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Energy Efficiency Is Not the End Goal: Socio-Economic Sustainability Lessons from Four Rural Housing Cases in Scotland

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Abstract

The pursuit of energy efficiency has dominated sustainable housing policy and research, yet growing evidence suggests that technical performance alone cannot guarantee positive outcomes, particularly in rural contexts where housing is embedded within complex socio-economic systems. This study addresses this gap by developing and applying a context-specific analytical framework for evaluating the socio-economic sustainability of rural housing in Scotland. Through a structured literature review of 43 peer-reviewed articles and thematic coding, four core sustainability dimensions were identified: People and Community, Land and Site, House, and Energy and Infrastructure. The framework was developed and tested through four contemporary rural housing case studies in Scotland, spanning private and social tenures across Aberdeenshire, Moray, Dumfries & Galloway, and Shetland Islands. Data were collected through semi-structured interviews, on-site observations, and documentary evidence. A multi-evidence traffic-light evaluation system was developed to cross-check assessment results across distinct data sources. The findings reveal that sustainability outcomes are conditional, sometimes uneven, and shaped by multiple factors. While all cases demonstrated strong performance in community cohesion, affordability, and non-speculative land access, some persistent challenges emerged around energy resilience, fuel poverty mitigation, transport accessibility, and participatory practices for social-house design. The study contributes a replicable analytical framework to develop and evaluate rural housing sustainability beyond energy-efficiency assessments, providing empirical insights for policy and practice in Scotland.

Keywords: rural housing; socio-economic sustainability; Scotland; sustainable development

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1. Introduction

Human settlement and housing have long been cornerstones in global frameworks to promote sustainable development and have evolved to focus on the imperatives of addressing the challenges of global climate change [1,2]. Improving energy performance has dominated sustainable housing research and policy over the past decade. Concepts such as green building, Passive House, zero-carbon housing and net-zero housing have increasingly defined sustainability through measurable technical indicators, including energy efficiency, energy consumption, and carbon emissions [2–4]. These approaches have

undoubtedly contributed to reducing environmental impacts. However, an increasing body of research argues that designed energy efficiency alone cannot guarantee sustainable housing outcomes as housing is always embedded within socio-economic and cultural contexts [5–8].

Recent studies have therefore called for a broader understanding of sustainable housing that extends beyond building performance. Bennetts et al. [5] note that sustainability's varied ethics, objectives and contexts complicate architectural expression. Social practices, not technology, are key to evaluating a sound sustainable building. McMINN & Polo [9] emphasize region-specific architectures to adapt to local climate, geography and culture. They criticize modern sustainable buildings for prioritizing quantitative energy performance, resulting in utilitarian outcomes that erase regional identities, whilst integrating technology within cultural and social characteristics of places can deliver community acceptance and successful operation.

Moore & Karvonen [6] categorized sustainable housing into three types: context-bound (local crafts, limited resources), context-free (tech-driven energy efficiency), but prefer and advocate context-rich (a balance of tradition and innovation). A critical question remains: how to reconcile regionality with modern technology? Further, is compromise required or is it possible to maintain economic, social and environmental feasibility? Choguill [7] questions whether housing can be sustainable if it remains unaffordable for low-income groups, and Mulliner et al. [8] frames affordability as social and environmental preoccupations. Collectively, these studies suggest that sustainable housing should be understood as a multidimensional socio-technical system rather than evaluated solely through the measurement and appraisal of technical performance and cost.

Such issues become particularly significant in rural areas. Compared to urban settlement, rural housing needs to serve dispersed populations with limited transport connectivity and restricted access to civic services and public utilities. There is greater dependence on local physical resources and tight social networks [10–12]. Consequently, the sustainability of rural housing is closely associated with broader territorial development rather than individual building performance alone. Scotland [a devolved nation within the United Kingdom] represents a particularly valuable context for examining such interactions. Although rural Scotland occupies approximately 98% of the national land area, it accommodates only 17% of its population [13]. Rural communities are characterised by dispersed settlement patterns, diverse land tenure arrangements, ageing populations, fuel poverty, transport dependence and uneven infrastructure accessibility [14–17]. At the same time, Scotland has adopted ambitious climate targets and rural housing policies, creating increasing pressure to reconcile decarbonisation objectives with long-term community sustainability [18–20].

Despite growing recognition of these challenges, existing research exhibits two important limitations. First, most sustainable housing assessment frameworks have been developed primarily for urban contexts and consequently emphasise measurable technical indicators, mostly energy efficiency, and carbon emissions, while giving comparatively limited attention to the distinctive socio-economic characteristics of rural settlements [18,20]. Second, although individual studies have examined specific rural challenges, including fuel poverty, accessibility, community development, land reform and renewable energy transitions in Scotland [11,12,15–17,21,22], these are usually investigated independently rather than treated as interconnected dimensions that can define housing sustainability.

Accordingly, this study addresses the following research questions (RQs):

RQ1. How can the socio-economic sustainability of rural housing in Scotland be conceptualised and then developed through an integrated analytical framework?

RQ2. When tested, how do selected different contemporary rural housing case studies perform across a range of socio-economic measures of sustainable response?

RQ3. What insights can these case studies provide for developing future rural housing policy and practice in Scotland and comparable rural regions?

This study contributes to the literature in three ways. First, it builds a context-specific analytical framework through a systematic review of Scottish rural housing literature. It consolidates fragmented evidence into a model to analyse socio-economic sustainability in Scotland. This framework identifies practical Scottish rural housing challenges and provides a replicable tool for evaluating housing sustainability in comparable contexts. Second, four Scottish rural housing cases (both private and social tenure) are employed as pilot sites to test the methodology. Thirdly, the four case studies reveal opportunities and challenges and can be used to discuss the implications for developing rural housing policies and practices. Given the exploratory nature of this research and the limited number of case studies, the findings should be interpreted as analytical insights rather than statistically generalisable conclusions.

2. Materials and Methods

2.1. The Theoretical Framework: Tailored for Rural Scotland

2.1.1. Identifying Core Dimensions via Structured Literature Screening and Three-Stage Thematic Coding

To establish an analytical framework suitable for evaluating the sustainability of contemporary rural housing in Scotland, a structured review of the existing literature was undertaken. Rather than conducting a standalone systematic literature review (SLR) as the primary objective of the study [23,24], the review was used as a framework-building exercise to identify the key dimensions shaping rural housing sustainability within the Scottish context, followed the five-step SLR process outlined by Denyer & Tranfield [25].

The review focused on peer-reviewed journal articles published between 2004 and 2024. Literature searches were conducted in the Web of Science and Scopus databases using combinations of the keywords “rural”, “countryside”, “rurality”, “Scotland”, “Scottish”, “housing”, “house”, and “households”. The search generated 218 records. Following the PRISMA (2020) screening procedure, duplicate and irrelevant records were removed according to predefined inclusion and exclusion criteria. A final sample of 43 articles was retained for analysis.

The selected literature was analysed using an iterative thematic coding process adapted from qualitative content analysis. The objective was not to quantify keyword frequency but to identify recurring sustainability concepts and progressively abstract them into analytical themes. The coding process consisted of three stages (Figure 1). Dual coding was conducted to test inter-coder reliability, resolving coding discrepancies collaboratively to minimise subjective bias.

In the first stage, open coding was conducted to extract meaningful sustainability-related concepts from each article. Codes represented recurrent issues discussed in relation to rural housing, including neighbourhood relationships, community governance, housing affordability, fuel poverty, accessibility, land ownership, and energy equipment. Similar concepts appearing across multiple studies were coded consistently regardless of terminology. A total of 127 coding tags are generated in this step.

The second stage involved axial coding, during which conceptually related codes were grouped into broader analytical categories. For example, neighbourhood interaction, social trust and community participation were integrated into the broader concept of community cohesion, while energy supply and energy-saving awareness were grouped into

energy resilience. This stage reduced conceptual redundancy while preserving the diversity of sustainability issues identified in the literature. A total of 29 coded labels are generated in this step.

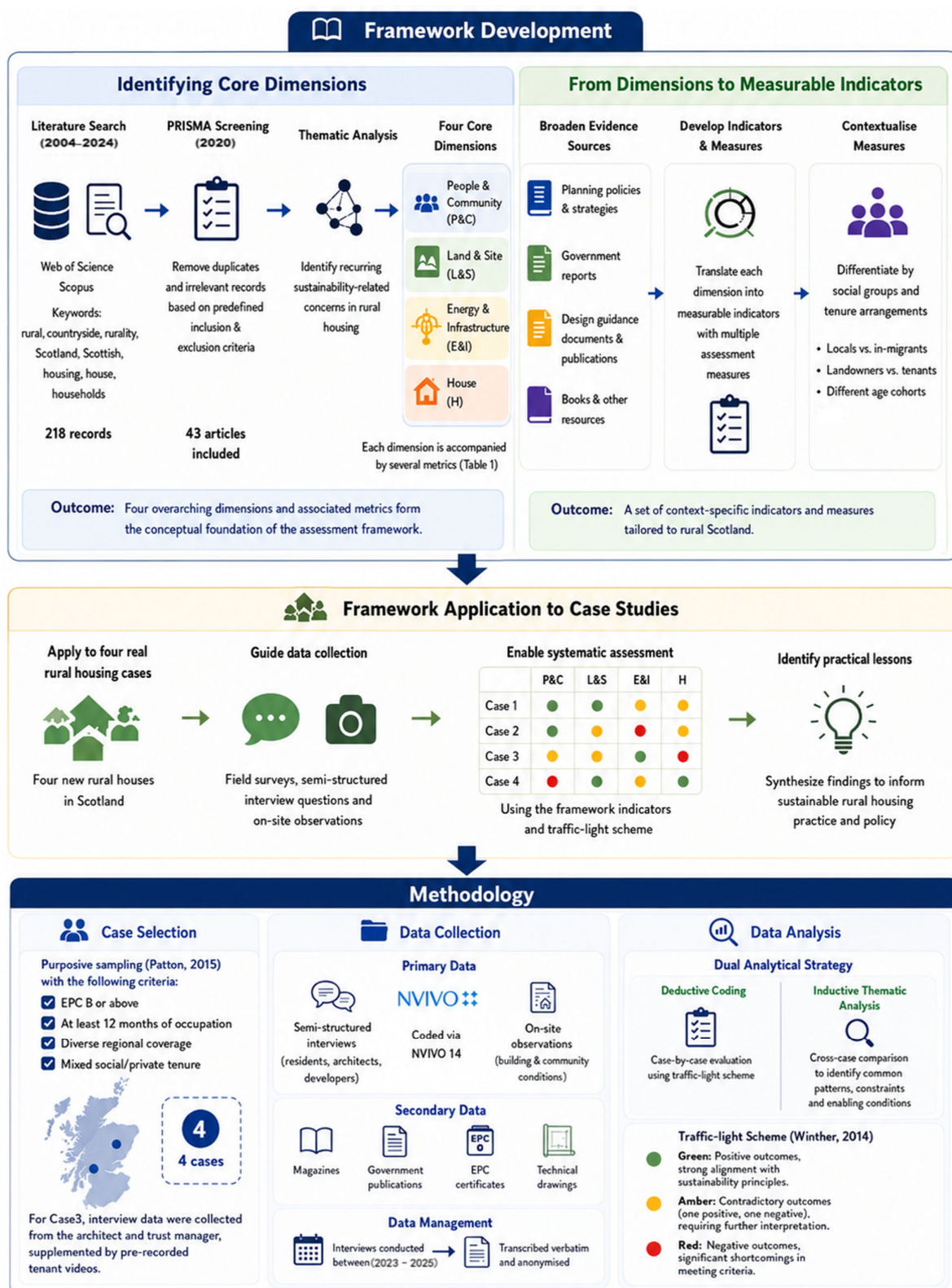


Figure 1. Conceptual Framework Development and Research Methodology.

Finally, theme abstraction was undertaken to organise these analytical categories into higher-order dimensions representing the principal components of socio-economic sustainability. Four dimensions consistently emerged throughout the coding process: People and Community (P&C), Land and Site (L&S), House, and Energy and Infrastructure (E&I).

2.1.2. Metrics Selection

This subsection explains the rationale for retaining the current set of specific metrics under each thematic dimension and establishes a transparent, replicable set of screening criteria applicable to all raw codes generated during the open coding and axial coding stages. This approach differs from the basis used to construct the four high-level dimensions described earlier.

Following the analysis of 43 documents, which yielded 127 raw open codes and 29 axial coding labels, all potential metrics were required to pass two mandatory screening procedures before being consolidated into the final metrics presented in Table 1.

Table 1. The framework for sustainable rural housing in Scotland.

Sustainability	Housing Elements	Metrics	Source
Social sustainability	P&C	01 Build good relationships with neighbours	01 [26–29]
		02 Maintaining the stability of community structures	02 [30–37]
		03 Promoting community participation and governance	03 [32,33,38,39]
	L&S	01 Long-term land use rights	01 [30,33,40,41]
		02 The location of the site meets the daily needs of residents	02 [28,31,42–46]
	House	01 Ensuring house meets residents' own specific needs	01 [29,39,47,48]
	E&I	01 Energy supply is stable and can meet daily needs	01 [49,50]
		02 Residents have energy-saving awareness	02 [51,52]
Economic sustainability	P&C	01 Promote the increase in relevant jobs and relevant skills training for local people	01 [37,53–55]
	L&S	01 Housing plot is affordable	01 [56,57]
		02 Reduce impact on local land markets	02 [57–59]
	House	01 Good for housing affordability	01 [36,40,56,60]
		02 Contributing to housing supply	02 [10,38,54,61]
	E&I	01 Energy infrastructure and home energy equipment investment	01 [53,54,62,63]
		02 Eliminating fuel poverty	02 [15,16,49,51,52];

Criterion 1: Frequency of occurrence across multiple documents.

Only concepts appearing as core sustainability themes in at least two independent, peer-reviewed documents within the corpus were retained. Concepts mentioned in only isolated cases or a single document were insufficiently validated factors regarding rural housing and were consequently excluded. For instance, the concept of “water poverty” found in [34] appeared only in that specific document; however, the underlying issue of housing-related water accessibility fell under the broader category of “basic daily needs.”

Criterion 2: Relevance to the long-term stability and sustainability of rural housing in Scotland.

This served as a critical contextual screening criterion for all recurring candidate codes. Even frequently mentioned concepts were excluded if no link could be demonstrated between them and the long-term viability of the rural living system. For example, in some rural areas of Scotland, access to formal healthcare and related services is limited; however, strong neighbourly relations foster mutual aid mechanisms that compensate for this scarcity, enabling residents to remain in the community long-term without needing to relocate. Thus, this form of sustainability implies a positive impact directly linked to

housing, whereas the absence of such a metric would result in negative consequences. This dynamic is precisely described in [28,29]. Consequently, regarding factors related to subjective attitudes, a candidate metric was retained only if peer-reviewed literature documented a clear correlation linking it to “sustainable rural living.”

2.2. Methodology

2.2.1. Case Selection

Four new rural houses in Scotland were selected as case studies. Purposive sampling [64] was used with the following criteria: EPC B or above, at least 12 months of occupation, diverse regional coverage, and mixed social/private tenure (Table 2). For Case 3, interview data were collected from the architect and trust manager, supplemented by pre-recorded tenant videos due to privacy restrictions.

Table 2. Basic information of cases.

Local Council	Ownership Type	Household Structure	Interviewee	Housing Type	House Age
Case 1 Aberdeenshire	Private	Living alone	House owner (self-occupant) P1	Detached	2011
Case 2 Moray	Social	Living alone	Tenant P2	Flat (4 studio)	2022
Case 3 Dumfries & Galloway	Social	Young couple with 1–2 children	Architect P3 Trust Manager P4 ¹	Flat (3 units)	2021
Case 4 Shetland Islands	Private	Young couple with 3 children	House owner (self-occupant) P5, P6	Detached	2021

¹ To eliminate data bias caused by differentiated interview access, a multi-source triangulation strategy is adopted for Case 3: interview records (archived videos), interviews with professional architect and trust manager are mutually verified to guarantee data quality and research robustness.

2.2.2. Data Collection

After identifying the four core dimensions and their associated metrics, this study operationalised the framework for empirical case analysis. This step converted normative sustainability metrics derived from the literature into concrete measurable items for field data collection. Rather than adopting predefined indicators from existing assessment systems, the indicators were developed through an iterative synthesis of recurring sustainability issues identified within the reviewed literature. To achieve this, secondary thematic refinement on the full texts of the 43 core articles was conducted, supported by supplementary literature including Scottish planning policies, housing strategies, official reports, design guides, rural development publications and relevant monographs. Recurring sub-themes were extracted to build measurable items, with particular focus on context-specific social issues typical of rural Scotland.

Let us take the metric “Build good relationships with neighbours” as an example. Multiple papers in the corpus repeatedly identify lasting social gaps between long-term local residents and new arrivals [29,35,38,40], even where neighbourhood cohesion was not the central research focus. Combined with additional supporting literature [65], we developed differentiated measurable items grouped by resident identity: “For long-term local residents: accepting and embracing community members from diverse backgrounds; maintaining positive interpersonal relationships with neighbours and community mem-

bers. For newcomers: avoiding social exclusion by established local residents; actively integrating into local culture and interacting with long-term residents to foster community cohesion.”

Following this consistent workflow, measurable items were generated for all metrics to reflect diverse rural housing experiences and stakeholder viewpoints. Where applicable, measures were split across distinct groups and housing tenures, such as local residents versus in-migrants, landowners versus tenants, and different age brackets. Full supporting sources and detailed measurement items are listed in Appendices A.1 and A.2, which complement the information summarised in Table 1.

Multiple independent data sources are integrated to cross-validate the coded evaluation scores for each sustainability metric, so as to reduce bias from a single type of evidence [66]. The dataset relies on semi-structured interviews with residents, architects and developers, whose transcripts are coded via NVivo 14 [67]. All interviews were conducted between 2023 and 2025. This semi-structured interview protocol is designed around the four framework dimensions, and customized questions are adjusted and tailored according to the types of ownership, household structure, etc. Interviews were transcribed verbatim, and all transcripts were anonymised by removing personal names and specific location identifiers.

It also incorporates at least one additional source from two categories: on-site observations, and secondary documentary materials including magazines, official government publications, energy performance certificates (EPCs) and architectural technical drawings [68–70]. Details regarding all triangulation data other than interviews, collected across various case scenarios, are presented in Appendix A Table A3.

2.2.3. Data Analysis

A dual analytical strategy was used: deductive coding for case-by-case evaluation with a traffic-light scheme, and inductive thematic analysis for cross-case comparison, synthesising data to identify common patterns, constraints and enabling conditions. Dual coding was implemented to improve inter-coder reliability: a co-researcher independently coded 30% of interview transcripts, and inconsistent results were resolved via joint discussion to reduce single-researcher interpretive bias. The assessment followed a traffic-light assessment protocol developed as a subjective–objective hybrid evaluation approach (Table 3). Rather than assigning ratings solely according to interview responses or quantitative evidence, each measure was evaluated through the convergence of multiple empirical evidence sources against predefined normative sustainability criteria. The final evaluation results are visualized as heatmap matrices across four dimensions.

Table 3. Traffic-light system coding principle.

		
A green light indicates that both subjective and objective evidence present positive outcomes, suggesting strong alignment with sustainability principles.	An amber light is assigned when subjective and objective data are contradictory—one being positive and the other negative—indicating an inconsistency that requires further interpretation.	A red light represents cases where both subjective and objective data are negative, indicating significant shortcomings in meeting the assessment criteria.

For measures primarily characterised by objective evidence such as fuel poverty and the provision of renewable energy infrastructure, assessment relied principally on documentary evidence, quantitative information and field observations, with interview data providing contextual interpretation. Conversely, measures primarily reflecting residents’

experiences such as neighbourhood relationships and community participation were assessed mainly through interview evidence, supported where possible by observations and documentary materials (Table 4).

Table 4. Classification of primary data sources for traffic-light system coding of measures.

Dimension of Measures		Objective Evidence-Led	Subjective Evidence-Led
SS	P&C	01-(1–5), 02-(1–2, 4–5),	02-(3)
	L&S	02-(1–2)	01-(1–4)
	House	01-(1, 7–8)	01-(2–6, 9)
	E&I	01-(1–3), 01-(1–2)	01-(4)
ES	P&C	02-(2)	01-(1–3), 02-(1)
	L&S	01-(1, 3–4), 02-(1)	01-(2), 02-(2)
	House	01-(1, 3)	01-(2), 02-(1), 03-(1–2)
	E&I	01-(1–3), 02-(1)	01-(4), 02-(2)

Importantly, the traffic-light ratings represent interpretive judgements rather than quantitative scores. Their purpose is not to rank individual case studies but to facilitate systematic comparison across cases while preserving the complexity and context-dependency of rural housing sustainability.

Finally, a systematic theoretical framework and methodological framework specifically for rural areas have been established, as shown in Figure 1. The proposed framework should be understood as a hybrid normative–empirical analytical framework. Its normative component lies in the construction of sustainability indicators and the evaluation criteria derived from the literature, whereas its empirical component derives from the triangulated evidence collected through interviews, observations and documentary sources. The framework therefore does not seek to measure sustainability directly but provides a structured approach for interpreting how normative sustainability objectives are realised, negotiated or constrained within different rural housing contexts.

3. Results

3.1. Community and People

Figure 2 assesses the P&C dimension’s five social and economic sustainability metrics, with all four cases showing predominantly green ratings; only isolated amber/red scores emerge, confirming P&C as a core strength of socio-economic sustainability in the studied Scottish rural housing. All cases exhibit robust social sustainability, marked by strong community cohesion, effective newcomer integration and high community identity. Case 3 is the sole case with red economic sustainability ratings here, failing to link housing development to local employment creation and workforce skill training despite strong social performance in cohesion and governance.

Cases	Social sustainable			Economic sustainable	
	P&C-01	P&C-02	P&C-03	P&C-01	P&C-02
Case1	Green	Green	Green	Green	Green
Case2	Green	Amber	Green	Green	Green
Case3	Green	Green	Green	Amber	Red
Case4	Green	Amber	Green	Green	Green

Figure 2. Sustainable heat map related to community and people.

3.1.1. The Role of Socially Spatial Design in Sustaining Neighbourhood Cohesion and Fostering Inclusivity for Newcomers

Neighbourhood cohesion and newcomer inclusivity in all cases hinge on interaction to facilitate and develop spatial design, with daily activity and casual communication spaces critical for connection and integration, to nurture cohesive communities. Case 1 lacked such spaces: despite the resident's long local tenure and community councillor role, no nearby gathering places hindered neighbourly connections, and being childless disconnected them from key social nodes like schools, exacerbating isolation (P1: "Since I don't have children... the school is the main thing that brings the community together in the village."). By contrast, Case 2's well-planned shared open spaces between households encourage integration of long-term residents and newcomers (P2: "Here is the spiritual energy of the community... A lot of people don't lock doors at night. It's a very safe place to bring up families and for people to live."). Case 3 integrated green spaces and schools to support intergenerational interaction. Such space was then used for community galas and shared activities that encourage close, interconnected social ties among residents. As reflected in the manager's account, residents maintain a well-connected social network where information and daily updates circulate freely (P4: "We regularly organise community events... for example, we have an annual gala where people come together and talk about all sorts of things"; "People know your business, they know who you are, and sometimes they even know where you're going."). A "croft", is a type of traditional smallholding that serves as the spatial foundation in parts of remote rural Scotland. In Case 4, the interview data illustrates how crofting practices were associated with reciprocal neighbourly assistance and opportunities for everyday interaction. (P5: "We have neighbours who have a tractor... They can move our big black bales for us. But we'll go and help them, we'll give them some feed. There's a symbiotic relationship; everybody down here is a crofter."). This example illustrates how such reciprocal interactions foster communication among new and established residents. The "croft", a type of traditional smallholding in the region, serves as the spatial foundation for these activities.

3.1.2. Housing Layout and Local Population Change: Impacts on Long-Term Community Stability

According to the cases, stable communities are tied to housing's ability to adapt to the many changes households experience, as age and relationships make ever-changing demands on the home. Case 3 integrates housing with schools to attract young families, creating a virtuous cycle where new housing sustains schools, and stable schools draw more families (P5: "We want to encourage people to either stay in our village or move here because we have a primary school. We hope families with young children will come, so that our primary school can remain strong."). Case 2 revealed vulnerabilities during the pandemic: housing tied to temporary employment led to resident departures after job loss, leaving homes vacant and disrupting community stability (P2: "A lot of people who were working here from foreign countries, and their visas were contingent upon them working for the Foundation. So, when they were made redundant, they had to go back to their countries."). Shetland's housing market issues (land shortages, rising prices/rents) deter young families, causing population decline and school closures, with the community losing its generational roots (P5). Based only on the conditions seen across these four sites, matching housing provision to actual local residential demand appears important for steady community life: shortages hinder population retention, while oversupply causes vacancy and erodes cohesion. In areas with low natural demand, social amenities like schools are vital for attracting residents and driving demographic regeneration.

3.1.3. Localized Housing Economies: The Coordinating Role of Housing Practitioners and Community Support

Architects and builders act as bridges between place and construction, integrating local context into design, with distinct coordination patterns observed across cases. Case 1's local construction team built trust through shared norms (P1: "a big thing in construction is actually trust."), while Case 4's architect translated on-site and crofting culture into tailored plans (P5: "He understood what kind of community we were living in and the way we wanted to live."). Case 2 achieved effective localization via community land trusts, local procurement and knowledge transfer, embedding construction in long-term community growth. In contrast, Case 3 excluded local builders for lacking advanced technical skills (P3: "If they don't have a satisfactory local firm, they have to choose another one."); this approach reduces investment in the immediate community being driven only by considerations of budget and efficiency (P3). Based solely on the empirical observations of these four cases, effective localised housing economies depend on basic coordination between housing practitioners and local communities. Positive local outcomes appear where construction craftsmanship fits local contextual features, project delivery builds trust-based local cooperation, and universal technical standards are appropriately adjusted to suit local conditions. This locally coordinated model helps embed housing construction within community development, rather than treating house building merely as a one-off commercial transaction.

3.2. Land and Site

Figure 3 assesses the L&S dimension across four social and economic sustainability metrics, showing dichotomous performance: uniform green ratings for social metric L&S-01 (long-term land use rights) and economic metrics L&S-01 (land affordability) and L&S-02 (low market impact), ensuring stable, low-cost land use for residents. All cases record amber/red ratings for social metric L&S-02 (site location meeting daily needs), driven by systemic rural infrastructure inadequacies, notably poor public transport and uneven digital connectivity.

Cases	Social sustainable		Economic sustainable	
	L&S-01	L&S-02	L&S-01	L&S-02
Case1	Green	Yellow	Green	Yellow
Case2	Green	Yellow	Green	Green
Case3	Green	Red	Green	Green
Case4	Green	Yellow	Green	Green

Figure 3. Sustainable heat map related to land and site.

3.2.1. Conditional Accessibility Shaped by Infrastructural Dependencies and Socioeconomic Positioning

The four case studies demonstrate that meeting daily needs is closely linked to social status, personal resources, the provision of infrastructure, and adaptive strategies. All four cases face accessibility constraints, but the impact varies based on individual circumstances such as car ownership and digital literacy. A shared limitation is inadequate rural public transport, which forces heavy reliance on private vehicles. P1 considers local bus services "good" only by regional standards, with his workplace proximity and car access making accessibility feel positive. Case 2 has no scheduled buses, and its car-sharing scheme failed because the app was ill-suited to elderly non-drivers with limited

smartphone skills. Case 3 faces both transport and pedestrian exclusion, with unsafe walking conditions and infrequent, inconvenient buses. P5 deals with just three daily buses and no Sunday service, needing a car even to reach bus routes. Automobility is the primary condition for spatial access in all contexts. Without private transport, daily needs become inaccessible. Yet impacts differ: P1 relies heavily on online shopping supported by robust broadband, reducing his dependence on local provision, but this lifestyle is not universally replicable. P2's perception of accessibility shifted sharply after retirement (P2: "Now I'm not working, I probably go out six times a week. It's convenient so far as I have a car."). Case 3's low-income tenants face acute exclusion, as affordability barriers limit both transport and digital access (P4: "It's very difficult unless you have money... Online shopping is okay, but you have to spend at least £50 or £60. For some people in our rural area, that is a problem."). P5 benefits from crofting self-sufficiency despite inadequate local broadband, confirming rural Scottish accessibility is shaped by both objective disparities and subjective conditions.

3.2.2. Varied Non-Market Land Access Across Four Sustainable Rural Housing Cases

Although the four cases differ significantly in their land acquisition paths, including private transactions, charitable transfers, public asset transfers, and intergenerational leasing arrangements, they all achieve a long-term stability. Results from the four cases reveal a common thread in that they bypass the commercial market for land and instead rely on socially mediated land acquisition:

P1 purchased the land at a price significantly lower than the regional market average, through mutual connections and support of local landowning farmers. This non-open market transaction enabled him to lock in what became zoned development land before land prices rose significantly. In Case 2, its community relied on internal transfers between charities and community enterprises to "gift" land at a symbolic price, that came with a clearly defined community governance structure for the land and subsequent community. Such arrangements therefore circumvent open markets and land commodification. Case 3 acquired land at a nominal price through a public asset transfer agreement with the Local Authority, who subsequently supported its development through public funds, that clearly reflected a policy of "land serving the public interest". Case 4 obtained the right to use the croft land through a long lease offered within the family, which enables long-term occupation and development rights without ownership of the land.

3.2.3. Market Commodification of Land as a Source of Rural Residential Exclusion

As shown in Table 5, while two private ownerships exist across the cases, it is precisely this avoidance of the risks brought about by land shortages that has become the key point where SS and ES converge: from a social perspective, the right to long-term land use can reduce the risk of relocation or loss of residence, making residents more willing to live here for a long time and participate in community building. From an economic perspective, land is not hyped up at market prices, which helps prevent overheating of land prices and lowers the investment threshold for housing projects at the initial stage.

Table 5. Land ownership and its integration (or separation) from speculative market.

	Case 1	Case 2	Case 3	Case 4
Private Land	√ ¹	√		√
Non-private land			√	
Commercial land	√			
Non-commercial land		√	√	√

¹ A checkmark indicates that the case belongs to this land type.

For example, in Aberdeenshire, land prices have risen by 58% over the past three years, while local housing prices and wages have declined due to the oil industry's downturn. This disconnect between land prices and house prices in particular stems from increased land purchases by commuters and investors, alongside land concentration of land ownership. This artificial demand inflation has made land and housing unaffordable for ordinary locals, particularly low-income groups. A similar issue has emerged in the traditional croft system. Some private landowners refuse to sell land to local young people even when reasonable prices are offered, instead choosing higher bids from foreign buyers.

"The owner wants to get rid of it, but he won't accept an offer from young people who want it." (P5)

However, examples exist where protected land can achieve fair, sustainable development without entering speculative investment markets.

Case 2 adopts a Community Land Trust (CLT) model. The land is community-owned, with regulations prohibiting speculation and resale. It can only be transferred at reasonable prices to residents. These rules prevent land unaffordability from surrounding housing price increases, maintaining long-term accessibility. Similarly, Case 4 families transfer land through traditional family inheritance, viewing it as an intergenerational responsibility rather than a saleable asset. They said this "has no impact on us," (P5) meaning that market fluctuations will not affect their land use.

Within the boundaries of this four-case sample, treating land primarily as an investment commodity easily excludes disadvantaged groups and undermines stability. The findings point not to land ownership as a key factor to rural development but instead mediation of the open market through asset transfer and controlled sale, to ensure the broader issues of community and resilience are supported.

3.3. House

Figure 4 presents analyses at the scale of the house across five social and economic sustainability metrics. Private housing (Cases 1 and 4) achieves nearly full green social sustainability ratings, with Cases 2 and 3 receiving "red" ratings due to negative performance in one or more measures—whether subjective or objective. All four cases perform well in economic sustainability, delivering strong housing affordability and supply contribution regardless of tenure type.

Cases	Social sustainable		Economic sustainable	
	House -01	House -03	House -01	House -02
Case1	Green	Green	Green	Green
Case2	Red	Green	Yellow	Green
Case3	Red	Green	Green	Yellow
Case4	Green	Yellow	Green	Green

Figure 4. Sustainable heat map related to house.

3.3.1. Contradictory Experiences: Resident Participation Across Different Housing Tenure Sectors

The four case studies showed contrasting patterns of resident participation in housing design across different tenure, with implications for the measures (SS-House-01-(2,5)) relating to housing suitability, future adaptability and user satisfaction. P1 and P5 held full property rights with high decision-making power, leading tailored design processes:

P1 acted as part of the design team, and P5 participated in 3D modelling with consistent architect communication (P5: “It was a really interesting process, collaborative and respectful of our creative input. They didn’t override us... They really listened to what we wanted.”). This high level of design autonomy, from the homeowners’ perspective, allowed their homes to meet daily needs and retain flexibility. In contrast, social housing design and allocation were developer- and manager-led. Case 3 allocated housing by need but used uniform unmodifiable layouts, with all units designed for families with children and residents required to relocate if household structures changed (P4: “We had selection criteria that were biased in favour of young families... we did not select single individuals or young couples.”). P4 noted inefficiencies as children grew, leading to underoccupied units deemed a waste of resources. P2 highlighted unmet needs in Case 2, including insufficient storage and persistent mechanical ventilation noise (P2: “There’s no storage space. All my clothes are behind that red thing over there, and some of my stuff is under the bed”; “I don’t like hearing the electrical humming sound because when it’s on, it stays on the whole time, it never goes off.”). These issues reveal tensions between limited resident participation and lived experience. Within the assessment framework, these findings contributed to contrasting evaluations of the house dimension for social sustainability. From the lived experiences captured across the four case studies, a core contradiction emerges: social housing addresses affordability and equity but maybe lacks participation and adaptability, while two private housing cases deliver high satisfaction and flexibility but are financially exclusive.

3.3.2. Driving Housing Supply: Coordinating Model Replication and Demonstrative Innovation

Four case studies indicate that housing supply contributes to dwelling quantity and generates replicable models and innovative design insights for future development. Case 1 demonstrated strong replicability, with an identical house built for another local family, proving market feasibility and multi-site applicability. Case 2 provided an institutional solution for private housing market excluded groups; the trust-led project met core aims and expanded units, confirming the sustainability of community-led housing for targeted challenges. Case 3 directly addressed homelessness by providing stable accommodation for vulnerable families, reducing residential mobility and insecurity with tenancies replacing repeated evictions. Case 4 was highly customised and non-replicable but offered innovative family-centred design within crofting system constraints (P5: “A croft house doesn’t have to be merely a functional space... It can still be beautiful or interesting. And I think that’s really exciting.”). Its value lay in expanding feasible design options for rural contexts rather than volume supply.

3.3.3. Dual Safeguards for Sustainability: The Interdependence of Occupant-Centred Affordability and Non-Speculative Intent in Housing Development

Across the four studied housing developments, projects all set resident affordability and limits on speculative property use as key considerations. Based only on these four examples, affordable housing outcomes can be delivered under different ownership and tenures when projects centre on long-term local residency rather than short-term financial gain. P1’s house was built with cost-efficient methods, priced 28.58% below the local average (£185,000 vs. £259,000) and designed for personal occupation rather than investment. Case 2’s community-led social housing had construction costs covered by the organisation, with £370 monthly rent deemed reasonable; resale and speculation were prohibited, with allocation via a points system for vulnerable and key community members (P2: “There would be an interview... and we would give a points system. If they were over a certain age, or if they were vulnerable, or if they were homeless, or if they were key workers in

the community, all of those things would be taken into consideration.”). Case 3 provided moderately priced rentals for low-income families with anti-speculation rules and strong tenancy agreements to prevent gentrification exclusion (P4: “All of our tenants have the Scottish Tenancy Agreement ... it’s a very strong agreement for tenants. Unless they are misbehaving or do not pay their rent for a long time, it is very difficult to make them leave.”). Case 4’s £285,000 construction cost was offset by a £38,000 subsidy, improving affordability; the property was restricted to permanent croft residential use, banning holiday or investment use. Project success stemmed from integrated affordability and non-speculation within the scope of these four cases: protection from market speculation maintained affordability, and a focus on resident and community long-term interests upheld non-speculative development.

3.4. Energy and Infrastructure

Figure 5 assesses four metrics for the Energy & Infrastructure dimension, including two social sustainability metrics and two economic sustainability metrics, with the overall performance of the four cases dominated by amber and red ratings, indicating notable inadequacies in the socio-economic sustainability of energy and infrastructure across the studied Scottish rural housing developments. For social sustainability, metric E&I-02 (resident energy-saving awareness) shows a universally deficient performance across all four cases, emerging as a consistent weak point in the social sustainability of the Energy & Infrastructure dimension. Case 4 performs poorly across all four evaluation metrics of the Energy & Infrastructure dimension, recording non-green ratings for both social and economic sustainability metrics in this dimension, and is the only case with inadequate performance in all related indicators.

Cases	Social sustainable		Economic sustainable	
	E&I-0	E&I-0	E&I-0	E&I-0
	1	2	1	2
case1				
case2				
case3				
case4				

Figure 5. Sustainable heat map related to energy and infrastructure.

3.4.1. The Diversification of Energy Supplies May Influence Energy Resilience

Although all households are connected to the national power grid, the four case studies suggest that the ability to maintain a stable daily energy supply was associated with the availability of backup or auxiliary systems, such as wood-burning stoves, solar water heaters or community energy systems (Table 6). Across the cases, households with access to multiple energy sources appeared to experience greater resilience during supply disruptions, particularly in locations exposed to extreme weather or infrastructure instability.

Table 6. Energy systems for housing cases.

Cases	National Grid	Mains Gas	Main Heating	Hot Water	Resilience Mechanism
Case 1	On grid	Without	Wood-burning stove	Solar heating panels + Electric heater	Wood stove and solar heating panels
Case 2	On grid	Without	District heating system (DHS)	DHS	Dual grid (microgrid + national grid)
Case 3	On grid	Without	ASHP (radiators)	ASHP (water tank) + Electric heater	None
Case 4	On grid	Without	ASHP (underground heating)	ASHP (water tank) + Electric heater	Wood stove and gas hob

P1's household employs a multi-modal energy system that combines off-peak electricity, a wood-burning stove for heating, and solar thermal panels for hot water. This layered arrangement maintains normal function during occasional power outages and strengthens energy resilience. P1 also criticised urban-centric policies such as bans on wood-burning stoves, which overlook rural conditions. Unstable rural power supplies make wood stoves a reliable backup. Case 2 is connected to the national grid and a small-scale community heating system. Despite occasional delays in hot water supply, the overall system remains reliable. Dual integration with the national grid and a community microgrid provides redundancy, ensuring continuous function if one system fails. This community-scale energy arrangement offers a valuable demonstration model. Case 4, located in remote Shetland, adopts a self-reliant energy strategy. The household uses wood-burning stoves, gas stoves, and backup generators. These systems provide essential support during extended power outages. Diversified energy provision is not an emergency measure but a routine practice adapted to local environmental conditions: "We prepared for it... that's just part of living here." (P5) This proactive and pragmatic approach supports resilience against natural disruptions.

In contrast, Case 3 relies exclusively on grid electricity with no backup arrangements. Any power outage results in complete energy failure. Even high-performance energy-efficient housing lacks basic security during critical disruptions without backup systems.

Overall, the four case studies consistently illustrate that households with access to diversified or redundant energy systems experienced greater energy resilience than the case relying solely on grid electricity. Although these findings cannot establish a general principle applicable to all rural housing, they suggest that diversified energy provision may enhance resilience in remote contexts where extreme weather and infrastructure disruptions are more likely.

3.4.2. The Negotiated Nature of Fuel Poverty: Mediation Between Knowledge, Infrastructure, and Socioeconomic Realities

The four cases reveal that energy-conscious practices and fuel poverty (FP) mitigation are inextricably mediated by infrastructural and financial conditions. As summarised in Table 7, the two social housing projects adopted environmentally friendly microgrid systems through community collaboration. However, such systems introduced unintended challenges as maintenance costs were transferred to residents. As P2 noted, "Any infrastructure maintenance costs should be borne by the residents." This creates financial pressure for low-income households, who are forced to limit room temperatures to 18 °C to reduce expenditure. A design intended for collective energy conservation has thus reinforced inequality. This highlights a critical issue. Resource sharing does not guarantee fair cost distribution.

Table 7. FP characteristics of housing cases.

Cases	Energy Bills	Energy System Investment Pressure	Energy Use Behaviour	Potential FP
Case 1	Approximately £60 per month (Wood biomass spending unclear)	None	Strong energy-saving awareness	None
Case 2	Approximately £80 per month	None (the maintenance costs are borne by the tenants)	Weak energy-saving awareness	Almost no
Case 3	Up to £50	None (assuming responsibility by the trust)	Rising energy-saving awareness and backed by ultra-high energy efficiency	None
Case 4	Approximately £270 per month (Wood biomass spending unclear)	Yes	Higher awareness of energy saving	Potential risk

By contrast, Case 3 demonstrates greater equity. Developers cover the initial costs of high-efficiency housing without increasing rents, and the project uses air-source heat pumps. Residents rarely require additional heating, resulting in very low operational costs. This approach alleviates energy poverty through design, rather than requiring residents to adjust lifestyles to reduce consumption.

The influence of energy conservation awareness is closely related to economic circumstances. P1 demonstrates strong environmental awareness and uses solar water heaters and off-peak electricity to reduce energy use. He can afford such technologies and adopts them based on personal values rather than financial necessity. However, P2 suspended the MVHR system due to distrust of new technologies and relied on natural ventilation, which increased overall energy consumption. These differences show that energy-related behaviours are shaped by both belief and attitude toward technology.

P5 is not currently classified as experiencing energy poverty, but rising energy prices and remoteness have increased financial pressure. Despite the use of energy-saving equipment and conservation awareness, the household feels increasingly vulnerable. In response, P5 has begun planning off-grid energy systems including wind and solar power, for both environmental benefits and protection against price volatility.

“We’d love to be off grid one day, but [we’re] on grid at the moment. We’d love a turbine and solar panels, that would be a longer term [goal].” (P5)

Ultimately, addressing energy poverty depends on systemic energy design rather than individual frugality. Success lies in redistributing the burden of high-cost technologies to the system, allowing residents to benefit from low energy bills and supporting the retention of young people in rural areas.

4. Discussion

4.1. Revisiting the Theoretical Framework: Strengths and Inherent Limitations

The four case studies demonstrate that the proposed framework provides a structured way of examining rural housing sustainability beyond conventional energy-performance indicators. Rather than functioning as a quantitative assessment tool, the framework enabled consistent comparison of diverse housing projects by considering interactions between four interconnected dimensions: People and Community, Land and Site, House, and Energy and Infrastructure.

Across the cases, the relationship between L&S and House was particularly evident. Different land governance arrangements influenced not only affordability but also residents’ opportunities to participate in housing design and adapt dwellings to changing

household needs. In the privately owned cases, residents were actively involved throughout the design process and generally reported that the completed houses reflected their lifestyles and future expectations. By contrast, the social housing cases demonstrated that standardised layouts and allocation procedures could limit opportunities for adaptation after occupation. These observations do not suggest that one tenure model is inherently preferable to another, but they illustrate how governance arrangements may influence different aspects of housing sustainability within the assessment framework [22,38].

The application of the framework also highlighted that several sustainability challenges originated beyond the dwelling itself. Indicators within the Energy and Infrastructure dimension consistently identified issues associated with transport accessibility, electricity supply and digital connectivity, none of which could be addressed solely through improvements to building fabric or energy efficiency. This reinforces the value of considering housing as part of a wider rural system rather than as an isolated building [16,21]. At the same time, the framework made visible the interdependence between housing design and wider infrastructure, demonstrating that similar housing standards may produce different sustainability outcomes under different local conditions.

The framework should be regarded as an interpretive assessment tool rather than a definitive measurement system. Its value lies in providing a transparent structure for organising multiple forms of evidence while allowing context-specific differences to remain visible. All judgements generated from its application are strictly bounded to the four studied Scottish rural sites and cannot be directly generalised to other regions. However, identifying these interconnected rural sustainability challenges constitutes the core contribution of this study, and this analytical logic is transferable to rural housing research across Europe and beyond. Taking European rural regions as an example, parallel structural dilemmas mirror the patterns observed in rural Scotland across all four analytical dimensions.

On the People and Community dimension, rural areas in Northern, Eastern and Western Europe share identical pressures with Scottish villages: population ageing, youth out-migration and unaffordable housing collectively erode long-term community cohesion [71,72]. For Land and Site, post-privatisation land fragmentation and unregulated speculative land purchases restrict the supply of developable residential plots across Eastern Europe [73]. The competition between second-home investor demand and permanent local housing needs, which inflates rural land prices, is a widespread pan-European phenomenon [72,74]. In terms of house itself, Nordic welfare states operate large stocks of standardised social rental housing with inflexible layouts that lead to under-occupancy once residents grow older, replicating the mismatch seen in Scottish social housing [75]. Custom self-build homes remain financially out of reach for low-income households throughout Europe [71,72], and the financialisation of housing widens intergenerational and class inequalities uniformly across the continent [76,77]. Regarding Energy and Infrastructure, fuel poverty, inadequate rural public transport and limited broadband coverage represent universal vulnerabilities for European rural settlements. Outdated building stock, scattered residential layouts and underfunded public services generate identical sustainability burdens in Eastern, Southern and Northern Europe as those found in rural Scotland [71,72]. Remote Nordic villages face similarly prohibitive heating costs as Scottish rural areas, while one-size-fits-all EU energy retrofitting policies fail to match distinct local contextual conditions across all European rural territories [72]. Financial hardship stemming from energy costs undermines community stability in consistent ways, and energy poverty disproportionately disadvantages vulnerable resident groups across all these regions [77,78].

This comparison demonstrates that systematically unpacking fragmented rural housing dilemmas through an integrated sustainability lens carries substantial analytical value for rural research in any national context.

4.2. Implications for Policy and Practice

The four case studies do not provide a basis for prescribing universal policy solutions. However, they identify several practical considerations that may assist policymakers, housing providers and practitioners when planning sustainable rural housing in Scotland. It is worth noting that, with a full awareness of the study's limitations, all proposed measures are framed as evidence-based conceptual pathways; the core logic underpinning these directional recommendations derives from consistent qualitative evidence gathered through four rural cases in Scotland. Prior to formal policy formulation, these concepts require dedicated follow-up fiscal and institutional assessments.

4.2.1. Land Governance

First, the findings suggest that land governance should be considered alongside housing delivery rather than as a separate policy issue. Across the four cases, housing developed on non-speculative land appeared to reduce development costs and increase long-term affordability. Future land policy may benefit from expanding flexible non-speculative land mechanisms, such as community landownership, public land transfer programmes and key-worker housing initiatives [79] while allowing greater resident involvement during project development.

4.2.2. Participatory Housing Design

Second, the case studies suggest that resident participation should extend beyond housing allocation to include earlier stages of the design process. The contrast between the private and social housing cases indicates that opportunities for future adaptation were influenced not only by dwelling size but also by residents' ability to communicate household needs before construction. For housing providers and architects, this suggests that relatively low-cost measures, such as structured design workshops, pre-occupancy consultations and post-occupancy feedback, may improve the long-term suitability of rural housing without fundamentally changing standardised construction systems.

4.2.3. Long-Term Funding Mechanisms

Third, the findings indicate that funding mechanisms should consider the long-term operation of rural housing rather than focusing solely on initial construction costs. For example, case 2 demonstrated that community-based energy infrastructure can improve environmental performance but may also introduce additional financial burdens for residents. Future funding programmes may therefore benefit from combining capital investment with longer-term operational support, particularly for community energy systems and housing projects serving lower-income households. Such arrangements may help prevent operating costs from offsetting the social benefits of affordable housing provision. Future funding programmes should distinguish between capital funding and operational funding. While current grants frequently support initial construction, dedicated maintenance funds could reduce the long-term financial burden placed on low-income residents.

4.2.4. Integrated Rural Infrastructure Planning Tied to New Housing Delivery

Finally, the case studies suggest that sustainable rural housing cannot be planned independently from wider infrastructure provision. Difficulties associated with transport accessibility, electricity reliability and digital connectivity were observed across several cases, despite differences in housing type and tenure. Future rural housing strategies may

benefit from stronger coordination between housing, transportation, energy and digital infrastructure sectors. Rural housing planning applications could be accompanied by a basic infrastructure readiness assessment covering electricity resilience, broadband availability, public transport accessibility and emergency service access. Such assessments would allow housing proposals to identify infrastructure constraints.

4.3. Limitations and Future Refinement of the Framework

Like most qualitative case studies, this study inevitably has several limitations that should be considered when interpreting the findings.

First, the framework was empirically applied to only four purposively selected rural housing projects in Scotland. Although the cases were intentionally selected to maximise variation in tenure, geographical setting and housing type, they cannot represent the full diversity of rural housing across Scotland. Consequently, the purpose of the study is not to establish universally applicable sustainability criteria but to demonstrate how the proposed analytical framework can be used to support systematic comparison between different rural housing contexts. Future research involving a larger number of case studies would allow the robustness and consistency of the framework to be further examined.

Second, while the framework combines multiple forms of empirical evidence through multi-source cross-checking, different indicators inevitably rely on different forms of evidence. Some indicators, such as energy infrastructure, transport accessibility and fuel poverty, can be supported by relatively objective documentary and observational evidence, whereas others, including neighbourhood relationships and perceived housing suitability, depend primarily on residents' lived subjective experiences. Rather than representing a fatal methodological weakness, this reflects the inherently multidimensional nature of socio-economic sustainability. All coding and traffic-light evaluations were completed mainly by the lead author, with only a random 30% subset of transcripts subjected to dual coding to test inter-coder reliability; full cross-coder verification across all data was not implemented, leaving residual researcher interpretive bias. Nevertheless, future research could integrate this with the authors' previous work on energy efficiency and emissions in rural Scottish housing [80], adopt full dual coding for all materials to strengthen inter-coder reliability, and incorporate further quantitative evidence to refine the framework where appropriate, particularly for indicators that currently rely predominantly on qualitative data.

Third, the framework was deliberately developed from the Scottish rural context. Both the indicator selection and their operationalisation were derived from Scottish literature, policy documents and empirical evidence. Consequently, although the analytical logic underpinning the framework may be transferable to other rural contexts, the specific indicators should not be assumed to be universally applicable. Applying the framework elsewhere would require a new process of context-specific literature review, indicator identification and empirical validation to reflect different socio-economic conditions.

Finally, this study should be regarded as an initial application of a hybrid normative–empirical assessment framework rather than its final form. The framework remains open to refinement as additional empirical evidence becomes available. Future comparative research involving different countries, housing systems and governance contexts would provide valuable opportunities. Such iterative development is consistent with the objective of the framework: not to produce a universal checklist for sustainable rural housing but to provide a transparent and adaptable methodology for systematically examining rural housing sustainability in context.

5. Conclusions

This study developed and piloted a hybrid normative–empirical four-dimensional analytical framework tailored to rural Scottish housing, responding to the widespread overreliance on energy efficiency as the sole yardstick for sustainable housing assessment. The structured literature screening and three-layer thematic coding procedure delivered a transparent set of contextually grounded metrics, each validated against clear inclusion rules to avoid arbitrary indicator selection. Through its application to four contemporary rural housing case studies, the research demonstrates how combining literature-derived sustainability indicators with empirical evidence collected through interviews, field observations and documentary sources can facilitate systematic comparison across different rural housing contexts.

Consistent patterns observable across the four sites show that sustainable socio-economic outcomes are jointly shaped by land governance systems, spatial community design, housing tenures and rural energy infrastructure. Non-speculative land access mechanisms, including community land trusts, public asset transfers, intergenerational croft leasing and off-market private land transactions, lower local housing costs and reduce resident displacement risks, forming a foundational support for stable rural communities. Shared communal spaces and reciprocal rural livelihood practices facilitate newcomer integration and sustained neighbourhood cohesion, whereas standardised social housing layouts restrict resident adaptability and personal design input, creating mismatches between layout and evolving household needs. Meanwhile, the E&I dimension reveals the most pervasive sustainability deficits across all cases: exclusive reliance on national grid power without diversified backup systems raises energy resilience risks; rural transport and digital service shortages create structural accessibility inequalities that no high-performance housing fabric can resolve. Across the four cases, no housing project consistently performed well across all dimensions. Instead, each case exhibited a different combination of strengths and compromises, highlighting the context-dependent nature of rural housing sustainability.

The practical implications emerging from the four Scottish case studies suggest that sustainable rural housing may benefit from closer integration between land governance, resident participation, long-term funding arrangements and infrastructure planning. These recommendations should be regarded as evidence-informed considerations rather than universally applicable policy prescriptions and require further evaluation under different institutional and geographical conditions.

Rather than proposing universally applicable sustainability metrics, the principal contribution of this research lies in the methodological framework itself. The framework offers a transparent process through which context-specific sustainability indicators can be identified, developed and empirically assessed using multiple sources of evidence. This research carries clear limitations that bound the scope of its inferences. The empirical analysis draws on only four purposively selected cases, which cannot represent the full spectrum of rural housing across Scotland or other international rural territories. Some framework metrics rely predominantly on subjective resident experience rather than quantifiable objective data, despite triangulation procedures to mitigate bias.

Ultimately, this study posits that the primary value of the framework lies not in establishing a set of universal indicators but in providing a transparent and flexible methodology capable of uncovering and identifying sustainable housing challenges within specific contexts. The framework should be viewed as an evolving analytical tool designed to foster a more systematic and context-sensitive understanding of rural housing sustainability. From the perspective of assessment criteria, energy efficiency is merely one component of rural housing sustainability; achieving balanced socio-economic development

requires a comprehensive evaluation that treats “community & people, land & site, house, energy & infrastructure” as an interconnected territorial system.

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Abbreviations

The following abbreviations are used in this manuscript:

CLT	Community Land Trust
EPC	Energy Performance Certificate
MVHR	Mechanical Ventilation with Heat Recovery
FP	Fuel Poverty
SS	Social Sustainability
ES	Economic Sustainability
P&C	People and Community
L&S	Land and Site
E&I	Energy and Infrastructure

Appendix A

Appendix A.1

Table A1. General metrics and measures of sustainability.

Metric	Measures	Source
P&C-03	(1) Participated in some form of community-led housing project;	[65,81,82]
	(2) Residents have participated in the development planning or management of the community.	
SS	(1) Residents are currently satisfied with the connectivity to services;	[11,83–86]
	(2) Future household planning is not limited by location.	
E&I-01	(1) The house is connected to the national electricity grid and the mains gas grid;	[12,18,21,87]

ES		(2) The house is connected to a small-scale energy network developed by the local community;	
		(3) The house is equipped with off-grid energy facilities to meet daily needs.	
		(4) No frequent energy failure issues.	
		(1) Residents know the importance of good insulation and sealing of the housing fabric.	[14,52,87]
	E&I-02	(2) Residents know the importance of efficient heating appliances and distribution systems.	
	P&C-01	(1) Entrust a local architectural design firm to design the project;	[87,88]
		(2) Give priority to local suppliers and contractors;	
		(3) The construction team is from the local area.	
	P&C-02	(1) The project involves new local apprentices;	[82,85,89]
		(2) Some project tasks require training, provided to local participants.	
	L&S-02	(1) Avoid price competition with locals for the same land;	[90–92]
		(2) Purchase already developed land to avoid burdening land supply.	
	House-02	(1) Housing costs prioritize spending on fabric energy efficiency.	[14,18,52,87]
	House-03	(1) The development of housing has partially alleviated the severe housing supply pressure in the area;	[20,93,94]
		(2) The house has been designed as a template for future development.	
	E&I-02	(1) Residents do not yet experience FP;	
		(2) Residents can enjoy adequate energy for comfort and well-being.	[14,52,87]

Appendix A.2

Table A2. Metrics and measures of sustainability based on housing typology.

Community Structure Related (Only SS Included)			
By locals and new entrants	SS-P&C-01		
	For local residents		
	(1)	Accept and include community members from different backgrounds;	
	(2)	Have good relationships with neighbours and community members.	[35,95,96]
	For new entrants		
	(3)	Avoid exclusion;	
	(4)	Engaging with local culture and people;	
	(5)	Integration into local community.	
	SS-P&C-02		
	For all residents		
	(1)	No sense of frequent changes in neighbours or other community members.	[93,95,97–99]
	(2)	There is no plan to leave this area for some reason.	

	(3) All the houses in the community are used for the benefit of the community.	
	For new entrants	
	(4) Plan to live here for a long time for some purpose;	
	(5) Not a second home.	
	SS-House-01	
	For all	
	(1) Satisfy with the quality of the house.	
	For young adults	
	(2) Relatively flexible or expandable layout of housing to adapt to future changes;	
	(3) Considering the need to work from home.	
By young generation and retirees	For aging populations and special needs	[100–102]
	(4) Have supportive resources;	
	(5) Design considers the potential mobility issues that current or future residents may face due to their age;	
	(6) Avoid housing equipment that requires complex operation, or provide clear instructions for use and ensure that residents have mastered how to use it.	
Ownership related (both social and Economic sustainability included)		
	SS-House-01	
	For all	
	(7) Residents are satisfied with their current living arrangements and conditions.	
	For owner-occupiers	
	(8) Residents ensure their feelings and needs are fully understood and responded to.	[20,91,93,94,103]
	For tenants	
	(9) No more homelessness due to forced termination of tenancy.	
	ES-House-01	
By owner-occupiers and tenants	For owner-occupiers	
	(1) Housing investment does not lead to tight financial burden, or the economic pressure of building new houses was alleviated through some kind of welfare policy.	[91,104,105]
	(2) Housing costs are not significantly higher than the local market to prevent potential gentrification risks.	
	For tenants	
	(3) Rents are affordable.	
	ES-E&I-01	
	For community-led housing	[87,88]
	(1) Investing in community-led RE projects.	

	For owner-occupiers	
	(2) Installed micro-RE systems.	
	For all	
	(3) Investing in high-efficiency heating system.	
	(4) The energy infrastructure/equipment investment is affordable, or alleviate the pressure of limited funds through government subsidies, interest-free loans, external investment, etc.	
SS-L&S-01	For crofters	
	(1) The household is a Croft as determined by the Crofting Act.	
	(2) The croft is viable.	
	(3) Own a croft house, or be an owner-occupier crofter, or Land acquired through Crofting Community Right to Buy.	[22,106–108]
	For other tenants	
By landowners (private and communal), tenants and crofters	(4) Have a stable long-term lease, or becoming a landowner, or Land acquired through Community Right to Buy.	
ES-L&S-01	For landowners	
	(1) The land purchased is affordable.	
	(2) For families or communities with limited budget, the land purchased was subsidized by policies or external funding.	[22,85,109]
	(3) The process of applying for a building warrant is affordable.	
	For tenants	
	(4) Rents are affordable and leases are stable.	

Appendix A.3

Table A3. Triangulation data sources of measures beyond semi-structured interviews across cases.

Measures	Case 1	Case 2	Case 3	Case 4
P&C-01-(1–2)		Observation		
P&C-01-(3–5)	N/a P1 is a local	N/a P2 is a local	Observation, Supplementary interview with Trust manager	Observation
P&C-02-(1)		Streetcheck		
P&C-02-(2)		Demographics		
SS P&C-02-(3)		Current work and living conditions		
P&C-02-(4–5)	N/a P1 is a local	N/a P2 is a local	Observation	
P&C-02-(4–5)	N/a P1 is a local	N/a P2 is a local	Current work and living conditions	
P&C-03-(1–2)	Local online news (P1 was a councilor)	Community online magazine (P2 served as a community trust manager)	Online news, Supplementary interview with Trust manager	Online news, Interviews with two family members
L&S-01-(1–3)	N/a P1 is not a crofter	N/a P2 is not a crofter	N/a P3 is not a crofter	Observation

L&S-01-(4)	Land purchase records released by local authorities	the Scottish Tenancy Agreement	N/a P5 and P6 are crofters
L&S-02-(1–2)	Streetcheck nearby services statistics, observation		
House-01-(1)	observation		
House-01-(2–3)	N/a P1 is semi-retired.	N/a P2 is retired.	observation
House-01-(4)	Streetcheck “Nearby services” statistics, observation	Streetcheck “Nearby services” statistics, observation	N/a The tenants in case 3 are all young families with children. N/a Case 4 is a young family with children.
House-01-(5–6)	observation	observation	
House-01-(7)	Housing technical drawings, observation		
House-01-(8)	observation	N/a P2 is a tenant	N/a The households in case 3 are all tenants. observation
House-01-(9)	N/a P1 is an owner-occupier	Observations, the Scottish Tenancy Agreement	N/a P1 is an owner-occupier
E&I-01-(1–3)	Observation		
E&I-01-(4)	Grid Statistics		
E&I-02-(1)	Observation, EPC data		
E&I-02-(2)	Observation		
P&C-01-(1–3)	Online housing project information, technical drawings information		
P&C-02-(1–2)			
L&S-01-(1)	Land purchase records		Land purchase records
L&S-01-(2)	N/a P1 has good financial situation	N/a P2 is a tenant	N/a The households in case 3 are all tenants. Crofting funding
L&S-01-(3)	Land statistics of the local authorities		Land statistics of the local authorities
L&S-01-(4)	N/a P1 is a landowner	the Scottish Tenancy Agreement	N/a P5 and P6 are landowners
L&S-02-(1)	HM Land Registry, Office for National Statistics		
L&S-02-(2)	Observation		
House-01-(1)	UK House Price Index (HPI), Office for National Statistics		UK House Price Index (HPI), Office for National Statistics
ES House-01-(2)		N/a P2 is a tenant	N/a The households in case 3 are all tenants. National Statistics
House-01-(3)	N/a P1 is an owner-occupier	Rent bill	Rent bill (online information) N/a P5 and P6 are owner-occupiers
House-02-(1)	Housing technical drawings		
House-03-(1–2)	Observation, online information of housing project		
E&I-01-(1)	N/a P1 is an owner-occupier	Observation	N/a P5 and P6 are owner-occupiers
E&I-01-(2)	Observation	N/a case 2 is a community-led housing	N/a case 3 is a community-led housing Observation
E&I-01-(3)	Observation		
E&I-01-(4)	Observation, online information		
E&I-02-(1)	Energy bills align with EPC.		
E&I-02-(2)	Observation		

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