

## Conference Paper

# Urban Green Infrastructure Framework for Housing Climate Resilience

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## Abstract

Climate change is affecting urban areas by increasing the intensity and frequency of climate-related disasters such as flooding, sea level rise, drought, etc. The trend is expected to rise significantly without proper intervention. Urban housings as the concentration of people and economic growth are the most impacted. This condition calls to study green infrastructure/GI strategies as a more sustainable way than the conventional. Such GI approach not only mitigate and adapt the impacts but also improve the urban climate resilience, particularly in the housing sector.

Therefore, this study aims to propose a conceptual framework to integrate the elements for the implementation of GI for mitigating and adapting climate impact for urban resilience improvement. This study identified elements to employ GI for housing climate resilience: public awareness; land use and development regulation; land and property acquisition; environmental management plan; housing strategy; fiscal and taxation; and governance. This framework is a new tool for scoping and assessing urban housing vulnerability to climate change by helping stakeholders to systematically consider the benefit to introduce GI scheme in respective efforts.

**Keywords:** Urban, Green Infrastructure, Framework, Housing, Climate Resilience, Sustainability.

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## 1. Introduction

Climate change is one of the most urgent problems facing the world's community. Cities are making efforts to mitigate, adapt and reduce the impacts of climate change as they use about 60-80 percent of the global energy and release for over 67 percent of energy-related global greenhouse gases. This trend is expected to rise to 74 percent by 2030, and It is estimated that 89 percent of the increase in CO<sub>2</sub> from energy use will be from developing countries [1]. As urban populations grow, the development of the housing sector is in high demand. Report of the Intergovernmental Panel on Climate Change/ IPCC (2014) shows that the housing sector is one of the main contributors to greenhouse gas emission [2]. According to United Nations/ UN (2015), 54 percent of the world's population lives in urban areas in 2014, and it is expected the proportion



will increase to 66 percent by 2050 concentrating in India, China, and Nigeria [3]. The urbanization combined with the growth of the global population may increase another 2.5 billion people to urban areas by 2050, with nearly 90 percent take place in Asia and Africa. Consequently, this could imply a growing demand for energy services and increase in gas emission for construction and operation. For instance, in 2010 housing sector accounted for 32percent of total global final energy use, 19 percent of energy-related Greenhouse Gas emissions (including electricity-related), nearly one-third of black carbon emissions, and an eighth to a third of fluorinated-gases [2].

While housing is viewed as the main contributor to climate change, it is also one of the most vulnerable sectors to climate change impact particularly those sheltering the urban poor [4]. The impact could have the potential to affect many aspects of the housing sector including safety, prices, insurance premiums, residential mobility and urban spatial arrangements [5-7]. Therefore, it is important to regard housing as one of main sector for mitigating and adapting the impact through suitable urban policies and implementation to improve the community resilience. Resilience in this paper can be described as the ability of housing to absorb impacts of climate hazards and bounce back to normalcy in a timely and efficient manner without critical alterations of its basic functions [8, 9]. The development and reconstruction housing be mean to improve resilience regarding social, economic and environmental functions [8, 10]. Despite related agencies and stakeholders have widely employed disaster risk reduction (DRR) for climate impacts, problematic issues are acknowledged in terms of sustainability scheme to achieve the effect in the housing sector for mitigating and adaptation the climate impacts. Therefore, this paper argues that green infrastructure (GI) development can be a sustainable approach to achieve housing resilience. However, this method requires an integrated framework at any level due to complexity and connectivity with another urban subsystem.

Although GI has been employed for mitigating and adapting the impact in urban areas, the critical issues in the housing sector are rarely studied. As the housing sector can be a main emission contributor while as one of the most vulnerable sectors, these study aims propose a conceptual framework to integrate the element for the implementation of GI to mitigate and adapt climate impact to improve urban resilience. This paper begins with a literature review on the function of urban green infrastructure to mitigate climate-related disaster, urban resilience, and housing in cities. The critical issues of green infrastructure development in housing sectors areas are also discussed as a basis to develop the framework. The last part is the result and conclusion.

## 2. Literature Review

Ensuring the housing sector may mitigate and adapt to climate change is considered challenging for related agencies and parties. The consequence of climate-related hazards combined with increasing intensity and frequency have imposed the cost of environment, society, economy, and finance [11]. International Energy Agency/ IEA (2017) concludes that the housing sector responsible for at least 17 percent of world carbon dioxide (CO<sub>2</sub>) emissions in 2016. Promoting low carbon development for housing have been popular policies adopted by the government, for instance, low carbon initiative to low-income housing in the UK, Mexico, and Argentina [12]. Such initiatives not only benefit the environment but also increase the standard of living for the urban poor [13]. However, as the housing sector not only made up the building itself but also in the broader term including site context, social system, etc. at any scale, therefore, it is important to view and integrate those sources into one comprehensive approach.

The housing sector is mostly responsible for creating and modifying much of the residential built environment [14]. While at the same time housing represents the highest losses due to natural disasters like climate-related disasters. According to McAneney, three ideas making the housing sector are strongly related to climate change [15]. First, the production and modification of the built environment contribute to climate change for instance energy used for construction and operation of buildings. Second, the nature of the housing development like location, scale or infrastructure influence the degree to which consumer is exposed to climate hazard. Third, parties related to housing development such as developers and consumers are vulnerable to directly impact such as flooding or indirectly such as insurance, financing or more stringent regulations.

Due to the rapid urban population growth, a higher risk of urban housing to the consequence of climate-related hazards increase. Moreover, the impact is influenced by education attainment, economic openness, the strength of the financial sector, the capacity and size of government [16]. For instance, the urban poor in developing countries is considered the most vulnerable to the climate impact due to poor housing quality and site location on hazard-prone areas [17-19]. Improving the housing condition and infrastructure particularly for urban poor could reduce the impact and improving the resilience capacity for coping with the consequence. This is an important issue as the urban poor housings such as slum areas are estimated reaching 900 million while about 170 million housing units must be developed or rehabilitated by 2020 [20]. An inappropriate housing approach policy together with poor design houses can be as one

of the main sources of risks to climate hazards. Improving climate resilience housing may benefit for financial saving, green job, residence health, and urban resilience.

In developed countries housing sector has been a long-standing considered the climate change issue through planning, policies, and design. This respective concern became requirements for permission like sustainable housing or low carbon housing. Housing sector principally has not been acknowledged as urban infrastructure and tend to be isolated as a particular issue while it is must be understood as integrated urban system as happening in developing countries. This integration approach could be broader the positioning of housing sector in response to climate change policy. Such broader view may support the urban planning process to integrate the critical issue such as sprawl, transportation, infrastructural networks, green space or energy consumption with housing sector [22, 23]. The transformation of cities and urban environment according to interests of mitigating and adaptation of climate change have been central to urban planning policies and process.

There is a critical demand for using the sustainable approach to integrate housing sector with other urban infrastructure and ecological features to mitigate the climate impact [24-26]. This approach seeks for the solution in the term of social, economic and environmental issues regarding with climate impact consequences that housing sector has a twofold role: on the one hand, it significantly vulnerable to climate impacts; on the other hand, it is often responsible for emission contributing to increase risk conditions [27]. In line with it, this study believes that the using of green infrastructure/ GI can be a sustainable scheme to achieve respective objectives. Nevertheless, this intervention requires an integrated and comprehensive approach at any level over multi stakeholder's cooperation.

Green infrastructure (GI) is described as the development and interconnected network of green space for instance parks, greenways, retention ponds, etc. that providing a variety of social, economic and environmental benefits. These benefits include conservation of habitats and preserving a natural service, decreasing the urban heat island effect, improving urban air quality, managing floods, improving water quality and quantity, mitigating and adapting climate change, providing recreation space [28] and improving property values [29]. The connectedness and integration of pre-existing natural and gray infrastructure could support the achieving of GI's objectives. GI can be designed at regional, city, neighborhood and site scale. At regional scale, GI is the element network of land conservation and ecological corridor. GI is made up of the urban forest/ tree canopy, urban parks, parkways and boulevards at an urban scale. At neighborhood scale GI composed of the element of local parks, constructed wetlands,

and green streets while at site scale it applies to stormwater planters, rain gardens, green roofs and living walls (Figure 1). Generally, GI elements are aimed to maintain natural hydrology functions by absorbing, infiltrating, and storing systems.

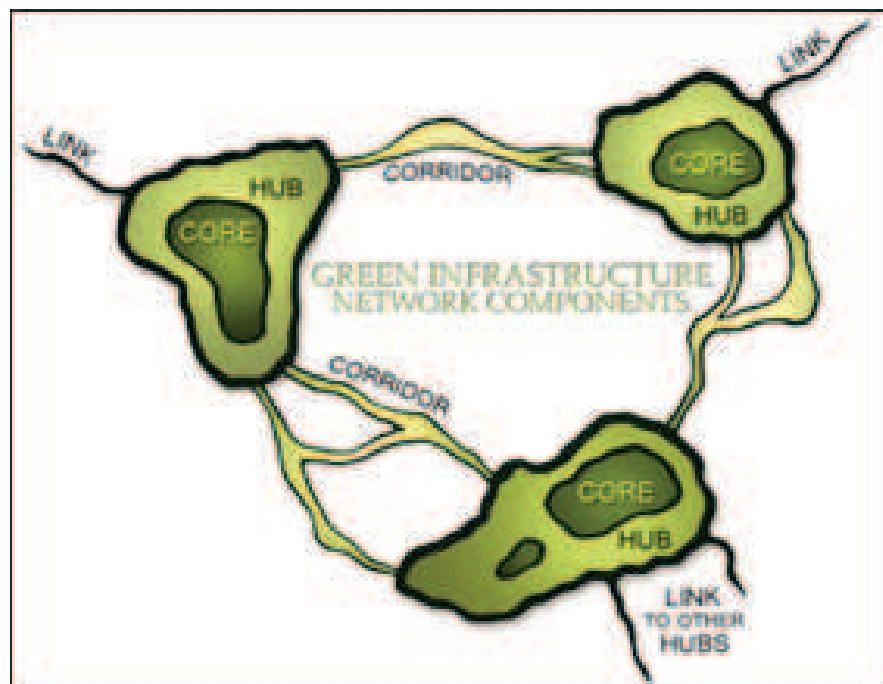


**Figure 1:** Green Infrastructure at any scales and forms. (Source: The Conservation Fund, 1999).

GI networks can be viewed as hubs and links. A centre is defined as the concentrating place for the human and ecosystem, and a link refers to the interconnection from one hub to another (Figure 2). Benedict et al. add that the hub and the link have its functions due to the present needs, place, and situation. For instance, the hubs could be the housing area where the GI's elements could function as a link to the hubs. The integration of GI into housing not only could benefit regarding sustainability but also enhancing climate resilience [30, 31].

Climate-related flooding has become more frequent and intense meteorological phenomena in the urban areas due to increased temperature and precipitation pattern [32]. Conventional gray infrastructure to control flood have failed to cope with intensified and extreme flooding that exceed its capacity [33]. Communities are more vulnerable because of the excessive development like land use change in an unsustainable way [34]. The application of GI can be an alternative strategy in managing, mitigating and adapting climate change-related flooding [35]. It is also regarded as a mean for acknowledging climate justice for communities [36].

Current criticism among scholar regarding urban resilience is the conception relates to only single types of disturbances particularly to the housing such as urban flooding [37]. Though, the higher levels of frequency, intensity, and uncertainty brought by climate change mean that there is a growing need to build resilience to a broader range of



**Figure 2:** Green Infrastructure Networking (Sources: Urbanism 2015).

climate-related disturbances. These disturbances can comprise droughts, heat waves, torrential rain, storm surges, mudslides, typhoons, shifts of ecological systems, changes in land-use and land cover, land subsidence, seawater encroachments, and deterioration in water and air quality [38]. Cities must be resilient to a wider range of shocks and stresses in order to be prepared for related climate change disasters. This resilience must be bundled with the program to support urban development and sustainability [39, 40]. Urban resilience needs collaboration approach in plan and implementation [41]. Nevertheless, resilience characteristics and metrics of success are still highly contested [42, 43].

Several approach and frameworks have been developed to measure the climate resilience such as Rockefeller Foundation's Asian Cities Climate Change Resilience (ACCCRN), Assessments of Impacts and Adaptations of Climate Change (AIACC), UNDP Community-Based Resilience Analysis (CoBRA) Framework, etc. Though, these frameworks have not explicitly mentioned integrating the housing sector and green infrastructure for climate resilience [44]. Due to this gap, such integration approach thinking is needed to guide the stakeholders to adopt and develop a measurement for climate policy. Therefore, this paper aims to propose a framework for climate resilience housing based on literature review and existing tools for vulnerable housing area in cities. By this way, GI development potentially can improve the current housing situation

from vulnerable to resilient status for sustainability development of climate exposed communities.

### 3. Methodology

This study contributes a literature review to a broader aim the framework of climate change adaptation and mitigation in urban housing environments. In brief, this study elaborates on strategies for the implementation of climate change mitigation and adaptation for climate housing resilience. These strategies are a combination of several policy strategies that should themselves be capable of assuring the implementation of climate change mitigation and adaptation efforts.

### 4. Conceptual Approaches

The conceptual approaches were derived from the literature review outcomes and case studies and were underpinned by literature, theoretically confirming their feasibility and respective conditions. Previous studies concluded that climate change adaptation and mitigation for climate resilience would not be implemented in the housing sector because of lack of any framework. This study identifies elements of GI employment for housing climate resilience: public awareness; land use and development regulation; land and property acquisition; environmental management plan; housing strategy; fiscal and taxation; and governance. Through abstracting of these elements, this study proposes a conceptual framework that can be used for policies process and similar future research.

#### 4.1. Public awareness

The critical issue for reducing climate change consequence is widespread public awareness and education. It is viewed as the key to an effective and sustainable mean in mitigation policy and practice. It must involve as many as urban key stakeholders as possible to recognize the principle and actions in reducing the natural disaster impacts. Public awareness can also improve what people think and perceive about disasters in order to act properly to climate-related disasters. The development of GI for climate housing resilience to some degree will also greatly depend on public participation as the result of public awareness and education programs. Raising public awareness on climate change impacts and GI application for mitigation and adaptation aims to encourage housing resilience.

Therefore, a successful program for climate resilience housing using GI approach need to incorporate strategies to raise public awareness including (1) Conducting public education & risk communication program (e.g. education and training), (2) Conducting risk communication regularly for the community to maintain sustainable awareness, adaptation and mitigation for resilience, (3) Development of comprehensive climate-related hazard maps and GI plan like inundation maps with public participation for raising public's awareness and (4) The direct involvement of marginalized group (the elderly, the young families, the poor, other needing special physical and mental attention, and ethnic minorities) in planning and implementation of GI for climate housing resilience programs

## 4.2. Land use and development regulation

Land use and development regulation are significantly important in the development and management of GI. It is one of the primary tools for climate mitigation and adaptation at the community level with the most straightforward, cost-effective strategy and local approaches, particularly for the housing sector. The regulation of land use can reduce the exposure of urban housing residents to climate-related disaster by controlling the amount, timing, density quality, and location of GI network development. Nevertheless, in reality, development in climate-related disaster vulnerable area are significantly shaped by urban land use policies, and those local land use adoption, in turn, greatly influenced by federal/ national and state/provincial incentives scheme.

Some strategies and techniques of land-use planning to mitigate and adapt climate-related disaster through GI application can include (1) Adopting a zoning ordinance to limit exposure of new housing development in climate-related hazard-prone area and planned such limited area for GI elements, (2) Designation of undeveloped vulnerable areas to keep housing development at a minimum level, (3) Plan of adequate areas for GI network development and extended future growth to support housing areas to increase its resilience, and (4) introducing GI into existing housing development through redevelopment, retrofit, and land re-use plans

## 4.3. Land and property acquisition

Land and property acquisition has several advantages over strictly regulatory approaches like zoning. The acquisition method ensures that the land and properties can be controlled, managed and used that are compatible with GI development for

mitigating and adapting climate consequence especially for housing sector by a government agency or nonprofit organization and removing any law disputes over a regulatory taking. The primary obstacle to acquisition is high cost. The issue of property right in the local system context must be scrutinized since it contains a great deal of political weight while also having some degree of constitutional rights protection. The cost of maintenance and preservation of acquired lands also another factor that needs to be considered.

#### 4.4. Environmental management plan

The environment and disasters are inherently linked while they are interacting with the human community in complex ways. Reducing environmental quality can modify natural processes increasing vulnerability. For instance, massive conversion of urban green space to other uses can substantially reduce natural capacity to absorb or store the flooding. From the GI perspective, the environmental system has a main and critical role in mitigating and adapting to the impact of climate change. Environmental management can be effectively implemented if combined with other measures such as regulations, incentives, and acquisition for private landowners or cooperation with non-profit conservation or land trust agencies. An effective environmental management plan to ensure that GI natural system may mitigate and adapt the impact can be accomplished in ways: (1) Environmental management plan which maintain and restore natural protective ecosystem for GI network, (2) Environmental plan which provides incentives to development of GI infrastructure located inside private lands, and (3) Environmental management plan that identifies environmental impact and benefit assessment of GI in the plan, design and intensity of housing development.

#### 4.5. Housing strategy

Housing sector is the important element in GI planning that needs to acknowledge as they are particularly vulnerable to climate-related hazards while also as trigger as emission contributor. As previously discussed, the GI plan for housing sector should be incorporated due to the high concentration of people and assets in the urban area. The integration of GI plan and housing strategies can include: (1) The reduction of surface coverage and balancing the density of built units to achieve the quality of spatial planning and green spaces as element of GI, (2) Application of green infrastructures such as green wall as means of natural cooling and shading offers as low-cost solutions

to better urban microclimate and urban environmental quality, and (3) Mixed-use and high-density housing policy to provide more space for GI element such as retention pond that not only storing temporary water during flooding event but also as space for species for living.

#### 4.6. Fiscal and taxation strategy

Capital and budgeting planning can have a significant impact on the pattern of urban development. On the one hand, it can support climate change mitigation and adaptation efforts, on the other hand, it can discourage it. The capital and budgeting planning for spending may strengthen the resilience of community when GI program is included explicitly in comprehensive public facility and land management policy. Although its cost-effectiveness compare to grey infrastructure, the critical issue regarding with finance exists due to the lack of legal framework and the absence of private sector to invest in GI scheme due to a lack of a cost-benefit analysis data and tools. The use of financial incentives and disincentives affect the employment of GI by the private sector such as developers. For instance, any government program that provides grants, loans, tax credits, insurance or another type of financial assistance has a large profound consequence on both public and private development.

#### 4.7. Governance

Governance is a critical element to integrate GI with the housing sector. The governance culture more support the provisioning of grey infrastructure that favors a centralized system. In contrast to grey infrastructure, GI needs decentralization structure through public participation. Another governance barrier is the spatial and functional fragmentation of institutions or agencies at many levels. As these institutions are sometimes significantly different in goals, priorities, and interests, multisectoral cooperation is required for the effectiveness of policy adoption and implementation of GI for housing. The lack of motivation and willingness to comprise housing resident or other related stakeholders in the GI process and development by governments is another issue in the governance model that is often happening in the developing world. The efforts to incorporate another housing stakeholder with local government is effective to educate respective agencies on how GI functions and benefits. This acknowledging could change of governance culture to employ the decentralization system as required by GI. However,

it is important to highlight that dealing with governance issue could take a long process and persistence due to political complexity and uncertainty.

## 5. Conclusion

This framework for housing climate resilience facilitates elements of urban planning for climate mitigation and adaptation. It integrates social, environment, economy and institutional resilience factors to employ GI. The framework provides an organizing element comprising of public awareness; land use and development regulation; land and property acquisition; environmental management plan; housing strategy; fiscal and taxation; and governance that are well rooted in the theory and practice of case studies related to climate adaptation and mitigation which has not previously been synthesized in this approach. A framework is a new tool for scoping and assessing urban housing vulnerability to climate change by helping stakeholders such as government, developers, and residents to systematically consider the benefit of GI scheme in the respective efforts. Housing climate resilience is an innovative concept for urban stakeholder, practitioners, and planners. For that reason, this study hopes the framework can translate this broad and complex concept into readily identifiable issues to concern parties and related future research in an urban context..

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