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Climate Change Mitigation & Adaptation through Publically-Assisted Housing

Theoretical Framework for the IDB's Regional Policy Dialogue on Climate Change

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Executive summary

In both developed and developing countries, sustainable and resilient public housing construction has been described as a convenient solution to the simultaneous challenges of 1) climate change mitigation, 2) adaptation to the impacts of climate change, and 3) insufficient housing supply. Indeed, designing, installing, and maintaining "green" land and construction techniques within national public housing programs has the potential for allaying a portion of these formidable challenges as they are most likely to be realized in the Latin American and Caribbean Region. Sustainable and resilient housing construction also yields long-term economic and social benefits in additional to environmental ones. The vehicles for this solution, however, are complex, constrained, and evolving.

Centrally administered public housing programs that generate newly constructed subsidized units exist in various forms across the region. This ranges from the direct provision of units to low-income households, to the regulation of all units' physical construction, to public interventions in private housing finance that specify physical qualities. Programs can expedite new sustainability and resilience requirements at the national level, but agencies and bureaucracies often lack technical capacity and, most importantly, ample funding. Regional and local issues—like land availability, land use policies, the reliance on energy-intensive materials, rigid construction industry tradition, and occupant behaviors—rise as further challenges to implementation particularly when there is conflict between national goals and local constraints.

Resource gaps could be filled with the increasing number of international financing mechanisms geared towards climate change actions, though the use of these resources may encounter further difficulty in achieving actual greenhouse gas reductions. Private-sector financing opportunities exist as well, since many of the technologies and practices reduce long-term operating costs for housing developers and owners. The gaps in knowledge can be filled by sharing best practices from the architecture and planning professions and in industry and occupant training with an eye towards application in each nation's unique public housing policy and local housing industry.

Fortunately, various design, construction, and site selection strategies and techniques exist that attempt to overcome these hurdles and that may be replicable throughout the Region. While still in nascent stages of development, these strategies demonstrate that "smart" design and land use goals can potentially be met in practical ways. Examples for overcoming these challenges can be found throughout the Americas. This paper defines the problems that new green public housing attempts to address, the physical techniques of sustainable and resilient land use and construction, and the policy and resource questions that currently limit their implementation.

I. Introduction: A tale of three challenges

Throughout the greater part of history, the natural environment and socioeconomic growth were seen as being at odds with one another. At best, human activity could maintain a net minimal impact on the environment while, at worst, it could imperil full ecosystems, air, water, and material resources, and, ultimately, climate. These consequences, in turn, would create further social, economic, and political crises. However, a growing movement in the last few decades examines both the extent to which human activity has altered natural processes and the potential for reframing this relationship. These efforts crystallized in the 1990s with reports from the United Nations' World Commission on Environment and Development (the "Brundtland Commission") and the Intergovernmental Panel on Climate Change (IPCC) among others that sounded alarms regarding the environmental consequences of business as usual (WCED, 1987; IPCC, 1990). It was at this time that the environmental movement embraced market-based strategies for reducing impacts and a "green economy" movement was born. These strategies became especially sophisticated as evidence began to build that addressing greenhouse gas emissions would be a "smart" long-term economic growth tool.

One sector on which this evolving debate has focused is the building design, construction, and land development industry.[1] As a sizable component of the economies of all nations, building was identified early in the movement as an opportunity for change, and the green building movement was formally born with the founding of the U. S. Green Building Council in 1993 and the World Green Building Council less than a decade later (USGBC, 2008; WGBC, 2013). The attention paid to green building stemmed not only from its economic size, but also from its proportionally high environmental impact, including its contribution to global greenhouse gas emissions. This sector requires massive quantities of natural resources for its basic material inputs. It expends a significant amount of energy in both its construction and long-term operations. It also consumes land for its physical placement and, in turn, requires a considerable transportation network which leads to further fossil-fuel burning.

Building and land use activities that consider these impacts are deemed "smart": they consider the economic, societal, and environmental costs of short-term actions (like cheaper inefficient light bulbs that must be replaced regularly) weighed against more suitable long-term plans (like slightly more expensive but longer-lasting energy-efficient bulbs). While the goals became clear, new strategies were explored in every component and activity related to the sector.

In short, the move towards green building is not only viewed as helpful for addressing a wide cross-section of environmental challenges, but also as essential for climate change mitigation and adaptation in particular. In its earliest stages, the green building movement was concerned with a wide variety of environmental impacts, including those on water, indoor air, flora and fauna, and non-renewable material sources. With an increased focus on the hazards of human-induced climate change through greenhouse gas emissions, the call to action

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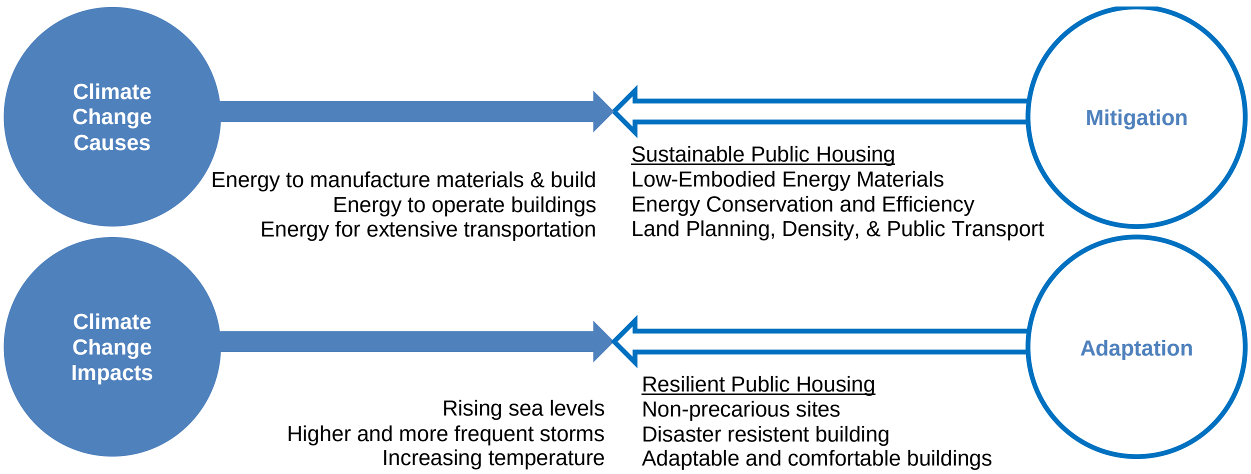
[1] *Recent studies have estimated that improving construction and setting energy efficiency standards for appliances could reduce between 1.4 to 2.9 GtCO_2 by 2020 (UNEP 2013).*

includes reducing buildings' carbon footprint (***mitigation***), and preparing them for the effects of climate change on sea levels and weather-related incidents (***adaptation***).[2]

Mitigation involves directly reducing buildings' energy use—specifically, the amount of carbon-based energy that buildings utilize that directly contributes to greenhouse gas emissions. Mitigation also involves selecting land for building which minimizes the demand for carbon-based transportation and the energy used to construct other urban infrastructure. Environmentally "*sustainable*" building refers to the collective actions that reduce fossil fuel use in the sector and address the challenge of climate change mitigation.

Building and land development are also vulnerable to the effects of climate change and can be adapted to minimize that vulnerability. Adaptation can consist of the selection of construction materials and designs that reduce damage from flooding and storms. The selection of building sites on land that is not prone to these natural disasters is another adaptation strategy. These planning and design actions constitute "*resilient*" development techniques that address the challenge of adaptation to climate change. Exhibit 1 graphically depicts how sustainable and resilient building contributes to mitigation and adaptation strategies.

Exhibit 1. Climate Change Effects and Strategies in Public Housing



Sustainable and resilient building presents an opportunity to mediate environmental and social processes and partially addresses the mitigation and adaptation challenges. However, the volume of building—particularly in growing economies—presents an additional complexity. The demand for building continues and, in the case of housing for low-income households, continues to grow. A third challenge faced by green public housing involves simply meeting this ***housing demand***.

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[2] *Because this paper focuses on the sector's direct and indirect contributions to greenhouse gas emissions stemming from non-renewable energy consumption, other environmental impacts are not discussed further. However, many of the green building or sustainable techniques presented in this paper also address other impacts exclusively or partially along with reduced energy use and greenhouse gas emissions such as water and air quality, land and species conservation, and indoor environmental health effects.*

With limited financial resources, national and local governments face housing demands at the same time as land and building development costs are increasing. Sustainable and resilient strategies may face opposition from the private and public sectors by initially increasing construction and land acquisition costs for new public housing. The costs of changing traditional methods of planning and constructing housing may seem daunting, though the costs are shown to be minimal and recuperated in the long-term (Bourland, 2010). In recognition of this increased costs, the international community has set several mechanisms to mobilize international climate funds for addressing such incremental costs. Climate fund are currently targeted at the $100 billion per year mark, though the use of these kinds of international resources for housing programs has been limited globally.

However, the long-term consequences of not addressing the causes and effects of climate change are likely too great to bear, both on the occupants of public housing and on future public finances. The economic and human toll from more frequent natural disasters, rising sea levels, water salinization, and more variable temperatures and rainfall are predicted to increase (Magrin et al., 2007). All social and economic activities will be harmed, from water supplies and urban infrastructure to manufacturing and industry.

Low-cost alternatives and feasible policies for dealing with the three challenges of climate change mitigation, adaptation, and housing deficits must be explored. In short, harnessing all available international funds, technical advances, and existing local housing policies to this end is an imperative. Given the projected economic growth for the region, Latin American and the Caribbean have the opportunity to take small actions today that could prevent future emissions tomorrow. This document reviews the challenges and opportunities associated with the construction of new publicly-assisted housing programs for the climate change mitigation and adaptation plans in the Latin American and Caribbean region.

II. The challenges

The link between greenhouse gas emissions from human activities and climate change has been confirmed. Preventing global average temperatures from escalating beyond 2 degrees Celsius this century would require that no more than 20 gigatons (Gt) of CO_2 be emitted by 2050. Under current population growth projections, this implies a 40 percent decrease in current emissions levels worldwide. It is estimated that 1.4 to 2.9 Gt of those 25 Gt could come from energy efficiency measures in new and existing construction and related sectors globally.

Over the last few years, the evidence base for describing the relationship between human activity and climate change over all and predicting the effects of climate change has improved. Yet, there are currently still very little data at the national level that tease out the role from and impact on public housing. Information on the average energy consumption in public housing units from which emissions might be calculated is also generally not available. In some cases in the Americas, like Brazil and Mexico, there is limited information about the sector-specific emissions from the broader building and development industry (Matzinger, 2009; Johnson, 2009). Regardless, global estimates can help provide an overall assessment of the current state of emissions, climate change impacts, and housing demand in the region.

A. Climate change causes and mitigation

The entire region's emissions account for about 11 percent of the global total (IDB, 2013). A wide set of activities contribute to this total count, such as deforestation. However significant emissions come from transportation, energy use, and land use changes associated with urban development. This especially includes building construction and use (including new public housing developments), though at a relatively small rate of direct contribution. include those activities that can be categorized between the greenhouse gas emissions in the region from both construction and transportation sources that require mitigation on the one hand, and the risk and vulnerability from the resulting climate change on the other. Annexes 1 and 2 provide more detailed accounts of greenhouse gas emissions for all nations in the region per capita. Not surprisingly, those nations with higher economic output and populations in the region like Mexico, Argentina, and Brazil tend to have significantly higher emissions. On a per capita basis, however, there are also a few smaller nation states that have high per capita emissions like Aruba, the Cayman Islands, and Trinidad and Tobago.

The path of emissions from low -income housing in particular involves multiple channels. The contribution from different activities to any given nation's emissions varies tremendously. There are three primary channels of energy consumption associated with housing: transportation from housing to other locations; production and manufacture of building materials; and electric and gas usage of occupants. All three are a source of greenhouse gas emissions when the energy used in their activity is produced by fossil fuels. Annex 3 illustrates some examples from the region of this variation.

Transportation accounts for over 13 percent of total global emissions, three quarters of which is from vehicle or road transport alone. In Latin American and the Caribbean, the proportion is a slightly more modest 8 percent of total emissions. As Annexes 4 and 5 demonstrate, transportation in individual nations in the region can be significant sources of emissions and, in some cases like Costa Rica, Guatemala, Haiti, and Paraguay, can be the largest sources of emissions from fuel combustion activities. While the selection of a housing development's location cannot necessarily predict the future transportation patterns of the housing's occupants, the selection does determine the ultimate distances that the occupants will travel to meet daily needs and, often, determines how they will travel (Condon et al., 2009). Because suburban and exurban land is generally less expensive, public housing projects are often sited there with little attention to complementary infrastructure and transportation access.

Land selection and development result in many key characteristics for the eventual housing and surrounding neighborhood that affect the amount of travelling occupants do and their mode of travel. This plays out in distinct ways depending on the metropolitan region. For example, the density of the housing community is associated with the size of individual units (the smaller of which generally use less energy) and with transportation options and access. Proximity to employment centers, other daily needs and transportation networks also partially determine housing residents' transportation patterns and costs (US EPA, 2013). Some studies estimate that many Latin American cities are seeing reduced densities as they develop (Angel et al., 2010). Though few studies of household travel patterns and behaviors exist for the region's nations, these development choices undoubtedly affect the amount of fuel used and the volume of greenhouse gasses emitted by those occupants.

Yet, transportation affects development as well, as land surrounding active transportation networks tends to be significantly higher priced and, therefore, less accessible to households with modest means. In the case of many rapidly growing metropolises in the region, considering the placement of housing developments quickly becomes a complex patchwork of available and affordable plots of land that may or may not be readily accessible to jobs, schools, food, and other urban needs or to the public transport that can take them there. New public housing, then, could easily exacerbate this problem if their location is not fully considered.

The two other channels primary sources of greenhouse gas emissions in new public housing both relate to the total building industry (including commercial and infrastructure construction beyond residential). The design and construction of housing and its later use produce approximately 30 percent of greenhouse gasses globally, 80 to 90 percent of which are emitted during the course of post-construction building operations. Residential buildings alone account for almost 10 percent of greenhouse emissions on their own, putting it on par with road vehicle transport as being a major source of emissions (UN Habitat, 2011). In the Latin American and Caribbean region, the proportion of greenhouse gas emissions from the building sectors is more modest, accounting for about 8 percent of total regional emissions.

Several other building-related activities also contribute to housing's global contributions. The intensive energy required for producing the many building materials common to the Latin American and Caribbean region is a significant source of emissions, with cement and steel constituting almost 4 percent and over 3 percent of the region's total emissions, respectively. This embodied energy is a particular concern in the construction of new buildings which, by definition, require more and freshly produced materials. The production of plastic construction materials and finishes also relies on fossil fuel energy production. Further, the waste produced during construction and the water used during building use all are directed to landfills and wastewater treatment facilities, both of which typically require energy whose production emits gasses, or the facilities directly emit gasses themselves.

Still, the primary source of greenhouse gas emissions that are most relevant to public housing administrators is the energy used after occupancy in the buildings they finance and develop. Among those nations for which residential sector information is available, though, there are a few whose residential building sectors account for over 10 percent of fuel-related greenhouse gas emissions (Annexes 6 and 7). These include Argentina, Dominican Republic, and Ecuador.

In general and with very few exceptions, energy production for electricity and heat is consistently the highest proportional source of emissions for countries in the region. The production of electricity and heat and the burning of transportation fuels each make up approximately 15% of emissions in the whole Latin American and Caribbean region, where globally these sources make up only 13% and 6% respectively. Because of electricity's and transportation's fundamental role in developing economies, the greenhouse gas effects from these sectors are disproportionately larger. Further exploration of these sources reveals more insight for future solutions.

Among the few nations in the Americas for which end-use residential energy data are available, Brazil, Mexico, and the United States demonstrate important trends. Annex 8 shows exhibits of the proportional end uses of energy in average residential units for these three countries. In Brazil, for example, a relatively equal proportion of energy is used across the three highest end uses: water heating, refrigerators, and air conditioning. In Mexico, water heating and refrigerators also rank highly. In the United States, in contrast, space heating is by far by the highest consuming end use for energy in the average home. By virtue of the fact that most of the nations in the region have more temperate climates than the U.S. and Canada, this is not surprising. However, as standards of living increase in the region, the likelihood of access to air conditioning equipment and other appliances is likely to increase as well. If these nations continue to rely to any degree on non-renewable energy sources, this will also result in increased greenhouse gas emissions.

In all cases, it should be remembered that the current proportion of climate change-inducing greenhouse gas emissions from the region is modest overall compared to the developed world. Further, the emissions which can be attributed to buildings in general and publically-subsidized housing in particular are even more restrained.

However, the expected growth in population and increase in overall urbanization rates will yield consequent increases in the number of housing units needed. Increased standards of living are also likely to demand higher housing quality—including more reliance on cooling and ventilating air systems, more energy-intensive appliances and lighting, and increase water heating without necessarily compensating increases in thermal and structural performance from the structures (e.g., more insulation). As such, the region faces the decision of whether to commit to maintaining its modest contribution to climate change in the future through simple techniques today.

B. Climate change impacts and adaptation

The primary impacts from climate change involve the flooding and storm increases that are likely to affect significant portions of the region (IPCC, 2000). Coastal and low-lying areas in the region are obviously more vulnerable, but this risk is particularly a concern for the small island states whose primary population centers are at or near current sea levels, overlaid by those areas of the Caribbean and the southern U.S. states are prone to hurricanes (IPCC, 2012). Other areas such as mountainous tropical areas or high-slope communities in large urban areas are particularly susceptible to landslides during storms regardless of their proximity to coasts (Alexander, 2005). Many of these vulnerable and sensitive areas on coasts and on slopes have been populated and developed significantly in the last century across the region, including through informal settlement (Bassett and Scruggs, 2013).

The costs from the impacts of the likely 2 degree Celsius increase from human-induced climate change are expected to reach US$100 billion annually by 2050 (IDB, 2013). In the Latin American and Caribbean region, there have been several attempts to further quantify both vulnerability and the capacity for resiliency. For example, the IDB's Prevalent Vulnerability Index depicts the vulnerability conditions of the region's countries by measuring both direct effects of exposure and susceptibility along with the indirect effects of hazard events from socioeconomic risks and lack of resilience (Cardona 2010). For new public housing particularly, vulnerability increases due to poor placement decisions while resilience decreases via inadequate construction.

In many nations, the primary drivers of increased vulnerability and decreased resilience are socio-economic. Increased land values in coastal areas, rapid urbanization, and concentration of infrastructure and capital assets make coastal cities and settlements particularly vulnerable (DeSherbinin et al., 2007). Among these communities, the highest risk populations are those poor and low-income households living in informal settlements whose housing is of poor construction and not connected to public services (Satterthwaite, 2008). Attempts to regularize or resettle these communities into better quality and better situated housing would almost certainly reduce this risk. Yet, the conditions faced by public housing recipients too are likely to be tenuous if their homes are in precarious physical locations (Bull-Kamanga et al., 2003). In some cases, increased housing quality could also lead to increased vulnerability since it may be accompanied by inappropriate construction techniques for the area. This vulnerability becomes a great risk for public housing owners who have increased assets by virtue of their housing. However, there have been few studies if any surveying the location and quality of the current public housing stock in the region—let alone the new public housing stock that is planned for the future.

C. Housing demand

What is known about most nations' public housing, in fact, is not its long-term current or future performance but rather how it has satisfied past housing deficits. The challenge that public housing attempts to address is, in fact, the sheer growing volume of low-income households within a nation living in irregular, precarious, or unsuitable housing. By some estimates, about 36 percent of the region's population will still be living in inadequate housing by 2015, with only 5 percent of families having been helped through public housing programs (Ruprah, 2009). These deficits are both quantitative—that is, encompassing households without housing or that occupy housing that is entirely unsuitable for living—and qualitative—including housing constructed of poor materials, with no or minimal public services or infrastructure, without secure tenure, or that is overcrowded. Recent IDB studies place the total region's quantitative housing shortages at 6 percent of the region's households, and estimates that 31 percent of the

region's households living in housing with qualitative shortages (Bouillon, 2012). The cost of closing all of these gaps is estimated at 7.8 percent of the entire region's gross domestic product, where currently the nations in the region appropriate only 1 percent on housing programs on average. The problem of the region's housing needs is obvious, yet the solutions are not (Rojas and Medellín, 2011; Jha, 2007).

Even less clear is the effect of publically-funded homeownership programs on satisfying this need. The nature of the public housing programs or policies varies significantly across the region in ways that prohibit a conclusive verdict (IDB, 2007). For example, some programs subsidize land acquisition for developers, while others subsidize mortgages or other credit access for the low-income home buyers. In these cases, the value of the actual units on the market is not distorted but the units are still accessible to a wide number of households—assuming these units actually exist and are available. In other cases, physical housing units are directly provided to low-income households. Fewer households are ultimately served than may have been through programs that leverage funds, but there is clearly more ability to specify the physical properties of the housing.

Yet, little is known comprehensively about the physical qualities of the resulting subsidized units in either construction type or location in relation to other amenities and transit. The most pervasive design for the region's public housing units includes basic floor plans of 2- to 3-bedroom units with functioning bathrooms and kitchens in 4- to 6-story midrise concrete construction. While basic electrical and water provision are provided, central air systems are rare and households often purchase window-unit air conditioners, refrigerators, and other energy-consuming appliances after occupancy. Water heating, either through purchased gas or electrical showerheads, ranks among the few amenities.

With regard to siting, anecdotally, most of this new public housing is constructed either in the existing informal settlements whose housing it is meant to replace, or in the outskirts of major cities. In both of these cases, land costs are minimized though there are no or few direct transit lines. Even less is known about the typical owner-occupant behaviors with regard to energy and transit choices after moving in, though many nations provide significant utility subsidies to low-income households. In the case where the price of electricity or combustible fuels is subsidized, the overall costs to the consumer are reduced. Therefore, the household is de-incentivized from conserving energy or purchasing energy-efficient appliances.

For all development types, the cost of land, the expenses from land regulation and zoning, and costs of construction all serve as common challenges in the Region (Bouillon, 2012). For public housing, these barriers have yielded a relatively traditional and rote design and construction model applied on the most feasibly acquired land. In short, the solution proposed by public housing programs is one of adequate shelter for an urgent and immediate population, not one of long-term housing performance necessarily. The challenges that public housing faces are, then, generally different than those faced by authorities who want to reduce their nation's greenhouse gas emissions or increase its resilience.

III. Current solutions

Challenges as significant as those defined above—climate change causes, impacts, and housing demand—are exacerbated by the fact that the key stakeholders in government, the private-sector, and the civil sector often do not understand the connections between them. Public housing agencies and developers do not understand the impacts and challenges of climate change on their products, and environmental analysts and advocates are unfamiliar with the missions, costs, and bureaucracies of getting housing for the poor on the ground. Fortunately, there is some common ground.

The technological solutions for addressing these challenges are straightforward. The strategies that housing authorities can implement include:

1. Reducing energy consumption in building construction, including the embodied energy in the manufacture of construction materials along with any on-site activity
2. Reducing energy consumption in operating and maintaining housing through changes in design, construction, systems, and appliances as well as occupant behavior
3. Reducing households' carbon footprint within the urban environment through reductions in occupants' vehicle travel in going from the housing location to other urban amenities. Vehicle travel is partially determined by the relative location of housing to other commercial and employment locations, urban density, and the existence of other transit options.

To develop resilient new housing, the overall strategy is even simpler. It involves reducing the vulnerability or likelihood of damage from natural disasters, and preparing the building for future temperature increases—all of which are the consequences of climate change—by:

1. Reducing the likelihood of exposure to floods, landslides, and storms through proper site selection
2. Reducing the potential damage from natural disasters through design and construction choices
3. Increasing the flexibility of the structural and mechanical systems for future capacity

Housing authorities have some degree of control over these activities given their management of the development contracts and lending terms, possible land acquisition responsibilities, capacity to generate design and construction specifications, and processes for homeowner selection and training. Effective mitigation and adaptation strategies involve a portfolio of actions and programs rather than a single selection. They also involve bridging national, state, and local governments to pull resources and knowledge, as well as account for program requirements and constraints. For example, national funding caps on housing development could encourage sprawl by forcing developers and homeowners to seek more affordable suburban land. In contrast, local building codes and land zoning may prohibit the types and siting of housing that a national program encourages. More often than not, the details of their implementation can and should integrate local knowledge, technologies, and monitoring as much as if not more than transfer of technologies.

Perhaps the most important parameter for selection of strategies involves the capacity for long-term and constant monitoring and vigilance by public entities regarding the physical performance of units or by the new homeowners in operating and maintaining the units. For example, an energy-efficient air conditioner that is installed by a builder but that is left running constantly while windows are open is not effective technically or economically. For sustainable strategies like energy-efficient design, the actual occupant behavior may counteract the expected housing performance. Resilience through improved construction or site selection can also diminish in the long-term when actions create a false sense of security. All of these considerations should be kept in mind while reviewing the following strategies.

A. Technological and planning instruments

The physical options for sustainable and resilient new housing are well documented thanks to the development of green architecture and construction over the last three decades, as well as the experience of pre- and post-disaster responses in both developing and developed nations.

Sustainable building materials

The selection of low-embodied energy materials is critical for ensuring that the entire building's lifecycle reduces energy consumption. For Latin American and Caribbean countries, this strategy is particularly difficult given the traditional reliance on concrete construction. Increasing the use of substitutes for traditional cement and alternatives to traditional cement-production and installation (like insulated concrete forms, fly ash concrete, autoclaved aerated concrete, and concrete aggregate substitutes) would be the most effective and comprehensive change in material specification. However, indigenous construction techniques like renewable earthen structural components and mixtures (such as adobe, soil-cement brick, and agricultural waste) may be a viable and inexpensive option that reduces environmental impact significantly (UN Habitat, 2012).

Energy efficiency and conservation

Designing and building housing that uses energy more efficiently or conserve energy reduces the total amount of energy—and, therefore, the greenhouse gasses emitted—while providing the same quality of performance (Levine et al., 2007). Current green building programs such as the Leadership in Energy and Environmental Design (LEED) in the U.S., Brazil's Selo Casa Azul, and Germany's Passive House accommodate many of the more effective energy strategies for the region, though strategies that are appropriate to the nation's industrial practices are better received (Kalra and Bonner, 2012). National housing programs and financial products, like Mexico's Hipoteca Verde, have created de facto certification programs by specifying technologies that will be financed. Annex 9 provides a listing of the criteria used by these green building certifications. These vary based on local construction options as well as by specification versus performance approaches. Most of these criteria-based programs include:

- Passive design techniques that maximize heating and lighting (from solar exposure) and cooling (from passive ventilation). These include natural and built shading like overhangs, solar chimneys, window coverings, and green and white roofs. With proper assessment of the site's natural amenities and knowledgeable builders, passive techniques maximize heating and cooling without the need for mechanical systems.
- There is also some evidence that certain structural and mechanical design choices could lead to increased energy efficiencies, such as smaller units in higher density multifamily buildings with stacked utility cores and distribution networks.
- Insulation and window selections at the maximum level appropriate to the current and future temperatures can be added to the framing structure of a home to further reduce any wasted heat or cooling if a mechanical system will be installed or used at any point in the future (including window air conditioning units). Many of the current technologies available are known in the region, but there are local versions of many of these energy-conserving designs and materials with still other innovations that may be developed in local research and industrial development laboratories.
- Transitioning from carbon-based fuels to renewable energy sources may be a national goal but it generally falls outside of the purview of an individual public housing program or development. Site-specific renewable installations are also far too expensive for most public housing in the region. However, some smaller scale alternatives, like solar water heating, may be cost-effective.
- Appliances and lighting that rank highly in energy-efficiency standards or voluntary certifications (like Brazil's Selo Procel, Mexico's Sello FIDE, or the U.S.' EnergyStar) can play a significant role in reducing energy loads.
- Finally, maintaining the hardware for the above strategies falls on the shoulders of the new homeowner, who may or may not be familiar with housing operations and repairs improves long-term performance. This basic training can also communicated good energy conservation behaviors to further reduce energy consumption.

Some of these technologies add to the initial cost of design and construction, but most are demonstrated as cost effective over their lifecycle depending on the specific equipment that is selected, the method of installation, and subsequent occupant use and maintenance. For example, the simple substitution of energy-efficient light bulbs over incandescent bulbs may be more costly but the financial return from electricity savings and longer operable use is significant and relatively quick (EPA, 2013; IEA, 2013).

Sustainable transportation and land planning

Planning, providing, or incentivizing housing near the employment centers and daily needs of households or near public transit that provides access to those locations provides an opportunity to reduce the energy used in vehicle transit. This involves planning for a diversity of activities and housing options within a given neighborhood tied to employment centers or multimodal transportation options (Holway 2011). Improving the infrastructure of public services to allow them to take more loads without extending to the outskirts of urban peripheries is a necessary, parallel activity. Housing agencies might encourage:

- Transit-oriented development (TOD), or residential and commercial building designed with access to public transportation in mind, encourages both reduced auto dependence as well as building density. TODs generally include promotion and careful planning for development around a transportation node whose network connects to other critical urban needs, like employment.
- Increased densities for residential communities is a contributor to reduced personal transit use both because higher density planning has the potential to reduce distances while providing housing for the same size of population, but also because density increased the viability of public transit infrastructure.
- Mixed-income, mixed-use communities reduce distances travelled between employment and urban amenities (or "uses") and potentially diminishes the differential distances travelled by households of different means—a social outcome which, in turn, encourages further density and reduced private auto use.
- Infill development through the rehabilitation of unused or underused plots of land within the center city enhances already existing densities and accessible infrastructure and urban amenities.

Resilient site selection

Land management is an effective tool for reducing the impacts of climate change. Included in the scholarship and practice in this field are land use, planning and zoning, conservation zones, buffer zones, and land acquisition, all of which are local planning techniques. Three primary options exist for selecting sites that are less sensitive to current development (like wetlands) and less vulnerable to future climate change impacts (like floodplains, coastal areas, and hillsides) (Burby, 1998). The first and preferable option is simply to avoid these areas altogether. Another option is to build in or near them but construct barriers of some sort, like levees or dykes. This option is not readily available to agencies focused on individual, cost-constrained housing developments. The third option is to build in or near these areas while taking proper design and construction precautions. Some of these are listed below.

Resilient design and construction

Like energy-efficient construction, many of the design and construction techniques for disaster resistance are tested. For example, designing homes on platforms or stilts will keep occupants, possessions, and primary living spaces away from harm. The use of concrete for base floors or similar structural strengthening will resist hurricane winds. Water-resistant durable materials will similarly resist the damage from flooding (World Bank, 2011). Similar to the energy-efficiency technologies described earlier, these design and construction techniques are often more costly initially but provide savings in terms of reduced damage and repair costs after storms and disasters.

Flexible design and construction

Increasing the flexibility of structural, mechanical, electrical, water, and ventilation systems in housing will allow it to accommodate increased loads in the future. For example, ensuring that electrical systems will be able to handle more volume and more regular air conditioning demands may be needed in the long-term. Similarly, building the connections for installing rainwater harvesting in the future may be needed to avoid any additional energy demands that traditional plumbing systems may require. Though less critical than the other resilient strategies, flexible design is a direct adaptation to climate change's impacts.

B. Policy and capacity-building instruments

The above strategies are technically clear and straightforward, but the political and administrative processes that are available to housing authorities to accomplish these strategies are much more complicated. There has been some evidence that specific policy, capacity-building, and financial instruments have been successful in getting residential developments of all kinds to adapt the above technology and site strategies either individually or in combination with others. The following instruments range from pilot projects and demonstrations to well-established mechanisms.

Building regulations

Because of the dialogue's focus on new public housing, building codes are an appropriate policy vehicle to consider both for sustainability and resilience goals since increased energy-efficiency as well as disaster resistance can be inscribed in these legal mandates. Building codes can also, though much more rarely, specify building materials (which can decrease the use of those with high-embodies energy) and structural requirements in vulnerable areas (such as building elevation in floodplains) (Petal et al., 2008). Developments in the model building codes in the U.S. and Mexico to include more energy-efficient standards supported by national public housing agencies demonstrate this approach. With industry input, these model codes ensure that environmentally desirable strategies are balanced with cost and other practical concerns.

The advantage of using building codes as a vehicle for change in public housing is that it does not burden public housing disproportionately with additional costs of compliance compared to other new housing, though it does ensure a qualitative distinction with the existing housing stock. The disadvantage is that, in many cases, building codes must be adopted and enforced at the various scales of government (including local and state government). Many of these entities do not have the resources or capacity for implementation of codes through a lack of permitting and inspection officials or the local political contexts. Other requirements or incentives often are placed to ensure enforcement, such as mandatory code compliance of homes by mortgage lenders or home insurers.

Further, codes must be regularly revisited and refined in the face of changing socio-economic conditions and technological advances. This is particularly true as advances in climate change mitigation and impacts are known. Yet, more complex codes often increase the regulatory burden on housing developers, thereby increasing costs of construction both through the content of the code as well as its implementation. As an effort to reduce this burden, housing agencies can work with building departments to reduce other regulatory requirements, expedite permits and inspections, and potentially reduce or eliminate the fees associated with typical land transfers and permit applications for low-income housing developments.

Developer requirements and incentives

Barring changes or improvements in the regulations that affect all residential building, public housing agencies can impose a combination of requirements (when contracted directly by the public agency) or incentives (when subsidized through homebuyer subsidies) on developers of affordable housing only. The specifications that developers must meet should be significant enough to make a difference towards the mitigation or adaptation goals, but not so broad as be economically infeasible. Often, they involve specifications from a regionally or nationally known energy or green building seals and certifications. The pilot demonstration of energy-efficient or solar water heaters in Brazil's Minha Casa Minha Vida units is one example. In the program's first phase, developers were offered an additional incentive for including solar water heaters for either multifamily or single-family homes. The second phase introduced requirements on single-family homes. Similarly, but for a much wider set of strategies, the Ciudad Verde example in Colombia demonstrates a sustainable twist to existing public housing development guidelines.

This type of strategy has primarily been used for mitigation-related strategies, like reductions in energy use. However, similar specifications can be used for adaptation strategies that go beyond current building code authority. For example, in areas for which environmental assessments are not required, requirements or incentives for identifying and avoiding floodplain or sensitive coastal lands can be as effective.

While these strategies apply to the developers of public housing only, there are other requirements that could be placed on all developers. For example, "inclusionary zoning," or programs, regulations, and laws which require or provide incentives to private developers to incorporate affordable or public housing as a part of private developments are being tested in many developed nations. These policies allow developers to comply by incorporating the affordable housing into the private developments, building the affordable units elsewhere, or contributing money or land for the production of social or affordable housing into a trust instead of building them. These are often required in exchange for density bonuses or other development incentives. These polices encourage mixed-use communities, often in infill lots. However, they typically extend beyond the authority of public housing agencies.

Land acquisition and assembling

Many lots in critical urban areas are unutilized or underutilized, including ones owned by federal, state, and local governments. Privately-owned abandoned properties are also a potential source for public housing though they require significantly higher investments. One example comes from the Municipality of Rio de Janeiro, whose *Novas Alternativas* (New Alternatives) Program aims at promoting infill development by identifying vacant properties in the downtown area, undertaking the lengthy process of acquiring (or taking) the property, and then rehabilitating the property for low-income housing. Because of the intense time and resources required to acquire these properties, the program is more of an innovative model of environmentally-preferable infill development than a productive contributor of housing units.

Other strategies that have been employed to ensure new public housing developments are sited on land either in central urban locations or with ready access to them have been developer requirements and incentives that often function with subsidies. In Mexico, for example, recent CONAVI subsidies tack on additional funds based on a point system that includes location efficiency. Previous programs in the country, like the heavily incentivized *desarrollos urbanos integrales sustentables* (DUIS, or "integrated sustainable urban developments") also yielded potential models for supporting assisted housing with an eye towards reducing transportation-based emissions.

Education, training, and awareness campaigns

Training and capacity building among both the developer communities and the homebuyers in the region can help lead to the construction of more sustainable and resilient housing, but also ensure that they are appropriately maintained. In many cases, the development community needs additional pilots and demonstrations to reduce the learning curve for implementing new technologies. Creating transparent technological information and forums for manufacturers or technology developers to present their wares to public housing developers can be a convenient, cost-effective way of integrating changes gradually to the new housing units. There has been much success measured in the form of technology adoption with such industry programs.

Likewise, homeowner education and training programs can also help to ensure that units are properly maintained. In some cases, the housing agencies manage properties themselves, or hire contractors to perform ongoing maintenance and awareness paid for by subsidy and household payments. With Mexico's INFONAVIT offerings, for example, *promotores vecinales* (neighborhood "promoters" or organizers), promote long-term community education opportunities as part of the program's funded housing development. Requiring participation in training as a condition for subsidy or loan receipt, providing easy-to-read manuals for homeowner's about their new units, and performing periodic unit visits afterwards can all provide opportunities to ensure that the units continue to meet their designed performance. Creating homeowner associations that provide peer instruction and enforce building requirements can be an even more effective mechanism. To date, however, there have been no rigorous evaluations or evidence of outcomes from these homeowner training programs yet.

Disaster planning and education campaigns

Like energy-efficiency training, a significant educational campaign is necessary to promote developer and homeowner capacity with regard to building and maintaining disaster-resistant technologies as well as running through disaster alarm and preparation scenarios (Pelling, 2003). Public awareness campaigns can ensure not only that damage to physical facilities is minimized but also that occupants are prepared to act in relation to their housing during emergency scenarios (such as the removal of obstructions and waste, and proper emergency safety actions). Several examples exist through the region of initiatives that have used toolkits and community meetings to educate particularly vulnerable populations (UN Habitat, 2012c).

R&D funding

One policy option that received little attention but that has been shown to yield significant outcomes in the long-term is the public support for researching and developing new cost-effective energy-efficient and sustainable housing technologies that can be used in both public housing and the wider market. This strategy also builds on the knowledge and physical materials in the local construction industry, thereby involving the private development community in the pursuit of new technologies and reducing the hesitancy of local professionals to innovation. The products of this research could also yield more cost-effective technologies that are appropriate for the local housing construction industries. Examples of these kinds of R&D program abound in the higher income nations in the region, such as those funded by Mexico's CONACYT and Brazil's FINEP.

C. Financial instruments

Aside from direct regulations or specifications and capacity-building programs, public agencies also play a critical role in regulating and structuring financial markets in support of accessible and affordable credit for low-income housing developers and households. This task is particularly challenging given that some sustainable and resilient technology strategies add upfront costs to traditional design and construction as depicted earlier.

Further, most housing development projects are too small to attract investors and financial institutions. Combined with the disproportionately higher transaction costs that still face these projects, there is limited funding available to these developments beyond traditional development and housing credit. In nations with limited housing finance reforms currently, this is further complicated (UN Habitat, 2005). Though many design and construction improvements provide substantial returns on investment through energy savings, reduced insurance premiums, and minimal repair costs, there is limited financing to bridge the initial cost. As such additional funding mechanisms are needed to overcome these higher initial expenses while considering the longer-term savings that many (especially energy-efficient strategies) will bring.

Clean development mechanisms

The clean development mechanism for financing mitigation strategies developed through the Kyoto Protocol were originally seen as potentially benefitting to the building industries in developing nations and the magnitude of the overall industry's greenhouse gas emissions. However, these mechanisms have largely been underutilized in the residential construction industry primarily because of the significant costs of developing and validating the reductions in emissions and the difficulty in pooling all of the industry's products (Novikova et al., 2006). In fact, though the industry's products play a significant role in emissions *in total*, the products are individually constructed in very small quantities. In the first few years of clean development mechanisms, only 4 out of 149 projects registered related to buildings. One of these did involve a massive residential development in South Africa, though (UN Habitat 2012b). These funding streams for mitigation strategies are not available to cities which may be more likely to harness them for energy-efficient residential developments, and equivalent funding streams for adaptation strategies have not been used at all to date (UN Habitat 2011b and 2011c).

Energy-efficient mortgages (EEM)

Mortgage-backed energy efficiency financing provides additional borrowing capacity for new homebuyers looking to purchase a new energy efficient home or investing in energy improvements in an existing home by including the costs of energy upgrades into the life of the mortgage based on the estimates of savings that the upgrades will provide and the assumption that those savings allow the buyer to take on a larger loan value than if he or she had purchased an inefficient traditional home. In Mexico, an early version of the "Hipoteca Verde" was piloted in 2007 with significant support from international multilateral organizations. This has since evolved into a more robust INFONAVIT credit program that allows developers and homeowners to select from a list of *ecotecnologías* (or, green technologies) that meet certain performance requirements and whose savings can be readily monetized for additional credit. The program provided affordable mortgages with subsidies from other public entities within the federal government (like CONAVI) to low-income households whose homes include a basic package of technologies.

Bulk purchase programs

A final financial strategy that national housing entities may consider involves the development of bulk purchase programs for nationally-sponsored mortgage programs and other publically assisted housing programs. Through these negotiations, agencies work directly with manufacturers to make the price per housing unit of a specific technology competitive with traditional technologies. A disadvantage of this approach is that the volume required to reduce the costs significantly is limited by the expected amount of housing units to be assisted—a condition that is often not achievable. For example, new light bulbs would require a purchase of millions of units in order to make noticeable reductions in a per unit price. Further, as an intermediary, the public agency itself would be responsible for apportioning the actual costs and units between the manufacturers and developers or homeowners. There is some evidence that government procurement improves the rate of private sector purchases of innovations though and, in some cases, could conceivably lead to permanently reduced costs for the technology (Harris et al., 2005). As part of its Hipoteca Verde program, Mexico's INFONAVIT has also solicited bulk rates for developers and homeowners with major suppliers and retailers of *ecotecnologías*, and Brazil's Minha Casa, Minha Vida program did so with the suppliers of solar water heaters on behalf of the developers that incorporated them.

Energy service companies (ESCOs)

An increasingly common financing approach for institutional facility owners in developed nations is the reliance on an energy service company, often called ESCOs. In exchange for a portion of the savings from implementing energy-efficient technologies, ESCOs either provide the upfront costs of energy-efficient upgrades directly or through savings guarantees (US GAO, 2005). They then perform energy audits, implement energy-efficient construction, monitor, maintain, and operate the housing's energy systems in order to ensure the savings. With proper contractual due diligence and vigilance, ESCOs can fill the funding gaps brought on by additional design and construction costs for public agencies, housing developers, or even associations of new homeowners. The key challenge for applying this instrument in the Latin American and Caribbean region primarily comes in ensuring that utility costs are transparent between the energy service company and the housing development, and that the housing development is capable of contracting with the energy service company as a single entity.

Utility on-bill financing

On-bill financing programs work much like ESCOs in that a third party covers the upfront costs of energy improvements. The difference in this case is that the public utility service is the third party, and they recover the costs of improvements through reductions in individual homeowners' utility bills. These reductions are balance by the savings from the improvements. Several on-bill financing programs are being run in developed nations, and have been refined to improve service and user-ease for individual households. For public or private utilities that have greenhouse gas reduction requirements or that run energy-efficiency programs, these programs are particularly attractive. However, this kind of agreement requires significant buy-in from multiple parties, including the public housing entity, the developer, the occupants, and of course, the utility. In LAC, public service utilities would need to have the capacity to incorporate this credit servicing in their billing and either provide financing or collaborate with a third-party financial entity.

Property-assessed clean energy (PACE) programs

Through their periodic property tax assessments, city governments have served as the third party investor for the upfront costs associated with energy-efficient upgrades in new housing. Through revolving loan funds or by floating public bonds, cities are able to pay for upgrades and recoup the costs through the tax assessments. This was a popular financing scheme in the U.S. because the nature of the municipal assessments required that the repayment be tied to the house rather than the household. As such, selling of the energy-efficient home would not deter repayment of the loan, in contrast to some of the financing mechanisms. However, many residential PACE programs were terminated in 2010 after the decision by mortgage guarantors not to allow their liens on properties to be second to municipal liens when those liens were potentially riskier. Commercial PACE programs, however, continue. Depending on the property tax structure for municipal entities in Latin American and Caribbean nations, PACE programs may be a reasonable instrument for financing individual home energy efficiency and renewable energy improvements.

Public natural disaster insurance programs

In contrast to the policy and finance instruments for mitigation approaches for sustainable strategies, there are precious few adaptation instruments for producing new resilient public housing. In fact, the primary instrument for adaptation at the household level is the same as that used for other natural disasters: insurance.

But, publically funded insurance programs have a long and generally troubled history. When insuring municipal or national recovery funds, the costs to governments have generally been exorbitant given the precarious condition that many nations may be facing, particularly less developed ones (Cardenas et al., 2007). Pooling funds, such as that done through the Caribbean Catastrophe Risk Insurance Facility, can assist in sharing this risk across nations in the region (Ghesquiere et al., 2006).

When used to insure individual homeowners, like in the US FEMA National Flood Insurance Program, public insurance can disproportionately benefit wealthier households and, in some cases, subsidize more precarious and vulnerable housing along with being a drain on public coffers. Despite these financial constraints, insurance programs tend to be more aware of and responsive to improvements in building construction. In fact, most insurers are keenly aware of the risks posed by climate change on their relevant properties.

Private disaster insurance incentives

The involvement of formal insurers in homeowner disaster and climate change policies provides the additional benefits of identifying key risks at the level of individual housing units, and incentives for removing those risks through improved construction techniques or appropriate site selection. In this way, private insurance de-incentivizes riskier housing. Given that most lower-income housing is more likely to be vulnerable, public resources are best used to regulate and structure the insurance industry within a nation's borders to promote accessible and equitable insurance policies while still accounting for the actual risks faced by homeowners in precarious living situations. Micro-insurance or other non-traditional methods of pooling risk for the lowest-income households should be explored.

Public revolving loan funds

For both mitigation and adaptation efforts, public entities could develop revolving loan funds to pay for the gap financing needed to ensure that public housing is both sustainable and resilient. In most cases, however, public loan funds are not securitized and can therefore not be brought to scale to a volume that can address the entire public housing need in a nation.

Grants and philanthropic investments

Philanthropic investment can also be used to cover financing gaps beyond that which a nation's housing finance or insurance systems can carry. These can be used for startup costs for pilots, and for training and capacity building among public entities, developers, and homeowners.

IV. Case Studies

Though often limited to the more developed nations in the region, there are many examples of the above instruments for implementing the necessary construction and land use strategies in the Americas. In fact, virtually every country is developing either preliminary action plans through their environmental or housing ministries, or has already developed some of the fundamental building blocks for promoting sustainable housing. These include preliminary voluntary guidelines for sustainable social housing such as those found in Chile (PUCC, 2009). Argentina has an energy-efficient certification program for electrical appliances known as the Sello IRAM. Among nations with more robust or longer-lived sustainable building programs, several examples are worth mentioning. The majority of these exist currently as pilot projects, with full outcomes and impacts yet to be measured and analyzed. Regardless, they demonstrate promising practices for the region.

Mexico: Hipoteca Verda, EcoCasa, and NAMA

Mexico presented the world´s first Nationally Appropriate Mitigation Action (NAMA)—a voluntary activity focused on reducing greenhouse gas emissions—for sustainable new housing in 2010-2011 (CONAVI, 2012a and 2012b). Learning the lessons from its earlier piloting of the *Hipoteca Verde* ("Green Mortgage") and green incentives in its *Ésta es tu casa* ("This is your house") subsidy programs, the NAMA expands the monitoring and validation strategies by to support financing directly to developers: *EcoCasa*.

The original component, the *Hipoteca Verde,* is a version of the EEM instrument described earlier but with a wider purview since the resulting housing could potentially include technologies that benefit the environment beyond reductions in energy use. It provides an additional credit to enable the homebuyer to purchase a home with technologies that reduce the consumption of water, electricity and gas with the expectation that the monetized savings from reduced utility bills in the long run with allow the homeowner to easily repay. To ensure that the appropriate technologies are installed and operate correctly, the homeowner must comply with INFONAVIT's technical verification requirements (and those of CONAVI if a subsidy is provided). This is done through developer-provided verification from a third-party and supplier installations, as well as proof of basic training on use and maintenance to the homeowner (INFONAVIT, 2013).

The developer component, *EcoCasa*, in contrast requires performance verification post-construction. Homes cam meet three performance levels: Eco Casa 1 (which is similar to the original *Hipoteca Verde* requirements), Eco Casa 2 (which is more stringent), and Eco Casa Max (which is equivalent to the Passive House rating system). Mexico's mortgage securitizer, Sociedad Hipotecaria Federal, issues bridge loans to developers that will reduce their expected products' greenhouse gas emissions by at least 20 percent. These loans finance up to 65 percent of the total project costs, thereby covering the additional costs of the green technologies and their verification. The investment funds pooled through the NAMA, including those from multilateral organizations, are directed towards subsidies for developers and mortgages for homebuyers (CIF, 2013).The buyers for the homes can then use Hipoteca Verde products for the purchase. In the current 7-year implementation phase, SHF will reinvest the proceeds of the loans to other eligible projects with a goal of constructing and selling 27,600 houses. These three vehicles are relatively new, yet they are only the latest in almost a decade of pilots by Mexico's National Housing Commission. Earlier, Mexico funded research and development, demonstrations in collaboration with private builders and developers and, most significantly, the creation of a model energy and green building code for the residential building industry.

Information Box 1.
Hipoteca Verde

Period of Existence: 2011-Present

Target Sector: New and existing private housing

Outcome to Date:
- 113,000+ mortgages (2011), 52% with subsidy*
- 4,600 affordable housing units

Expected Outcomes:
- Mortgage issuance (37,530 units)
- Energy (and other) reductions
- GHG emission reductions (3.8 M tons of CO_2)**

Instruments (Technological):
- Sustainable Materials
- Sustainable Energy

Instruments (Policy):
- Developer Requirements
- Homeowner Requirements

Instruments (Financial):
- Energy Efficient Mortgage
- Subsidy (Limited)

Source: * (SEMARNAT, 2011); **(SEMARNAT, 2012).

Colombia: Ciudad Verde

Through the existing program for funding low-income housing known as the *Macroproyectos de Interés Social Nacional* (MISN, or the "National Public Mega-Projects"), the Colombian government has entered into numerous public-private partnerships to increase the housing supply for up to 350,000 low- and mid-income people. The projects are also meant to leverage the knowledge and capacity of developers to improve the amenities available to each development's residents.

The largest of the MISN is the township of Soacha outside of Bogota: *Ciudad Verde* ("Green City") which broke ground in 2010. The project intends to mix 50 percent of land area to assisted housing units with 17 percent for market-rate households, 11 percent for public facilities, and the remaining for green spaces and walkable transit. The development will also connect to the city's Transmilenio's second line. Led by the firm Amarilo, S.A., a consortium of 8 builders and developers received expediting permitting and land transfers in exchange for the overall project concept and the profits from sales (Henao Padilla, 2011; MADS, 2011).

The uniqueness of this MISN lies not only in its size but also in two key characteristics: 1) its location within the metropolitan area of Bogotá and the environmental benefits that this type of infill development elicits; and 2) the unique land acquisition and development arrangement that allowed this specific land to be assembled for assisted low-income housing. The land on which Ciudad Verde is being developed was previously owned privately and by the municipality of Soacha. A market-rate development of this land would have resulted in relatively expensive housing—thereby, eliminating the opportunity for low-income residents. By taking advantage of the economies of scale offered by the size of the terrain, interspersing commercial and retail development to service the new community, and leveraging public funding, the developers were able to maintain affordability.

Information Box 2.
Ciudad Verde MISN

Period of Existence: 2007-Present

Target Sector: New subsidized housing development

Outcome to Date: 20,700 units sold (June 2013)*

Expected Outcomes:

- 42,000 housing units
- 328 hectare development of near infill
- 57 hectares for green space and walkways
- Instruments (Technological):
- Sustainable Transportation
- Instruments (Policy):
- Developer Requirements
- Land Acquisition and Assembling

Source: * (Ciudad Verde, 2013)

Brazil: MCMV y Selo Casa Azul

Brazil is integrating its significant advances with regard to public housing funding on the one hand and energy-efficient housing practices on the other through to major programs: the *Minha Casa Minha Vida* (MCMV, or “My House My Life”), a massive housing development subsidy program, and the green residential construction rating system, *Selo Casa Azul* (“Blue House Seal”). MCMV subsidizes developers of acceptable housing projects as well as the mortgages for qualifying families who earn between 0 and 10 times the minimum monthly wage. The level of production currently underway and expected in the future through MCMV throughout the country provides both economies of scale for the diffusion and dissemination of many green building technologies and practices, but also provides a propitious “learning lab” for the incorporation of many innovations.

Administration and finance are provided through the government-owned Caixa Econômica Federal, which establishes the design and construction requirements for developers (Caixa, 2013). More recently, CAIXA has also incentivized water solar heater installation in the MCMV program by subsidizing the cost of the heater (up to R$2,500 in multifamily and R$1,800 in single-family construction). By 2011, the number of MCMV units with the subsidized solar water heaters surpassed 40,000 (Rodrigues Benevides, 2010).

The Selo Casa Azul (“Blue House Seal”) rating system was launched by CAIXA in 2010 with the goal of promoting green housing development in Brazil (Caixa, 2010). It is a voluntary set of guidelines developed by a team of Brazilian experts, including faculty involved in FINEP’s sustainable housing research programs and follows a similar set of scoring criteria, performance categories, and technological measures as other foreign green rating systems. As detailed in Annex 9, the criteria employed in Selo Casa Azul are similar to those used in other green certification systems globally. The first MCMV development to receive the Selo last year (pictured). Similar to the early promotion of other green rating systems, Selo Casa Azul offers great symbolic value in advocacy, awareness, and in technological possibility. The Selo is also being considered in state public housing programs in São Paulo and Rio de Janeiro.

Information Box 3.
Minha Casa Minha Vida and Selo Casa Azul

Period of Existence: 2010-Present

Target Sector: New subsidized housing development

Outcome to Date: 20,700 units sold (June 2013)*

Expected Outcomes:

- 2,000,000 housing units total

V. Summary

The policy goal of linking public housing with climate change mitigation and adaptation strategies is a necessary vision. It reduces the climate-change inducing greenhouse gas emissions that would have come from this housing otherwise if constructed using traditional methods. It also adopts to the changes in climate that have already taken their toll, such as increased storm and flooding, through proper site selection and disaster mitigation construction. Just as importantly, it satisfies these two environmental demands while still fulfilling its social promise of reducing housing need. The goals and long-term benefits are obvious, and developing strategies for meeting them is smart policy. But, which strategies?

The instruments presented in this discussion can, and in many cases have been, integrated into national housing policy agendas and programs. The challenge for housing officials involves matching their current and planned housing strategies with the available sustainable and resilient housing instruments. In Annex 10, a preliminary crosswalk is provided between the general types of housing programs promoted in the Region and the instruments presented in this document that may be applied within each. In cases in which the state provides housing directly or other physical inputs, public entities can specify sustainable and resilient technologies. For example, a housing program can require that only certain building materials be installed or that only certain lands be made available for development since they act as developer and preliminary owner.

Not surprisingly, most of the financial instruments described in this document are more applicable in contexts in which the state supports private housing markets rather than direct physical intervention. In this context, however, the governments do not need to be completely neutral or agnostic about the physical conditions of the homes that result in the free market. Rather, combining market interventions that financially incentivize sustainable and resilient technologies (like energy-efficient mortgages) with policy instruments that improve the overall conditions of the housing stock (like building codes) can maximize public housing programs' effects on greenhouse gas emissions across all sectors while targeting low-income households appropriately.

However, the actual story is far less straightforward. The magnitude of the actual problem that public housing creates for climate change is still not known on the one hand. On the other, there is still precious little evidence to suggest that proposed solutions will actually address that problem. This is, in fact, a tale of three complex and interconnected challenges. Additional discussion and exploration are needed.

Related issues

This discussion has focused only on the climate change adaptation and resilience outcomes of newly planned and built public housing for ownership by low-income households. This housing, in fact, is only a portion of the wider housing inventory, market, and options facing low-income households in the Latin American and Caribbean region. Other housing types and their respective policy responses play just as much a critical role in determining a nation's climate change and resilience condition, if not more so. These include:

- informal housing and settlement upgrading
- existing housing and retrofitting
- rental housing production and maintenance
- market-rate new housing that serves low-income households and building regulations
- rural housing and public infrastructure and services

Along with the variety of housing types beyond the construction of new publically-assisted owner-occupied units that are not directly addressed in this discussion, there are also a wide variety of environmental conditions beyond those related specifically to climate change. Other critical environmental concerns like water and air quality, indoor air health pollutants, material resources, and wildlife and soil protection also benefit from sustainable and resilient construction and land use—not to mention human comfort issues like acoustics and pest management. Energy-efficient and resilient construction may have some benefit to these outcomes, but is not a solution for all housing construction challenges. Future investigations of the connections and co-benefits between the specific housing types and environmental impacts beyond climate change should make these connections clear.

A final related concern involves cost. The gap between the possible increased upfront costs for many of the sustainable and resilient construction techniques described here and the long-term savings that can be realized during a building's lifecycle is a critical concern to housing authorities with limited resources and large housing deficits. Numerous cost analyses have been performed on the technologies presented in this document, but additional detailed analysis must be performed for each country in the region based on availability of the products and equipment, local energy costs for consumers, and expected use. This is another area for exploration in the region.

Ongoing questions

As some of the solutions presented here are applied in member countries, there is an ongoing quest for more appropriate solutions that are feasible given each country's public finances, the demand for public housing, and their environmental predicament. Numerous questions can guide these discussions:

- What is the extent of the climate change challenge regionally and nationally?
- What are the core technical contributors to public housing's lifecycle contribution to each nation's greenhouse gas emissions?
- Which are the sources of vulnerability and risk in public housing construction and siting?
- How is public housing produced (financed, developed, located, designed, built, and maintained) in each nation currently?
- What experience do other public housing entities have in integrating other non-housing requirements or demands?
- How can this production system address the unsustainable and vulnerable components of physical public housing development and construction?
- How can the users of sustainable and resilient housing be integrated into these housing decisions as well as receive the resources to maintain them?

Conclusion

Fortunately, the building sector is one in which there are many potential synergies between mitigation and adaptation goals. As new buildings are constructed, the design can address both mitigation and adaptation aspects while filling housing deficits. Of the potential strategies and instruments for implementing the strategies presented in this report, those action that provide obvious synergies under current climate and a range of future climate change scenarios, or the "low-regrets measures," should be encouraged and scaled across the region. They offer measurable benefits today and can lay the foundation for addressing projected continued changes in climate conditions.

The instruments reviewed in this discussion include low-cost energy-efficient technologies in public housing specifications, promoting national sustainable and resilient construction standards, revisiting zoning and land use strategies to harness infill land, and extensive capacity building among public officials, private developers, and ultimately the low-income households that will occupy the housing units.

There are tremendous spillover benefits from these strategies and instruments as well, including advancing housing finance systems, highlighting the need for urban transport expansion, and possible water and air quality improvements. Sustainable and resilient public housing programs and policies lead to benefits for both housing agencies and environmental authorities. For housing ministers, these strategies can reduce the long-term costs of building and maintaining housing while providing access to additional funding resources. Environmental ministers that have explicit targets for greenhouse gas reductions and are preparing adaptation strategies to deal with climate change's effects in their nations can see a ready tool in publically-administered housing.

Ultimately, however, there is no single policy or finance instrument that can capture the full complexity of each nation's climate change conditions. A variety of scenarios should be analyzed and actions tested.

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VII. Annex 1. Per capita greenhouse gas emissions (CO_2) in Latin American and Caribbean countries (metric tons per capita), 2000-2009

Country Name	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Antigua & Barbuda	4.44	4.36	4.54	4.80	4.98	4.97	5.10	5.17	5.24	5.35
Argentina	3.82	3.56	3.28	3.51	4.08	4.03	4.39	4.41	4.59	4.37
Aruba	24.58	24.08	23.74	23.25	22.88	22.73	22.55	23.29	22.58	22.63
Bahamas, The	6.03	5.93	6.74	5.93	6.68	6.91	6.94	7.08	7.06	7.29
Barbados	4.45	4.55	4.56	4.68	4.76	4.95	4.99	5.16	5.42	5.64
Belize	2.89	2.90	1.43	1.45	1.44	1.46	1.46	1.49	1.39	1.38
Bermuda	8.01	7.92	8.34	8.05	10.53	6.92	8.07	7.97	5.96	7.10
Bolivia	1.20	1.13	1.08	1.57	1.42	1.33	1.58	1.33	1.41	1.45
Brazil	1.88	1.91	1.85	1.77	1.84	1.87	1.85	1.91	2.02	1.90
Canada	17.37	16.91	16.55	17.46	17.26	17.43	16.89	17.03	16.36	15.24
Cayman Islands	10.91	10.50	10.49	10.44	10.31	10.48	10.56	10.40	10.26	9.46
Chile	3.80	3.37	3.50	3.44	3.71	3.75	3.80	4.04	4.20	3.93
Colombia	1.45	1.39	1.35	1.37	1.29	1.41	1.44	1.43	1.47	1.56
Costa Rica	1.39	1.44	1.55	1.59	1.63	1.64	1.75	1.92	1.91	1.81
Cuba	2.34	2.28	2.33	2.27	2.22	2.31	2.42	2.37	2.64	2.80
Dominica	1.47	1.63	1.47	1.62	1.56	1.61	1.56	2.12	1.81	1.81
Dominican Republic	2.32	2.30	2.41	2.41	2.04	2.10	2.22	2.24	2.16	2.06
Ecuador	1.67	1.83	1.89	2.00	2.12	2.13	2.13	2.17	2.04	2.04
El Salvador	0.96	0.99	1.01	1.09	1.05	1.06	1.12	1.13	1.06	1.02
Grenada	1.91	2.05	1.98	2.11	2.00	2.10	2.24	2.30	2.36	2.36
Guatemala	0.88	0.93	0.94	0.87	0.94	0.99	0.98	1.02	0.91	1.09
Guyana	2.16	2.13	2.11	2.08	2.15	1.88	1.69	2.03	2.01	1.99
Haiti	0.16	0.18	0.21	0.19	0.22	0.22	0.23	0.25	0.25	0.23
Honduras	0.81	0.90	0.94	1.02	1.09	1.10	0.98	1.20	1.16	1.03
Jamaica	3.99	4.08	3.94	4.08	4.06	4.02	4.51	5.04	4.45	3.18
Mexico	3.67	3.75	3.67	3.75	3.76	3.93	3.94	4.02	4.15	3.83
Nicaragua	0.74	0.77	0.77	0.83	0.82	0.79	0.78	0.82	0.78	0.78

Panama	1.90	2.25	1.84	1.90	1.68	1.73	1.92	1.80	1.91	2.17
Paraguay	0.69	0.70	0.70	0.72	0.71	0.65	0.66	0.68	0.70	0.71
Peru	1.17	1.03	1.02	0.97	1.16	1.35	1.26	1.54	1.44	1.64
St. Kitts and Nevis	2.25	3.97	4.22	4.61	4.70	4.78	4.71	4.94	4.88	5.03
St. Lucia	2.10	2.29	2.04	2.22	2.18	2.22	2.19	2.26	2.29	2.20
St. Vincent & Gren.	1.46	1.66	1.73	1.79	1.79	1.82	1.85	1.85	1.85	1.85
Suriname	4.56	4.79	4.69	4.60	4.65	4.77	4.85	4.80	4.75	4.75
Trinidad and Tobago	19.33	19.67	21.05	21.57	24.02	22.04	24.67	26.76	35.77	36.13
Turks and Caicos	0.78	0.73	4.55	4.39	4.10	4.58	5.17	5.51	5.35	5.33
Uruguay	1.60	1.53	1.39	1.38	1.69	1.74	2.00	1.80	2.49	2.35
United States	20.25	19.66	19.65	19.58	19.78	19.72	19.23	19.35	18.60	17.28
Venezuela, RB	6.24	6.94	7.63	7.45	6.41	6.80	6.25	6.31	6.48	6.47

Source: World Bank, World Development Indicators

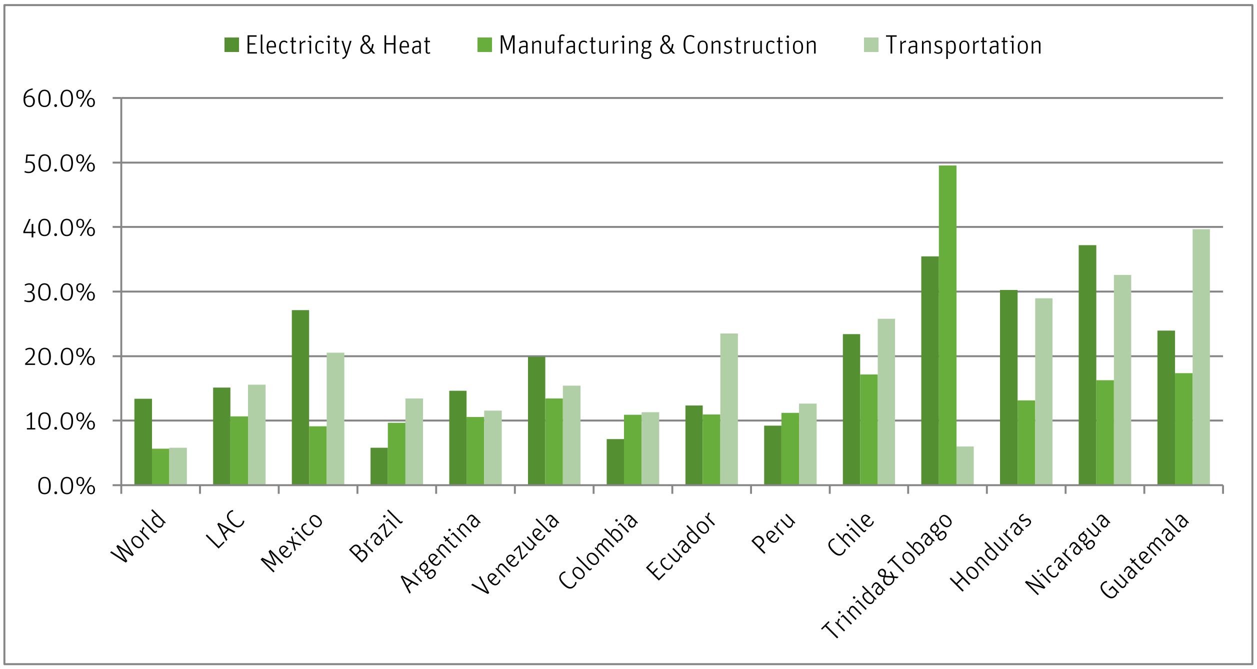
VIII. Annex 2. Total greenhouse gas emissions (CO_2) in Latin American and Caribbean countries (millions of metric tons), 2000-2009

Country Name	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Antigua & Barbuda	0.3	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.5
Argentina	141.1	132.6	123.3	133.1	156.2	155.6	171.2	173.6	182.1	174.7
Aruba	2.2	2.2	2.3	2.3	2.3	2.3	2.3	2.4	2.3	2.3
Bahamas, The	1.8	1.8	2.1	1.9	2.2	2.3	2.3	2.4	2.5	2.6
Barbados	1.2	1.2	1.2	1.3	1.3	1.4	1.4	1.4	1.5	1.6
Belize	0.7	0.7	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Bermuda	0.5	0.5	0.5	0.5	0.7	0.4	0.5	0.5	0.4	0.5
Bolivia	10.2	9.8	9.6	14.1	13.1	12.5	15.0	12.9	13.9	14.5
Brazil	328.0	337.4	332.3	321.6	337.8	347.3	347.7	363.2	387.7	367.1
Canada	534.5	525.7	519.2	553.2	552.3	563.1	550.2	560.8	545.0	513.9
Cayman Islands	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Chile	58.7	52.8	55.4	55.1	60.0	61.3	62.7	67.3	70.7	66.7
Colombia	57.9	56.3	55.7	57.4	55.1	60.9	62.9	63.4	66.4	71.2
Costa Rica	5.5	5.8	6.3	6.6	6.9	7.1	7.7	8.6	8.6	8.3
Cuba	26.0	25.5	26.1	25.5	25.0	26.0	27.4	26.7	29.8	31.6
Dominica	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.1	0.1
Dominican Republic	20.1	20.2	21.5	21.9	18.8	19.6	21.0	21.5	21.1	20.3
Ecuador	20.9	23.4	24.7	26.5	28.7	29.3	29.8	30.9	29.7	30.1
El Salvador	5.7	5.9	6.0	6.6	6.4	6.5	6.8	6.9	6.5	6.3
Grenada	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Guatemala	9.9	10.6	11.1	10.5	11.6	12.6	12.7	13.6	12.5	15.2
Guyana	1.6	1.6	1.6	1.6	1.6	1.4	1.3	1.6	1.6	1.6
Haiti	1.4	1.6	1.8	1.7	2.0	2.1	2.1	2.4	2.4	2.3
Honduras	5.0	5.7	6.1	6.8	7.4	7.6	6.9	8.6	8.5	7.7
Jamaica	10.3	10.6	10.3	10.7	10.7	10.6	12.0	13.5	11.9	8.6
Mexico	381.5	394.8	391.3	405.6	410.7	435.0	441.8	456.8	476.6	446.2
Nicaragua	3.8	4.0	4.0	4.4	4.4	4.3	4.3	4.6	4.4	4.5

Panama	5.8	7.0	5.8	6.2	5.5	5.8	6.6	6.3	6.8	7.8
Paraguay	3.7	3.8	3.9	4.1	4.1	3.8	4.0	4.1	4.4	4.5
Peru	30.3	27.2	27.2	26.4	31.9	37.4	35.3	43.5	41.3	47.4
St. Kitts and Nevis	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3
St. Lucia	0.3	0.4	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.4
St. Vincent & Gren.	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Suriname	2.1	2.3	2.3	2.2	2.3	2.4	2.4	2.4	2.4	2.5
Trinidad and Tobago	24.5	25.0	26.9	27.7	31.0	28.6	32.2	35.1	47.1	47.8
Turks and Caicos	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2
Uruguay	5.3	5.1	4.6	4.6	5.6	5.8	6.6	6.0	8.3	7.9
United States	5713.5	5601.4	5651.0	5681.7	5790.8	5826.4	5737.6	5828.7	5656.8	5299.6
Venezuela, RB	152.4	172.5	193.3	192.1	168.3	181.6	169.9	174.5	182.3	184.8

Source: World Bank, World Development Indicators

IX. Annex 3. Percentage of national GHG emissions from sectors for sample countries in the region, 2010



Source: Author's Analysis of IDB 2013 estimates based on World Resources Institute 2010 Data.

X. Annex 4. Greenhouse gas emissions (CO_2) from transport in select Latin American and Caribbean countries (millions of metric tons), 2000-2009

Country Name	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Antigua & Barbuda	-	-	-	-	-	-	-	-	-	-
Argentina	40.21	36.49	33.98	34.87	36.24	37.89	39.86	40.55	42.7	37.87
Aruba	-	-	-	-	-	-	-	-	-	-
Bahamas, The	-	-	-	-	-	-	-	-	-	-
Barbados	-	-	-	-	-	-	-	-	-	-
Belize	-	-	-	-	-	-	-	-	-	-
Bermuda	-	-	-	-	-	-	-	-	-	-
Bolivia	3.51	3.44	3.51	3.77	4.13	4.33	4.8	5.35	5.88	6.07
Brazil	124.16	126.7	128.58	126.07	134.89	135.59	138.59	144.21	149.54	146.98
Canada	148.8	146.7	149.28	151.93	156.67	159.58	158.79	164.27	161.11	164.4
Cayman Islands	-	-	-	-	-	-	-	-	-	-
Chile	16.81	15.9	16.41	16.16	16.75	18.37	18.1	19.61	20.37	20.5
Colombia	18.39	19.28	17.11	17.58	20.06	20.26	21.2	21.67	22.08	20.74
Costa Rica	2.94	3.14	3.47	3.54	3.89	4.03	3.92	4.21	4.32	4.37
Cuba	2.15	2.19	2.04	1.87	1.95	1.89	1.81	1.83	1.8	1.43
Dominica	-	-	-	-	-	-	-	-	-	-
Dominican Republic	6.64	6.12	6.01	5.3	5.59	5.89	5.68	5.13	5.2	5.25
Ecuador	8.94	9.97	10.29	10.71	9.56	10.95	11.54	12.66	12.73	14.51
El Salvador	2.5	2.51	2.44	2.66	2.81	2.89	2.76	2.51	2.4	2.56
Grenada	-	-	-	-	-	-	-	-	-	-
Guatemala	3.8	4.05	4.33	4.84	4.69	5.08	5.18	5.47	4.93	5.57
Guyana	-	-	-	-	-	-	-	-	-	-
Haiti	0.7	0.77	0.81	0.79	1.11	1.14	1.17	1.31	1.34	1.29
Honduras	2.09	2.23	2.31	2.27	2.09	2.23	2.22	3.17	2.94	3.01
Jamaica	1.91	1.86	2.15	2.14	2.18	2.38	2.92	3.1	3.74	2.94
Mexico	105.49	107.3	109.27	116.06	122.62	129.61	136.99	144.8	151.37	147.27

Nicaragua	1.44	1.45	1.51	1.51	1.44	1.44	1.48	1.53	1.48	1.52
Panama	2.3	2.21	2.34	2.46	2.53	2.83	3.01	2.78	3.09	3.36
Paraguay	2.77	2.96	3.13	3.34	3.33	3.02	3.2	3.43	3.39	3.77
Peru	9.61	8.96	8.83	9.28	10.5	9.97	10.71	11.17	13.65	14.87
St. Kitts and Nevis	-	-	-	-	-	-	-	-	-	-
St. Lucia	-	-	-	-	-	-	-	-	-	-
St. Vincent & Gren.	-	-	-	-	-	-	-	-	-	-
Suriname	-	-	-	-	-	-	-	-	-	-
Trinidad and Tobago	1.62	1.62	1.67	1.67	1.77	1.97	2.14	2.67	2.9	2.79
Turks and Caicos	-	-	-	-	-	-	-	-	-	-
Uruguay	2.41	2.42	2.18	2.1	2.22	2.28	2.37	2.55	2.65	2.83
United States	1708.1	1710	1724.6	1749.4	1771	1789.9	1788.2	1788.5	1691.4	1606.6
Venezuela, RB	33.78	36.42	35.4	35.96	37.6	42.08	48.35	42.87	44.26	46.37

Source: World Bank, World Development Indicators

XI. Annex 5. Greenhouse gas emissions (CO_2) from transport in select Latin American and Caribbean countries (% of total fuel combustion), 2000-2009

Country Name	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Antigua & Barbuda	-	-	-	-	-	-	-	-	-	-
Argentina	28.9	28.4	28.0	26.6	24.7	25.1	24.9	24.4	24.9	22.8
Aruba	-	-	-	-	-	-	-	-	-	-
Bahamas, The	-	-	-	-	-	-	-	-	-	-
Barbados	-	-	-	-	-	-	-	-	-	-
Belize	-	-	-	-	-	-	-	-	-	-
Bermuda	-	-	-	-	-	-	-	-	-	-
Bolivia	49.2	50.3	48.0	47.4	47.3	45.8	46.7	47.7	48.4	47.6
Brazil	40.9	41.0	41.7	41.6	42.1	42.0	42.3	42.1	41.3	43.5
Canada	27.9	27.9	28.0	27.3	28.3	28.5	29.2	28.9	29.3	31.3
Cayman Islands	-	-	-	-	-	-	-	-	-	-
Chile	32.0	31.5	31.9	30.3	29.0	31.6	30.2	29.2	29.7	31.3
Colombia	31.3	32.8	30.2	31.6	35.7	35.2	36.8	37.4	37.3	33.8
Costa Rica	65.5	64.1	69.0	66.0	72.2	70.8	66.4	63.9	65.6	69.6
Cuba	7.9	8.3	8.1	7.6	8.0	7.5	7.1	7.0	7.2	4.5
Dominica	-	-	-	-	-	-	-	-	-	-
Dominican Republic	38.1	35.8	32.5	28.9	31.2	33.7	30.2	27.2	27.1	29.1
Ecuador	49.2	52.2	48.5	49.2	44.8	45.2	45.6	49.3	48.0	49.7
El Salvador	48.0	45.2	43.9	44.9	47.2	47.2	43.4	36.4	38.6	41.1
Grenada	-	-	-	-	-	-	-	-	-	-
Guatemala	44.9	45.7	45.5	50.8	46.3	48.4	49.2	48.1	48.6	50.0
Guyana	-	-	-	-	-	-	-	-	-	-
Haiti	49.6	50.0	46.8	48.2	58.7	57.6	57.6	56.7	57.3	54.4
Honduras	47.1	42.6	41.7	36.7	31.1	32.1	35.1	39.5	37.7	41.1

Jamaica	19.7	19.1	21.5	20.8	21.4	22.8	24.7	23.4	31.6	35.6
Mexico	30.2	30.7	30.7	32.0	33.3	33.6	34.7	35.3	37.5	36.8
Nicaragua	40.9	39.3	39.6	38.2	35.1	35.7	34.9	35.1	35.7	36.7
Panama	46.6	37.5	45.3	47.2	47.0	41.5	41.8	39.4	46.7	43.2
Paraguay	85.2	87.6	87.9	90.8	89.3	87.8	86.7	89.3	90.2	91.3
Peru	36.3	36.6	34.3	36.9	36.1	34.5	37.7	36.1	38.3	38.9
St. Kitts and Nevis	-	-	-	-	-	-	-	-	-	-
St. Lucia	-	-	-	-	-	-	-	-	-	-
St. Vincent & Gren.	-	-	-	-	-	-	-	-	-	-
Suriname	-	-	-	-	-	-	-	-	-	-
Trinidad and Tobago	7.7	7.0	6.8	6.3	6.3	5.8	5.5	6.6	7.4	6.9
Turks and Caicos	-	-	-	-	-	-	-	-	-	-
Uruguay	45.8	51.2	51.3	50.0	41.3	43.1	38.2	44.0	34.4	36.6
United States	30.0	30.1	30.8	30.8	30.7	31.0	31.5	31.0	30.3	31.0
Venezuela, RB	26.7	27.5	27.4	29.2	29.4	28.4	28.4	27.7	26.3	27.5

Source: World Bank, World Development Indicators

XII. Annex 6. Greenhouse gas emissions (CO_2) from residential buildings and commercial and public services in Latin American and Caribbean countries (millions of metric tons), 2000-2009

Country Name	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Antigua & Barbuda	-	-	-	-	-	-	-	-	-	-
Argentina	19.32	18.47	17.46	18.5	19.22	20.35	22.67	24.07	23.4	23.35
Aruba	-	-	-	-	-	-	-	-	-	-
Bahamas, The	-	-	-	-	-	-	-	-	-	-
Barbados	-	-	-	-	-	-	-	-	-	-
Belize	-	-	-	-	-	-	-	-	-	-
Bermuda	-	-	-	-	-	-	-	-	-	-
Bolivia	0.81	0.85	0.9	0.95	1.03	1.09	1.12	1.17	1.17	1.17
Brazil	21.19	21.4	21.21	19	19.54	19	18.99	19.66	19.7	19.41
Canada	85.08	82.71	87.98	93.6	92.02	91.37	85.99	90.42	90.9	74.9
Cayman Islands	-	-	-	-	-	-	-	-	-	-
Chile	4.15	4.21	4.06	3.83	4.22	4.02	4.06	4.45	4.54	4.71
Colombia	4.74	4.27	4.81	4.81	4.39	4.54	5.32	5.31	5.22	4.94
Costa Rica	0.25	0.25	0.29	0.27	0.25	0.21	0.23	0.24	0.24	0.24
Cuba	1.09	0.99	0.84	1.07	1.66	1.35	0.84	0.62	0.65	0.62
Dominica	-	-	-	-	-	-	-	-	-	-
Dominican Republic	2.58	2.48	2.28	2.29	2.55	2.03	2.16	2.24	2.7	2.3
Ecuador	2.07	2.11	2.28	2.4	2.61	3.06	3.11	3.08	2.96	2.92
El Salvador	0.44	0.46	0.4	0.51	0.51	0.52	0.62	0.5	0.52	0.55
Grenada	-	-	-	-	-	-	-	-	-	-
Guatemala	0.86	0.9	0.89	0.63	0.68	0.55	0.57	0.59	0.6	0.56
Guyana	-	-	-	-	-	-	-	-	-	-
Haiti	0.23	0.28	0.24	0.24	0.24	0.27	0.28	0.24	0.24	0.21
Honduras	0.29	0.38	0.41	0.68	0.68	0.42	0.38	0.28	0.26	0.25

Jamaica	0.35	0.35	0.24	0.25	0.31	0.35	0.4	0.39	0.29	0.26
Mexico	26.16	25.71	25.95	24.8	25.4	24.18	24.64	24.2	23.8	22.8
Nicaragua	0.21	0.18	0.2	0.19	0.32	0.32	0.34	0.29	0.26	0.33
Panama	0.34	0.34	0.42	0.4	0.32	0.35	0.48	0.49	0.38	0.47
Paraguay	0.22	0.18	0.18	0.18	0.2	0.19	0.19	0.19	0.18	0.19
Peru	3.24	3.29	3.55	2.94	2.26	2.05	1.8	1.83	1.97	2.13
St. Kitts and Nevis	-	-	-	-	-	-	-	-	-	-
St. Lucia	-	-	-	-	-	-	-	-	-	-
St. Vincent & Gren.	-	-	-	-	-	-	-	-	-	-
Suriname	-	-	-	-	-	-	-	-	-	-
Trinidad and Tobago	0.46	0.44	0.5	0.43	0.42	0.39	0.5	0.47	0.49	0.7
Turks and Caicos	-	-	-	-	-	-	-	-	-	-
Uruguay	0.67	0.61	0.59	0.56	0.54	0.53	0.54	0.6	0.57	0.62
United States	595.1	577.7	579	602	586.4	568.2	514.3	545.5	553	547.9
Venezuela, RB	5.96	6.17	5.96	5.18	6.31	7.67	5.84	10.68	6.21	6.01

Source: World Bank, World Development Indicators

XIII. Annex 7. Greenhouse gas emissions (CO_2) from residential buildings and commercial and public services in Latin American and Caribbean countries (% of total fuel combustion), 2000-2009

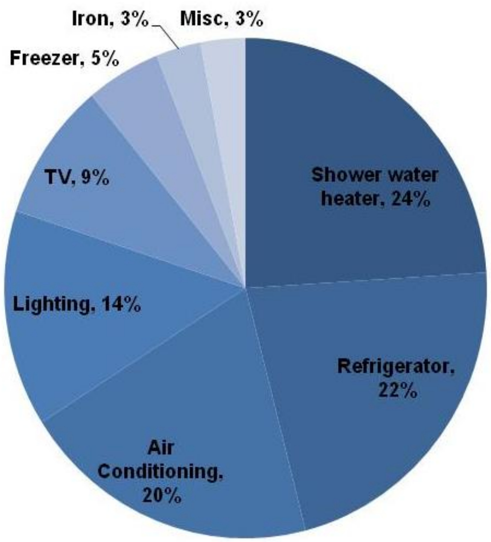
Country Name	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Antigua & Barbuda	-	-	-	-	-	-	-	-	-	-
Argentina	13.9	14.4	14.4	14.1	13.1	13.5	14.2	14.5	13.6	14.1
Aruba	-	-	-	-	-	-	-	-	-	-
Bahamas, The	-	-	-	-	-	-	-	-	-	-
Barbados	-	-	-	-	-	-	-	-	-	-
Belize	-	-	-	-	-	-	-	-	-	-
Bermuda	-	-	-	-	-	-	-	-	-	-
Bolivia	11.4	12.4	12.3	11.9	11.8	11.5	10.9	10.4	9.6	9.2
Brazil	7.0	6.9	6.9	6.3	6.1	5.9	5.8	5.7	5.5	5.7
Canada	16.0	15.7	16.5	16.8	16.6	16.3	15.8	15.9	16.5	14.3
Cayman Islands	-	-	-	-	-	-	-	-	-	-
Chile	7.9	8.3	7.9	7.2	7.3	6.9	6.8	6.6	6.6	7.2
Colombia	8.1	7.3	8.5	8.6	7.8	7.9	9.2	9.2	8.8	8.0
Costa Rica	5.6	5.1	5.8	5.0	4.6	3.7	3.9	3.6	3.6	3.8
Cuba	4.0	3.8	3.3	4.3	6.8	5.4	3.3	2.4	2.6	2.0
Dominica	-	-	-	-	-	-	-	-	-	-
Dominican Republic	14.8	14.5	12.3	12.5	14.2	11.6	11.5	11.9	14.1	12.7
Ecuador	11.4	11.0	10.7	11.0	12.2	12.6	12.3	12.0	11.2	10.0
El Salvador	8.4	8.3	7.2	8.6	8.6	8.5	9.7	7.3	8.4	8.8
Grenada	-	-	-	-	-	-	-	-	-	-
Guatemala	10.2	10.2	9.3	6.6	6.7	5.2	5.4	5.2	5.9	5.0
Guyana	-	-	-	-	-	-	-	-	-	-
Haiti	16.3	18.2	13.9	14.6	12.7	13.6	13.8	10.4	10.3	8.9
Honduras	6.5	7.3	7.4	11.0	10.1	6.1	6.0	3.5	3.3	3.4
Jamaica	3.6	3.6	2.4	2.4	3.0	3.4	3.4	3.0	2.5	3.1

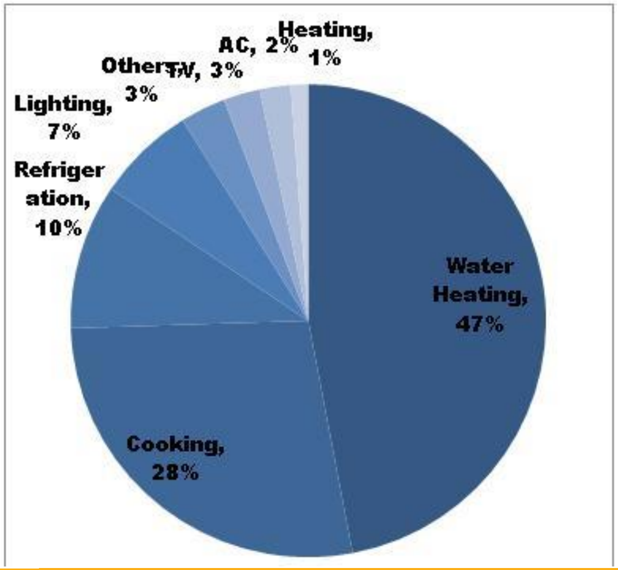
Mexico	7.5	7.4	7.3	6.8	6.9	6.3	6.2	5.9	5.9	5.7
Nicaragua	6.0	4.9	5.2	4.8	7.8	7.9	8.0	6.7	6.3	8.0
Panama	6.9	5.8	8.1	7.7	5.9	5.1	6.7	7.0	5.7	6.0
Paraguay	6.8	5.3	5.1	4.9	5.4	5.5	5.1	4.9	4.8	4.6
Peru	12.2	13.4	13.8	11.7	7.8	7.1	6.3	5.9	5.5	5.6
St. Kitts and Nevis	-	-	-	-	-	-	-	-	-	-
St. Lucia	-	-	-	-	-	-	-	-	-	-
St. Vincent & Gren.	-	-	-	-	-	-	-	-	-	-
Suriname	-	-	-	-	-	-	-	-	-	-
Trinidad and Tobago	2.2	1.9	2.0	1.6	1.5	1.2	1.3	1.2	1.2	1.7
Turks and Caicos	-	-	-	-	-	-	-	-	-	-
Uruguay	12.7	12.9	13.9	13.3	10.0	10.0	8.7	10.3	7.4	8.0
United States	10.4	10.2	10.3	10.6	10.2	9.8	9.0	9.5	9.9	10.6
Venezuela, RB	4.7	4.7	4.6	4.2	4.9	5.2	3.4	6.9	3.7	3.6

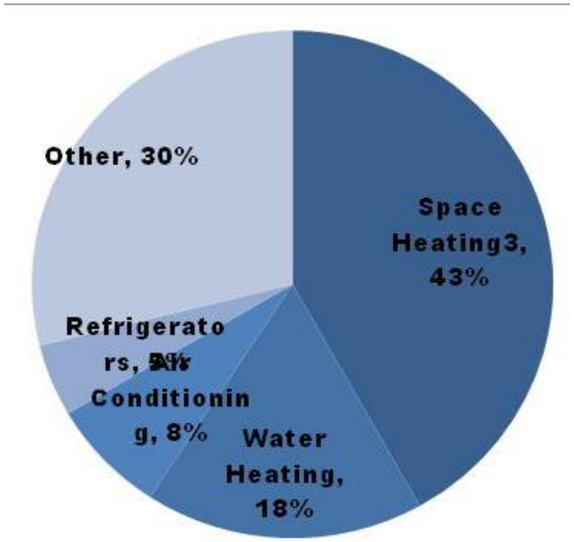
Source: World Bank, World Development Indicators

XIV. Annex 8. Proportional energy consumption by end use (% of total household consumption): Brazil, Mexico, and U.S.

BRAZIL (2007)	MEXICO (2008)	U.S. (2009)







Sources: ELETROBRAS, PROCEL – Programa Nacional de Conservação de Energia Elétrica. Pesquisa de Posse de Equipamentos e Hábitos de Uso – Ano Base 2005 – Classe Residencial – Relatório (2007); SENER, Indicadores de eficiencia energética en México: 5 sectores, 5 retos (2011); U.S. Energy Information Administration, 2009 RECS Survey Data (Release Date: January 2013).

XV. Annex 9. Summary Criteria from Common Green Building Certifications

LEED for Homes (version 2008, US)

Categories / Criteria	Rating			
TOTAL POINTS (out of 100)	CERTIFIED 45-59 points	SILVER 60-74 points	GOLD 75-90 points	PLATINUM 90-100 points
Innovation and Design Process	Max Points = 11			
1. Integrated Project Planning				
2. Quality Management for Durability				
3. Innovative or Regional Design				
Location and Linkages	Max Points = 10			
1. LEED for Neighborhood Development				
2. Site Selection (Floodplain, Endangered habitat, Wetlands, Park land, or Prime soil)				
3. Preferred Locations (Edge, Infill, Previously Developed)				
4. Infrastructure				
5. Community Resources/Transit				
6. Access to Open Space				
Sustainable Sites	Max Points = 22			
1. Site Stewardship				
2. Landscaping				
3. Reduce Local Heat Island Effects				
4. Surface Water Management				
5. Nontoxic Pest Control				
6. Compact Development				
Water Efficiency	Max Points = 15			
1. Water Reuse				
2 Irrigation System				
3. Indoor Water Use				
Energy and Atmosphere	Max Points = 38			
1. Optimize Energy Performance				
2. Insulation				

3. Air Infiltration	
4. Window	
5. Heating and Cooling Distribution System	
6. Space Heating and Cooling Equipment	
7. Water Heating	
8. Lighting	
9. Appliances	
10. Renewable Energy	
11. Residential Refrigerant Management	
Materials and Resources	Max points = 16
1. Material-Efficient Framing	
2. Environmentally-Preferable Products	
3. Waste Management	
Indoor Environmental Quality	Max points = 21
1. ENERGY STAR with Indoor Air Package	
2. Combustion Venting	
3. Moisture Control	
4. Outdoor Air Ventilation	
5. Local Exhaust	
6. Distribution of Space Heating and Cooling	
7. Air Filtering	
8. Contaminant Control	
9. Radon Protection	
10. Garage Pollutant Protection	
Awareness and Education	Max points = 3
1. Education of Homeowner or Tenant	
2. Education of the Building Manager	

Source: US Green Building Council (2008): http://www.usgbc.org/leed/rating-systems/homes

Passive House (version 2012, Germany)

Categories / Criteria

1. Certification Criteria
Heating Demand or Load
Cooling Demand or Load
Primary Energy Demand
Airtightness (Pressure Test)
2. Documentation Requirements
Passive House Planning Package (Areas, U-Values, U-list, Windows, Ground, Shading, Ventilation, Heating Demand/Method/Load, Cooling Demand/Load/Units, Distribution, Solar Collector, Heat Generation, Electricity Demand, Climate Data)
Planning Documents
Supporting Technical Documents
Verification
HRV Commissioning
Construction Manager Declaration
Photographs
3. Calculation Method Requirements and Standards

Source: Passive House Institute (2012): http://passiv.de/downloads/03_certfication_criteria_residential_en.pdf

Hipoteca Verde Technology Package (version 2007-2010 and version 2011, Mexico)

Technology (2007)	**Climate Requirements**		
	Cold Climate	Moderate Climate	Hot Climate
Water-Efficient Fixtures			
Showerhead with Flow Control			
Dual-Flush Toilet			
Energy-Efficient Lighting			
Solar Water Heater			
On-Demand Water Heater			
Roof Insulation			
Exposed Wall Insulation			
Air Conditioning			
Technology (2011) (Savings Requirements per Climate Zone)			

Infrastructure
Solar Photovoltaic for Public Lighting
Natural Gas Installation
Waste and Recycling Separation
Electric Energy
Efficient Lighting (CFL)
Efficient Lighting (CFL and LED)
Efficient Window Air Conditioning Units (Window and Mini-Split)
Efficient Refrigerator (Sello FIDE)
Roof Insulation
Wall Insulation
Reflective Roof Covering
Reflective Wall Covering
Residential Transformer
Double-Paned Windows
Gas Energy
Solar Water Heater (Direct and Indirect)
On-Demand Water Heater
Water
Low-Flow Toilet
Low-Flow Showerhead
Low-Flow Fixtures (Kitchen and Bathroom)
Flow Control Fixtures
Health
Water Filters (Fixtures)
Water Filter (Drainage)
Waste Separation

Source: INFONAVIT (2007 and 2013).

Selo Casa Azul (version 2010, Brazil)

Categories / Criteria	Rating		
1. URBAN QUALITY	BRONZE	SILVER	GOLD
1.1 Site Quality – Infrastructure	mandatory	Mandatory	Mandatory
1.2 Site Quality – Impact	mandatory	criteria + 6	criteria + 12
1.3 Site improvements		optional	optional
1.4 Restoration of degraded areas		measures	measures
1.5 Rehabilitation of buildings			
2. DESIGN AND COMFORT			
2.1 Landscaping	mandatory		
2.2 Design flexibility			
2.3 Relationship with the neighborhood			
2.4 Alternate transportation solution			
2.5 Selective garbage collection area	mandatory		
2.6 Leisure facilities (social and sports)	mandatory		
2.7 Thermal performance – air sealing	mandatory		
2.8 Thermal performance – sun and wind orientation	mandatory		
2.9 Natural illumination of common areas			
2.10 Natural ventilation and illumination of bathrooms			
2.11 Physical adaptation/customization to the site			
3. ENERGY EFFICIENCY			
3.1 Energy-saving lamps (private areas)	mandatory for < 3 MW		
3.2 Energy-saving devices (common areas)	mandatory		
3.3 Solar water heating system			
3.4 Gas water heating systems			
3.5 Individual measurement (gas)	mandatory		
3.6 Efficient elevators			
3.7 Efficient appliances			
3.8 Alternative energy sources			
4. CONSERVATION OF MATERIAL RESOURCES			

4.1 Modular coordination	mandatory
4.2 Quality of materials and components	
4.3 Industrialized or prefabricated components	
4.4 Reusable forms and anchors	mandatory
4.5 Construction and demolition waste management	mandatory
4.6 Optimum dosage concrete	
4.7 Fly ash (CPIII) and Pozolanic (CP IV) cement	
4.8 Pavement with recycled construction and demolition waste	
4.9 Easy maintenance of facade	
4.10 Planted or certified wood	
5. WATER MANAGEMENT	
5.1 Individual metering of water	mandatory
5.2 Efficiency devices - flushing system	mandatory
5.3 Efficiency devices – aerators	
5.4 Efficiency devices –flow regulator	
5.5 Rain water utilization	
5.6 Rain water retention	
5.7 Rain water infiltration	
5.8 Permeable areas	mandatory
6. SOCIAL PRACTICES	
6.1 Construction and demolition waste management education	
6.2 Environmental education of employees	
6.3 Personal development of employees	
6.4 Capacity building of employees	
6.5 Inclusion of local workers	
6.6 Community participation in project design	
6.7 Training for residents	mandatory
6.8 Environmental education of residents	

6.9 Management training	
6.10 Actions for mitigation of social risks	
6.11 Actions to generate employment and income	

Source: Caixa Econômica Federal (2010): http://www.labeee.ufsc.br/sites/default/files/projetos/Selo_Casa_Azul_CAIXA_versao_web.pdf

XVI. Annex 10. Crosswalk of Housing Approaches and Sustainable & Resilient Housing Instruments

Housing Programs in Latin America and the Caribbean*

Approach	**State guarantees housing**					**State facilitates housing markets**				
Program Type	Direct public intervention in the housing sector					Promarket interventions				
Sustainable and Resilient Instrument	Direct provision of finished houses	Direct provision of incremental houses	Provision of serviced land for housing	Provision of subsidized housing finance	Settlment upgrading	Housing upgrading	Housing vouchers	Government financing of incremental housing	Regulations to facilitate land subdivisión	Expansion of private housing finance
Technological Instruments										
Sustainable materials										
Sustainable energy										
Sustainable transport										
Resilient sites										
Resilient design										
Flexible design										
Policy Instruments										
Building regulations										
Developer requirements										

Land acquisition
Education and awareness
Disaster planning
R&D funding
Financial Instruments
Clean development
Energy service cos.
Utility on-bill financing
Property-assessed
Energy-efficient mortgage
Bulk purchase
Public disaster insurance
Private disaster incentives
Public loan funds

** Adopted from Bouillon 2012, Table 9-3. References to other housing types (particularly, informal housing) are included here though the focus of this paper is on new publically-assisted housing developments.*