

Review

Circularity and Reuse Readiness in Sustainable and Affordable Modular Housing: A Systematic Scoping Review

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Abstract

The growing demand for sustainable and affordable housing requires construction systems that reduce material consumption, embodied environmental impacts, construction waste, and life-cycle costs while retaining the value of building components across multiple use cycles. This study presents a systematic scoping review and evidence map of circular economy strategies and reuse readiness in modular sustainable and affordable housing. A structured literature search covering publications from 2016 to 2026 identified 283 records, of which 49 studies were included following screening and eligibility assessment. The included studies were coded according to circular economy strategies within the 0R–10R framework, building life-cycle stages, modular technology typologies, sustainability and affordability indicators, and reuse-readiness attributes. The evidence map shows that the literature remains predominantly focused on life-cycle assessment, carbon emissions, waste reduction, reuse, and recycling. In contrast, early-stage circular strategies, including refuse, rethink, reduce, and redesign, as well as repair, refurbishment, remanufacturing, social value, life-cycle affordability, and operational reuse readiness, remain insufficiently examined. The findings further demonstrate that prefabrication or modularity alone does not ensure circularity. High reuse readiness depends on demountable connections, non-destructive disassembly, component standardization, durability, repairability, material traceability, reverse logistics, and credible second-life scenarios. Based on the mapped evidence, this study develops an evidence-informed Integrated Digital Circular Modular Ecosystem pathway that connects circular design, material passports, reuse-readiness assessment, BIM and digital twins, component grading, reverse logistics, circular marketplaces, and life-cycle performance evaluation. By integrating reuse readiness, life-cycle affordability, and digital traceability within a single evidence-informed pathway, the study provides a structured basis for researchers, policymakers, and industry stakeholders to evaluate and advance modular housing beyond construction efficiency toward long-term circularity and component value retention. As a conceptual synthesis, the pathway requires further validation through expert assessment and application to actual modular housing projects.



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Keywords: circular economy; modular housing; reuse readiness; affordable housing; design for disassembly; evidence mapping; life-cycle affordability

1. Introduction

The ever-increasing demand for housing makes the housing sector a crucial sector that must simultaneously address the issues of building quality, affordability, and environmental impact reduction [1,2]. In the context of modern development, housing provision is no longer solely focused on increasing the number of residential units but must also consider material efficiency, energy consumption, life-cycle costs, durability, and the building's ability to adapt to occupant needs in the long term [3,4]. This challenge is becoming increasingly important because the building and construction sector is known to be highly material-intensive, generating large amounts of waste and contributing significantly to environmental impacts throughout a building's life cycle [5,6]. Therefore, new approaches to housing provision need to be directed toward systems that are not only technically and economically efficient but also capable of preserving material value, reducing resource waste, and extending the useful life of building components [7,8].

The building industry is responsible for considerable environmental impacts due to its consumption of resources and energy, and the production of wastes [5,9]. Meanwhile, the global affordable housing crisis found that reducing construction costs through value engineering and increasing operational and maintenance efficiency along with other external factors can reduce housing costs by 20–50% [3,4]. The walling materials can determine the cost of the building as well as the total life-cycle cost of a dwelling unit. Even though the brick has a higher embedded energy and construction cost, in the long run brick is less expensive than hollow cement block and Cabook walling material [3]. Therefore, the relationship between sustainability and affordability needs to be placed within a life-cycle thinking framework, as early design and material decisions will impact the cost, emissions, quality, and performance of the building over its lifetime [4,10].

In recent years, the circular economy has been increasingly used as an approach to address the weaknesses of the linear construction model, which tends to follow a take, produce, use, and dispose pattern [7]. In the building sector, the circular economy aims to maintain the value of materials and components for as long as possible through strategies such as reducing material consumption, reusing components, repairing, refurbishing, remanufacturing, repurposing, recycling, and recovery [6,8]. This approach is relevant because buildings are not only the final product of construction but can also be viewed as long-term material stocks that can be dismantled, recovered, and reused if designed with circular principles from the outset [11]. However, implementing a circular economy in the construction sector still faces challenges because definitions, indicators, life-cycle boundaries, and measurement methods for circularity are not yet fully consistent across studies [12,13].

One technological pathway widely associated with implementing a circular economy in the housing sector is modular construction or modular building technology [14]. Modular technology allows for much of the construction process to be moved to a more controlled factory environment, allowing for more consistent improvements in production quality, material efficiency, waste reduction, and construction speed [14,15]. In the context of affordable housing, modularity has the potential to lower costs through design standardization, production repeatability, labor efficiency, reduced construction time, and reduced risk of project delays [4,10]. However, modular technology does not automatically translate into a circular system, as the potential for circularity depends heavily on material choice, connection systems, dismantling capabilities, maintenance strategies, transportation, and component reuse scenarios at the end of a building's life [16–18].

For modular technology to truly become a pathway to circular construction, building design must be guided by the principles of design for disassembly, adaptability, standardized connections, and material documentation that allow for components to be dismantled

without major damage [17,19]. Design for disassembly principles are crucial because the quality of a building's circularity is largely determined by the ability of its elements to be separated, repaired, relocated, reused, or reconfigured in the future [20]. Furthermore, digital support such as BIM, material passports, and material information systems can help improve component traceability, strengthen decision-making processes, and reduce information gaps in building material reuse practices [21,22]. Therefore, modular technology needs to be understood not only as a prefabrication method to accelerate construction but as a design and production platform that can strengthen material efficiency, cost affordability, and component value retention throughout the building's life cycle [23].

Although sustainable housing, affordable housing, circular economy, and modular construction have been extensively discussed in the literature, the relationships among these four domains remain fragmented and have not been sufficiently synthesized within a unified analytical framework [24]. Previous studies have predominantly emphasized environmental performance, including carbon emissions, construction waste, material efficiency, and life-cycle assessment, whereas affordability, social value, component reusability, and implementation across multiple building life cycles remain comparatively underexplored [10,24]. Moreover, differences in system boundaries, circularity indicators, building typologies, life-cycle assessment methods, and interpretations of affordability make the findings of previous studies difficult to compare directly [12,18]. These limitations indicate that the main research gap is not merely the absence of studies on circular or modular construction but the limited integration of environmental, technical, economic, and social evidence within a coherent framework for sustainable and affordable housing.

Recent studies have begun to connect circular economy principles with industrialized and modular housing systems [2], for example, demonstrating that circular industrialized construction can support sustainable and affordable housing through process-oriented strategies involving planning, design, manufacturing, assembly, disassembly, and reuse. However, the available socio-economic evidence remains limited, and affordability is often inferred from construction efficiency rather than evaluated through measurable life-cycle costs and occupant-related outcomes [2,4]. Similarly, modular construction studies have reported benefits related to production standardization, reduced construction time, improved quality control, and lower material waste, but modularity alone does not guarantee circularity [14,15]. Circular performance depends on whether modules and components are designed with demountable connections, adaptability, material traceability, non-destructive disassembly, repairability, and credible opportunities for reuse in subsequent life cycles [17,19]. Therefore, reuse readiness needs to be treated as an analytical bridge between modular construction technology and circular economy implementation.

Accordingly, the aim of this study is to systematically map and critically synthesize the evidence on circularity and reuse readiness in sustainable and affordable modular housing. Specifically, the study has four objectives: (1) to map the distribution of circular economy strategies across building life-cycle stages using the 0R–10R framework; (2) to identify and compare modular building typologies, materials, and connection systems according to their reuse-readiness attributes; (3) to identify the environmental, economic, affordability, and social indicators used to evaluate circular modular housing; and (4) to synthesize the principal evidence gaps, digital enablers, technical requirements, and implementation mechanisms required to support circular, reusable, sustainable, and affordable modular housing systems. This analytical orientation positions reuse readiness and life-cycle affordability as central dimensions for evaluating whether modular housing systems can retain material and economic value across multiple use cycles.

Accordingly, this study addresses four research questions. First, how are circular economy strategies distributed across the life-cycle stages of modular sustainable and affordable

housing? Second, which modular building typologies, materials, and connection systems demonstrate the strongest attributes of reuse readiness? Third, which environmental, economic, affordability, and social indicators have been used to evaluate circular modular housing? Fourth, what evidence gaps, digital enablers, technical requirements, and implementation mechanisms need to be addressed to support circular, reusable, sustainable, and affordable modular housing? These research questions provide a structured basis for connecting circular economy strategies, modular technology characteristics, building life-cycle stages, and sustainable–affordable housing outcomes.

The contribution of this study is threefold. First, it provides an evidence map that integrates circular economy strategies, modular technology typologies, building life-cycle stages, and sustainable and affordable housing outcomes. Second, it develops a structured assessment of reuse readiness based on design for disassembly, demountable connections, component standardization, durability, repairability, material documentation, transportability, reverse logistics, and second-life potential [17,19,21]. Third, the mapped evidence is synthesized into an Integrated Digital Circular Modular Ecosystem pathway that connects circular design, material passports, BIM and digital twins, reuse-readiness assessment, component grading, reverse logistics, circular marketplaces, and life-cycle performance evaluation. This proposed pathway positions modular technology not merely as a rapid construction method but as a potentially reusable circular building system capable of supporting material value retention, reduced environmental impacts, and improved life-cycle affordability [2,23]. Nevertheless, the pathway is presented as an evidence-informed conceptual synthesis that requires subsequent validation through expert assessment and application to actual modular housing projects.

2. Methods

This study employed a systematic scoping review and evidence-mapping approach to identify, screen, classify, and synthesize publications concerning circular economy strategies for sustainable and affordable housing toward modular building technologies. A systematic scoping review was selected because the relevant literature encompasses heterogeneous research designs, including conceptual studies, literature reviews, life-cycle assessments, case studies, simulation studies, technology assessments, and empirical investigations. The review process followed the methodological principles of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews (PRISMA-ScR) [25,26]. A completed PRISMA-ScR checklist was also prepared to document adherence to the recommended reporting items and to improve the transparency and reproducibility of the review process. The literature search was designed to capture studies connecting four principal domains: circular economy, modular construction technology, sustainable housing, and affordable housing.

Scopus was used as the primary bibliographic database because it provides broad coverage of peer-reviewed publications in construction engineering, sustainable buildings, circular economy, housing, and modular construction. Google Scholar was used as a supplementary discovery source to identify additional potentially relevant studies. ScienceDirect, Taylor & Francis Online, and Emerald Insight were used primarily for targeted searches and full-text retrieval. Records retrieved from these publisher platforms were not counted as separate studies when the same publications had already been indexed in Scopus. The literature search covered publications from January 2016 to 2026 and was restricted to publications written in English.

The search terms were developed from three main groups of concepts. The first group represented circular economy strategies and included “circular economy,” “circularity,” “circular construction,” “design for disassembly,” “design for reuse,” “component reuse,”

“repair,” “refurbishment,” “remanufacturing,” and “repurposing.” The second group represented modular technologies and included “modular construction,” “modular building,” “modular housing,” “modular integrated construction,” “prefabricated building,” “off-site construction,” “industrialized construction,” “panelized system,” and “volumetric modular.” The third group represented the housing context and included “housing,” “residential,” “dwelling,” “affordable housing,” “social housing,” and “sustainable housing.” Boolean operators were used to combine these concept groups.

The principal Scopus search string was structured as follows:

TITLE-ABS-KEY

((“circular economy” OR circularity OR “circular construction” OR “design for disassembly” OR “design for reuse” OR “component reuse” OR repair OR refurbish OR remanufacture OR repurpose) AND (“modular construction” OR “modular building” OR “modular housing” OR “modular integrated construction” OR prefabricate OR “prefabricated building” OR “off-site construction” OR “offsite construction” OR “industrialised construction” OR “industrialized construction” OR “panelized system” OR “volumetric modular”) AND (housing OR residential OR dwelling* OR “affordable housing” OR “social housing” OR “sustainable housing”)) AND PUBYEAR > 2015 AND PUBYEAR < 2027 AND LANGUAGE (English).

Additional targeted searches were conducted using combinations of “construction waste,” “life cycle assessment,” “life-cycle cost,” “material passport,” “reuse readiness,” “reverse logistics,” and “digital twin.” Backward reference searching was also conducted by examining the reference lists of relevant studies and review articles. The complete database-specific search strategies, search dates, filters, and numbers of retrieved records are provided in Table 1 to enable replication of the literature search.

Table 1. Inclusion criteria for publications.

Criteria	Rationale	Included	Excluded
Types of publications	To select academically reviewed publications relevant to the review scope	Peer-reviewed journal articles, review articles, and peer-reviewed conference papers with sufficient methodological information	Editorials, commentaries, books, book chapters, dissertations, theses, reports, and non-peer-reviewed publications
Publication quality	To ensure the traceability and academic reliability of the evidence base	Publications indexed in recognized academic databases and containing complete bibliographic and methodological information	Duplicate records, incomplete publications, and records lacking sufficient bibliographic or methodological information
Timeframe	To capture recent developments in circular economy and modular housing research	Studies published from January 2016 to the final search date in 2026	Studies published before 2016
Language	To ensure consistent interpretation and coding	Full-text publications written in English	Publications not available in English
Housing context	To maintain alignment with the research objectives	Studies addressing housing, residential buildings, affordable housing, social housing, or dwelling-related systems	Studies focusing exclusively on infrastructure, industrial facilities, or commercial buildings without direct housing relevance

Table 1. *Cont.*

Criteria	Rationale	Included	Excluded
Circular economy relevance	To ensure that the study contributes evidence concerning circularity or resource-value retention	Studies addressing circular economy strategies, design for disassembly, reuse, repair, refurbishment, remanufacturing, repurposing, recycling, recovery, material traceability, or multiple life cycles	Studies containing only general sustainability claims without identifiable circular economy or value-retention content
Modular technology relevance	To support analysis of modular building technologies	Studies examining modular, prefabricated, panelized, volumetric, off-site, industrialized, component-based, or kit-of-parts construction systems	Conventional construction studies without modular, prefabricated, industrialized, or reusable-component relevance
Sustainability and affordability outcomes	To support multidimensional evidence mapping	Studies examining environmental, economic, affordability, social, technical, life-cycle, or reuse-readiness outcomes	Studies without relevant assessment indicators or outcomes
Full-text availability	To permit complete eligibility assessment and data extraction	Publications with accessible full text	Abstract-only records or publications for which the full text could not be obtained

The selected studies were analyzed using a structured coding framework. Each study was coded according to its publication year, country or geographical context, research objective, methodological approach, housing context, modular technology typology, principal material or structural system, building life-cycle boundary, circular economy strategy, sustainability indicator, affordability indicator, social indicator, digital enabler, and evidence of reuse readiness. Modular technology typologies included volumetric modular units, modular integrated construction, panelized systems, prefabricated components, flat-pack or kit-of-parts systems, and hybrid modular systems. Building life-cycle stages were classified into design and planning, material sourcing, manufacturing, construction and assembly, use and maintenance, disassembly, reuse and refurbishment, and recycling or recovery.

Circular economy strategies were classified according to the 0R–10R framework, consisting of R0 Refuse, R1 Rethink, R2 Reduce, R3 Reuse, R4 Repair, R5 Refurbish, R6 Remanufacture, R7 Repurpose, R8 Recycle, R9 Recover, and R10 Redesign. A strategy was coded only when it was explicitly discussed, assessed, or demonstrated in the study. Strategies that were only inferred from general sustainability claims were not automatically recorded as circular economy evidence. The relationships among circular economy, modular technology, and sustainable or affordable housing were assessed using the 0–2 scoring system applied in the evidence map. A score of 0 indicated that the relationship was not discussed. A score of 1 indicated that the relationship was mentioned or discussed conceptually without a specific method, indicator, or empirical assessment. A score of 2 indicated that the relationship constituted a principal research focus and was supported by an explicit analytical method, an indicator, a case study, a simulation, or empirical evidence. The same scoring rules were applied consistently to the CE–modular, modular–sustainable/affordable housing, and CE–sustainable/affordable housing relationships. Reuse readiness was assessed using eight technical and implementation attributes: design for disassembly, demountable connections, non-destructive disassembly, component standardization, material durability, repairability or replaceability, material documentation or traceability, and the availability of a second-life or reverse-logistics scenario. Each attribute received a score of 0 when no evidence was provided and 1 when the attribute was explicitly discussed or assessed. The total score was classified as follows: 0 indicated

Low readiness, 1–2 indicated Low–Medium readiness, 3–4 indicated Medium readiness, 5–6 indicated Medium–High readiness, and 7–8 indicated High readiness. This assessment was used as an evidence-mapping instrument rather than as a validated engineering certification system.

Differences in screening or coding decisions were resolved through discussion and re-examination of the full-text publication. If the screening and coding were conducted by only one reviewer, this condition should be reported explicitly and acknowledged as a methodological limitation. The coding process enabled the development of an evidence map, building life-cycle boundary mapping, circular economy strategy mapping, modular technology typology assessment, and reuse-readiness analysis. The eligibility criteria applied in this review, including publication type, timeframe, language, housing context, circular economy relevance, modular technology relevance, and full-text availability, are presented in Table 1.

Additional search combinations were also used to capture studies discussing affordable housing, prefabricated construction, circular building systems, reuse strategies, modular technologies, and life-cycle-based sustainability assessment. This study applies a time constraint in searching for publications by limiting the data to the last 11 years, specifically from 2016 to 2026. This period was selected because research on circular economy, modular construction, and sustainable housing has grown significantly during the last decade, particularly in relation to life-cycle assessment, design for disassembly, prefabrication, and circular construction strategies. The initial search identified 283 records from the selected databases. Before screening, duplicate records and irrelevant records were removed, resulting in 268 records for the first screening stage. The screening process was conducted by evaluating the title, abstract, and keywords of each publication. Articles that were outside the topic, not related to housing or construction, not connected to circular economy or modular technologies, or not aligned with the sustainability and affordability scope were excluded. After the screening and eligibility assessment process, 49 studies were included in the final review. For transparency and reproducibility, the complete set of included studies is explicitly identified by reference number in Appendix A. These studies constitute the primary evidence base used for the evidence mapping, circular economy strategy mapping, and reuse-readiness analyses. Additional references cited throughout the manuscript are used to provide methodological, theoretical, or contextual support and are not counted as part of the PRISMA-included review sample. The overall study selection process is presented in Figure 1.

After the document filtering process, bibliometric analysis was performed using VOSviewer (version 1.6.21). VOSviewer© was used to visualize and analyze publication trends, keyword relationships, and thematic structures within the selected literature. The selected documents were classified based on bibliographic information, including authors, publication year, citation data, and keywords. The keyword co-occurrence analysis was then used to identify the dominant research themes and the relationship between circular economy, sustainable housing, affordable housing, and modular building technologies. The result of the keyword co-occurrence network is presented in Figure 2, while the highlighted thematic pathways of circular economy strategies toward modular building technologies are shown in Figure 3. Meanwhile, Figure 2 keyword co-occurrence network of circular economy strategies for sustainable and affordable housing toward modular building technologies. Colors indicate clusters of closely related keywords identified by VOSviewer; larger nodes indicate more frequently occurring keywords, and links indicate co-occurrence relationships. Figure 3 highlighted thematic pathways of circular economy strategies toward modular building technologies. Colors correspond to the keyword

Table 2. *Cont.*

Item/Topic	Status	Concise PRISMA-ScR Requirement	Location/Reporting in Manuscript
5—Protocol/registration	Not reported in supplied manuscript	State whether a protocol exists and provide access/registration details if applicable.	No protocol/registration statement is present. Author confirmation is required before final submission.
6—Eligibility criteria	Reported	Specify and justify eligibility characteristics such as publication type, years, language, context, and evidence relevance.	Section 2, Table 1 reports publication type/quality, 2016–2026, English, housing context, CE/modular relevance, outcomes, and full-text availability.
7—Information sources	Partially reported	Describe all information sources and report the most recent search date.	Section 2 and Table 1 identify Scopus, Google Scholar, ScienceDirect, Taylor & Francis Online, Emerald Insight, and backward searching. Exact day/month is not stated.
8—Search	Reported	Provide a reproducible electronic strategy for at least one database, including limits.	Section 2 and Table 1 reproduce the full Scopus TITLE-ABS-KEY string plus English and 2016–2026 limits.
9—Source selection	Reported with procedural caveat	Describe screening and eligibility procedures.	Section 2 and Figure 1 report screening, eligibility, exclusion, and final inclusion. The reviewer/coder sentence in Methods should be finalized by the authors.
10—Data charting	Partially reported	Describe data-charting/extraction procedures, including calibration and independent/duplicate charting where applicable.	Section 2 describes a structured coding framework and coding rules; calibration and independent/duplicate charting are not explicitly documented.
11—Data items	Reported	List and define variables/data fields sought from each source.	Section 2 lists year, geography, objective, method, housing context, modular typology, material/system, life-cycle boundary, 0R–10R strategy, indicators, digital enablers, and reuse-readiness evidence.
12—Critical appraisal	N/A—no formal appraisal described	If formal appraisal was undertaken, explain rationale, methods, and use in synthesis.	No formal risk-of-bias/critical-appraisal method is described. Evidence-map and reuse-readiness scores are explicitly mapping instruments, not validated appraisal/certification tools.
13—Synthesis methods	Reported	Describe how charted data were handled and summarized.	Section 2 reports evidence mapping, life-cycle mapping, 0R–10R coding, reuse-readiness scoring, and VOSviewer analysis.
14—Source selection results	Reported	Report numbers screened, assessed, excluded, and included, preferably with a flow diagram.	Section 2, Figure 1: 283 records identified and 49 studies included; exclusion stages/reasons are shown in the flow diagram.
15—Source characteristics	Reported across manuscript/ Appendix A	Present relevant characteristics of included sources and cite them.	Section 3 evidence map, Section 4 synthesis, tables/figures, and Appendix A. Appendix A identifies the 49 included studies by reference number.

Table 2. Cont.

Item/Topic	Status	Concise PRISMA-ScR Requirement	Location/Reporting in Manuscript
16—Appraisal results	N/A	If formal appraisal was conducted, present its results.	Not applicable because no formal critical appraisal is described.
17—Individual-source results	Reported	Present charted data from individual sources relevant to the questions/objectives.	Section 3 (Table 3 and evidence synthesis) and Section 4 provide source-level evidence and comparisons.
18—Synthesis results	Reported	Summarize charting results in relation to the review questions/objectives.	Sections 3 and 4 synthesize CE-modular-SAH evidence, reuse readiness, whole-life circularity, enabling ecosystem, and the ID-CME pathway.
19—Summary of evidence	Reported	Summarize main concepts/themes/types of evidence and link to objectives/questions and relevance.	Section 4 integrates whole-life circularity, technical reuse readiness, affordability, digital traceability, institutional conditions, and ID-CME.
20—Limitations	Reported	Discuss limitations of the review process and evidence base.	Section 5 final paragraph reports English-only restriction, 2016–2026 timeframe, primary reliance on Scopus plus targeted sources, heterogeneity, non-validated scoring, and lack of empirical validation.
21—Conclusions	Reported	Provide overall interpretation, implications, and next steps relative to review questions/objectives.	Section 5 aligns conclusions with the four objectives and recommends future empirical and expert validation.
22—Funding	Needs completion in main manuscript	Describe funding of the scoping review and, where available, funding of included evidence.	The main-manuscript Funding field still contains an MDPI placeholder. Actual funding/APC wording should be inserted; funding of individual included studies was not charted.

3. Evidence Synthesis of Ce-Modular-Sustainable/Affordable Housing

Evidence maps explaining the integration of the circular economy (CE), modular technology (M), and sustainable/affordable housing (SAH) remain uneven in the literature, as only a small number of studies truly connect all four domains simultaneously [27,28]. Table 3 illustrates the evidence map, using a score of 0–2 to quickly assess the strength of the interrelationships between domains in each study: 0 = not discussed, 1 = mentioned/partially, 2 = strongly discussed + a focus. Most research remains fragmented: some studies focus on CE and the built environment, others on modular construction, and others on social or affordable housing, but not all have developed a complete trilinear framework [29,30]. The study by [2] is one of the closest references to this research direction because it directly links circular industrialized construction, sustainable housing, and affordable housing through a process framework that emphasizes disassembly and industrialized pathways [2]. The author of [27] also provides strong evidence through a whole-building life-cycle assessment based on BIM, EPD, and a cradle-to-cradle approach on a modular CLT building designed for disassembly and reuse. However, generalization of the results still requires caution due to the reliance on specific prototypes, market contexts, and material assumptions [27]. Liu and Loo (2025) strengthen the discussion of CE in modular integrated construction through LCA and circularity indicators, but their contribution is still more dominant on environmental performance than on proving affordability and social impacts for occupants [28].

A major criticism of the high-scoring study group is that technical and environmental robustness has not always been accompanied by sufficient economic and social evidence to declare a system truly sustainable and affordable [24,27]. In the context of SAH, affordability should not simply be assumed from production efficiency, waste reduction, or accelerated construction but needs to be demonstrated through life-cycle costs, maintenance costs, operating costs, occupant affordability, and long-term financing models [4]. LCA-based studies are indeed important because they can quantify the carbon and energy impacts of modular or prefabricated systems, but the dominance of LCA can be limited when social and economic variables only appear as implications rather than as primary indicators in the evaluation [16,18]. Therefore, this evidence map shows that many studies are strong in explaining the potential for environmental sustainability but are not consistent enough in linking it to housing affordability, market viability, and direct benefits for residents [2].

Another group of studies shows a more fragmented pattern, with some studies strong on CE–SAH but weak on modular technology, while others are strong on modular–SAH but have not yet made CE a primary framework [31]. Refs. [29,32,33] enrich the discussion on social housing, circular housing, and product-service system-based business models, but technical pathways such as prefabrication, modular technology, design for disassembly, and reusable components have not been thoroughly examined. In contrast, Refs. [31,34,35] show that modular or industrialized housing systems can support construction efficiency, sustainability, and energy targets, but CE strategies such as reuse, repair, refurbishment, remanufacture, repurpose, and recovery is not always explicitly operationalized. This situation indicates that modular technology is not automatically a circular system, as circularity can only be achieved if connection design, component standardization, material documentation, dismantling capabilities, and reuse mechanisms are designed early in the building’s life cycle [19,20].

Overall, this confirms that the main gap in the literature lies not in the lack of research but in the weak integration of technical, environmental, economic, and social evidence within a single operational CE–modular–SAH framework. Strong studies on technical aspects often fail to directly address affordability, while strong studies on social and institutional aspects often fail to explain how modular technology, disassembly, reusable components, and circular design can be applied at the housing project level. Furthermore, digital studies such as Refs. [36,37] demonstrate the importance of data, BIM, material passports, and knowledge graphs to support reuse and traceability. Meanwhile, these digital technologies are still more appropriately positioned as enablers of circularity rather than direct evidence that the housing system has become circular and affordable [22,36,37]. Thus, this evidence synthesis provides a strong basis for further research to map life-cycle boundaries, CE 0R–10R strategies, and reuse-readiness typologies so that the path to CE-based modular, sustainable and affordable housing can be formulated in a more measurable and applicable manner.

Table 3. Evidence map (CE–modular–sustainable/affordable housing).

Reference	CE–M (0–2)	M–SAH (0–2)	CE–SAH (0–2)	Trilinear Integrated?	Evidence Used (LCA/EE/LCC/Social)	Brief Critical
[5]	1	0	1	–	Conceptual framework/critical review	Strong CE framing for built environment, but not housing-specific and not modular-focused
[2]	2	2	2	✓	Systematic review + thematic synthesis	Directly targets sustainable + affordable housing and industrialized/disassembly pathways; still notes socio-economic evidence is thin.

Table 3. Cont.

Reference	CE-M (0–2)	M–SAH (0–2)	CE–SAH (0–2)	Trilinear Integrated?	Evidence Used (LCA/EE/LCC/Social)	Brief Critical
[27]	2	2	2	✓	WBLCA (cradle-to-cradle), BIM quantities, EPDs	Strong triad proof of concept; generalizability beyond single-family prototype and market conditions needs caution.
[28]	2	2	1	✓	LCA + CE indicator (dual life cycle)	Strong CE–MiC–residential environmental quantification; affordability/social outcomes not materially analyzed.
[38]	1	2	0	–	LCA-based EoL carbon model (case study)	Strong modular–residential EoL quantification; circularity is operationalized via reuse, but CE framing is not central.
[32]	1	2	2	✓	Policy/strategy analysis + social integration lens	Clear CE + social housing connection; “modularity” appears more as design principle than full modular technology adoption.
[29]	0	0	2	–	Social/behavioral lens (community role)	Strong CE-in-social-housing narrative; lacks modular/industrialized construction pathway testing.
[33]	0	0	2	–	Multiple-case study; interviews + documents	Strong circular housing business-model (PSS) framing; construction/technology pathways (modular/DfD) are indirect.
[36]	0	0	2	–	Data/knowledge graph; stock-level integrated assessment	Strong affordability–energy–footprint integration for housing; modular technologies are outside scope.
[39]	1	1	1	–	Systematic + narrative review (ReSOLVE)	Residential CE strategies mapped; off-site is included, but modular is not treated as primary lever nor linked to affordability outcomes.
[40]	0	1	2	–	Semi-structured interviews; governance lens	Strong housing–CE governance; modular is mentioned only as one possible investment/strategy, not evaluated.
[41]	0	0	2	–	Institutional theory; empirical city/housing case	Strong CE adoption drivers in transitional housing; modular pathway is not core.
[31]	0	2	0	–	Energy simulation + PV strategy; real-world case	Strong modular + social-housing + net-zero evidence; circular economy strategies are not formally operationalized.
[34]	0	2	0	–	Multi-criteria sustainability assessment; surveys + literature	Strong modular sustainability benchmarking; CE is not the analytical frame, and affordability is not central.

Table 3. Cont.

Reference	CE–M (0–2)	M–SAH (0–2)	CE–SAH (0–2)	Trilinear Integrated?	Evidence Used (LCA/EE/LCC/Social)	Brief Critical
[42]	2	0	0	–	Multicycle LCA + MFA; scenario analysis	Strong CE-at-EoL for modular steel; housing/affordability not the unit of analysis (component/module level).
[30]	2	0	0	–	Review (Scopus/WoS search + thematic mapping)	Strong CE–prefab trend mapping; housing outcomes (SAH) are not made explicit as evaluation criteria.
[18]	1	0	0	–	Systematic review (LCA of prefab/modular buildings)	Strong LCA method mapping; weak/variable linkage to affordability and to explicit CE strategy evaluation.
[37]	1	0	0	–	Systematic review (digital tools: BIM/DPP/material passport)	Important enabler layer for CE (data/traceability); housing affordability and modular construction are secondary.
[43]	1	0	0	–	Case database (65 projects) + decarbonization potential	Strong evidence of circular strategies in practice; housing affordability and modularity are not consistently captured variables.
[44]	1	0	0	–	Index development (CiBEC) + scenario assessment	Strong metric contribution for circular actions vs. embodied carbon; housing/affordability and modularity are not the focal unit.
[35]	0	2	0	–	Empirical value-chain + environmental impact lens	Directly addresses industrialized housing/resource efficiency; CE language is limited and modular tech is framed via industrialized wall systems.

Note: CE = circular economy; M = modular technology; SAH = sustainable/affordable housing; ✓ indicates explicit integration of all three domains; – indicates that full trilinear integration was not identified.

The relationship between circular economy (CE) and modular (M) can be explained by the definition of CE as “a regenerative system” that seeks to minimize resource input, waste, emissions, and energy leakage by slowing, closing, and narrowing the flow of materials and energy [7]. In the context of buildings, this principle becomes relevant because the transition to “circular buildings” requires a way of thinking that sees construction not only as an initial building process but also as a system that must maintain the value of materials and components throughout its life cycle [5]. Therefore, Figure 4 shows that the CE–M intersection is on a common path such as design for disassembly, reusable components, adaptability, lower material waste, and efficient construction, because circular construction relies heavily on the ability of building elements to be “disassembled and reused or rearranged” after their initial design life [17]. This relationship is further strengthened by the argument that product platforms in construction can support CE through “repetitions, standardization, and modularization,” which have the potential to increase resource efficiency and reuse [23]. Thus, modular construction cannot be directly considered circular, as circularity is only established if the modular design incorporates disassembly strategies, detachable joints, component reuse, and reduced material loss from the outset [19].

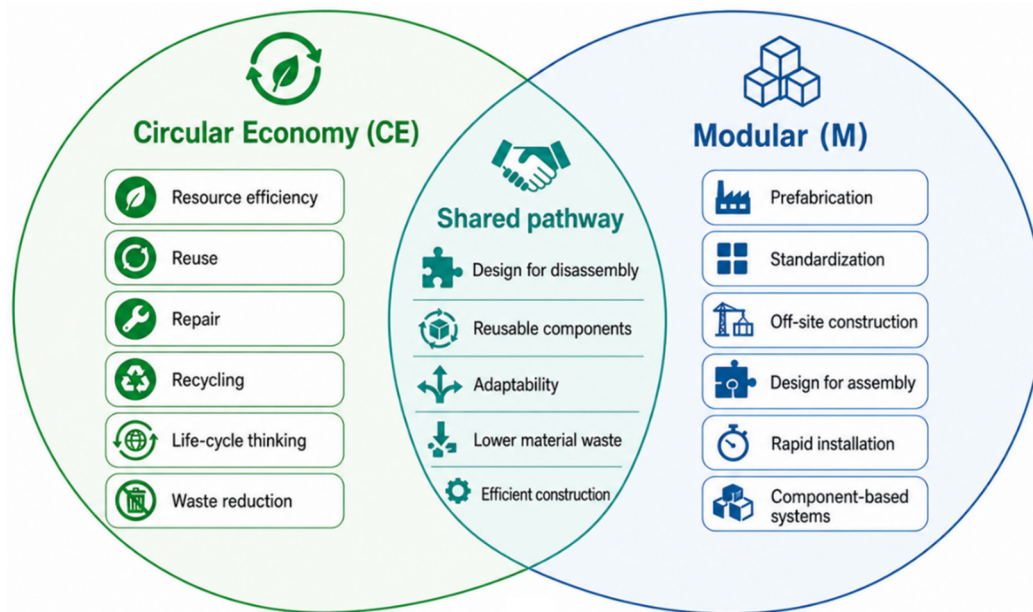


Figure 4. The relationship between circular economy (CE) and modular (M).

The relationship between modular (M) and sustainable/affordable housing (SAH) explains that modular construction can be a technical approach to accelerate housing delivery through prefabrication, standardization, off-site construction, rapid installation, flexible configuration, and quality control [14]. Kamali and Hewage’s study confirms that modular buildings generally exhibit better life-cycle performance, making this technology relevant for improving quality, energy performance, and construction efficiency compared to conventional methods [14]. In Figure 5, the M–SAH intersection explains that the benefits of modular for sustainable and affordable housing emerge through the shorter construction time, reduced waste, better building quality, scalable housing delivery, and adaptable living spaces [15]. However, affordability claims need to be criticized because studies on prefabricated construction conclude that “environmental dimensions of PBs have been studied more than economic ones,” so the economic aspects of modular housing still require stronger evidence [10]. Thus, modular housing can be a pathway to sustainable and affordable housing, but affordability must be proven through life-cycle costs, maintenance costs, operating costs, and economic viability for residents, not just through construction speed [3].

The relationship between the circular economy (CE) and sustainable/affordable housing (SAH) demonstrates that CE strategies can strengthen sustainable and affordable housing through resource efficiency, reuse, repair, recycling, life cycle thinking, and waste minimization [8]. Within the CE framework, these strategies can be understood as “resource value retention options” that aim to maintain the value of products, components, and materials so they do not quickly become waste [8]. Therefore, Figure 6 positions lower embodied impact, reduced resource use, life-cycle affordability, improved resilience, and long-term sustainability as the intersection of CE and SAH, as sustainable and affordable housing should be assessed based on both environmental performance and costs throughout its life cycle [4]. Victoria et al. point out that affordable housing can be a “prototype that performs well in both life-cycle carbon and cost,” making the integration of carbon and cost crucial in assessing the quality of sustainable–affordable housing [4]. However, CE–SAH should not stop at claims of waste reduction, because systematic reviews of the building sector show the need for a balance between “environmental, economic, and social dimensions” in the application of CE to buildings [24].

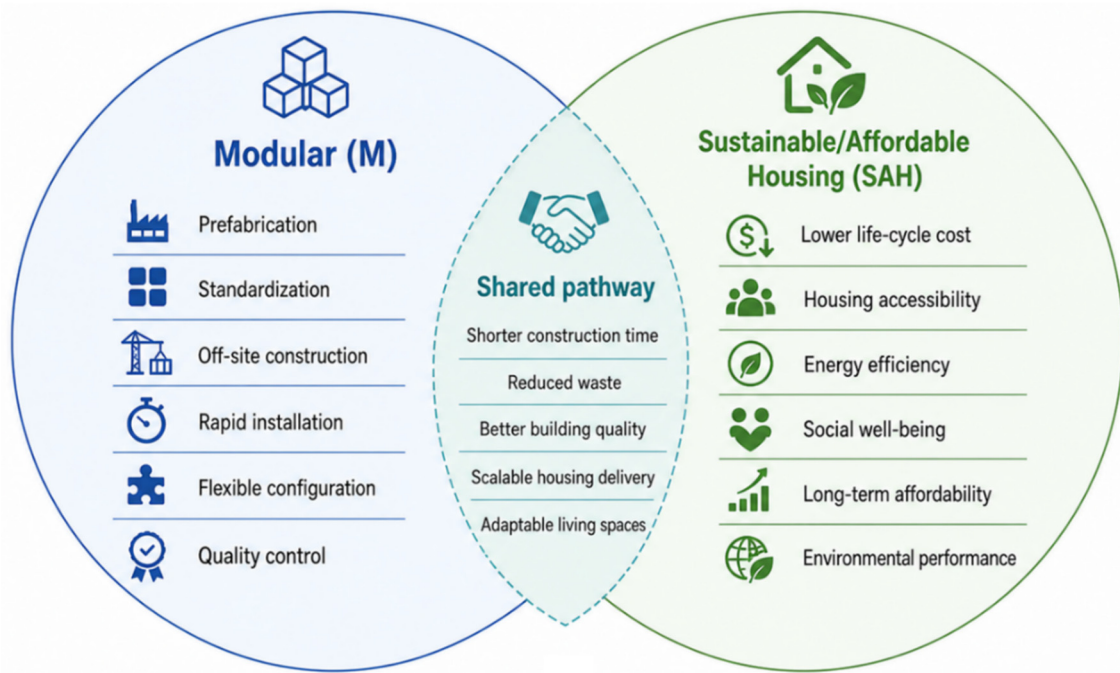


Figure 5. The relationship between modular (M) and sustainable/affordable housing.

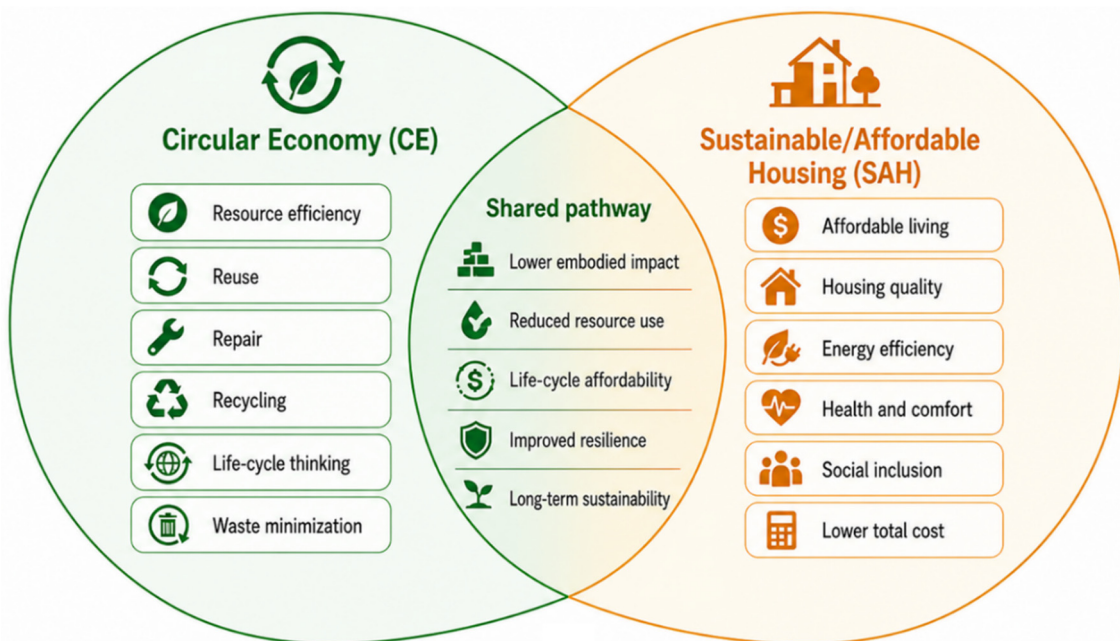


Figure 6. The relationship between circular economy (CE) and sustainable/affordable housing (SAH).

The trilinear integration of circular economy, modular, and sustainable/affordable housing demonstrates that circular modular housing should be viewed as a synthesis of resource efficiency, prefabrication, knock-down design, reusable components, rapid delivery, scalable housing, life-cycle affordability, and lower environmental impact [2]. Recent literature describes circular industrialized housing as an approach supported by component design for “future disassembly and reuse” and with the potential to provide “sustainable and affordable homes at scale” [2]. In Figure 7, the central area of the trilinear integration can be understood as the intersection of circular modular housing, sustainable delivery, and resource-efficient and affordable systems, as studies of modular CLT demonstrate the importance of buildings “designed for disassembly and reuse” in comparative

life-cycle assessments [27]. This integration is also in line with MiC research showing that replacing some cast-in situ processes with prefabricated components can “significantly reduce the carbon footprint of buildings” in the context of modular construction [28]. Thus, Figure 7 can be used as a key conceptual synthesis because it shows that robust housing solutions are not just modular or circular in isolation but must combine reuse, disassembly, standardization, affordability, and sustainability in one scalable design system [23].

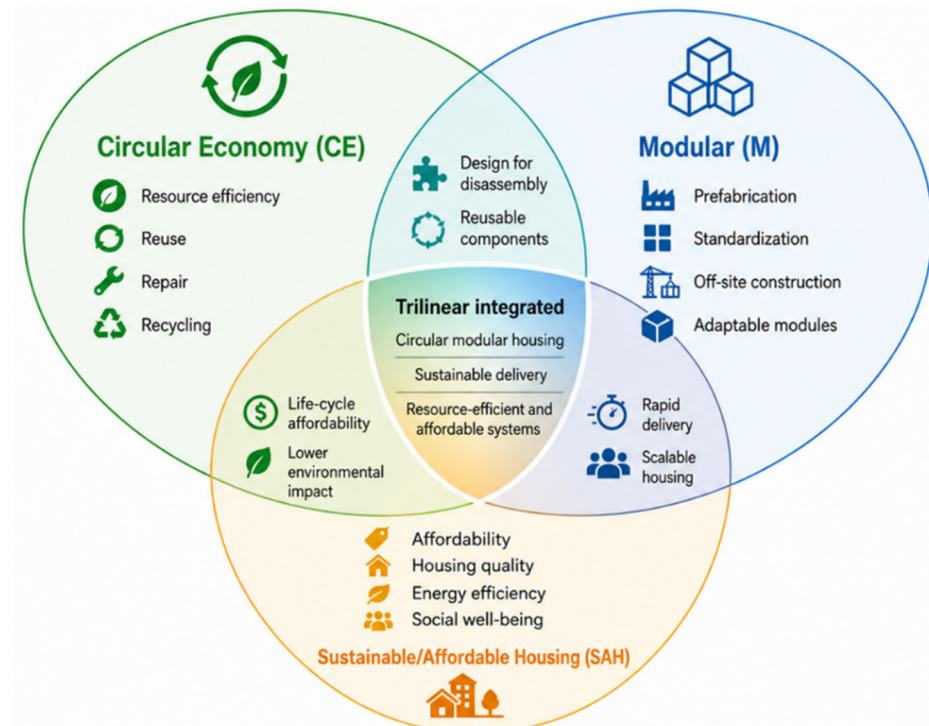


Figure 7. Trilinear integration of circular economy, modular and sustainable/affordable housing.

4. Circularity, Reuse Readiness, and the Enabling Ecosystem for Sustainable and Affordable Modular Housing

The evidence base shows that circular economy (CE) research relevant to modular and affordable housing is broad but still uneven across the building life cycle. Framework studies on CE targets and assessment methods demonstrate that the R-strategies provide a useful hierarchy for value retention, yet their application remains inconsistent across design, use, disassembly, and second-life stages [45–47]. In particular, the literature continues to emphasize measurable downstream actions such as reuse and recycling more strongly than preventive and higher-value strategies implemented before waste is generated. Systematic building-level reviews similarly report that CE principles are frequently discussed through waste reduction and material recovery, while repair, refurbishment, remanufacturing, repurposing, and redesign remain less consistently operationalized [48,49]. This imbalance is important because a genuinely circular modular housing system should not begin at demolition; it should begin with early decisions about need, modular dimensions, material selection, connection design, adaptability, maintenance, and future disassembly. Evidence from modular and prefabricated construction reinforces this interpretation. Case studies demonstrate that modular buildings can support reduction, reuse, adaptability, and recyclability, but the benefits depend on how circular principles are embedded in the system rather than on prefabrication itself [50,51]. Research on critical success factors further shows that CE integration in modular projects requires coordinated technical, organizational, supply-chain, and project-management conditions [52]. Bibliometric and systematic reviews of the intersection between prefabrication, modularity, and circular

construction confirm that the field is expanding rapidly but also identify a continued gap between conceptual CE ambitions and implementation at building or component level [53,54]. Recent work on sustainable social housing similarly indicates that circularity must be connected to architectural design, material choices, housing quality, and long-term social outcomes rather than being treated solely as a waste-management strategy [55].

The life-cycle evidence also requires careful interpretation. Design-for-disassembly LCA studies show that carbon benefits depend strongly on assumptions regarding recovery, reuse, transport, replacement, and subsequent life cycles [56]. Methodological comparisons of reusable components reveal that allocation across multiple life cycles remains a major source of uncertainty [57], while recyclability assessment research argues that end-of-life potential should be considered during the design stage rather than only after materials become waste [58]. The economic dimension is similarly conditional: life-cycle cost research suggests that greater circularity can influence long-term cost, but the relationship depends on investment, maintenance, replacement, and retained component value [59]. Multi-life-cycle studies of buildings designed for disassembly further demonstrate that environmental performance changes across repeated cycles and cannot be inferred from a single end-of-life scenario [60]. Therefore, environmental improvement, circularity, and affordability should be assessed together rather than treated as interchangeable outcomes. Standardization and remanufacturing-oriented studies provide an additional bridge between CE principles and practical reuse. Standardization has been identified as an essential enabler for the circular reuse of construction components because consistent dimensions, interfaces, documentation, and quality expectations can reduce uncertainty when components are recovered and reintroduced into another project [61]. Analytical work on design for disassembly and target components for remanufacturing similarly indicates that future value retention depends on identifying which components can be dismantled, inspected, processed, and returned to use without disproportionate damage or cost [62]. Taken together, these studies suggest that the main challenge is no longer simply demonstrating that reuse is environmentally desirable; the challenge is creating a repeatable technical and informational pathway through which reusable components can be recognized, evaluated, and accepted for a subsequent life cycle.

The second major theme concerns the distinction between modularity and reuse readiness. Recent evidence on reusable timber modular buildings demonstrates that interlocking and removable connections can directly support assembly, disassembly, and component recovery [63]. Experimental work on reusable cross-laminated timber systems further shows that replaceable and demountable components can be incorporated while maintaining structural performance requirements [64]. At the broader structural-system level, reviews of modular steel buildings and inter-module connections emphasize that connection performance, joining technique, constructability, repair, and disassembly are central to whether a modular unit can realistically be reused [65,66]. These findings are important because they demonstrate that modularity is a production and configuration principle, whereas reuse readiness is a performance condition. A building can therefore be highly modular while still having low circular potential if its joints are destructive, its components are difficult to inspect, or no second-life pathway exists. The same conclusion emerges from a recent review of the literature. Digital-age reviews of modular construction describe a growing innovation ecosystem involving automation, smart technologies, BIM, and sustainability, but reuse readiness is not consistently operationalized at the module or component level [67]. Reviews of modular terminology show substantial diversity among volumetric, panelized, flat-pack, kit-of-parts, and hybrid systems, meaning that the word “modular” alone does not indicate how easily a system can be dismantled or reused [68]. Design-for-reuse research on prefabricated timber buildings demonstrates that explicit

evaluation of reuse criteria can distinguish genuinely reusable alternatives from systems that are merely prefabricated [69]. Reviews of high-rise modular systems and joining technologies also show that rapid assembly does not necessarily imply non-destructive disassembly or a credible reuse route [70]. Comprehensive modular construction reviews similarly identify reuse and circularity as emerging opportunities but emphasize that practical performance remains system specific [71].

Longer-term reviews of modular construction indicate that timber, steel, concrete, and mixed systems are progressively being assessed in relation to circularity, design for disassembly, and material recovery, but the availability of typology-specific reuse metrics remains uneven [72]. Residential modular reviews also highlight broad opportunities for efficiency, quality, and scalability while identifying future challenges associated with end-of-life management, adaptability, and circular implementation [73]. Across these studies, a consistent message emerges reuse readiness is determined by a combination of connection design, non-destructive disassembly, durability, repairability, replaceability, standardization, material documentation, transportability, and an identifiable second-life scenario. These criteria should be interpreted as evidence-mapping attributes rather than as a validated certification system, but they provide a clearer analytical bridge between modular construction and circular implementation than the modular label alone. A further implication concerns post-disassembly structural integrity. A component that was originally designed to carry load cannot be assumed to retain the same performance after one service period and a dismantling process. Connection damage, local deterioration, deformation, moisture exposure, fatigue, handling damage, and previous repair can all affect second-life suitability. Consequently, circular reuse requires an assessment sequence that goes beyond the original design documentation: inspection, condition grading, repair decision, residual-capacity assessment where relevant, and recertification must precede re-entry into the construction supply chain. This requirement strengthens the argument that reuse readiness is not simply a design characteristic; it is a life-cycle condition that must be verified again when a component moves from one use cycle to the next. Table 4 summarizes the sequential evidence emerging from the reviewed literature before the conceptual pathway is interpreted. The table places the main findings into three connected domains: whole-life circularity, technical reuse readiness, and the enabling ecosystem required for repeated component use. This organization is important because the literature does not support treating any one domain as sufficient on its own; the evidence instead indicates that circular design strategies, technically reusable components, and implementation mechanisms must operate together.

The table indicates that the strongest new interpretation does not arise from adding another CE indicator or another modular typology. It arises from connecting evidence that has usually been studied separately. The first domain defines the circular objective across the whole life cycle; the second asks whether modules and components are actually capable of safe recovery and reuse; and the third determines whether the recovered component can be documented, accepted, transported, traded, warranted, and placed into another project. This sequence provides a more cautious and operational interpretation of circular modular housing than simply equating prefabrication with circularity. Figure 8 illustrates how these three evidence domains are brought together within the Integrated Digital Circular Modular Ecosystem (ID-CME). The figure is positioned as a conceptual synthesis rather than a validated implementation model. Circular design and planning initiate the pathway, modular manufacturing and assembly translate that intent into physical components, and the use, maintenance, return, reuse, refurbishment, and recycling stages generate information that feeds back into subsequent design. The digital layer connects material passports, reuse-readiness assessment, BIM or digital twins, grading, reverse

logistics, circular marketplaces, and life-cycle performance evaluation so that decisions can be supported across multiple use cycles.

Table 4. Integrated evidence synthesis and the new knowledge emerging from the reviewed studies.

Evidence Domain	Evidence Represented in the Literature	Main Limitation	Integrated Interpretation
Whole-life circularity	CE target frameworks, assessment methods, modular cases, LCA/LCC, standardization, and recent CE mapping [45,48,49,51,53–55,60,62].	Evidence remains concentrated on downstream strategies and often separates environmental, economic, and social outcomes.	Circular modular housing should be evaluated as a whole-life value-retention system beginning at design and extending through repeated use cycles.
Technical reuse readiness	Reusable timber/CLT, modular steel, connection studies, typology reviews, design-for-reuse and residential modular reviews [63–73].	Modularity does not automatically demonstrate non-destructive disassembly, post-disassembly integrity, or second-life suitability.	Reuse readiness is the technical bridge that converts modularity from a production method into a potentially circular building system.
Enabling ecosystem	Traceability, documentation, component grading, recertification, reverse logistics, market and governance needs are repeatedly identified across the evidence base.	Technical potential can remain unused when data, certification, liability, logistics, market demand, or cost mechanisms are absent.	Circular intent and reuse readiness require an enabling information, economic, market, and institutional ecosystem to support repeated component use.

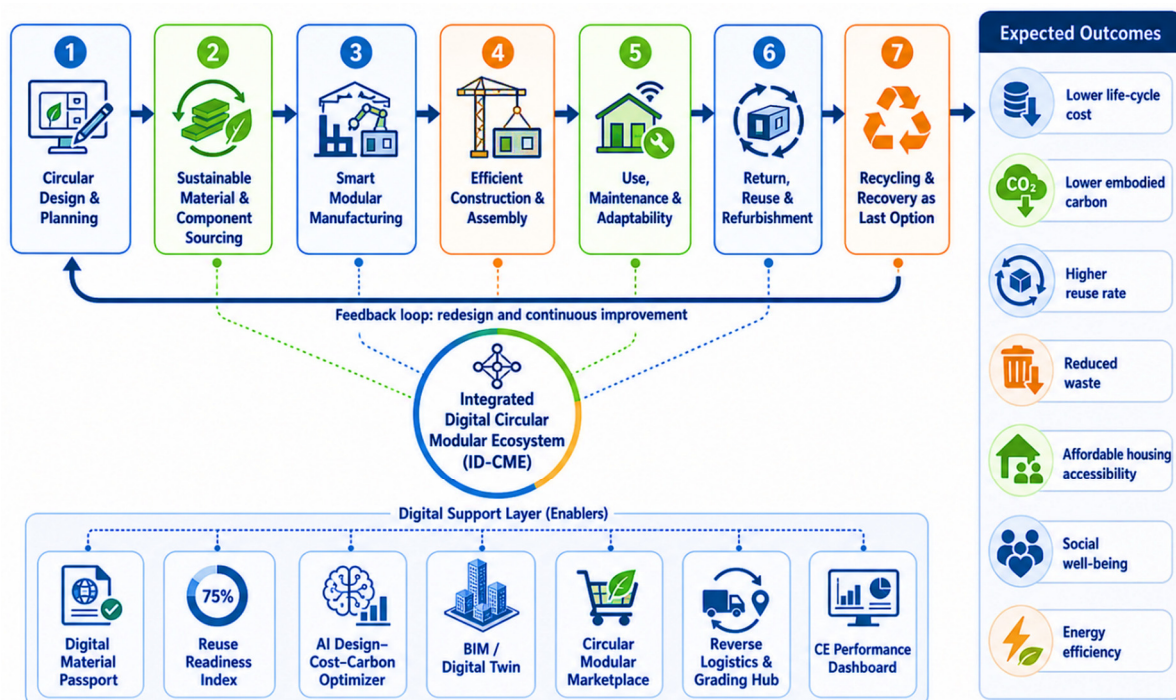


Figure 8. Integrated Digital Circular Modular Ecosystem (ID-CME) pathway for sustainable and affordable modular housing.

The deeper implication of Table 3 and Figure 8 is that circular modular housing can be understood through three sequential layers. The first layer is circular intent: the decision to avoid unnecessary material use, design for adaptability, preserve component value, and plan for multiple use cycles. The second layer is technical reuse readiness: the ability of a module or component to be dismantled without unacceptable damage, inspected, repaired where necessary, documented, and considered suitable for another use. The third layer is the enabling ecosystem: the information, certification, logistics, market, financial, and

governance mechanisms that allow for a technically reusable component to return to the construction sector. The principal new knowledge generated by the synthesis is therefore the relationship among these layers. Modularity becomes meaningfully circular only when circular intent is translated into verifiable reuse readiness and is supported by an ecosystem that enables repeated use.

This interpretation also reduces the risk of overclaiming. The reviewed evidence does not demonstrate that every demountable modular system will be reused in practice, nor that digital passports or reverse logistics will automatically reduce housing costs. Instead, the literature identifies enabling conditions and unresolved constraints. For example, a technically recoverable component may still fail to be reused if inspection procedures are unavailable, certification is uncertain, transport is uneconomic, market demand is absent, or liability cannot be allocated. Conversely, a mature marketplace and digital platform cannot make a component reusable if connection damage or residual structural performance is unacceptable. Circular performance is therefore conditional on the interaction between technical, informational, economic, market, and institutional factors.

Life-cycle affordability should be interpreted with the same caution. Demountable connections, improved documentation, digital infrastructure, inspection, grading, storage, and reverse logistics can increase initial expenditure, particularly during early implementation. Their economic justification depends on whether those investments are offset over time by reduced replacement, lower waste, longer component service life, maintenance efficiency, residual value, or avoided end-of-life cost. The evidence base therefore supports whole-life-cost evaluation rather than a simple claim of lower initial cost. For sustainable and affordable housing, this distinction is critical because a technically circular solution that raises total housing costs or transfers excessive risk to residents or developers would not satisfy the broader affordability objective.

Institutional readiness is equally central. Reused load-bearing elements require credible procedures for inspection, grading, recertification, code compliance, warranty, and liability allocation. The ID-CME can support these processes by maintaining traceable information on provenance, service history, maintenance, disassembly condition, inspection results, and second-life status, but it cannot replace statutory approval or professional responsibility. This means that future implementation must involve engineers, manufacturers, developers, certifiers, regulators, insurers, logistics providers, and potential second-life buyers. In practical terms, the ecosystem becomes circular only when the physical component and its information record can move together through a recognized decision process.

The proposed synthesis should therefore be treated as a research proposition derived from the mapped evidence, not as a universally validated solution. The reviewed studies vary substantially in material system, building typology, geographic context, life-cycle boundary, analytical method, and affordability indicator. Such heterogeneity is appropriate for a systematic scoping review, but it limits direct causal inference and quantitative generalization. Future research should test the three-layer relationship through real modular housing projects and expert evaluation, with particular attention to post-disassembly structural integrity, whole-life cost, certification, liability, reverse logistics, and market acceptance. Validation across timber, steel, concrete, and mixed modular systems would establish whether the proposed relationship between circular intent, reuse readiness, and the enabling ecosystem can be operationalized consistently in practice.

5. Conclusions

This systematic scoping review mapped the current evidence on circularity and reuse readiness in sustainable and affordable modular housing in relation to the four research objectives. First, the OR–10R mapping indicates that the literature remains concentrated on

reuse, recycling, waste reduction, and other downstream strategies, while earlier and higher-value retention strategies such as refuse, rethink, repair, refurbishment, remanufacturing, repurposing, and redesign remain comparatively less explored. Second, the assessment of modular typologies indicates that modularity alone does not ensure reuse readiness; stronger evidence is associated with design for disassembly, demountable connections, non-destructive disassembly, component standardization, durability, repairability, material traceability, reverse logistics, and credible second-life scenarios.

Third, the reviewed literature shows that environmental indicators, particularly carbon emissions, energy use, waste reduction, and life-cycle assessment, are more extensively represented than life-cycle affordability, social value, occupant-related outcomes, and long-term economic performance. Fourth, the synthesis identifies important gaps in the integration of circular design, modular technology, affordability, digital traceability, and implementation mechanisms. Based on these mapped patterns, the proposed Integrated Digital Circular Modular Ecosystem provides an evidence-informed conceptual pathway linking circular design, reuse-readiness assessment, material passports, BIM/digital twins, component grading, reverse logistics, circular marketplaces, and life-cycle performance evaluation. The pathway should be interpreted as a conceptual synthesis requiring further empirical and expert validation rather than as a validated implementation model.

This study has several limitations. The review was restricted to English-language publications from 2016 to 2026 and relied primarily on Scopus, complemented by targeted searches and additional discovery sources. The heterogeneity of study designs, modular typologies, geographical contexts, life-cycle boundaries, and assessment indicators limits direct comparison across studies. In addition, the evidence-mapping and reuse-readiness scoring frameworks were developed to identify patterns in the literature and should not be interpreted as validated engineering or certification tools. The proposed conceptual pathway has not yet been tested through expert validation or application to actual modular housing projects. Future research should therefore validate the identified reuse-readiness attributes and conceptual pathway across different housing typologies, geographical contexts, and real-world modular projects.

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Conflicts of Interest: The authors declare no conflicts of interest.

Appendix A

Studies Included in the Systematic Scoping Review: The following references constitute the 49 studies included in the final systematic scoping review and evidence synthesis. These studies were selected according to the eligibility criteria described in Section 2 and provide the evidence base for the CE–modular–sustainable/affordable housing evidence mapping, 0R–10R circular economy strategy analysis, and modular technology reuse-readiness assessment presented in

this study. Included studies ($n = 49$): [2,8,17,18,27–42,45–73]. Full bibliographic details of all included studies are provided in the References section.

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