from the materials and the construction process.

Figure 2. Share of building sector GHG emissions over global energy and energy-related emissions



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In total, buildings are responsible for 37% of global energy related GHG emissions (UNEP, 2021).

Emissions from energy generated on-site at buildings account for 9% of global GHG emissions. Adding in the emissions from grid electricity used by buildings brings the sector's GHG emissions to 27% of global energy related emissions (UNEP, 2021).

Emissions from materials and construction are another 10% of global energy related GHG emissions. Embodied carbon accounts for the land use and industrial sector emissions that result from materials used in buildings, as well as the emissions tied directly to construction activities (UNEP, 2021).

The relevance of the buildings sector is even higher for cities where, on average, buildings contribute to over half of all urban emissions (C40, 2016).

2.2 A BUILDING PERFORMANCE DEFINITION ADEQUATE TO ITS IMPACTS

The role of buildings in generating emissions beyond those produced on-site needs to be reflected in the definition of what buildings should look like in a net zero world. Several definitions and terms are used for buildings to describe their environmental impact, energy use, and emissions. Some are shown in Table 1. This complicates the discussion of buildings sector decarbonization by limiting the comparable data from different sources. In addition, the criteria used to measure buildings GHG emissions performance do not account for all the sources of building-related GHG emissions.

Table 1. Definitions of low carbon buildings

Criteria considering/Definitions	Green buildings	Net zero energy building	Net zero carbon buildings (including embodied carbon emissions)
Reducing energy demand during construction and life cycle (Operational)	✓	✓	✓
Decarbonizing the power supply from buildings by using on- and off-site Renewable Energy (Operational)	✓	✓	✓
Addressing embodied carbon stored in building materials	(Depends on context)		✓

(IFC 2019; WRI 2019 a,b; World Green Building Council 2019).

An adequate net zero carbon building definition must be comprehensive and should take whole life carbon into account by including energy use, operating emissions, and embodied carbon from materials. In this paper we define a net zero building as one that is powered by on-site or off-site carbon free energy and whose materials have net zero lifecycle emissions or use carbon removal to offset residual lifecycle emissions (LETI 2021; World Green Building Council 2019). Net zero carbon buildings at scale are currently an aspirational but important goal for the full decarbonization of the buildings sector. The terms green building and low-carbon building are used to refer to buildings that do not meet the bar for net zero carbon buildings but make significant progress compared to peer buildings in reducing energy use and emissions.

2.3 THE INVESTMENT CHALLENGE OF A DECARBONIZED BUILDINGS SECTOR

Decarbonizing the whole building sector will require investment in new and existing buildings. There are several estimates covering investment needs and opportunities for elements of net zero buildings and a decarbonized buildings sector.

The IEA's Faster Transition Scenario estimates a total investment increase in the global buildings sector from USD 4.9 trillion in 2017 to approximately USD 5.4 trillion in 2050. Almost 60% of investment in the buildings sector is estimated to be in China, India, the European Union, and the United States. The biggest bulk of investment is estimated to be in construction with 67%, followed by heating and cooling with 18% of cumulative investment by 2050. In addition, the scenario shows a significant decrease in fossil fuel use in buildings, with the annual spending reduced by three quarters by 2050, while investment in renewables is estimated to increase nearly sixfold by 2050. Building envelope measures have a greater share in capital costs, hence long-term investment returns rely on energy prices and savings from lower spending on heating and cooling (IEA 2019b).

The Glasgow Financial Alliance for Net Zero (GFANZ) estimates a **global investment need of USD 5.2 trillion to decarbonize existing buildings and reach net zero by 2050** (GFANZ, 2022). An annual average investment of USD 700 billion is required for existing buildings to reach net zero by 2050, which is mostly concentrated in retrofitting and heating and makes up 80% of all needed investments, followed by appliances. The annual investment need is projected to quadruple between 2020 (USD 186 billion) to 2040 (USD 714 billion), while 70% of all investment needs for existing buildings are concentrated in developed economies (GFANZ, 2021a; b).

For new green buildings in emerging markets, IFC estimates there is a USD 24.7 trillion investment opportunity by 2030. IFC defines green buildings as buildings that are at least 20% more energy efficient than baseline buildings. Most of the investment opportunity is in East Asia Pacific and South Asia (USD 17.8 trillion). The investment opportunity in residential construction, estimated at USD 15.7 trillion, represents 60% of the market (IFC, 2019).

3. CONTEXTS FOR BUILDINGS SECTOR DECARBONIZATION

Social, economic, and environmental contexts shape what gets built, where, and how it is used. Taken together, they frame the scale and character of the buildings sector decarbonization challenge in each country. Exploring the contexts for buildings sector decarbonization will help to scope and characterize the net zero buildings challenge and prioritize the areas the Alliance can focus on to have the greatest impact.

3.1 DRIVERS OF BUILDING STOCK GROWTH

Increasing population growth and urbanization, along with growing household incomes are key drivers of demand for new buildings.

3.1.1 POPULATION GROWTH AND URBANIZATION

Low and middle-income countries in Africa and Asia will have the most population growth and urbanization. By 2050, over two-thirds of the world's population will live in cities, an increase from 56% in 2020. Almost all this growth, 86%, will occur in Africa and Asia, and over half will be in countries that are currently lower-middle income. Countries that are currently low-income will have the fastest urban population growth, almost quadrupling between 2020 and 2050 (UN DESA, 2018).

Urbanization brings challenges for building quality. **Almost 1-in-4 urban residents (1.2 billion) will live in slums or informal housing in 2030** (UNSD, 2022). This represents an improvement from the 29% in 2018, but the total number of people living in slum conditions will increase because of the increase in urban populations (UNSD, 2022; UN Habitat, 2022). Over half the urban population in Sub-Saharan Africa live in informal and slum conditions (UN Habitat, 2022).

3.1.2 ECONOMIC GROWTH

Income growth increases the resources available to construct new buildings and leads to higher floor area per capita. Total floor area is the major driver of materials-related emissions and leads to higher operational energy use with more space to heat, cool, and light (WorldGBC, 2019). The relationship between income growth and floor area per capita growth is strongest at lower incomes (Isaac and van Vuuren, 2009). **Low and lower-middle income countries will experience both the greatest population growth and the fastest GDP per capita growth, both of which will amplify demand for buildings** (Riahi et al., 2017).

3.1.3 BUILDING TURNOVER

The longevity of existing buildings and the rate at which they are replaced is also a driver for the share of new construction in a country's building stock. Europe stands out in this metric, where low building turnover means that 80% of the buildings in use in 2050 have already been built (WorldGBC, 2019). In other advanced economies, more than 60% of currently existing buildings will remain in use in 2050, compared with 505 in China, 40% in India, and 30% in other emerging economies (IEA 2020a).

The building stock is expected to double by 2050, but population growth, urbanization, economic growth, and building turnover indicate that most of that 80% of building stock growth will occur in lower income countries in Africa and Asia (WorldGBC, 2019). Existing buildings will play a larger role in the building stock in wealthier, highly urbanized countries with low population growth while lower income and rapidly growing countries will have high rates of new construction (WorldGBC, 2019). These differences lead to different priorities in addressing emissions from existing buildings versus new construction, and to embodied carbon that is primarily emitted during construction.

3.2 DRIVERS OF ENERGY USE AND EMISSIONS

Energy use and emissions intensity vary widely between countries and buildings based on household income, energy end use, and climate. In developing countries, energy use will rise due to expanding energy access and increased need for cooling from climate change-driven rising temperatures, making expanding carbon-free energy crucial to mitigation. In OECD countries, the priority will be reducing the emission intensity of existing assets.

3.2.1 ENERGY ACCESS

Energy poverty – the lack of energy access – occurs when households do not have physical access to electricity or clean cooking or lack the ability to pay when there is physical access (UNDP, 2018). The IEA estimates that 759 million people lacked access to electricity in 2019, primarily in Sub-Saharan Africa and developing Asia

(IEA, 2021a). A third of the world's population - 2.6 billion people - lack access to clean cooking fuels and technologies (IEA, 2021a). Clean cooking will also play a major role in reducing emissions and air pollution from cooking, which is responsible for 0.5 $GtCO_2e$ of emissions annually (Ritchie, 2021). **Expanding access to electricity in buildings is a development imperative and SDG goal, but it will also increase building energy use**. In both business-as-usual and 2C scenarios, buildings will consume more than half of all electricity generated until 2050 (IEA 2017b). Energy efficiency improvements can lead to rebound effects that offset potential energy savings. This can have positive effects in reducing energy poverty but limits the mitigation effect of efficiency improvement (Cabeza et.al 2022). Income growth in higher income brackets will also drive higher energy consumption as ability to pay for energy and energy using appliances increases (WorldGBC 2019).

3.2.2 CLIMATE

Rising temperatures, growing populations, and higher incomes in warmer countries will lead energy use for cooling to grow rapidly while heating will decline as a share of buildings energy use (Levesque et al., 2018; Isaac and van Vuuren, 2009; Riahi et al., 2017). **Most of the expansion in building stocks will occur in countries with warm climates. These countries are also affected by rising temperatures due to climate change and have rapidly rising household incomes, all factors that will combine to make cooling the fastest growing energy end-use** (GlobalABC et al., 2020). Growth in energy use for cooling will be concentrated in developing countries (Levesque et al., 2018). Urban heat island effects will amplify warming and drive further increases in energy consumption for cooling by a median of 19% while reducing heating by a median of 18.7%, with widely varying city level impacts depending on the intensity of the effect and share of demand for heating versus cooling (Li et al. 2019).

3.2.3 ENERGY AND EMISSIONS INTENSITY

Energy intensity is a measure of the energy used per square meter or per capita. Emissions intensity is a function of the energy intensity and the carbon intensity of that energy, which varies depending on the energy sources used. Buildings in developed countries have per capita energy use that is four times higher than in developing countries (Levesque et al., 2018).

Buildings in OECD countries will continue to emit a disproportionate amount of GHG emissions. OECD countries will be home to just 20% of the world's building stock in 2050 but will emit 34% of the buildings related emissions between 2020 and 2050 (IEA, 2017a; Riahi et al., 2017; Isaac and van Vuuren, 2009; IEA, 2021b). Buildings in OECD countries emit an even larger share of direct emission from energy generated on-site. Half of all direct building emissions in 2020 came from OECD countries, which is only expected to decline to 44% by 2050 under current policies (IEA, 2017a).

3.3 PRIORITIZING ACTIONS BASED ON TYPOLOGY OF BUILDING STOCK DYNAMICS

The prioritization of specific zero carbon buildings measures will vary depending on a countries context and building stock characteristics. Differences in the share of new versus already constructed buildings, primary energy end uses, and energy sources change the priorities for mitigation.

Countries/Regions can be grouped into four general categories based on how much the buildings stock is expected to grow as a proxy for the importance of newly constructed buildings in emissions, and the energy use intensity per square meter, which serves as a general proxy for energy end use and fuel source. Table 2 shows some of the broad characteristics of these groups and areas where mitigation efforts can have the greatest effect. Table 2 should not be interpreted as outlining a sole priority for a set of countries, rather it highlights areas and characteristics that take on more prominence in those countries relative to others. These group provide a useful starting point to understand differences in buildings sector mitigation priorities, but they obscure country-specific characteristics and must be followed up with country-level analysis as is shown in Chapter 6.

Areas of intervention include renovation and retrofits in OECD countries, and decarbonization of the building industry, renewable electricity generation, and biomass in non-OECD countries.

In most OECD countries, where building stock growth is low and energy intensity is high, retrofitting existing buildings plays a key role, particularly by addressing heating and cooling energy use powered by methane gas and electricity. Countries such as China, South Africa, and Brazil are instead characterized by lower building stock growth and energy intensity. In this case cooking takes on a much more prominent role as an energy end-use factor in energy poverty. In other non-OECD countries, like India, new construction will play a larger role, as does cooking as an energy end-use.

Table 2. Building stock characteristics and key mitigation action areas

	Stock Types	**High building stock growth, low energy intensity**	**High building stock growth, High energy intensity**	**Low building stock growth, low energy intensity**	**Low building stock growth, high energy intensity**
	Country/region examples	India, Mexico, ASEAN, Non-OECD	USA	China, South Africa, Brazil	EU, Russia, OECD
Characteristics	Urban population living in slum conditions[2]	Medium-High	Low	Medium	Low
Characteristics	Energy efficiency potential (percent)[3]	Low-High	High	Low-High	Medium-High
Characteristics	Emissions reduction potential (percent)[4]	Medium-High	Medium	Medium-High	Low
Characteristics	Emissions intensity[5]	Low	High	Low	Medium
Characteristics	Share of emissions from grid electricity[6]	High	Medium	Low-High	Low-Medium
Action Areas	New and existing	New construction	New construction and existing building retrofits	Existing building retrofits	Existing building retrofits
Action Areas	Major energy end-uses	Cooking and cooling	Heating and cooling	Cooking and cooling	Heating and cooling
Action Areas	Major energy sources	Biomass	Electricity and methane gas	Biomass	Electricity and methane gas

[2] Based on percentage of the country/regions urban population living in slum conditions as defined by SDG 11.1.1 (UN Habitat 2022). The assessment bands are Low < 10%, medium 10% > 25%, high > 25%.
[3] Based on the percentage of total cumulative building operational energy use between 2020-2050 from all sources can be reduced in the IEA Sustainable Development Scenario (SDS) relative to the Reference Technology Scenario (RTS) (IEA 2017a). Assessment bands are low (8-9%). Medium (10-11%), and high (12-13%).
[4] Based on the percentage of total cumulative emissions between 2020-2050 from building operational energy use from all sources that can be reduced in the IEA SDS scenario relative to the RTS scenario, or (sum(RTS emissions) - sum(SDS emissions))/sum(RTS emissions). Direct emissions are from energy generated on-site, & indirect emissions are from energy generated off-site. (IEA 2017a). Assessment bands are low (30-45%), Medium (45-55%), high (55-65%)
[5] Based on total 2020 building operational emissions divided by estimated 2020 building stock ($KgCO_2/m^2/yr$) (IEA, 2017a; Riahi et al., 2017; Isaac and van Vuuren, 2009; IEA, 2021b). Assessment bands are low (0-50), medium (50-100), high (>100).
[6] Based on percentage of total cumulative emissions between 2020-2050 from grid electricity used by buildings (IEA 2017a). Assessment bands are low (40-60%), medium (60-75%), high (>75%).

4. TECHNICAL SOLUTIONS FOR DECARBONIZATION

Buildings are assemblies of multiple elements and systems, all of which play different roles, and contribute differently to GHG emissions. Each building element offers unique opportunities and challenges for decarbonization, making the best path to net zero different for different buildings. An overview of mitigation strategies for buildings is provided in this section, see Annex 1 for a more detailed review of specific carbon mitigation actions.

4.1 EMBODIED CARBON AND PASSIVE DESIGN: MITIGATION IN PLANNING AND DESIGN

Design choices for new construction can reduce embodied carbon, but high-quality carbon offsets are needed to address residual embodied emissions where mitigation options are not currently sufficient. New building design and existing building retrofits can deliver significant operational energy savings through passive design and improving thermal envelopes.[7]

4.1.1 DECARBONIZING MATERIALS

Embodied carbon is primarily emitted when materials are used to construct new buildings. Materials are a major source of GHG emissions that will be difficult to fully abate because of process emissions that cannot be eliminated with carbon free energy.

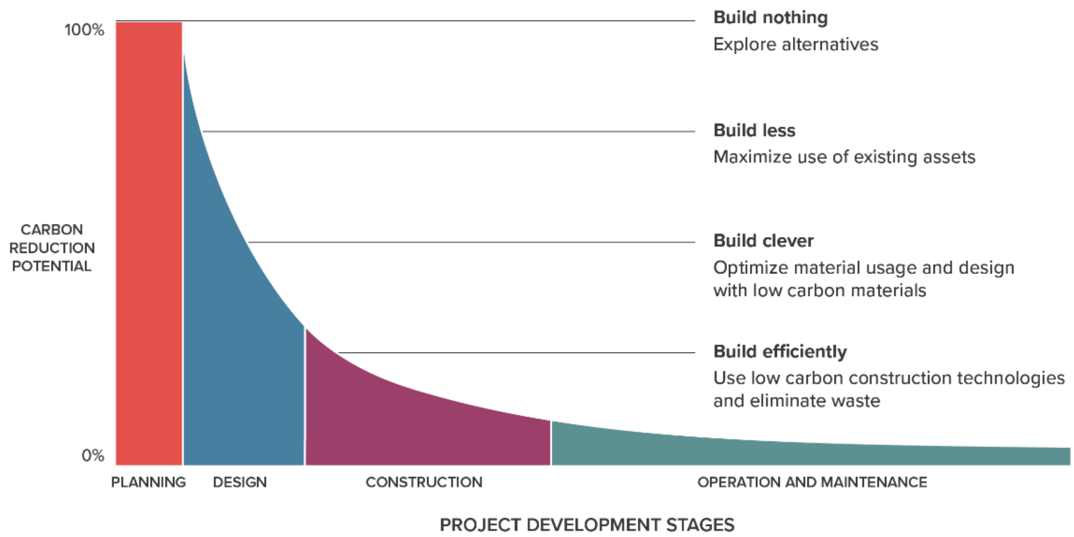
Currently, embodied carbon accounts for about 10% of total energy related emissions and a third of buildings related emissions (WorldGBC, 2019). The share of buildings emissions coming from materials is expected to increase as operational energy becomes cleaner and urbanization drives increased construction. The World

[7] Embodied carbon and passive design are considered together for three reasons: both are focused on the morphology and materials of the building; there are significant trade-offs and synergies between embodied carbon and thermal envelope performance; the actors and process to realize mitigation opportunities for embodied carbon and passive design are similar as they primarily take place in the design process.

Green Building Council estimates that half of the total emissions from buildings built between 2020 and 2050 will be embodied emissions (UNEP, 2021).

Concrete, which is the most widely used construction material globally, presents a particularly difficult decarbonization challenge. Sixty percent (~1.1GtCO_2 annually) of the emissions from cement, a key ingredient, are from process chemical reactions and cannot be eliminated with renewable energy (Project Drawdown, 2022a). Only a third of the cement emissions reductions needed for a 1.5˚C pathway is possible without some form of carbon removal and there is no clear technological path to net zero yet for cement (Krishnan et al., 2022).

Figure 3. Embodied carbon mitigation opportunities throughout the building lifecycle



Reproduced from WorldGBC 2019.

The major mitigation options for embodied carbon are reducing construction through extending buildings' useful lives and reducing demand for new buildings, reducing material use through efficient design, substituting lower embodied carbon materials, and offsets or carbon capture for unavoidable emissions.

Subnational governments have a medium amount of leverage over embodied carbon. Emissions from the manufacturing of materials and the choices of materials available are unlikely to be affected by subnational government action because of the large-scale industrial changes required, but urban planning policies and building codes have lots of leverage over how buildings are designed, and which materials are used. Cities can also offer incentives for lower-embodied carbon choices and require life-cycle analysis to measure, and report embodied carbon for new buildings. Cities also can help to foster local supply chains for low carbon materials through green procurement and design standards for public buildings (GlobalABC et al., 2020; CNCA, 2021) .

4.1.2 THERMAL ENVELOPE AND PASSIVE DESIGN

Design and material decisions can significantly reduce the energy needed to heat, cool, and light buildings through a building's thermal envelope and passive heating and cooling design.

A building's thermal envelope is the assembly of walls, roof, windows, and doors that limit the transfer of heat in or out of the building. It helps maintain a comfortable interior temperature without operational energy use. High performing thermal envelopes block airflow, use insulation and high-performance windows to keep heated or cooled air inside (Architecture 2030, n.d.).

Passive heating and cooling use sunlight, natural breezes, shading, and temperature changes between day and night to achieve comfortable temperatures without using active heating or cooling. Passive heating and cooling can reduce or eliminate the need for active heating and cooling. There are many design strategies suitable for different climates, sites, and building types that all use variations of maximizing or minimizing solar heat gain and controlling the exchange of indoor and outdoor air (Architecture 2030, n.d.).

A buildings thermal envelope and passive thermal performance has no operational energy use or emissions. This creates adaptation and resilience benefits because buildings have better thermal performance during disasters and can reduce or eliminate operational energy costs for heating and cooling (White and Wright, 2019). Passive design benefits households that cannot afford energy use for heating and cooling, and many passive design elements are achievable for self-built buildings.

Subnational governments typically have high leverage over thermal envelope and passive heating and cooling design. Many of the strategies can be permitted or mandated with building codes and zoning, but will also require the collaboration between architects, engineers, construction workers, and building owners (GlobalABC et al., 2020).

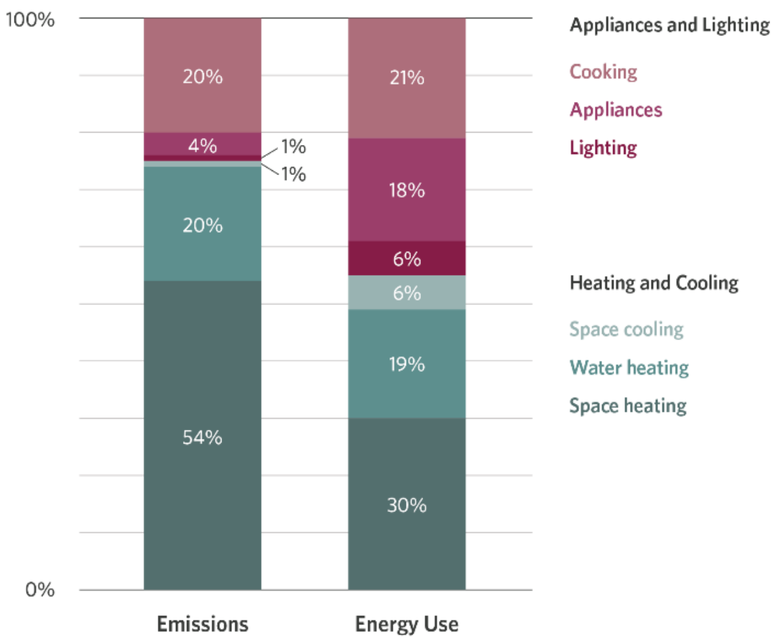
4.2 OPERATIONAL CARBON: HEATING, COOLING, AND APPLIANCES

On the demand side, mitigation options related to buildings operations from heating, cooling, and clean cooking, come from fuel switching and efficiency improvements. See Annex 1 for an overview of specific heating, cooling, and appliance mitigation strategies.

4.2.1 HEATING AND COOLING (HVAC)

Active heating and cooling, also called HVAC (heating, ventilation, and air conditioning) are the largest end-use of energy in buildings (55%), and are responsible for three quarters of buildings operating emissions (IEA, 2017a). Cooling is almost exclusively powered by electricity, while heating is currently mostly fueled by fossil fuels and traditional biomass (IEA, 2021b). Space cooling is the fastest growing energy end-use, and the world will add an estimate of 2.65 billion AC units by 2050, mostly in developing countries (IEA, 2021b; GlobalABC et al., 2020). Water heating consumes a third of the total heating and cooling energy use in buildings (GlobalABC et al., 2020).

Figure 4. Energy and Emission End Uses



Data: IEA 2017a, Estimates shown for 2025

Heating and cooling are also key to address adaption and resilience needs. Extreme heat is a deadly and growing hazard as a result of climate change. Over a billion people lack access to cooling, and heatwaves kill 12,000 people per year, a number expected to rise to 255,000 by 2050 unless cooling access is expanded (SEforALL, 2021).

Mitigation strategies for heating and cooling center around electrification to make the use of clean energy possible and improving the energy efficiency of heating and cooling equipment.

Subnational governments have medium leverage over HVAC. National governments, manufacturers, architects, and engineers, and building owners have the highest leverage (GlobalABC et al., 2020). Subnational governments do not typically have control over equipment efficiency and must work with what is available in their local markets. However, they can incentivize the lowest-emissions systems available, eliminate local regulatory barriers for low emissions systems, and raise regulatory barriers to high emissions systems.

4.2.2 APPLIANCES AND LIGHTING

Appliances and lighting make up the remainder of buildings operational energy use. Except for cooking, appliances and lighting are mostly powered with electricity. For lighting, efficiency improvements will primarily come from LED adoption, which is on track for the IEA Net-Zero 2050 scenario (IEA, 2020b).

Cooking is the main energy end-use in developing countries (Levesque et al., 2018). Inefficient cookstoves and dirty fuels have major health impacts – especially on women and girls who are largely responsible for cooking duties – and contribute to local air pollution in addition to GHG emissions (Clean Cooking Alliance, 2021a, Clean Cooking Alliance 2021b). However, cooking methods have ingrained cultural significance that can limit appetite to adopt new technologies that require changes in cooking practices.

Subnational governments have low leverage over appliances and lighting (GlobalABC et al., 2020). National governments, manufacturers, retailers, and suppliers have the highest leverage since appliance markets tend to be national rather than city specific.

4.3 OPERATIONAL CARBON: ELECTRICITY GENERATION

On the supply side, building-level renewable electricity generation and decarbonized electricity grids will be needed to support low-carbon building electrification.

The primary building level generation technologies are diesel generators, and solar PV, with micro wind turbines used in some specialized cases, primarily in rural areas

(Project Drawdown, 2022b; Heinemann et al., 2022). Electricity generation at the building level allows buildings to generate power when not connected to the grid, to compensate for grid unreliability and reduce costs (Heinemann et al., 2022).

Distributed solar is the least cost electrification option for many households that lack access to electricity, including in cities that lack comprehensive electricity grids (ESMAP and World Bank, n.d.).

Grid electricity will play a central role in providing clean energy to buildings. Even if IEA's distributed solar targets are met, two thirds of electricity used by buildings will be supplied by electrical grids, making grid decarbonization an essential enabling condition for zero carbon buildings (IEA, 2017a; 2021a).

Subnational governments have medium leverage over energy generation. National governments and utility companies have the highest leverage, particularly over grid supplied electricity (GlobalABC et al., 2020). Cities can support building level renewable generation by removing regulatory barriers and providing incentives to developers and owners.

4.4 PRIORITIZING ACTION BASED ON BUILDING ELEMENT PRIORITIES AND STRATEGIES

Emissions reductions from every building element will be needed for the buildings sector to reach net zero emissions. However, the priority for the greatest emissions reductions come from the management of heat and cold, while materials' embodied carbon will be fundamental to meet the sector's real net zero goals. The emissions reduction potential from electrification is also significant depending on the electricity's emissions intensity.

Emissions from operational energy use can be mitigated through efficiency improvements that reduce energy demand, electrification or fuel substitution, and clean energy generation. The combination of these strategies that are possible or optimal for any given building will vary, making it impossible to identify the exact mitigation potential of each strategy. Reducing embodied emissions will only occur in new construction. Table 3 highlights the mitigation potential of each buildings area, how much leverage subnational governments typically have to catalyze mitigation action, and the major non-emissions related benefits that mitigation in that building element can have.

Table 3. Building element mitigation priorities

Element	Mitigation Potential	Subnational Government Leverage	Benefits
Materials and Embodied Carbon	Up to ~30% of global buildings emissions and rising	Medium – can affect design choices but need changes to industry	Economic development potential
Thermal Envelope and Passive Heating and Cooling	Up to ~50% of global buildings' emissions	High – can set design standards through buildings codes and zoning	Adaptation and resilience
Heating and Cooling	Up to ~50% of global buildings' emissions	Medium – cities can encourage efficient choices	Adaptation and resilience
Appliances and Lighting	Up to ~20% of global buildings' emissions	Low – appliance efficiency primarily set at national level	Local air quality and health.
Electricity Generation	Up to ~70% of global buildings' emissions based on total operating emissions	Medium – can support building level generation but limited effect on grid mix	Resilience

Note: Mitigation potential is greater than 100% because of multiple paths to eliminate emissions. Mitigation potential is calculated based on current share of buildings emissions.

Different geographies will have different priorities for mitigation. Electrification and energy efficiency will be priorities in all geographies, while efficient design and passive heating and cooling has the highest potential in developing economies where new buildings are being developed. Retrofitting existing buildings and decarbonizing energy sources will play a larger role in developed countries with low levels of new construction. Despite differences in the predominant building types (classified by age and energy use intensity), it is important to note that every building type in this schema will be present in every country, and there are many other factors that will influence what strategies will be most effective for a given building. Trends in the priorities for selected geographies based on predominant building types are shown in Table 4.

Table 4. Mitigation priorities for specific buildings stock characteristics

Element	New buildings low energy use	New buildings high energy use	Existing buildings low energy use	Existing buildings high energy use
Country/Region examples where element will be prominent	India, Mexico, ASEAN, Non-OECD	USA	China, South Africa, Brazil	EU, Russia, OECD
Embodied Carbon	Efficient design, renewable materials	Efficient design, renewable materials	Extend life	Extend life
Thermal Envelope	Passive heating and cooling	Thermal envelope, Passive heating and cooling	Thermal envelope	Thermal envelope
Heating and Cooling	Electrification, energy efficiency	Electrification, energy efficiency	Electrification, energy efficiency	Electrification, energy efficiency
Appliances and Lighting	Energy Efficiency	Electrification, energy efficiency	Energy Efficiency	Electrification, energy efficiency
Electricity Generation	Grid-level generation, building-level generation	Grid-level generation, building-level generation	Grid-level generation, building-level generation	Grid-level generation, building-level generation

5. INSTRUMENTS AND POLICIES

Financial Instruments and policies are the tools that governments, together with financial institutions and real estate market players, can use to shift investment to net zero carbon buildings. Indeed, financial instruments throughout the building value chain are needed to bring financial flows that enable and directly finance net zero projects to scale. Policies and a set of non-financial tools can promote or enforce net zero carbon buildings, and direct how private funds are invested. Because of the wide range of contexts for net zero carbon buildings and the number of building elements contributing to buildings' GHG emissions, multiple instruments and policies are needed to support all the buildings sector decarbonization needs.

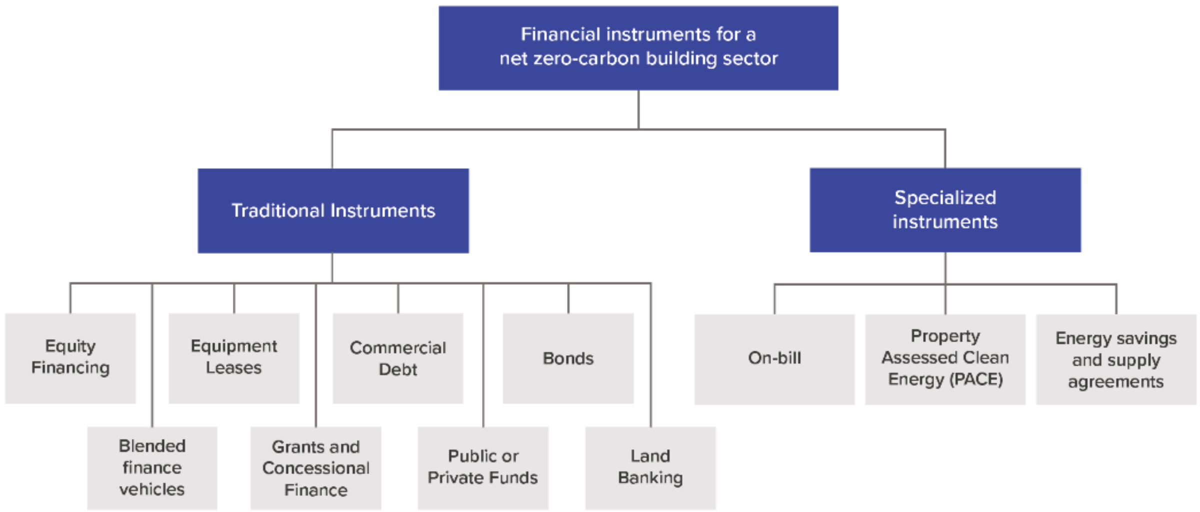
These instruments are critically underserving low-income households in developing and emerging countries. Many households sit outside of regulatory frameworks and simply do not have access to financing products. The ability to create instruments that also work at scale in these contexts will make or break any attempt at a meaningful net zero transition in the buildings sector.

5.1 FINANCIAL INSTRUMENTS

Financial instruments used for lower carbon and net zero carbon buildings include both traditional building financing mechanisms and more complex instruments specialized in the implementation of lower-carbon buildings, appliances, and construction (Better Buildings Initiative, n.d.; Leventis et al., 2016).

We identified 11 financial instrument categories (Figure 5) within the traditional and specialized instrument branches. Within these categories, each instrument faces distinct challenges to scaling support for net zero carbon buildings. While traditional instruments need to focus on improving net zero criteria, many specialized instruments face scalability challenges (Better Buildings Initiative, n.d.).

Figure 5. Classification of financial instrument types that can serve the net zero buildings sector transition.



5.1.1 TRADITIONAL INSTRUMENTS

Many of the instruments that are used to finance buildings generally are also suitable for financing zero carbon buildings. These include equity and self-financing, equipment leases, commercial debt, and bonds.

Many traditional instruments can serve the low-carbon transition in the buildings sector and to some extent, they already have. For years, traditional mortgages or equipment leases have been enabling energy-efficiency measures in buildings, without being specifically designed for such purpose. Indeed, traditional mortgages are used to finance both low-carbon and high-carbon buildings interchangeably. This results in no incentives for customers to build or buy green buildings and prevents financial players from identifying green opportunities and monitoring low-carbon projects.

However, the scale and pace at which the low-carbon transition needs to happen calls for these instruments to evolve. This can be done through the creation of green equivalents to these instruments that provide tailored terms to projects that comply with various sustainable requirements. These green financial products usually incentivize lower-carbon investment through lower-cost debt. For example:

- Green or Energy Efficient (EE) mortgages schemes: the source of finance – usually a commercial bank – offers discounted rates to better performing buildings. Some offer additional 'Energy Efficiency improvement' loans that can be attached to a green mortgage to cover expenditure on energy efficiency measures (EEMI, 2019).

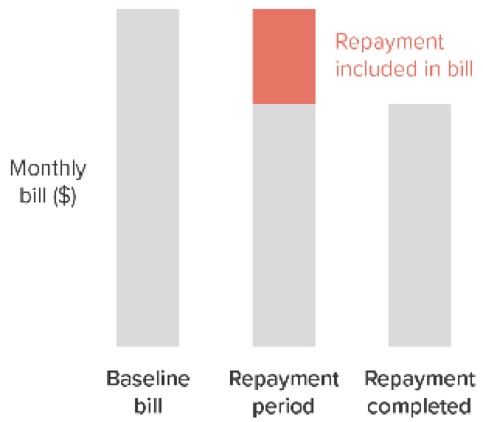
- Solar Leases: businesses and households install photovoltaic solar panels on their properties with no upfront cost while paying monthly rents for the panels. Depending on whether it is an operating or capital lease, the customer can buy the equipment at a reduced price at the end of the contract. In the U.S, solar leases were very popular in the 2010s but were outpaced by another tailored traditional instrument - solar loans, a USD 2.5 billion market in 2021(White, 2022).

5.1.2 SPECIALIZED INSTRUMENTS

A class of specialized instruments that harness buildings' ability to produce and retain energy in a more sustainable way has emerged. These mechanisms source their financial sustainability in the simple concept that better performing buildings require less external energy to operate. Typically, these products seek long-term profitability directly through energy efficiency and onsite energy generation measures that reduce utility bills.

The simplest structure that exploits this concept is on-bill financing and repayment (OBF and OBR): the utility or a third-party lender pay the upfront cost of installing energy efficiency measures in a building. Customers then repay the lender through their utility bills (Figure 6).

Figure 6. On bill financing mechanism



More complex financing systems exist such as Energy Performance Contracting (EPC, or ESPC in the U.S.). These arrangements directly involve the energy service companies (ESCOs) in charge of the project implementation and potentially transfer them the performance risk (IEA, 2018).

Another category of specialized instruments, Property Assessed Clean Energy (PACE) programs, allow property owners to finance the up front and then pay the costs back over time through property tax bill. Such assessments are attached to the property itself and the repayment obligation is therefore transferred with property ownership(Leventis et al., 2016). The largest market to date, the U.S, channeled USD 1.3 billion of PACE investment in 2020 (PACENation, 2022).

5.1.3 THE ROLE OF PRIVATE AND PUBLIC ENTITIES IN DEPLOYING FINANCING

Public and private actors have different roles in the deployment of financing to support the buildings sector transition. Together, they invested an annual average of USD 167 billion in urban low-carbon buildings and energy efficiency in 2017 and 2018 (CPI, 2021c). All actors now need to shift to a net-zero building financing strategy.

Relevant **public actors** include national and subnational government bodies, Development Finance institutions (DFIs), Export Credit Agencies, and sovereign wealth funds:

- Subnational bodies (regions, states, or cities), which have a better understanding their building stock's needs and are more likely to own or manage local buildings, play a more direct role in financing projects, and can act as implementers.

- National governments, by contrast, also have enabling and coordinating roles because they have greater financial means and greater access to debt products.

- DFIs are both implementers and enablers. They can help the development of financial products used by local financial institutions through revolving loan funds, support Technical Assistance, or directly finance low-carbon building projects (IEA, 2017b; IDB, 2019; UNEP, 2019).

A more detailed view of public sources and the financial instruments they can leverage to finance the net zero building transition can be found in Annex II – Table 24.

Relevant **private financial players** range from commercial banks and infrastructure funds to property developers and energy services companies. For example:

- Commercial banks remain a front-line player in the buildings sector, especially when it comes to addressing smaller actors' needs, such as households and small businesses. Commercial banks have a long experience of providing traditional debt instruments but must tailor them to match green standards through green mortgages and energy efficiency loans is a key challenge (EEMI, 2019).

- Energy Service Companies (ESCos) are emerging as a source of finance through earlier mentioned specialized instruments, on top of acting as the actual of building upgrades.

A more detailed view of private sources and the financial instruments they can leverage to finance the net zero building transition can be found in Annex II – Table 26.

5.1.4 INSTRUMENTS' SUITABILITY TO SERVE THE NET ZERO TRANSITION

Not all instruments have the same role in the net zero buildings transition. Some can only be used in certain contexts; others only allow for a sub-set of building improvement measures. To understand instruments' suitability, scope, and impact, we analyzed a selection of 15 financial instruments of interest, listed in Table 5, and mapped them against a set of criteria. The complete mapping exercise can be found in Annex II tables 26, 27, 28, and 29.

Overall, there is not one financial instrument that covers all the needs of a net zero transition. Reaching net zero in the buildings sector requires all building types, all technical elements, and all recipients to be served. Obviously, no financial instrument with such scope exists. Instead, reaching net zero demands a network of financial instruments that *together* cover all these differentiated needs and uses. The factors that we identify as crucial, and that we used to assess the suitability of financial instruments are listed below.

Table 5. 15 traditional and specialized instruments for net zero carbon buildings. A short definition of these instruments can be found in Annex II Table 23.

	Category	Instrument
Traditional	Equipment leases	Operating lease finance
		Capital lease finance
		Solar lease
		Tax-exempt lease
	Commercial debt	Revolving Loan Fund

		Commercial loan
		Mortgage
	Bonds	Project bond
Specialized	Energy savings and supply agreements	Power purchase agreements for clean energy
		Energy Performance Contract (EPC)
		Energy Service Agreements (ESAs)
	On-bill	On-bill financing (OBF) & repayment (OBR)
	Property Assessed Clean Energy (PACE)	Residential-PACE
		Commercial-PACE

First, we differentiate improvements that reduce existing emissions and energy demand in buildings from those that avoid more emissions or energy demand in comparison to a BAU scenario. New net zero buildings fall in the latter category.

Another key differentiation factor lies in the nature of the project. Some instruments can be used to finance single-measure projects (a solar lease to install solar panels), while others are more suited to comprehensive, multi-measure ones. Through EPCs, energy service companies usually perform energy audits and then implement a series of measures (thermal insulation + new heating system + efficient glazing) that ideally optimize the energy performance of the building and minimize the energy bill. Instruments that allow deep, multi-measure improvements of buildings are better suited to the net zero transition than single-measure instruments, which often yield stacked, uncoordinated measures, and ultimately poorer energy performances (ADEME et. al, 2021).

Some traditional instruments can be used to finance both single- and multi-measure projects. For example, green bonds in the buildings sector have been used to finance all sorts of building improvements, from single-measure energy efficient equipment loans to the financing of new net zero buildings. In fact, most traditional instrument can be used for both, and it is usually up to investors to use the sustainable requirements of the green financial product they offer to influence project typologies.

Each instrument also has challenges and opportunities to supporting the implementation of low-carbon and low-energy buildings at scale. Private sector financial instruments underserve projects that need financing the most due to a combination of factors, including lack of affordable financial products, insufficient credit worthiness, and lack of investor appetite. This gap is notably visible in high energy-use countries, where lower income households often live in the most emissions/energy-intensive buildings but are not able to access financing solutions easily.

5.2 POLICIES AND ENABLING ENVIRONMENT

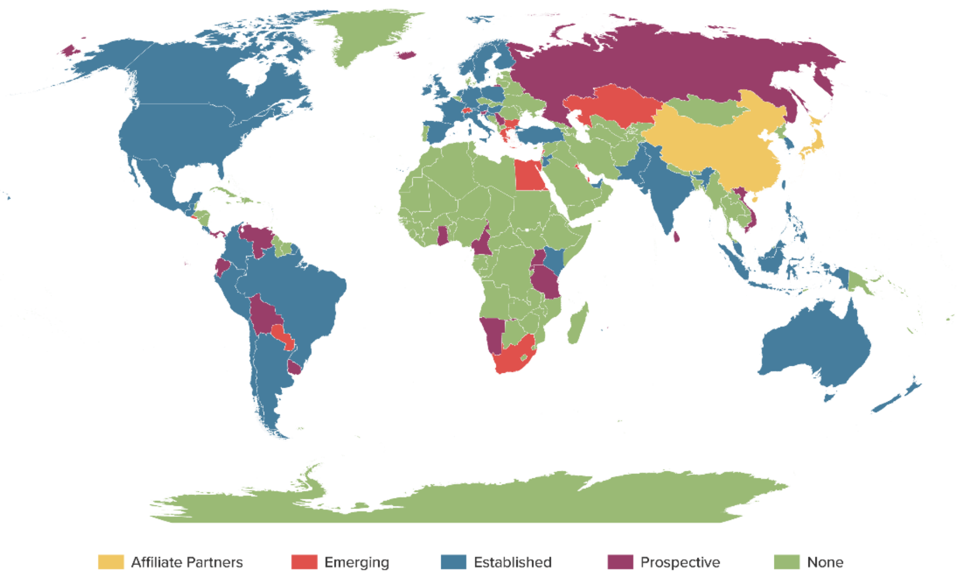
Major non-financial policies and elements of the enabling environments to support lower carbon buildings include green building councils, green building labelling, buildings codes, and equipment performance standards. These policies vary between voluntary and mandatory, the level of ambition, and how stringently they are enforced. When looking at policies and non-financial instruments, green building certifications have been the most ambitious programs to demonstrate low-carbon measures in buildings at scale. In developing countries, gaps still exist in the establishment of National Green Building Councils and in the adoption of mandatory building standards.

Beyond policies that effect individual buildings, spatial planning and city level climate action plans can reduce emissions from the building sector through compact development, and can reduce emissions from other sectors, such as transportation, land use, and infrastructure construction that are linked to buildings (GlobalABC, IEA, and UNEP, 2020).

5.2.1 GREEN BUILDING COUNCILS

Green Building Councils are non-governmental organizations can take up the role of coordinating entity for the design and construction industries, supporting the enabling environment for green buildings policies. The most prominent of which coordinate construction actors, equipment providers, energy service companies, and disseminate resources to potential customers and project developers. They can also monitor national progress and implementation rates.

Figure 7. National Green Building Councils



*The World Green Building Council defines three membership levels: "**Established** - a fully developed and operational organization that is running impactful green building programs of work – delivering change on a national level, and embracing best practice governance, accountability, and transparency. **Emerging** – an organization open to membership, and which has a strong foundation such as an elected board and staff to manage day-to-day operations. It is expected to progress to Established status within 24 months. **Prospective** – an organization at the early stages of development but which has put in place a comprehensive strategy on how it will operate and advance green building in its country. It is expected to progress to Emerging status within 24 months." **Affiliate Partners** are organizations that collaborate with the World Green Building Council but are not members.*

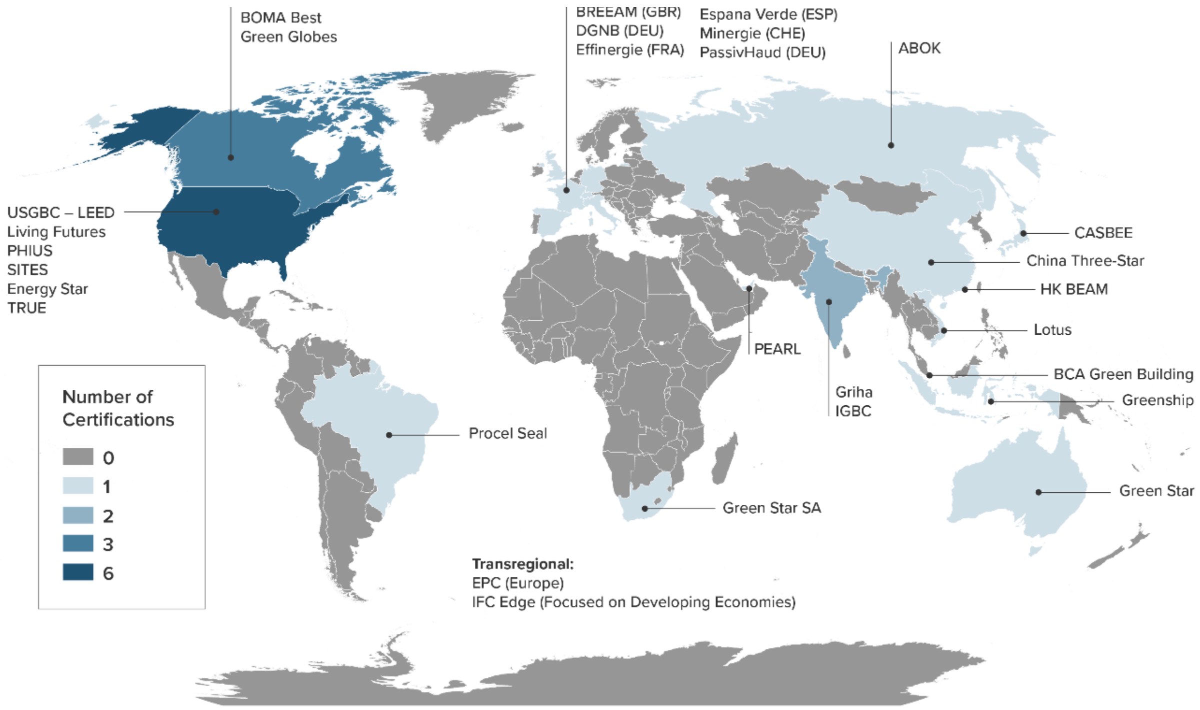
Underlying data retrieved from World Green Building Council in December 2021, available at: https://www.worldgbc.org/our-green-building-councils

5.2.2 GREEN BUILDING LABELS

Green building labels are ratings or certifications for buildings that meet certain level of performance against a set of environment and energy-related criteria. They are usually voluntary standards that exceed mandatory building codes and are managed by non-governmental organizations such as green buildings councils. Some green building certifications are well-established with over three decades of use such as PassivHaus, Leadership in Energy Efficient Design (LEED), and Building Research Establishment Environmental Assessment Method (BREEAM).

Despite concerns about the actual performance of the buildings they certify, green certifications are undoubtably the most ambitious formal programs that demonstrate the implementation of low-carbon measures in buildings at scale (CPI 2021b), **however their use remains limited.** Their use is heavily centralized in the global north, where they originate from. Indeed, out of the 24 green labels we examined, only six were based in non-OECD locations (China, Singapore, Hong-Kong, South Africa, UAE, Brazil). To tackle that gap, the IFC created the Excellence in Design for Greater Efficiencies (EDGE) certification targeting green building in emerging economies.

Figure 8. Green Building Certification Adoption

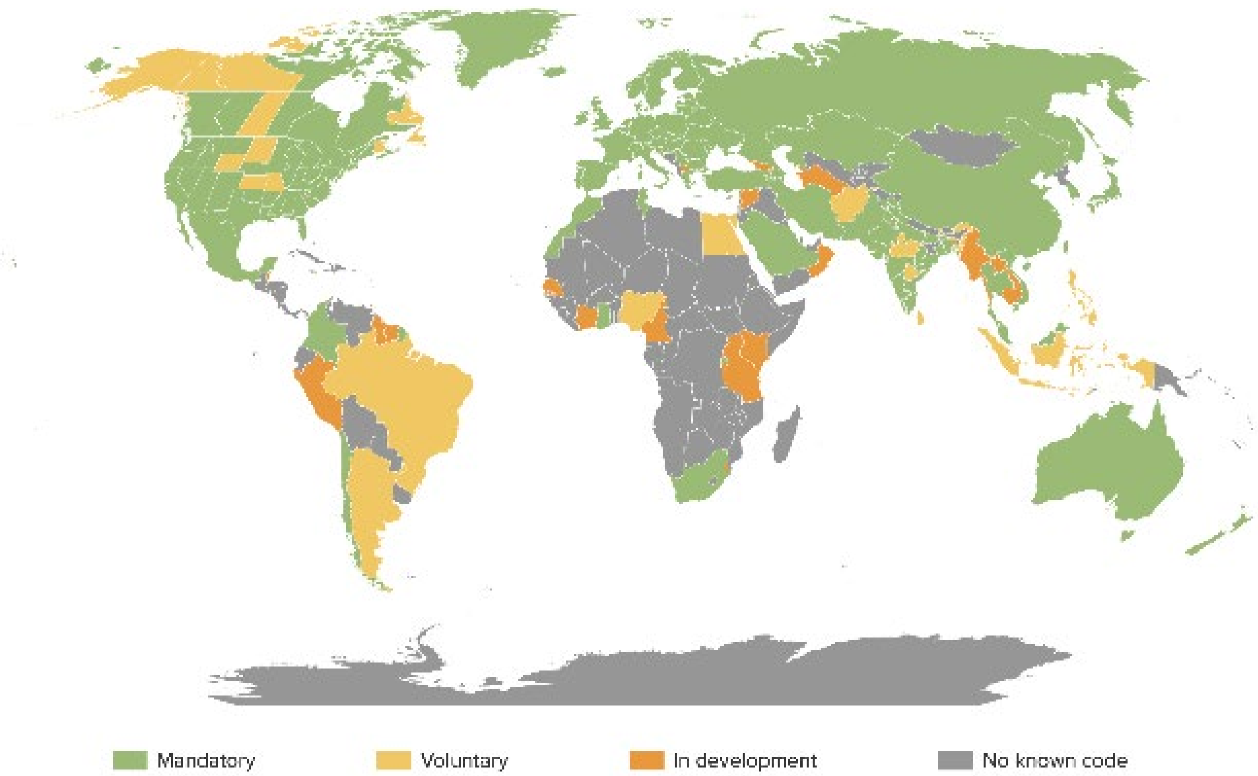


Source: CPI 2021b

5.2.3 BUILDING CODES

Building codes are powerful policy tools to make low-carbon measures in the buildings sector mandatory. They set minimum standards for new buildings related to structural stability, life-safety, and energy efficiency. Buildings codes can also set standards for equipment installed in buildings. However, to be effective, building codes require high enforcement and control capacity, as well as political will. Most of the established building codes are defined at the national or regional level, heavily focus on new constructions, and do not enforce standards stringent enough given the required targets. Mandatory building codes are lagging in South America and Africa (Figure 9), however some countries already rely on voluntary codes, while others are developing new ones.

Figure 9. Energy efficiency building code adoption



Reproduced from IEA 2021c.

Building energy performance standards are policies that complement building codes by applying standards for existing buildings. Several policy types exist, including:

- Single standards require all building of a certain type to comply with an energy performance threshold by a specific date
- Progressive standards create interim energy performance targets
- Deep renovations require least performing assets to be refurbished first

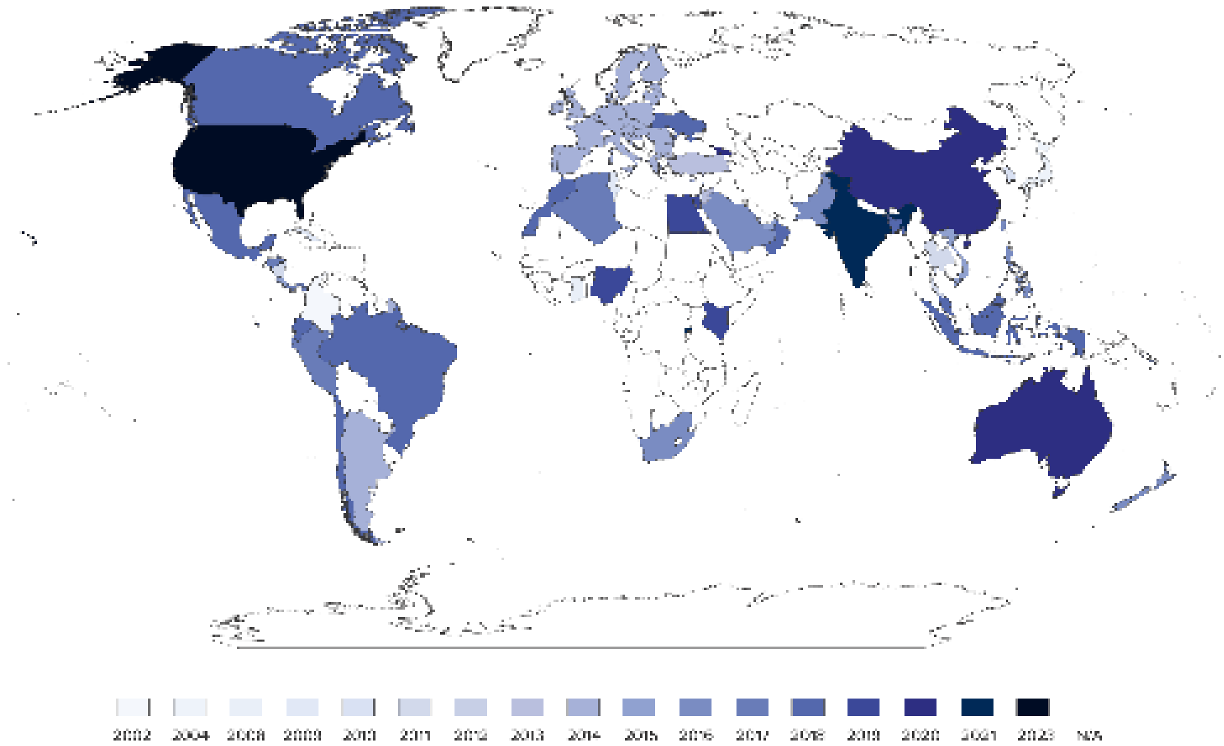
These standards require a heavy monitoring of the energy performance of the existing stock.

In regions where the bulk of the decarbonizing effort will be concentrated in existing buildings, ambitious targets are missing. Energy Performance Certificates in the EU, and Energy Star ratings in the U.S. & Canada, constitute the most utilized and comprehensive monitoring of buildings' energy performance (BPIE, 2021).

5.2.4 EQUIPMENT PERFORMANCE STANDARDS

In regions where energy demand is high or is bound to increase, controlling the minimum energy performance of selected equipment segments can be crucial. As described in the previous chapter, many developing countries will see demand for cooling explode in future years. Most of these countries lack policies to control the sales of poor-quality cooling equipment.

Figure 10. Air conditioner performance standard adoption



Source: IEA Policies database, n.d.

5.2.5 HOW POLICY INSTRUMENTS CAN SERVE THE TRANSITION

The characteristics of a country or city's building stock will determine which policies will have the greatest impact. However, there are some common challenges to the delivery of net zero carbon buildings.

Deep retrofits and new net zero building construction rates remain low not only because of a low demand, but also because of an underdeveloped green building industry. Many regions lack the local know-how and are missing a network of low-carbon construction companies and ESCos. Again, creating such complex ecosystem requires political will and support.

Many countries and cities lack the capacity and tools to monitor their building stock including composition, energy performance, emissions. As a result, building energy codes (e.g., MEPs) are either missing or inadequate. Building codes should be compatible with and derived from the low-carbon building strategy in place.

In high energy use countries, renovation rates remain low. Beyond policies and access to finance, some additional barriers come from how many buildings are managed by slow and complex ownership structures such as owners' associations. Identifying roles and responsibilities is a key parameter to speed up action.

Public incentives and policies tend to favor single-measure action (efficient equipment purchases) over multi-measure action. Single measures do not add up to the overall level of building performance needed for net zero carbon.

5.3 PRIORITIZATION OF FINANCIAL INSTRUMENTS AND POLICIES

Priorities for financial instruments and policies include increased building stock monitoring, science-based performance standards and strategies to enforce them, support to companies that enable locally mastered construction processes, and development of affordable and targeted financial products.

Building and context characteristics shape which policies and instruments are best suited to for specific situations. Table 9 summarizes the policy-based and financial-based intervention priorities in the four building archetypes identified in Section 4. More details are then provided for these four building categories.

Table 4. Instruments' priorities for specific buildings stock characteristics. +: priority, ++: strong priority.

Element	New buildings low energy use	New buildings high energy use	Existing buildings low energy use	Existing buildings high energy use
Country/Region examples where element will be prominent	*Sub-Saharan Africa, India, Indonesia*	*USA*	*China*	*USA, EU, Russia*
Performance-based Targets & Building Code	++	++	++	++
Energy performance monitoring of new buildings	++	++	+	+
Stand-alone Equipment MEPS & energy labels	++	+	++	+
Support to Low-carbon buildings sector	++	++	++	++
Creation of tailored financial products for new net zero constructions	++	+		
Support Low-carbon buildings sector & develop net zero buildings know-how	++	++	++	++
Scale up private finance offering for low-carbon HVAC & on-site generation	++	+	++	
Identification and monitoring of high energy use buildings		++	++	++
Enable financing solutions that require limited down payments & creditworthiness	++		++	
Public financing to enable deep retrofits in least efficient buildings & poor households		++	++	++
Streamline private finance solutions that target deep retrofits		++		++

New buildings in low-energy use countries:

- **Performance-based targets & building codes:** Developing science-based and country-specific asset-level performance targets is key in countries with fast-growing building stocks. To help national and sub-national governments deploy and enforce relevant energy standards, Development Finance Institutions (DFIs) should provide technical assistance and capacity building.
- **Equipment MEPS & energy labels:** Beyond building codes, the high electrification rate profile of these countries demand updated regulatory framework to ensure efficient electrification and prevent maladaptation (e.g. mass roll out of inefficient Air Conditioning equipment). Again, DFIs are needed to support with technical assistance and capacity building.
- **Support to low carbon buildings sector:** To make any transition feasible, creating a local green building expertise, offer, and networks remains central. The implementation of a net-zero strategy relies on established green building councils (public finance needed) and financial support to local construction and energy companies, especially those that promote local construction materials (public and private finance).
- **Creation of local and affordable financial products to support new net zero construction.** Households' and businesses' access to finance is a key obstacle in most of these countries. Improving accessibility demands harnessing both public and private finance to develop domestic financial institutions' affordable and net zero building-oriented offer (mortgages, leases, etc.)

Existing buildings in low-energy countries:

- **Identification and monitoring of high energy use buildings**: In lower energy use countries with slow building stock growth, missing data is preventing public bodies from tracking top emitting buildings in order to prioritize them. Again, public and concessional finance for technical assistance and capacity building is needed (e.g., implementation of building passports).
- **Equipment Minimum Energy Performance Standards (MEPS) & energy labels:** As electrification ramps up, mandatory energy and GHG labelling of equipment and appliances is required, especially for heating and cooling where demand is likely to grow the most.
  Support to low carbon buildings sector: Households and businesses need assistance to undertake energy retrofits. Green Building Councils can connect and promote relevant local actors while one-stop shops can provide support by communicating on existing financial incentives and assessing the work needed.

- **Enable financing solutions that require limited down payments and creditworthiness**. Multiple actors and solutions can be envisaged. Utility companies can set up on-bill financing or repayment schemes. Energy Service Companies can provide operating leases and pay-per-use schemes for efficient HVAC and on-site generation equipment. DFIs can provide viability gap financing targeting local ESCOs and utility companies to enable the creation of these schemes.

New buildings in high energy use countries:

- **Performance-based targets & building codes:** In most of these countries, building code requirements for new constructions are not aligned with a net zero target. New buildings' Building Energy Performance Standards (BEPS) should be derived from such target. Adding inefficient, high-carbon, new constructions to the building stock locks in GHG emissions for decades. Moreover, systematically assessing the actual need to construct a new building in these countries is crucial to limit further embodied carbon emissions, urban spread, and materials and resources depletion. Cities can contribute to that assessment through urban planning documents.
- **Incentivize net zero buildings: multi-measure financial instruments with science-based requirements:** Many green instruments use arbitrary requirements (e.g., threshold: energy performance 30% better than baseline). Both private sector and public sector financial instruments should prioritize new constructions that demonstrate comprehensive energy/GHG strategies (embodied carbon + operational emissions).

Existing buildings high energy use countries:

- **Performance monitoring of building stock**: Asset-level data is missing. This prevents an effective refurbishment strategy that would prioritize high energy use buildings. Solutions include building passports through systematic and mandatory building energy and GHG performance audits at trigger points (change in ownership, tenant, new construction, retrofit, etc.)or before a specific deadline.
- **Performance-based Targets & Building Code:** Again, setting Minimum Energy Performance Standards that reflect and are compatible with national GHG emission and sector-specific energy demand targets is an obvious yet hardly implemented measure. These MEPS need to be granular and context-specific. MEPS can be progressive and can aggressively target low performing buildings.

- **Combine public and private finance to scale a just and deep retrofitting strategy:** Public finance can help bridge viability gap for low-income households and small businesses. Financial instruments should incentivize multi-measure retrofits that add up (i.e., that combined, yield the necessary incremental GHG cuts). To that effect, solution aggregators (ESCos, one-stop shops, public bodies) are crucial.

6. COUNTRY DEEP DIVES

To explore country specific dynamics in the buildings sector, we applied the contexts, technical elements, financial instruments, and policies framework to two countries, Nigeria and Indonesia. Nigeria is Africa's most populous country, expected to double its population between 2020 and 2050 (UN DESA 2018). This, paired with current housing shortage problems, leads to significant growing demand for new buildings. The buildings and construction sector in Indonesia contributed to 38% of total energy-related carbon dioxide emissions in 2019, according to Indonesia's International Energy Agency (IEA).

6.1 NIGERIA

6.1.1 CONTEXT

Africa's building stock is expected to double by 2060, as emerging markets will experience the biggest growth in building floor area. Specifically, Africa's most populous country, Nigeria, is expected to double its population by 2050, which, paired with current housing shortage problems, leads to significant growing demand for new buildings (UN DESA, 2018; IFC, 2022; ESMAP, 2021).

Nigeria is notable for having the highest present and future demand for buildings in Sub-Saharan Africa. Nigeria is projected to become the third-largest country in the world and will need 700,000 house units annually by 2050 (PEEB, 2020; UN DESA, 2018).

Buildings are responsible for 55% of CO_2 emissions in Lagos city (GCOM, 2022) compared to 2% at the national level (Climate Transparency, 2021). The low national percentage can be explained by lacking data/ poor metering for electricity, heating, cooling, and lighting, and since most buildings generate electricity by using fossil fuel generators, which complicates the assessment (Climate Transparency 2021; Federal Ministry of Power, Works and Housing, 2016). A significant share of GHG emissions for residential and commercial buildings result from the use of fossil fuel generators and biomass for cooking (Climate Transparency, 2021; IEA, 2019a; ESMAP, 2021; Ministry of Environment and Water Resources, 2020). Demand for cooling is growing due to improving lifestyles, urbanization, and more frequent and severe heatwaves (Federal Ministry of Power, 2016; U4E, 2019). Prices of building materials increased by 300% in 2021, worsening the housing deficit and increasing the use of substandard materials (Gbonegun, 2021).

6.1.2 TECHNICAL SOLUTIONS TO INCREASE ZERO CARBON BUILDINGS IN NEGERIA

Most technical solutions in Nigeria will be applied to new buildings and will need to address increasingly hot climatic conditions. Both passive and – where those are not applicable – active strategies should be pursued to implement cooling more efficiently (Ministry of Environment and Water Resources, 2020). Replacement of fossil fuel back-up generators through Solar-Home Systems, or the use of storage batteries, is also a priority to address emissions from intensive use of fossil fuel generators (Ministry of Environment and Water Resources, 2020; Federal Ministry of Power, 2017).

Clean cooking is also a major need and opportunity for emissions reductions. Just 10% of the population has access to clean cooking, leaving 127 million people and more than 24 million households to cook in an open fire. Smoke causes 78,000 deaths in Nigeria annually, the highest number of smoke-related deaths in Africa ((ESMAP 2021, Nigeria Clean Cooking 2021). The government has set a target of 48% of the population (26.8 million households) using LPG and 13% (7.3 million households) using improved cookstoves by 2030 (Nigeria 2021). The adoption of clean cooking by 30 million households is estimated to reduce about 60 million tons of CO_2 emissions, which will achieve 15% of Nigeria's total emissions reduction target (Nigeria Clean Cooking2021). The rate of adoption by households and institutions has been very slow because of inadequate efforts to scale up domestic production of clean cookstoves, insufficient access to finance, inadequate awareness about the benefits to clean fuels and stoves, weak government policies, no legislative framework, and poor supply chain (Nigeria Clean Cooking2021).

6.1.3 FINANCING INSTRUMENTS

Specialized instruments for net zero carbon buildings are not yet in place, and traditional real estate financing instruments underperform in general. Issues of title validation, exchange rate, high interest rates, land speculation, limited regulatory protection of investors, high cost of building material, and issues relating to building permits have made real estate investment a rather high-risk venture, limiting the confidence of investors (Oluba, 2020). Financial institutions in Nigeria underinvest in real estate due to fear of taking on debt that could become delinquent due to poor construction standards and other quality issues (Owotemu, 2020). Green finance instruments must take this into account, but also have the potential to help overcome these wider structural barriers. Contributing to all major general barriers to the development of buildings, the enabling environment for private sector to invest in green buildings is still lacking, making it currently difficult to finance green buildings.

Green Sovereign bonds are part of the financing mechanisms identified to execute Nigeria's NDCs and could have an important role in the construction of green buildings, to accelerate the installation of Solar Home Systems (Oguntuase and Windapo, 2021).

Nigeria's mortgage market is severely underperforming (Oluba, 2020). Green mortgages could tackle part of the underperformance of the mortgage industry, through discounted rates for green home buyers and higher quality housing. Certification systems can help support green mortgages, as they assess buildings in a quantitative way to produce a simple score or rating (Abisuga and Okuntade, 2020; Owotemu, 2020).

6.1.4 POLICIES

Green buildings are not part of the larger picture of climate initiatives in Nigeria due to lack of legislation, planning, execution, coordination, and monitoring. Nigeria has several national and state policies that address elements of buildings sector decarbonization through clean energy access, energy efficiency, and clean cooking. The country's NDC and other plans do not tackle strategies in the buildings sector related to construction materials or design, but established targets for clean energy efficiency on buildings and clean cooking. The main strategies consist of expanding off-grid solutions, especially Solar Home Systems, and the expansion of LPG, electricity, biogas, and solar cookers. The NDC also mentions the need to future building standards to adapt to extreme weather conditions.

Table 5. Green building policies in Nigeria

Stakeholders/ actors	Clean Energy Access/Efficiency	Clean Cooking	LPG gas	Cooling	Design/Material	Certifications
Nationally Determined Contribution	X	X				
Nigerian Economic Sustainability Plan	X		X			
National Action Plan to Reduce short-lived climate pollutants		X	X	X		
Nigeria Building Code						
National Building Energy Efficiency Code	X					
National Adaptation Strategy and Plan					X	
Sustainable Buildings Certification Systems						X
Nigerian Electrification Project	X					
Lagos Climate Action Plan	X					

The government must integrate green buildings into their environmental protection agenda through approval of legislation and enforcement. Governments should partner with other stakeholders such as the manufacturers, architects, clients/owners, construction units, developers, and so on, and thrust for more advocacies and the standardization of conventional building materials to guarantee quality, supportability, health, and cost-effective building (Oluba Abisuga and Okuntade, 2020). The approval of a Building Code focusing on renewable building materials, sustainable design and construction, carbon emission, and energy preservation is essential.

6.1.5 PRIORITIES FOR ACTION

The use of fossil fuel generators to address power shortages, expected heat waves, and poor quality of building materials are key contextual elements to prioritize action. **Addressing cooling and building level electricity generation, as well as clean cooking,** are high impact areas for intervention in Nigeria but building the enabling framework for private investment in zero carbon buildings is a necessary precursor to any interventions at scale.

6.2 INDONESIA

6.2.1 CONTEXT

The building stock in Indonesia is expected to grow significantly in the decades ahead. Nationally, the urban population is expected to grow by 65% between 2020 and 2050 (UN DESA 2018). Growth will be concentrated in the Java and Sumatera regions, which will have 80% of the country's population growth. In 2021, the estimated need for new housing units is at 1.4 million per year (Real Estate Indonesia – REI, 2021). However, **embodied carbon in buildings is often very low**, as traditional houses are made from simple materials, such as stone, sand, and clay brick (Surahman, et. Al, 2015).

The buildings sector is Indonesia's third-largest final energy consumer. It accounts for 21%of the country's total energy consumption and is expected to rise to 40%by 2030 (MEMR, 2021). The growing middle-class energy demand in Indonesia means a continued relevance of the buildings sector, where emissions per capita have more than tripled since 1990.

In terms of NDC target and emission, there is no specific "Building" sector or subsector in most official documents. In most cases, buildings are addressed in the household and commercial subsectors under the energy sector. To address rising emissions, the government is pushing for higher energy efficiency in buildings as part of the 29% targeted reduction in emissions by 2030 in the NDC (Indonesia 2021).

A unique context in Indonesia is the establishment of a new capital to replace Jakarta. The new capital, named "Nusantara," will be built in stages through 2045, becoming home to 1.5 million residents and covering 2,560 km^2. Nusantara is intended to be a green city powered with 100% renewable energy, all buildings meeting green building standards, and three-quarters of the city will be green space

(Pocket Book of National Capital Transfer, 2021). The city is expected to cost USD 32 billion and will be financed by the state budget, public-private partnerships, and pure private investments (Maulia, 2021).

6.2.2 TECHNICAL SOLUTIONS

Much of the increase in energy use and emissions is due the growing air conditioning use which will become the biggest energy end use in buildings in the following decade, especially from the residential sector. Addressing the rising demand for cooling has large mitigation potential. Cooling adoption is low, at only 5%, but is expected to grow rapidly in the future and be the main driver of buildings emissions. Cooling systems are set to be the biggest energy-consuming appliance in the buildings sector, with split AC as the most prevalent type of cooling. AC units in Indonesia have low efficiency (GIZ 2017).

The picture for appliances and lighting is mixed. Efficient LED lights have been widely adopted and are cost competitive (CLASP 2021). However, other appliances are inefficient due to low energy prices, low energy performance standards, and limited awareness on the efficient use of electricity, making the overall energy consumption of building in Indonesia is exceptionally high (CPI 2021a).

6.2.3 FINANCING INSTRUMENTS

The challenge for financing has been addressing perceived risks for investors and building owners where ESCOs have so far failed. Financing options for green buildings have been developed, but the demand for them is limited. Energy efficiency projects unappealing because building owners and investors view them as having as high financial risk (CPI 2021a).

This lack of demand has also led to challenges for ECSOs. The two traditional energy efficiency business models offered by ESCOs—shared savings model and guaranteed savings model—have failed to address the business challenges in Indonesia (CPI 2021a).

The primary instruments used to finance green buildings are shown in Table 13.

Table 6. Green buildings financial instruments in Indonesia.

Instrument	Case
Self-financing	Self-financing is the most common way to fund building improvements, but there is very limited data to track self-financing for green buildings.
Green sukuk	The Indonesian government has issued USD 750 million (or IDR 11.25 trillion) of sovereign green sukuk in 2019 and USD 1.25 billion (or IDR 16.75 trillion) in 2018. Green buildings are eligible projects, but categorized light green, meaning the lowest prioritization for funds.
Green bonds	The Bank BRI Sustainability bond framework includes "Green buildings" which use the criteria of three green building certification systems, BREEAM, LEED, and GBCI. Manufacturing facilities may qualify through an independent energy audit with 15% energy efficiency compared to the baseline. Green buildings can be financed with proceeds from BRI's IDR 528 billion (USD 35 million) green bond.
Green mortgage	Two commercial banks in Indonesia offer green mortgages. Bank BTPN has green loan facility for property investment company, PT Kepland Investama at IDR 1.06 trillion, with a tenor of three years. This green loan facility in rupiah currency is one of the first in the Indonesian market. The OCBC NISP provides Green KPR, with lower fees with loan limits starting from Rp. 100 million for houses and apartments that have the GBCI or Excellence in Design for Greater Efficiencies (EDGE) certificate. Green mortgages allow for 10% down payment instead of the 15% for traditional mortgages.

6.2.4 POLICIES

Regulations on green building and energy efficient appliances are in place, but enforcement is lacking. To mitigate the impacts of growing demand, the Indonesian government has set targets to reduce total final energy consumption in the buildings sector (both commercial and housing) by 15% compared to a BAU by 2025 (ASEAN Centre for Energy and GIZ 2018).

The Indonesian government has recently published the overarching regulation on green building for both new and existing buildings. Limited municipal-level regulations for green building predated the national law, but only in the largest cities. Until recently, most of the scope of implementation on the green building criteria is only applied to the new building development, while the criteria of the existing building are not as tight as the new building criteria. The criteria only applied to some types of building with certain minimum sizes and specific uses.

The impact of the legislation setting targets has been limited because until recently there was no national legislation binding local governments to implement this regulation. **There are limited public resources to enforce the green buildings law and no legal consequences if the local governments do not implement it.**

6.2.5 PRIORITIES FOR ACTION

This profile of the buildings sector in Indonesia identifies three priorities:

Implementation of the green building regulations by local governments. The new national green building's regulations will require local governments to increase their capacity to implement green building standards, which to date have only been done by the green building council.

Addressing market failures for green building financing from both the finance supply from FIs and demand from building owners and project developers. This will require educating the market on what green buildings are and mapping the needs for financing.

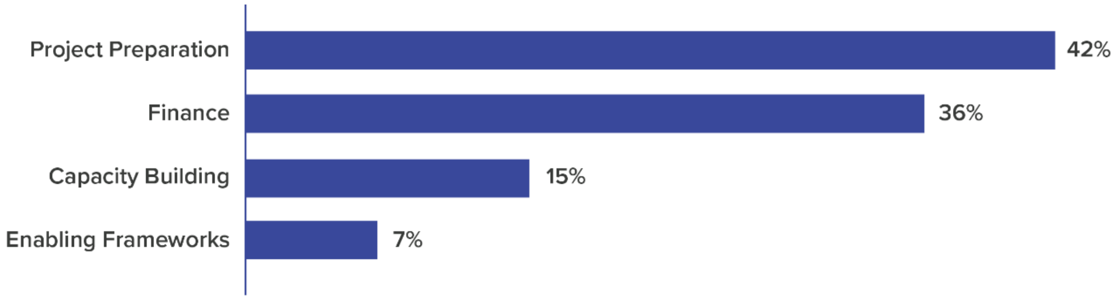
Addressing the energy needs for increased cooling. At the building element level, ensuring that the electricity demand from increased cooling is supplied by clean energy will be critical to expanding cooling access in a way that is consistent with the government's climate targets.

7. CONCLUSION: A ROLE FOR THE ALLIANCE TOWARDS NET ZERO BUILDINGS

7.1 ALLIANCE MEMBER ACTIVITIES

We mapped activities on net zero carbon buildings from 43 different Alliance members[8].

Figure 5. Alliance members' buildings program types



Alliance members' programs and initiatives related to zero carbon buildings are mainly working on project preparation or directly financing zero carbon buildings projects. All members' buildings activities are listed by type in Annex 3. Boxes 1 to 3 showcase some successful examples on how members are working on the zero carbon buildings. These examples show the variety of support that Alliance members work to finance zero carbon buildings at the city-level.

Box 1

Member Program – Program for Energy Efficiency in Buildings

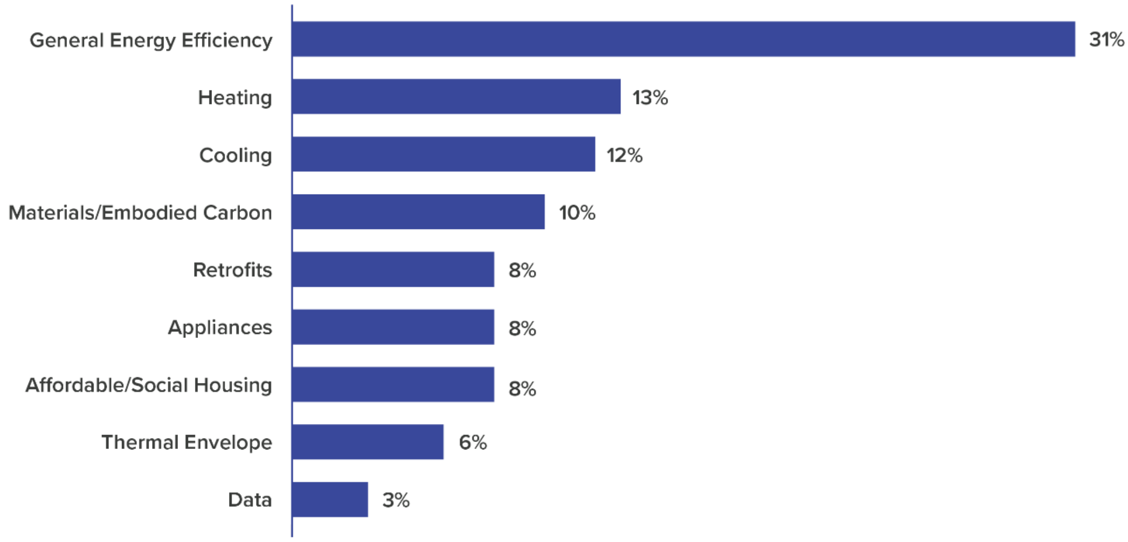
The Program for Energy Efficiency in Buildings (PEEB) combines financing for energy efficiency in large-scale projects with technical assistance through policy advice and expertise for buildings sector professionals

Learn more

[8] Until April 2022 the Alliance had 75 members in total.

Most Alliance member programs focus on general buildings' energy efficiency related activities, while others specified sectors of work such as heating and cooling.

Figure 6. Alliance members' buildings program types



Box 2

Member Program – Building Energy Efficiency in Cities and Regions

The OECD program on Building Energy Efficiency in Cities and Regions supports countries, regions, and cities to enhance their implementation of energy efficiency measures in buildings, through

1. Data and analysis
2. Self-assessment
3. Case studies

Learn more

Box 3

Member organization – Reall

Reall works closely with a broad network of innovative in-country partners across Africa and Asia, strengthening their collective impact to deliver clean, green homes. They offer essential investments, training, and support to implementing partners, to drive development of pioneering green-building solutions and ground breaking housing finance systems – disrupting the market and unlocking homeownership for millions.

Lean more

7.2 POSSIBLE WORK

The scoping process outlined in this paper has helped to identify several areas that the Alliance secretariat or its members could further develop on the zero carbon buildings space. The potential follow-up work is divided into first steps focused on big picture finance and policy needs, focused sectoral work on life-cycle embodied carbon emissions and clean cooling, improved definitions and raised ambitions for net zero carbon buildings, and research on how to support the development of the private net zero carbon buildings market. Although the Alliance will not develop all of the suggested work, it will guide our strategy and implementation in the near future.

7.2.1 FINANCE AND POLICY NEEDS

Initial steps need to be taken to improve information, general regulatory framework, and availability of financing for net zero carbon buildings.

Table 7. Building blocks for policy and finance

Needs / Conclusions	Possible city-level follow up work
Improve information and tracking of existing building stock and related performance.	A study exploring the role that cities can have in improving the monitoring of building stocks and what steps are needed to enable its implementation.
Improve policy framework: Setting up conducive regulatory framework for net zero buildings	A city-level policy guide could cover the main policies used to facilitate investment into low-carbon buildings and how they work together to help cities identify gaps in their policy frameworks.
Improve availability of financing: Support blended finance to scale a just and deep/comprehensive net zero building strategy that enables aggregation.	Cities are ideal hubs for the development of blended finance products and aggregators targeting buildings. A study could identify what measures already exist, and which ones could be scaled up at city level. It would then work as a blended-finance instrument replication guide for cities, highlighting instruments that have been implemented successfully, with guidance on how to replicate them in new settings.

7.2.2 SECTORS

Assess policies and financing instruments that can address life-cycle embodied carbon emissions and prioritize impactful technologies such increasing demand for clean cooling.

Table 8. Sectors focus area and potential follow-up work

Needs / Conclusions	Possible city-level follow up work
Targeted policy and blended finance support to address embodied carbon of buildings.	A study could look at possible policies and blended finance instruments that can be used to account for and mitigate embodied carbon in buildings, by targeting construction and materials sectors, and see how they can be adapted at city level.
Targeted policy and blended finance support for the cooling sector.	A study could look at possible policies and blended finance instruments that can be used to facilitate deployment of cooling strategies and approaches and see how they can be adapted at city level.

7.2.3 DEFINITIONS AND AMBITION

Improve standards and definitions around what constitutes net zero carbon buildings and net zero equipment.

Table 9. Definitions and ambition focus area

Needs / Conclusions	Possible city-level follow up work
Setting up Performance-based Targets for the buildings sector & Net Zero Building Code	A paper could explore the role that cities can have in the assessment of new construction needs and establishment and implementation of Minimum Energy Performance Standards (e.g., through urban planning documents).
Setting up equipment Minimum Energy Performance Standards & energy labels, particularly for HVAC and cooling.	This paper would explore the role that cities can have in the implementation of Minimum Energy Performance Standards for equipment (e.g., through urban planning documents).
Improve and incentivize financiers' assessment (and as a result demand) of actual net zero buildings.	No major role for cities

7.2.4 MARKETS

Explore solutions that can help develop a market for net zero carbon buildings.

Table 10. Markets focus area

Needs / Conclusions	Possible city-level follow up work
Supply-side support to build a Net Zero carbon building sector.	Cities are ideal hubs for the development of local know-how on buildings. A study could identify what knowledge-sharing, and capacity building initiatives already exist, and which ones could be scaled up at city level.
Development of local affordable lending instruments.	A study could contribute to exploring / developing mechanisms that allow cities to contribute to the creation of green mortgages.
Enable business models and financing solutions that require limited down payments and creditworthiness.	A study could provide an initial analysis of how cities can engage with local utilities and technology suppliers/construction companies, into developing pay-per-use/success schemes.

Decarbonizing the building sector and mainstreaming net zero carbon buildings will require work on many fronts. Developing supportive policy frameworks and unlocking finance will be two of the most impactful first steps.

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ANNEXES

ANNEX 1: BUILDINGS MITIGATION STRATEGIES

Table 11. Embodied carbon and materials mitigation strategies

Strategy	Sub-strategy	Description
Reduce construction	Reduce m^2 per capita	Space-efficient designs and non-building solutions reduce material use in new construction. Smaller building footprints reduces embodied and operational emissions but can require social and cultural changes (Circle Economy 2021).
	Extend life of existing buildings	Extending the life of existing buildings through maintenance and renovations reduces the need for new construction. Extending a building's life can be very low cost compared to replacing it with new construction, but it is difficult to scale depending on buildings' suitability for new uses. Extending buildings' lives relies on building owners and users to maintain buildings well (Circle Economy 2021).
	Design structures for adaptive reuse	Designing new buildings for adaptive reuse makes them flexible to changing needs. This extends the life of existing buildings and reduces the need for new ones. Design for adaptive reuse can increase embodied carbon and upfront costs if a stronger structure is required (Circle Economy 2021, AIA 2020).
Material efficiency	Lightweight structural design	Concrete and steel are the most common structural materials. Designing for material efficiency can reduce steel and concrete use by a third. Lightweight designs can have little to no cost premium for materials but can increase design costs and reduce opportunities for adaptive reuse (Pool 2020, IEA 2021b, Circle Economy 2021).
	Structural material is finish material	Finish materials like gypsum, carpet, and drop ceilings can be omitted by using structural materials like mass timber, concrete, and brick as finish surfaces (Architecture 2030 N.d., Concrete Centre 2016).
Low carbon materials	Decarbonizing manufacture	Switching to clean sources of heat for steel and cement manufacturing, alternative cements, carbon capture, and CO2 injection can eliminate energy emissions and chemical process emissions form the most common building materials (Project Drawdown 2022, IEA 2022a, IEA. 2022b, Circle Economy 2021).
	Renewable materials	Renewable materials such as wood, straw bales, unfired bricks, and rammed earth have lower carbon intensity and carbon neutral with sustainable management (GIZ 2021, Architecture 2030 N.d., Circle Economy 2021).

	Material reuse	Reusing materials such as bricks, steel, and CLT extends the useful life of the embodied carbon. Designing new building for disassembly makes it possible to reuse larger share of building materials (GIZ 2021, AIA 2020, Circle Economy 2021).
Offsets	Offset residual embodied emissions	Some emissions, such as the process emissions from cement calcination will need CCUS or offsets to fully eliminate. Only a third of the cement emissions reductions needed for a 1.5˚C pathway are possible without some form of carbon removal (Bécque et al. 2019, Krishnan et al. 2022).

Table 12. Thermal envelope and passive design mitigation strategies

Strategy	Sub-strategy	Description
High performance façade and roof	Insulation	Insulating buildings can reduce heating and cooling energy use by up to 80%. Some of the most common insulating materials have high embodied carbon, making material choice and lifecycle analysis is essential to optimizing the type and amount of insulation appropriate for specific building. Since insulation improves thermal performance passively, it increases buildings resilience to extreme temperature while reducing operating costs (Krishnan et al. 2022, Project Drawdown N.d., GlobalABC 2020, Architecture 2030 N.d.).
	High performance windows	High performance windows are built to maximize solar heat gain while preventing heat loss on cold climates or minimize solar heat gain while minimizing cool air loss in hot climates. They use technology such as multiple panes, argon gas, and low-e coatings (Project Drawdown N.d.).
	Air sealing	Sealing gaps and air leaks prevents air from bypassing insulation and treated interior air from being lost (US Department of Energy. N.d.a).
Passive heating and cooling	Sun shading	External sun shading can reduce solar heat gain by intercepting sunlight before it hits windows. It can be as simple as shutters or complex as automated shading systems (Architecture 2030 N.d.).
	Cool roofs	Light colored or reflective materials and coatings on roofs that reflect light rather than absorbing it as heat. Cool roof coatings can reduce indoor temperatures by up to 5˚C. Cool roofs can also reduce urban heat island effect because they emit less absorbed heat at night (Architecture 2030 N.d., Project Drawdown N.d.).
	Double roofs	In hot climates, double roofs that allow air to flow freely underneath block sunlight from reaching the buildings main roof and create shaded outdoor space (Architecture 2030 N.d.).

	Evaporative cooling	In hot, dry climates, evaporative cooling uses the cooling action of evaporating water to cool air, either with natural ventilation or fans. Evaporative cooling tower, cisterns with stack ventilation, fountains, and swamp coolers are all evaporative cooling approaches (Architecture 2030 N.d.).
	Thermal mass	Buildings can use the tendency of some materials, particularly masonry, brick, and concrete, to change temperature slowly, which can reduce temperature swings from day to night. Thermal storage walls use large windows to capture solar heat during the day that releases at night. Thermal mass can also be used to keep interior cooler during the day hot dry climates with cool nights year-round (Architecture 2030 N.d., New Zealand Ministry of Business, Innovation, and Employment N.d.).
	Building orientation and morphology	Building form and orientation affect passive thermal performance in complex, site-specific. Exposure or protection to the sun and prevailing winds will affect buildings' heating and cooling needs. Opportunities to take advantage of buildings orientation are often limited in dense, urban sites (Architecture 2030 N.d.).
	Natural Ventilation	Natural ventilation makes use of wind and temperature gradients within buildings to cool their interiors. Cooler outdoor air can be pulled through a building with cross-ventilation; the tendency of hot air to rise can be used to pull cooler air up through multiple floors of a building; wind-catchers are towers that catch prevailing winds and funnel down through buildings. Natural ventilation regulates building temperatures with no operational energy use when outdoor temperatures are moderate, but it must be stopped, and buildings sealed when they are being actively heated or cooled (Architecture 2030 N.d.).

Table 13. Heating and cooling (HVAC) mitigation strategies

Strategy	Sub-strategy	Description
Electrification	Geothermal heat	Geothermal heat pump systems, also called ground source heat pumps, are systems that are either closed or open loop systems to transfer heat between the building and the ground. Closed-loop systems pipe water or an antifreeze solution pump water into the ground or a body of water that has a stable temperature year-round. Open-loop systems use groundwater or surface water directly. Geothermal systems can provide efficient heating and cooling, including at district scales, but they are expensive, and their suitability is site dependent (US Department of Energy. N.d.b, Root et al. 2021).

	Heat pumps	Heat pumps are highly efficient systems that provide both heating and cooling. The IEA estimates heat pumps can meet 90% of buildings' heating and cooling needs. Heat pumps are the most efficient heat source; however, they are more expensive than single-function air conditioners, are less effective at extremely cold temperatures, and rely on refrigerants that are potent GHGs (Project Drawdown N.d.).
	Air conditioners	Air conditioners (ACs) are single-function heat pumps that cool air. ACs provide lifesaving cooling in extreme heat conditions, but they are energy intensive and rely on refrigerants that are potent GHGs, making them best suited in tandem with passive design and efficiency measures (Project Drawdown N.d.).
	Solar hot water heaters	Solar hot water heaters use sunlight to heat water. Different designs allow them to perform in most climates, even when air temperatures are below freezing. They are very energy efficient since electricity is used only to pump water if needed. However, they require roof or unshaded outdoor space and thus are not as suitable for mid and high-rise buildings (Project Drawdown N.d.).
Energy efficiency	Higher efficiency equipment	Equipment efficiency improvements reduce the energy needed to produce the same outputs. More efficient equipment has higher upfront costs, but most will have lifetime cost savings through reduced energy use (Project Drawdown N.d.).
	Energy recovery	Energy recovery systems use the residual energy from exhaust air or water to treat incoming air or water. This reduces the amount the water or air needs to be heated or cooled for use (RTM Engineering Consultants 2016).
	Water use reduction	Water efficiency measures that reduce hot and chilled water use, such as low flow showerheads and faucets, efficient dishwashers, and high efficiency washing machines lower building energy requirements. In addition, reducing overall water use reduces energy needed to treat and transport water, though that is not included in buildings energy or emissions calculations. Reducing water use requires conserving behavior changes so that water use does not rebound after the installation of efficient fixtures and equipment (Project Drawdown N.d.).
	District heating and cooling	District heating and cooling uses centralized plants with higher efficiency than is possible for single building systems. District heating and cooling is only appropriate to dense areas with short transport distances (Project Drawdown N.d., IEA 2021d, Root et al. 2021).

Table 14. Appliances and lighting mitigation strategies

Strategy	Sub-strategy	Description
Fuel substitution	Clean cookstoves	High efficiency cookstoves reduce fuel use, emissions, and other air pollutants (Project Drawdown N.d.).
	Electric Appliances	Replacing gas and biomass fueled appliances with electric ones improves efficiency and makes it possible to switch to carbon-free energy sources (GlobalABC 2020).
	Daylighting	Designing buildings to use daylight to light interior spaces through building orientation, room depth, window design, skylights, and nascent technologies like fiber optic skylights reduce or eliminate the need for electric lighting during the day (Architecture 2030 N.d.).
Energy efficiency	Higher efficiency appliances	Appliance efficiency improvements reduce the energy needed to produce the same outputs. More efficient appliances, including efficient biomass stoves, have higher upfront costs, but most will have lifetime cost savings through reduced energy use (Project Drawdown N.d.).
	LED lamps	LED lights are highly efficient, recyclable, and longer lasting than other light technologies. The IEA projects LEDs are on track for 100% market share by 2025. LED's currently have higher upfront costs than less efficient bulbs, but costs are declining (Project Drawdown N.d., IEA 2022c).

Table 15. Electricity generation mitigation strategies

Strategy	Sub-strategy	Description
Building level generation	Renewable generation (Solar PV and Wind)	Solar PV, and to a lesser extend micro-wind turbines, generate on-site electricity. On-site electricity generation avoids transmission losses, is the least cost electrification option for many households that lack access to an electricity grid and can operate independently of the grid or as part of a mini grid which provides resilience benefits. However, building level renewable electricity generation is usually higher cost than utility scale renewable, is not suitable for all building types, particularly mid and high-rise buildings that have a small roof area relative to building size, and it requires trade-offs with other roof space uses (Project Drawdown N.d.).
	Energy storage	Battery storage allows buildings to use building level renewable energy 24/7, replacing fossil fuel powered generators where the grid is unreliable, and providing resilience benefits. However, battery storage is expensive (Project Drawdown N.d.).
Grid decarbonization	Grid decarbonization	The IEA projects that three quarters of electricity used by buildings will be supplied by grid electricity, making decarbonizing the power sector a crucial enabling condition for net zero carbon buildings (IEA 2017a).

ANNEX 2: FINANCIAL INSTRUMENTS

Table 23 – Deep dive instrument definitions

Type	Category	Instrument Example	Instrument Short Description
Traditional	Equipment Leases	Operating lease finance	Allows a customer to use Energy Efficiency, Renewable Energy, or other generation equipment without purchasing it outright. Once installation complete, the customer makes regular fixed payments to the lessor on an agreed-upon schedule. (Better Buildings Initiative, n.d.)
Traditional	Equipment Leases	Capital lease finance	In a capital lease, the customer is the owner of the equipment for most legal and accounting purposes during the term. Therefore, the customer must declare the equipment as an asset and the lease payments as a liability on its balance sheet. At the end of the lease term, the customer can purchase the equipment for a discounted bargain price, typically a $1 "buck-out" payment. (Leventis et. al, 2016)
Traditional	Equipment Leases	Solar lease	Solar PV-specific operating leases. For solar leasing, customers pay monthly rent for the panels. A solar lease offers homeowners the option to bypass the upfront costs of solar panels and instead make monthly lease payments to power their homes with solar energy. With a solar lease, the solar company still owns the panels (Better Buildings Initiative, n.d.)
Traditional	Equipment Leases	Tax-exempt lease	A sub-category of capital lease. Also known as a municipal lease, a tax-exempt lease-purchase agreement is a common financing structure that allows a public organization to pay for equipment using its annual revenues. (Leventis et. al, 2016)
Traditional	Commercial Debt	Revolving Loan Fund	Revolving loan funds (RLFs) are pools of capital from which loans can be made for clean energy projects—as loans are repaid, the capital is then reloaned for another project.
Traditional	Commercial Debt	Commercial loan	A commercial loan is a debt-based funding arrangement between a business and a financial institution such as a bank. It is typically used to fund major capital expenditures and/or cover operational costs that the company may otherwise be unable to afford. (Investopedia n.d.)
Traditional	Commercial Debt	Green Mortgage	Green or Energy Efficiency mortgages (EEMs) are discounted mortgages for better performing buildings. (EEMI, 2019)
Traditional	Commercial Debt	Green Mortgage Loan	This type of loan allows a borrower to add lower-cost debt to their mortgage either at the time of purchase of the house or when the property is refinanced. The additional amount is used to finance energy-related improvements. (EEMI, 2019)
Traditional	Bonds	Green project bond	A fixed income debt instrument in which an issuer (typically a corporation, government, or financial institution) borrows a large sum of money from investors for use in sustainability-focused projects. Project bonds deviate from regular corporate bonds in that they are issued to finance a specific project and the bond proceeds are paid exclusively from the cash flow generated by that project, as opposed to the overall revenue of the issuing entity. (Deloitte, N.d.)
Traditional	Land Value Capture (LVC)	Land Banking	A city government pools or assembles the various privately owned land parcels in a given area and prepares a land use plan for the overall area including designating spaces for public infrastructure and services such as roads and open spaces. It then implements the plan and provides the necessary trunk infrastructure. At the end of the process, the government returns to each landowner a land parcel proportional to their original parcel but of smaller size (for instance, 50–60%of the original land parcel)—except that the new land parcel is of a higher value because it is now serviced urban land. The government retains selected strategic land parcels that it auctions or sells at market rates for cost recovery of its investment in infrastructure and service delivery (World Bank, 2015).
Specialized	Energy savings and supply agreements	Power purchase agreements for clean energy	A solar power purchase agreement (PPA) is another way to invest in solar power without purchasing the panels upfront. With a PPA, customers instead pay per kilowatt-hour (kWh) of energy generated. (Better Buildings Initiative, n.d.)

		Energy Performance Contract	Energy Savings Performance Contracting Services or Energy Performance contracts are arrangements between energy service companies (ESCOs) and their customers that guarantee that the efficiency project will realize a certain amount of energy savings, sufficient to offset the project's costs and debt service payments,
		Energy Services Agreement	Energy Services Agreements are contractual arrangements that allow a third party (ESA providers) to implement EE measures for a customer who then pays them backs through the resulting energy savings. ESA providers retain ownership of the energy conservation measures (ECMs) that they implement; the projects that are supported by an ESA can be financed through debt, equity, or lease financing. (Leventis et. al, 2016)
	On-bill	On-bill financing & repayments (OBR)	Utility or third-party lender (On-Bill Repayment) pays the contractor upfront. Customers repay lender over several years through their utility bills. (Leventis et. al, 2016)
	Property Assessed Clean Energy (PACE)	Residential-PACE	Residential version. Allow a property owner to finance the up front and then pay the costs back over time through property tax bill. Assessment is attached to property allowing the repayment obligation to transfer with property ownership. (Leventis et. al, 2016)
		Commercial-PACE	Commercial version. Allow a property owner to finance the up front and then pay the costs back over time through property tax bill. Assessment is attached to property allowing the repayment obligation to transfer with property ownership. (Leventis et. al, 2016)

Table 24 – Prioritization factors – Which financial instruments can public sources leverage to finance the net-zero building transition?

Actors	Primary investment instruments (proceeds used for primary investments)	Secondary investment & enabling instruments
Governments	Public Funds e.g., City Climate Funds, Revolving Funds; Bonds e.g., Municipal Bonds; Equity Financing; Public-Private Partnerships; Property Assessed Clean Energy (PACE); Land Banking	Bonds e.g., PACE assessments on secondary market; Public Funds
Multilateral & National Development Banks	Grants and Concessional Finance e.g., low-cost debt, viability gap funding; Energy Services e.g., Power Purchase Agreements (PPA); Bonds e.g., green portfolio bonds or sukuk; Public Funds e.g., Revolving Funds; Blended finance vehicles; Equity Financing	Grants and Concessional Finance e.g., Technical Assistance; Public Funds e.g., Revolving Funds serving local FIs
Export credit agencies	Blended finance vehicles; Public Funds; Energy Services e.g., Power Purchase Agreements (PPA)	Grants e.g., TA; Public Funds e.g., Revolving Funds serving local FIs
Sovereign wealth funds	Public Funds e.g., Green investment Funds; Blended finance vehicles; Equity Financing e.g., project-level equity; Energy Services e.g., Power Purchase Agreements (PPA); Bonds e.g., green portfolio or project bonds	Bonds e.g., Obligation bonds

Table 25 – Prioritization factors – Which financial instruments can private sources leverage to finance the net-zero building transition?

Actors	Primary investment instruments (proceeds used for primary investments)	2nd investment & enabling instruments
Energy & Construction Companies / Property developers	**Energy Services** e.g., Energy Performance Contracting, Energy Services Agreements, Power Purchase Agreements, Pay-as-you-save **Bonds** e.g., green project bonds **On-bill Financing**	**Bonds** e.g., green corporate bonds
Commercial banks	**Commercial Debt** e.g., Commercial loans, Project-level market-rate loan, Term loans, Green Mortgages + Energy Efficiency loans **Equipment Leases** e.g., Solar Leases, Capital Leases, Operating Leases **Blended finance vehicles** **Bonds** e.g., green project or portfolio bonds **Public Funds** e.g., Revolving Funds **Land Banking** **Property Assessed Clean Energy (PACE)** **Energy Services** e.g., EPCs, ESAs, PPAs **On-bill Repayment**	**Bonds** e.g., green portfolio bonds which proceeds can be used to offer green mortgages
Private equity funds & Infrastructure funds	**Equity Financing** e.g., project-level equity, private equity, equity futures **Commercial Debt** e.g., Syndicate loans, Project-level market-rate loan, Term loans **Equipment Leases** e.g., Solar Leases, Capital Leases, Operating Leases **Bonds** e.g., green project of portfolio bonds or sukuk **Private Funds** e.g., Green investment funds, Revolving Funds **Energy Services** e.g., EPCs, ESAs, PPAs **Blended finance vehicles**	
Institutional investors & Insurance companies	**Equity Financing** e.g., project-level equity, private equity, equity futures **Private Funds** e.g., Green investment funds, Revolving Funds **Blended finance vehicles** **Commercial Debt** e.g., Syndicate loans, Project-level market-rate loan, Term loans **Bonds** e.g., green project of portfolio bonds or sukuk	

Table 26. Prioritization factors – Suitability of instruments by recipient and building type

Type	Category	Instrument Example	Households - Tenants	Households - Owners	Businesses – Tenants	Businesses - Owners	Public – Subnational	Property Developers	Real Estate Asset Owners	Commercial - Small	Commercial - Large	Residential – Small	Residential –multi-family	Institutional/ Public
Traditional	Equipment Leases	Operating lease finance												
		Capital lease finance												
		Solar lease												
		Tax-exempt lease												
	Commercial Debt	Revolving Loan Fund												
		Commercial loan												
		Green Mortgage												
		Green Mortgage Loan												
	Bonds	Green project bond												
Specialized	Energy savings and supply agreements	Power purchase agreements for clean energy												
		Energy Performance Contract												
		Energy Services Agreement												
	On-bill	On-bill financing & repayments (OBR)												
	Property Assessed Clean Energy (PACE)	Residential-PACE												
		Commercial-PACE												

Table 27. Instruments' improvement measure suitability

			New buildings				Existing Buildings		
Type	**Category**	**Instrument Example**	**Single Measure** Efficient Equipment	**Multi Measures** Net-Zero Building	**Electricity Generation**	**Materials and Embodied Carbon**	**Single Measure** Replacement of equipment	**Multi-Measures** Deep Retrofits	**Electricity Generation**
Traditional	**Equipment Leases**	Operating lease finance							
		Capital lease finance							
		Solar lease							
		Tax-exempt lease							
	Commercial Debt	Revolving Loan Fund							
		Commercial loan							
		Green Mortgage							
		Green Mortgage Loan							
	Bonds	Green project bond							
Specialized	**Energy savings and supply agreements**	Power purchase agreements for clean energy							
		Energy Performance Contract							
		Energy Services Agreement							
	On-bill	On-bill financing & repayments (OBR)							
	Property Assessed Clean Energy (PACE)	Residential-PACE							
		Commercial-PACE							

Single measure: One of the following technical elements identified in section 2: HVAC, Appliances & Lighting, Thermal Envelope.

Multi measures: Combination of multiple technical elements identified in section 2. e.g., Thermal Envelope + HVAC + Electricity Generation

Table 28. Challenges and opportunities

Challenges in the implementation of the instrument	Opportunities associated with Instrument
Complex Instruments: Instrument relies on complex mechanisms and involves multiple parties	**Simple Instrument:** The instrument's mechanisms are simple making it easy to set up.
High transaction cost: Often associated with more complex instruments	**Accessible**: Requires little to no credit worthiness. Can be accessed by individuals/organizations that do not have access to most debt products.
Regulatory barriers: The instrument faces some regulatory barriers and requires enabling regulation.	**Flexible terms:** The instrument allows for convenient ranges of terms (tenor, use of proceeds, etc.)
Partial cost coverage: Instrument usually does not cover full project costs. A down payment is usually required.	**Scalable**: The instrument has been used at scale or should be easily scalable
Heavy monitoring: Instrument relies on heavy monitoring, such as use of proceeds and or energy monitoring.	**Affordable:** financial product is affordable – usually lower-cost debt.
Low size cap: Instrument not used above a certain amount	**Delivers impact**: instruments is conceived to or has been used in the past to achieve great energy efficiency reductions and emissions abatement.
Low financial sustainability: Instrument's financial performance is low or fails to deliver positive cash flows	**Low and/or shared risks:** Risks (financial, equipment, performance) is low or shared by multiple parties

Table 29. Instrument challenges

Type	Category	Instrument Example	Complex Instrument	High transaction cost	Regulatory barriers	Partial cost coverage	Heavy monitoring	Low size cap	Low financial sustainability	Accessible	Simple Instrument	Flexible terms	Scalable	Affordable	Delivers impact	Low/shared risk
Traditional	Equipment Leases	Operating lease finance														
		Capital lease finance														
		Solar lease														
		Tax-exempt lease														
	Commercial Debt	Revolving Loan Fund														
		Commercial loan														
		Green Mortgage														
		Green Mortgage Loan														
	Bonds	Green project bond														
Specialized	Energy savings and supply agreements	Power purchase agreements for clean energy														
		Energy Performance Contract														
		Energy Services Agreement														
	On-bill	On-bill financing & repayments (OBR)														
	Property Assessed Clean Energy (PACE)	Residential-PACE														
		Commercial-PACE														

ANNEX 3: ALLIANCE MEMBER ACTIVITIVIES RELATED TO BUILDINGS

Organization	Program/ Output name	Technical Solutions/ Topics	Program type	Website
AFD	Encouraging the acquisition of energy efficient housing	Energy efficiency, Materials and embodied carbon, Operational carbon	Finance, Project Preparation	More information here
	Developing the energy rehabilitation of commercial buildings	Energy efficiency, Operational carbon	Finance	More information here
	Supporting Wuhan's transition to a low-carbon model with the energy refit of public buildings	Energy efficiency, Operational carbon, Thermal envelope	Finance	More information here
	SUNREF	Energy efficiency, Operational carbon	Finance, Project Preparation	For more information here
	Sustainable Energy Efficiency Development in Palestine - SPEED Project	Energy efficiency, Operational carbon, Appliances, Heating	Finance, Project Preparation	For more information here
AFD/GIZ/ADAME	Programme for Energy Efficiency in Buildings (PEEB)	Energy efficiency, Operational carbon, Materials and embodied carbon, Appliances, Cooling	Project Preparation, Finance	For more information here
African Development Bank	Sustainable Energy Fund for Africa	Energy efficiency	Finance, Project Preparation	For more information here
	Ecofridges Initiative in West Africa	Cooling	Finance	For more information here

Asian Infrastructure Development Bank	Financing Infrastructure for Tomorrow	Heating, Cooling	Finance	For more information here
Bank of America	Better Buildings (Sustainable Finance Stream)	Energy efficiency, Materials and embodied carbon	Finance, Project Preparation	For more information here
Bankers without Boundaries	Retrofit and Built Environment	Retrofits	Capacity Building, Project Preparation, Business model	For more information here
C40	Private Building Efficiency Network	Retrofits, Policies, Data collection	Capacity Building, Project Preparation, Enabling Environment	For more information here
	C40 Cities China Buildings Programme	Energy efficiency, Retrofits	Capacity Building	For more information here
	Clean Construction Forum	Data collection, Materials and embodied carbon, Upfront Carbon	Capacity Building, Project Preparation	For more information here
	C40 Cities South Africa Buildings Programme	Policies	Capacity Building, Enabling Environment	For more information here
	Municipal Building Efficiency Network	Retrofits, Policies, Data collection	Project Preparation, Enabling Environment	For more information here
	New Building Efficiency Network	Policies	Capacity Building, Project Preparation	For more information here
C40 CFF	Quezon City business case for solar rooftops on 50 public schools in the city	Energy efficiency, Operational carbon	Project Preparation	For more information here
Children Investment Fund Foundation	Accelerating the cooling transition	Cooling	Finance	For mor information here

Citi Bank/ USAID/ World Bank	Power Africa	Energy Efficiency	Project Preparation, Finance, Capacity Building	For more information here
Cities Alliance	Urban Housing Practitioners' Hub	Affordable Housing, Social Housing	Enabling Environment, Project Preparation	For more information here
Cities Development Initiative for Asia	Ulaanbaatar Affordable Housing, Urban Renewal Project and Heat Supply	Affordable Housing, Retrofits, Energy efficiency, Heating	Finance, Project Preparation	For more information here
	PFS on District Cooling/Heating Co-Generation Project (CCHP) in Xiaolan	Cooling, Heating	Project Preparation	For more information here
Climate and Clean Air Coalition	Clean cooling	Cooling	Project Preparation	For more information here
	Household Energy	Energy efficiency, Heating, Appliances	Project Preparation	For more information here
Climate Investment Funds	Implementation support on Building Energy and Environment Rating System in Bangladesh and a Cool Roof Program in Dhaka	Cooling, Affordable Housing, Social Housing	Finance, Project Preparation	For more information here
Climate Investment Funds/ADB	Asian Green Development Program - Scaling Smart Energy and Efficiency Solutions	Cooling, Heating, Appliances	Finance	For more information here
Climate Investment Funds/ EBRD	Residential Energy Efficiency Finance Facility	Energy efficiency	Finance	For more information here
	District Heating Modernisation Framework	Heating	Finance	For more information here
Climate Investment Funds/ IBRD	District Heating Energy Efficiency	Heating	Finance	For more information here

	Climate Auctions for Energy Efficient Buildings	Energy efficiency	Finance	For more information here
	Energy Efficiency in Public Buildings	Energy efficiency	Finance	For more information here
Climate-KIC	Building Technologies Accelerator	Materials and embodied carbon, Energy efficiency, Retrofits, Operational carbon	Project Preparation	For more information here
Deutsche Bank	Sustainable Finance stream	Materials and embodied carbon, Energy efficiency	Finance	For more information here
Development Bank of Latin America	Energy stream	Energy efficiency	Finance, Project Preparation	For more information here
EBRD	Smart Building	Energy efficiency	Project Preparation	For more information here
	Ceiling Retrofitting Programme	Retrofits, Thermal envelope	Project Preparation	For more information here
	Energy performance contracting	Energy efficiency	Project Preparation	For more information here
EIB	Kenya: EIB backs EUR 180 million initiative to build thousands of affordable and energy efficient homes	Energy efficiency, Affordable Housing	Finance	For more information here
	Ukraine Public Buildings Energy Efficiency	Energy efficiency	Finance	For more information here
	GMP Energy Efficient Buildings	Energy efficiency, Appliances, Cooling, Materials and embodied carbon, Operational carbon, Thermal envelope	Finance	For more information here

	ELENA – European Local ENergy Assistance	Energy efficiency	Finance	For more information here
	Spain and Portugal: EIB and MERLIN join forces to boost the energy efficiency of buildings	Energy efficiency, Appliances, Thermal envelope, Heating	Finance	For more information here
Global Environment Facility/ EBRD	Financing Public Building Efficiency	Energy Efficiency	Finance, Project Preparation	For more information here
Global Environment Facility/ UNDP	Improving Energy Efficiency in Buildings	Materials and embodied carbon, Energy efficiency, Thermal envelope, Upfront Carbon	Finance, Project Preparation	For more information here
GIZ	Energy efficiency in public buildings (China)	Energy efficiency, Retrofits, Data collection	Capacity Building, Project Preparation	For more information here
	Energy efficiency in public buildings (Turkey)	Energy efficiency	Project Preparation	For more information here
	Morocco: green mosque and buildings	Energy efficiency, Appliances, Materials and embodied carbon, Operational carbon	Project Preparation, Capacity Building	For more information here
	Promoting energy efficiency in residential buildings	Energy efficiency, Materials and embodied carbon	Capacity Building	For more information here
	Making buildings more energy efficient	Energy efficiency, Affordable Housing, Social Housing	Capacity Building	For more information here
Gold Standard	Solar Water Heating in India	Heating	Project Preparation	For more information here
	Gold Standard and Mongolian government partner to meet ambition of Paris Agreement pledge	Energy efficiency	Project Preparation	For more information here

Green Climate Fund	Buildings, cities, industries, and appliances	Cooling, Heating, Appliances, Thermal envelope, Materials and embodied carbon	Finance, Project Preparation	For more information here
Green Finance Institute	Coalition for the Energy Efficiency of Buildings	Energy efficiency, Retrofits	Project Preparation	For more information here
	Zero Carbon Heating Taskforce	Heating	Project Preparation	For more information here
ICLEI	Under the Low Carbon Agenda, ICLEI supports local governments regarding energy-efficient buildings through their regional Secretariats (multiple programs)	Energy efficiency, Retrofits, Affordable Housing, Materials and embodied carbon, Operational carbon, Thermal envelope, Cooling, Heating	Capacity Building, Project Preparation	For more information here
IFC/ World Bank	EDGE (Certification)	Appliances, Cooling, Data collection, Energy efficiency, Retrofits, Materials and embodied carbon, Natural Solutions, Operational carbon, Policies, Thermal envelope, Upfront Carbon, Heating	Project Preparation, Enabling Environment	For more information here
Inter-American Development Bank	Energy Innovation Contest: efficient air conditioning	Cooling	Finance, Project Preparation	For more information here
KFW	KFW Loans and Grants for energy-efficient refurbishment and new construction (Certification)	Energy efficiency, Operational carbon, Thermal envelope, Cooling, Retrofits, Appliances, Heating	Finance, Project Preparation	For more information here
OECD	Building energy efficiency in cities and regions	Energy efficiency, Policies	Project Preparation, Enabling Environment	For more information here

REALL	Achieving the SDGs through affordable housing in Africa and Asia	Affordable Housing, Social Housing, Climate/ Building Finance, Appliances, Materials and embodied carbon, Operational carbon, Thermal envelope	Finance, Project Preparation	For more information here
Source SIF	Energy Efficiency in Buildings	Energy efficiency	Project Preparation	For more information here
	Modernization and management of heat supply systems in Tashkent	Cooling, Heating	Project Preparation	For more information here
South Pole	Swiss Smart Heating-Danfoss	Heating	Project Preparation	For more information here
The Climate Group	Built Environment	Materials and embodied carbon, Appliances, Energy efficiency	Project Preparation	For more information here
The Lab (CPI)	PopLuz | Distributed Energy for Social Housing	Affordable Housing, Operational carbon	Finance	For more information here
	Affordable Green Homes	Affordable Housing	Finance	For more information here
	Cooling as a Service	Cooling	Finance	For more information here
UNDP/GCF/World Bank	Investment in Low-Carbon Public Buildings	Energy efficiency	Finance, Project Preparation	For more information here
UNEP	Sustainable Buildings and Climate Initiative	Energy efficiency	Capacity Building, Project Preparation	For more information here
	Sustainable Buildings and Construction	Policies	Project Preparation,	For more information here

			Enabling Environment	
	Sustainable Social Housing Initiative	Social Housing, Policies	Project Preparation, Enabling Framework	For more information here
World Bank	Heat Reform and Building Energy Efficiency Project	Heating, Energy efficiency	Finance, Project Preparation	For more information here
	Clean and Energy Efficient Heating Initiative for Ger Area	Heating, Energy efficiency	Finance	For more information here
	Cooling Facility	Cooling	Finance, Project Preparation	For more information here
	Climate-Smart Mining Initiative	Materials and embodied carbon	Project Preparation, Finance	For more information here
	Energy Efficiency	Energy efficiency	Finance, Project Preparation	For more information here
World Resource Institute	Building Efficiency Accelerator implements local government building policies & programs	Energy efficiency	Project Preparation	For more information here