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# PLANNING NET-ZERO ENERGY COMMUNITIES: HOUSING STRATEGIES FOR POST-DISASTER RESETTLEMENT IN SRI LANKA - A NARRATIVE REVIEW

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## *ABSTRACT*

*Construction industry is a major contributor to global energy consumption and greenhouse gas emissions, while simultaneously being core of post-disaster recovery processes. Net Zero Energy Buildings (NZEB) have become as a key strategy for minimizing environmental impact of this sector, and the concept has increasingly expanded to the community scale as Net Zero Energy Communities (NZEC). Despite the significant potential of NZEC principles for addressing sustainability, resilience, and energy poverty, their application in post-disaster resettlement (PDR) contexts in developing countries remains largely unexplored. PDR communities provide a unique greenfield opportunity in Sri Lanka to integrate community-scale Net Zero Energy Housing (NZEH) at the earliest planning stages. However, there is no comprehensive framework exists to guide this integration. Through a narrative literature review, this paper explores the concepts and principles of NZEH and NZEC, analyses the socio-economic characteristics, climatic conditions, and energy requirements of Sri Lankan PDR communities, and identifies appropriate passive design strategies and renewable energy technologies for tropical community-scale NZE housing. Findings show significant synergies between NZEC principles and PDR housing requirements, including community orientation, shared resources, and local climate adaptation. The paper proposes a conceptual framework incorporating technical, social, and policy aspects for the implementation of community-scale NZEH in PDR context in Sri Lanka, contributing to national sustainability goals and disaster resilience.*

***Keywords:*** *Net Zero Energy Community; Passive Design; Post-disaster Resettlement; Renewable Energy; Sri Lanka.*

## 1. INTRODUCTION

The construction sector faces significant global pressure from climate changes, rising energy demands, and escalating environmental degradation (Ali et al., 2020; Lim et al., 2021). Globally, buildings consume approximately 40% of total global energy and emit approximately 36% of global greenhouse gas emissions (Xiaoxiang et al., 2024; Sajid et al., 2024). These figures reveal the necessity of the transition to the energy-efficient low-carbon models of building (Diliban et al., 2023). The urgency has intensified dramatically

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in the current geopolitical climate: constant Middle East crises and related oil supply chain shocks have led to a constant rise in fuel and electricity prices which have a disproportionate impact on energy-dependent developing economies (Shi, 2025; Sun et al., 2024). This aspect particularly exposes Sri Lanka, where the national electricity generation mix is heavily reliant on hydropower, which historically accounts for approximately 40-50% of total generation, while the remaining share is supplied predominantly through fossil fuels, including oil-fired thermal plants and coal, which together constitute around 45-55% of installed capacity (Fernando et al., 2017; Koswatte et al., 2024). The structural dependence on both hydropower and imported fossil fuels creates a dual vulnerability: first, a hydrological vulnerability, whereby reduced rainfall during dry seasons substantially diminishes hydropower output, triggering rolling power curtailments; and second, a fiscal and supply chain vulnerability, whereby increased reliance on imported fossil fuels exposes the national economy to global price shocks and foreign exchange pressures. During dry seasons, hydropower generation reduces substantially, forcing the country to rely even more heavily on costly fuel imports for power generation, and this reduction directly translates into rolling curtailments that directly affect household welfare and economic activity (Withanaarachchi et al., 2014; Fernando et al., 2017) The power cuts and subsequent rise in fuel prices remained in households in Sri Lanka at the start of 2026, which empowers the national significance of substituting built environments in the nation with energy-sustainable systems (Ananda & Thennakoon, 2026).

As a response to this global and national crisis, the notion of Net Zero Energy Building (NZEB) has become a leading holistic solution, whereby buildings have an annual balance of equal amounts of energy consumed and energy produced by renewable sources, and where the end result is zero net energy used (Jaysawal et al., 2022; Ibrahim et al., 2024). Building upon this, this idea has been extended to the community level as Net Zero Energy Communities (NZEC) where energy management and shared infrastructure produce economies of scale and greater resilience than a single building can provide separately (Carlisle et al., 2009; Moghaddasi et al., 2021). Globally, NZEC pilot projects have demonstrated compelling results. The '*Historic Green Village'* in Florida, USA, achieved its net-zero energy goal through shared solar PV, heat pumps, and community-scale energy management (Huang et al., 2021). The '*West Village Campus'* in California proved that mass production of solar PV arrays and bio-digester generation was able to cover majority of the community energy demands (Huang et al., 2021). All these examples prove that NZECs are technically viable and cost-effective, with lower per-unit costs and enhanced resiliency and co-benefits such as local employment and microclimate improvement (Isaac et al., 2020; (Mavrigiannaki et al., 2021).

The transition from NZEB to NZEC, and from NZEC to construction industry implementation, is an orderly and practically compelling process (Godin et al., 2021). The defining characteristic of NZEC namely the simultaneous, coordinated, green-field development of several buildings under a single planning authority is precisely the condition that PDR housing reconstruction provides (Shrestha et al., 2025; Sulzakimin et al., 2020). Sri Lanka is often exposed to natural disasters such as floods, cyclones and landslides that require massive housing reconstructions (Vijekumara, 2015). Most recently, cyclone '*Ditwah*', which occurred in November 2025, resulted in catastrophic damage to all 25 districts, leading to the largest reconstruction program in Sri Lanka, providing the timeliest opportunity to pilot community-scale NZEH on a national scale (Amaratunga & Kodituwakku, 2026).

However, past projects of Sri Lankan PDR have been more concerned with speed and quantity, not with sustainability, which has led to houses with low climate-responsiveness, high electricity bills, and poor levels of resident satisfaction (Mannakkara & Wilkinson, 2013). There is no existing comprehensive framework that would integrate the Net Zero Energy (NZE) principles with community-scale Post-disaster Resettlement Housing (PDRH) planning in Sri Lanka. This paper addresses this gap with the following scope and objective: to conduct a narrative literature review that synthesises the concepts and principles of NZEB and NZEC; analyses the socio-economic, climatic, and energy access characteristics of Sri Lankan PDR communities; identifies passive design and renewable energy strategies appropriate for tropical community-scale NZE housing; and proposes an original conceptual framework integrating NZEC principles with PDR housing planning in Sri Lanka. The paper concludes by proposing a conceptual framework that synthesizes finding. It is further suggested that a pilot project can be initiated within Sri Lanka's current cyclone Ditwah reconstruction programme. The benefits of lower household energy bills, better thermal comfort, stronger grid resilience, and faster development towards net-zero by 2050 could extend across country and serve as an incentive to others to adopt renewable energy.

## 2. RESEARCH METHODOLOGY

The study adopts a narrative literature review (NLR) methodology. The NLR methodology can be used when the aim is to synthesize a wide and heterogeneous body of knowledge in multiple, but related, domains and to develop a conceptual argument (Snyder, 2019). Unlike a systematic review, which follows a predetermined protocol in selecting studies, an NLR methodology gives the researcher more freedom to make interpretive judgments in selecting and synthesizing the studies, which is important in bridging the gaps in the related but distinct domains of energy engineering, sustainable construction, and disaster studies (Grant & Booth, 2009)..

Shandiz et al. (2021) employed a narrative review to map the state of the art in energy master planning for net-zero communities, and Gupta and Deb (2023) used the same approach to synthesize envelope design strategies for low-energy buildings in tropical climates. The NLR is particularly appropriate for emerging interdisciplinary fields where the evidence base is distributed across disciplines and where a heterogeneous body of literature needs to be brought together into a coherent conceptual argument, rather than subjected to quantitative meta-analysis (Snyder, 2019). The methodological choice is further justified by the fact that this study aims to develop a first-generation conceptual framework, which is an inherently interpretive and integrative task that precedes and informs subsequent empirical phases such as expert interviews or Delphi studies (Grant & Booth, 2009).

The literature was gathered from peer-reviewed journal articles, conference papers, books, government reports, and institutional publications, which were obtained via databases. The key search terms included combinations of: "*Net Zero Energy Building*", "*Net Zero Energy Community*", "*Post-disaster Resettlement*", "*Passive Design Tropical Climate*", "*Renewable Energy Sri Lanka*", and "*Community-scale Energy*". To make more practical, grey literature of the government agencies in Sri Lanka and reputable industry bodies of the United Nations were also included. The inclusion criteria prioritized studies that were published after 2010, but there were exceptions in the case of seminal foundational studies. The review was organized thematically and synthesized to discover the principles, gaps, synergies, and integration prospects.

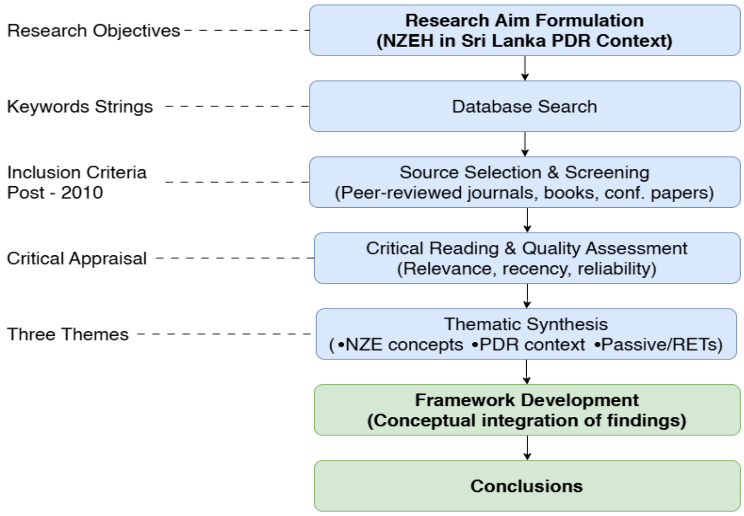


*Figure 1: Research process flowchart*

# 3. NET ZERO ENERGY CONCEPTS: FROM BUILDINGS TO COMMUNITIES

## 3.1 DEFINITION AND EVOLUTION OF NZEB

Net Zero Energy Buildings have emerged as the foundation of sustainable development in the built environment. An NZEB is defined as a building with an annual balance in which the energy consumption equals renewable energy production from on-site or off-site sources, resulting in zero net energy use (Jaysawal et al., 2022; Sartori et al., 2012). The initial systematic NZEB concept emerged in North America during the 1970s, gained traction in Europe through Germany's Passive House Institute in the 1990s, and was formalised when the International Energy Agency introduced the term "net zero energy" in 2008 (Attia, 2018). In 2010, the European Union subsequently proposed the "nearly zero energy building" (nZEB) standard, characterising buildings with extremely high energy efficiency whose minimal remaining needs are supplied by on-site renewable sources (Borowski et al., 2025). Nowadays, NZEB construction is increasingly feasible due to continuous developments of building technologies and renewable energy systems (Jaysawal et al., 2022).

The NZEB concept is based on two complementary strategies: 'Energy Efficiency Measures' (EEM) and 'Renewable Energy Technologies' (RET). EEM focus on reducing demand by building envelope optimisation, passive design, and efficient appliances and high-performance buildings targeting up to 70% energy reduction compared to national standards (Katipamula et al., 2015). RET then fulfil the reduced remaining demand through solar photovoltaic systems, solar thermal, wind, and biomass technologies (Lim et al., 2021).

## 3.2 TRANSITION FROM NZEB TO NZEC

The NZE concept has gradually extended beyond the individual building to encompass neighbourhood and community scales. A NZEC is defined as a set of buildings and related infrastructure within a defined area whose total annual energy consumption is balanced by renewable generation within or associated with the community (Alaifan & Azar, 2023; Carlisle et al., 2009). This scale change necessitates incorporating holistic planning policies related to grid management, transportation systems, and space planning coordination (Shandiz et al., 2021). Table 1 presents a comparative analysis.

*Table 1: Comparative analysis of NZEB vs. NZEC*

| Dimension | NZEB (Building Scale) | NZEC (Community Scale) | Sources |
|---|---|---|---|
| Operational boundary | Individual building | Multiple buildings + infrastructure | Carlisle et al., 2009; Moghaddasi et al., 2021 |
| Planning integration | Building-level design | Holistic spatial/grid/mobility planning | Shandiz et al., 2021 |
| Technology options | Limited to building-appropriate systems | Wider range including shared solar farms, district heating | Shandiz et al., 2021; Mudgal et al., 2019 |
| Economic efficiency | Higher per-unit costs | 16% lower average initial investment | Isaac et al., 2020 |
| Grid interaction | Individual bidirectional flow | Coordinated community-level management | Moghaddasi et al., 2021 |

Community-scale aggregation is useful in complex building typologies with diverse energy demand spaces to attain net-zero state where individual buildings with high energy demand did not achieve net-zero performance (Polly et al., 2016). The implementation of NZEC also has several co-benefits such as a better microclimate environment, increased compliance with energy-saving regulations, increased energy conservation, local employment creation, and economic growth (Mavrigiannaki et al., 2021; Ahmed et al., 2024). These broad advantages make NZECs particularly appropriate in the context of PDR where comprehensive community planning allows integrated sustainability from the earliest stages of development (Sulzakimin et al., 2020).

## 3.3 SOCIAL AND BEHAVIOURAL DIMENSIONS

The social and behavioural aspects are critical to NZEC adoption's success. In operational NZEH, performance is significantly affected by human-building interactions, often exceeding the impact of weather fluctuations (Nikdel et al., 2022). Community ownership and participation in the actual design of energy projects are critical to improve not only its acceptability but also operational engagement (Piselli et al., 2021). For PDR communities, this is not a choice, and community participation in the actual design of energy-efficient homes is a structural requirement, a condition under which communities always end up with culturally inappropriate homes, leading to low satisfaction and abandonment rates (Mannakkara & Wilkinson, 2013; Vijekumara, 2015).

# 4. POST-DISASTER RESETTLEMENT COMMUNITIES IN SRI LANKA

## 4.1 DEFINITION AND CONTEXT

PDR is defined as a process of planned, assisted, and permanent relocation of populations who have been displaced due to disaster events (Shrestha et al., 2025). PDRH includes initiatives to offer permanent homes to displaced populations, including on-site reconstruction or moving to new resettlement locations (Wijegunarathna et al., 2018). The concept of "Build Back Better" (BBB) implies that the reconstruction cannot be a mere restoration of pre-disaster conditions; instead, the community should be created by creating safer and more sustainable and resilient (Mannakkara & Wilkinson, 2013).

Sri Lanka is prone to natural disasters including floods, cyclones, and landslides that repeatedly destroy housing stock, necessitating massive reconstruction. Even though the most documented disaster of Sri Lanka in the literature is the Indian Ocean tsunami of 2004 that resulted in the death of above 35,000 people and displacement of an estimated of 516,000 people, with approximately 100,000 houses destroyed and approximately 100,000 partially affected (Mannakkara & Wilkinson, 2013; Lunuvila & Kulatunga, 2022), Cyclone Ditwah has fundamentally redefined the magnitude and covered an area of about a fifth of the land of Sri Lanka, over 2.3 million people in all 25 districts were affected, 646 people died, 209,000 displaced, more than 6,000 houses destroyed, and nearly 100,000 partially damaged (DMC, 2025). The total direct damages amount to USD 4.1 billion, which is about 4% of the Sri Lankan GDP in 2024. The timeliest and strategically significant opportunity to integrate NZE in the history of NZE integration in Sri Lanka is, the ongoing 'Presidential Task Force' reconstruction programme that is currently under monitoring by UN and World Bank and is projected to last through early 2026 (Amaratunga & Kodituwakku, 2026).

## 4.2 SOCIO-ECONOMIC AND CLIMATIC CHARACTERISTICS

Marginalised groups in society are disproportionately impacted by disasters, and vulnerability closely relates to poverty (Sridarran et al., 2018). Post-tsunami surveys show this pattern that 65% of affected households earned SLR 5,000 or less monthly, with livelihoods concentrated in fishing, trade, and manufacturing (Arunatilake, 2018). A fundamental problem identified in Sri Lankan PDR efforts is the failure to incorporate socio-economic conditions and cultural habits in housing design, which has resulted in people finding these homes alienating, leading to a high level of dissatisfaction, abandonment, and social conflicts (Mannakkara & Wilkinson, 2013; Vijekumara, 2015). These socio-economic characteristics are directly relevant to NZEC planning because the affordability constraints of PDR communities mean that energy cost savings and the reduction of energy poverty must be foregrounded as primary justifications for integrating NZE principles, rather than treating them as secondary sustainability co-benefits. The community-scale model of NZEC is particularly suited to low-income PDR contexts because shared infrastructure, cooperative energy ownership, and collective governance reduce per-household capital costs and maintenance burdens that would be prohibitive if borne individually (Isaac et al., 2020; Mavrigiannaki et al., 2021). Moreover, the cultural factors and livelihood patterns identified in the literature inform the social pillar of the NZEC implementation framework developed later in this paper.

Sri Lanka experiences a tropical climate with two monsoon seasons of great spatial variability. The Southwest monsoon (May–September) affects the Southern and Sabaragamuwa provinces most severely, while the Northeast monsoon (December–February) affects eastern, Northern, and North-central provinces (UNDRR, 2019). Climate change is intensifying these hazards, with flooding identified as the most critical and increasing threat in Sri Lanka. Another glaring weakness in Sri Lanka's PDR efforts is the failure to incorporate climate responsive designs, which has resulted in overheating and a need for mechanical air conditioning, which is unaffordable for low-income residents (Coorey et al., 2017).

### 4.3 ENERGY ACCESS AND PLANNING DEFICIENCIES

Energy poverty is an especially critical problem in PDRs. In Sri Lanka, it was identified that 67.8% of surveyed energy-poor households were not income-poor, thus reinforcing the fact that income poverty alone is not a cause of multidimensional energy poverty (Jayasinghe et al., 2021). Several tsunami-affected households relocated to resettlement programs lacked electricity connections entirely (Arunatilake, 2018). Inadequate thermal design creates a vicious cycle where housing is overheated, and people respond by purchasing cooling devices they cannot afford to run, thus creating energy poverty. (Coorey et al., 2017). There was an emphasis on speed over quality in PDR projects, with inadequate funding and poor planning further contributing to inadequate thermal and energy performance (Lunuvila & Kulatunga, 2022). In the backdrop of high and rising global energy costs in 2026, resettlement housing that does not incorporate passive thermal and on-site power generation technologies will perpetuate energy poverty on the very community's disaster recovery is meant to uplift. This directly validates the application of NZEC principles in PDR contexts: the community microgrid, shared solar generation, and passive design strategies that define a NZEC are precisely the tools required to break this vicious cycle of energy poverty in PDR communities. The energy access deficiencies documented here therefore constitute a core evidence base for the NZEC-PDR integration framework proposed in Section 6.

## 5. PASSIVE DESIGN AND RENEWABLE ENERGY TECHNOLOGIES FOR TROPICAL COMMUNITY-SCALE NZE HOUSING

### 5.1 PASSIVE DESIGN STRATEGIES FOR TROPICAL CLIMATES

In tropical climates such as in Sri Lanka, passive design strategies are found to be the primary and most cost-effective solution to reduce energy demands before any renewable technology is employed, which is an application of the hierarchy of Energy Efficiency Measures (EEM) first, as recommended by Gupta and Deb (2023) and Feng et al. (2019). At the community level, these strategies must be applied universally to all dwelling units to avoid mutual shading and wind obstruction. Table 2 summarises key passive design strategies for the Sri Lankan PDR context.

*Table 2: Passive design strategies for tropical climate NZE housing in Sri Lanka*

| Strategy | Application | Expected Benefits | Sri Lanka Considerations | Sources |
|---|---|---|---|---|
| Building orientation | East-west longitudinal axis | 20–40% cooling load reduction | Minimise east-west façade exposure | Hyde et al., 2012; Gupta & Deb, 2023 |
| Natural ventilation | Cross-ventilation; stack effect design | Mechanical cooling avoidance | Utilise monsoon wind patterns | Coorey et al., 2017; |
| Roof insulation | Reflective coatings; insulation layers | 30–50% heat gain reduction | Cost-effective local materials | Rathnasiri et al., 2023 |
| Solar shading | Extended overhangs (1–1.5 m) | 25–35% cooling load reduction | Balance shading with daylighting | Feng et al., 2019 |
| Daylighting design | Optimised window-to-wall ratio; light shelves; clerestory windows | 20–40% reduction in artificial lighting energy demand | Balance solar heat gain and glare control in tropical conditions | Gupta & Deb, 2023; Feng et al., 2019 |
| Raised floor levels | Elevated above grade | Flood protection; improved under-floor ventilation | Essential given cyclone flood risk | (Coorey et al., 2017) |

## 5.2 RENEWABLE ENERGY TECHNOLOGIES FOR THE SRI LANKAN CONTEXT

Sri Lanka has an ambitious goal of reaching net zero by 2050 with 100% renewable electricity (Fernando et al., 2023). As noted by Koswatte et al. (2024), the country receives 4.5-6.0 kWh/m²/day solar irradiance, giving solar PV a strong resource base. Hybrid systems that integrate solar, wind, and biomass are the most resilient for off-grid or semi-grid PDR communities, and this is confirmed through techno-economic analysis for the communities (Aberilla et al., 2020; Mudgal et al., 2019). Table 3 summarises key RETs applicable in the Sri Lankan NZE community context.

*Table 3: Renewable energy technologies for Sri Lankan NZE communities*

| Technology | Resource Availability | Capacity Range | Implementation Considerations |
|---|---|---|---|
| Solar PV | Excellent nationwide (4.5–6.0 kWh/m²/day) | 1–10 kW per household | Roof area requirements; grid connection; falling costs |
| Solar thermal | Excellent for water heating | 100–300 L per household | Simple technology; low maintenance; high reliability |
| Biomass gasification | Good in agricultural regions | 5–50 kW community systems | Fuel supply logistics; emissions control; community waste streams |
| Micro-wind | Variable (coastal/elevated areas) | 50 W–50 kW | Site-specific wind assessment required; noise considerations |

| Technology | Resource Availability | Capacity Range | Implementation Considerations |
|---|---|---|---|
| Hybrid systems | Excellent (combining sources) | 50–500 kW community scale | Complex design; energy management systems; optimal for off-grid PDR |
| Micro/mini hydro | Good in hill country and riverine areas (Sabaragamuwa, Uva, Central provinces) | 5–100 kW community systems | Site-specific hydrology assessment required; not applicable to coastal/flat PDR sites; high baseload reliability where available (Koswatte et al., 2024; Aberilla et al., 2020) |

The community microgrid is the operational mechanism that transforms individually efficient buildings into a functioning NZEC. Microgrids allow local energy generation, storage, and consumption to be optimised, allow peer-to-peer energy exchange, and provide islanding functionality in case of grid failures (Vindel et al., 2019; Piselli et al., 2021). Islanding capacity is no longer a supporting feature but a core requirement of resilience in PDR communities, where grid infrastructure itself might be damaged.

# 6. SYNERGIES BETWEEN NZEC AND PDR REQUIREMENTS: A CONCEPTUAL FRAMEWORK

## 6.1 MATCHING FEATURES

The preceding sections have established the distinct feature profiles of NZEC and PDRH independently. From the NZEC perspective (Sections 3.1–3.3), the defining features are: community-scale energy boundary with shared infrastructure; democratic and cooperative energy ownership models; integrated passive design and RET portfolios; community microgrid with islanding capability for resilience; and economies of scale that reduce per-unit initial investment by an average of 16% (Isaac et al., 2020). From the PDR context (Sections 4.1–4.3), the defining requirements are: rapid greenfield housing delivery at community scale; affordable construction and operating costs for low-income households; climate-responsive and thermally comfortable designs suited to tropical conditions; reliable access to electricity as a basic service; active community participation and social cohesion to prevent abandonment; and resilient infrastructure that can withstand future disaster events. The narrative review demonstrates significant synergies between NZEC principles and PDRH requirements, classified into three matching feature categories as illustrated in Table 4.

*Table 4: Synergies between NZEC features and PDR housing requirements*

| NZEC Feature | Corresponding PDR Requirement | Synergy Description |
|---|---|---|
| Community-scale focus; democratic energy ownership | Active community participation and social cohesion | NZECs foster collective welfare and shared goals, directly addressing PDR needs for robust social integration |

| NZEC Feature | Corresponding PDR Requirement | Synergy Description |
|---|---|---|
| Shared resources; distributed generation and storage | Reliable basic infrastructure (electricity, water) | NZECs leverage battery storage systems and microgrids for efficient power management, ensuring reliable essential amenities |
| Energy Efficiency Measures; passive design | Adaptable, climate-responsive, resilient housing | NZECs passive strategies tailored to local microclimates, supporting PDR requirements for resilient and affordable designs |

## 6.2 CONCEPTUAL FRAMEWORK

Figure 1 illustrates the conceptual framework developed through synthesis of the narrative literature review. It is presented in the form of a top-down causal flow chart comprising six layers that are interconnected: global and national context drivers, the conceptual evolution and application pathway, flanking barriers and enablers columns that simultaneously act on the implementation zone, the three-pillar implementation framework itself, the NZEC-PDR synergy band, and the NZE-housing outcomes. The feedback loop on the right side of the diagram connects the outcomes back to the context layer, signifying the cyclical and repetitive nature of the framework throughout the future PDR programmes.

The chart reflects interconnections and interrelationships between NZEB, NZEC, construction industry, and the PDR context, illustrating that these areas are not isolated, unrelated fields but a coherent, mutually reinforcing progression. Four global and national context drivers (climate crisis, energy insecurity, disaster frequency and policy imperative) that influence the system downwards. The conceptual evolution row directly plots the NZEB-to-NZEC-to-Construction Industry-to-PDR route, with Cyclone Ditwah reconstruction identified as the immediate entry point. Flanking the implementation zone, the barriers and enablers play the role of opposing forces on the implementation pillars. The three pillars have seven sub-elements each, representing the specific implementation requirements. The synergy band results to four measurable outcome categories: energy self-sufficiency, thermal comfort, disaster resiliency, and sustainability. The inclusion of the policy pillar within the three-pillar implementation framework is grounded in the evidence reviewed in Sections 4 and 5: the failure of past Sri Lankan PDR programmes to adopt energy-efficient designs was not merely a technical shortcoming but was driven by institutional prioritisation of speed over quality, inadequate funding mechanisms, and the absence of sustainability mandates in housing reconstruction policy (Lunuvila & Kulatunga, 2022; Mannakkara & Wilkinson, 2013). Similarly, the inclusion of financial incentives as a sub-element is grounded in the literature's consistent findings that the long-term economic benefits of NZE systems including energy cost savings and reduced utility expenditure are not immediately visible to low-income disaster affected households at the point of reconstruction. Policy instruments such as subsidies, green reconstruction grants, and community energy ownership schemes are therefore necessary enablers to bridge this gap between long-term NZE benefits and short-term recovery priorities (Godin et al., 2021; Mavrigiannaki et al., 2021).

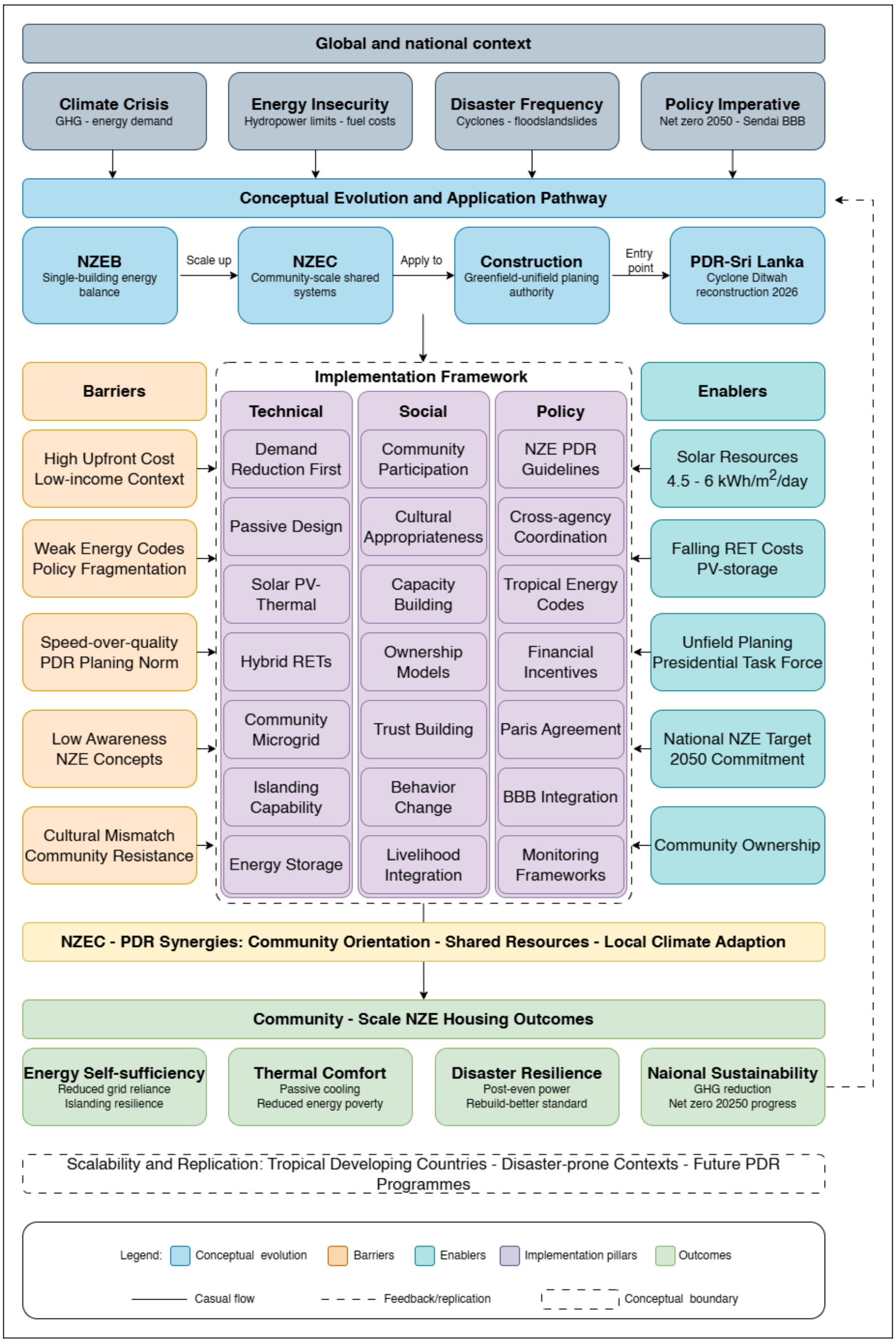


*Figure 2: Conceptual framework for community-scale NZEH in PDR communities in Sri Lanka*

## 7. CONCLUSIONS

The paper has analysed the convergence of concepts under NZE passive design, renewable energy, and post-disaster resettlement housing in Sri Lanka through a narrative literature review and synthesised the findings into an original conceptual framework.

The main contribution of this work is the framework illustrated in Figure 1. It maps, first of its kind, the logical and practical connections between NZEB and NZEC and the construction industry and the PDR context as forming a coherent progression of each level making possible the next, and not as an independent set of inquiry. Key findings confirm that the NZEC principles have certain tangible benefits that outweigh the individual NZEB strategies, including the economies of scale reducing the initial investment by 16% on average, resiliency imposed by community microgrids with islanding capability, and energy management imposed by distributed peer-to-peer systems, which directly counter the failures recorded in previous Sri Lankan PDR designs. Cyclone Ditwah reconstruction programme is the most strategically important and timely opportunity ever to pilot community-scale NZEH at national scale in Sri Lanka, against the background of global energy price shocks and the national vulnerability of hydropower.

The passive design strategies and RETs identified, building orientation, natural ventilation, roof insulation, solar shading, solar PV, solar thermal, and hybrid energy systems constitute a technically feasible and contextually appropriate toolkit for Sri Lanka's tropical climate and socio-economic conditions. The three-dimensional implementation framework (technical, social, policy) offers a novel and evidence-based framework to further empirical studies. Future research ought to consider this framework by validating and refining it using expert interviews and delphi-based consensus building, the development of quantitative energy performance models within Sri Lankan climatic regions and propose the framework as the foundation of a pilot NZE community in the current Cyclone Ditwah reconstruction programme. When successfully deployed, the positive outcomes, which include lower household energy bills, better thermal comfort, more resilient post-disaster grid, and faster deployment toward national Net Zero by 2050 will be demonstrable, quantifiable, and reproducible in future PDR programmes in Sri Lanka and other developing countries vulnerable to disasters.

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