

Original Article

Eco-Resilient Kitchen Frameworks: Civil-Interior Integration of Recycled Composites and Biophilic Aesthetics

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Abstract - Eco-friendly measures are evident everywhere, including in interior design. Greenery, organic food processing, and kitchen measures are potential trends at the moment. However, the study relates to this concept, as it discusses eco-resilient kitchen frameworks. On the other hand, the research examined the role of civil and interior professionals in integrating biophilic finishes into the kitchen interior. The study focuses on creating sustainable composite integration in modern kitchen appliances through civil engineering and design. This study presents statistical reports and several literature reviews by different authors on this subject. These facilitate different perspectives on the context, including the identification and coordination of recycled processes and material capabilities by both professionals. Also, the methodology of this study is defined as a secondary source and incorporates qualitative and thematic analysis, which perfectly addresses the research objectives. The study's findings indicate that the use of recycled steel in the kitchen can also minimise environmental impact and lower material costs. The high-purity materials developed recycled products that meet stringent quality standards. Further, it is also evaluated that civil engineering integration can enhance collaboration among other fields and sub-disciplines of civil engineering, such as environmental science, urban planning, and architecture.

Keywords - Recycled, Kitchen, Biophilic, Civil, Material, Resilient, Lifecycle Assessment.

1. Introduction

1.1. Overview of the Topic

In the current time, the market demand is rapidly shifting towards sustainability, cruelty-free practices, and eco-friendliness across the industry. Among these sustainable measures, eco-resilient kitchens are in the hot seat of demanding home interiors. An eco-resilient kitchen is more sustainable and provides long-term support to users than traditional infrastructure, which is built from materials that cause less environmental harm (Cabacungan et al. 2023, February). The design and materials in this aspect are chosen with a focus on longevity, high quality, and the planet's wellness. To be precise, the kitchen designs are built with materials such as recycled wood, glass countertops, ethically sourced bamboo, and cork, which are considered less harmful to the environment. However, the topic is the combination of eco-friendliness and biophilic aesthetics to boost users' physical health. In the context of professionals, civil and interior engineering synergy dictates the choice of the material, lays out the design, and applies the strategy for smart and sustainable kitchen appliances through lifecycle performance (Iyiola, 2025). On the other hand, biophilic design re-engages inhabitants with natural forms, lighting, and materials, thereby enhancing cognitive

recovery and thermal comfort in high-density urban schemes. Mechanical and plumbing coordination needs to respond to recycled frameworks, while still maintaining the sustainability and performance level of the products for kitchen use (Almusaed et al. 2024). Conversely, the lifecycle design obligated designers to assess recyclability, push professionals to exert effort in standardisation and feedback, and evaluate them as per the requirements.

This study prioritises professional use, aiming to be adopted by civil-interior engineering companies, materials producers, and regulatory organisations for real-time application across project types. However, the research achieves a balance between technical rigour and readable advice to facilitate adoption within standard civil-interior project work streams through training and procurement.

2. Research Aim and Objectives

2.1. Aim

The purpose of this research is to create holistic civil-interior guides that facilitate robust kitchen design with recycled and renewable materials and biophilic appearances for practical utilisation in industry.



3. Objectives

1. To assess the material and structural performance of recycled materials for kitchen applications regarding load carrying capability, effectiveness, durability, performance rate, and detailing of interfaces in actual service conditions.
2. To build up integration policies that organise civil engineering services and interior designers, so that mechanical, plumbing, and electrical systems are successfully accessible and resilient throughout the project framework.
3. To develop environment and lifecycle evaluation guidelines for recycled materials, quantifying embodied impact, repairability, and long-lasting pathways, and testing methods for validation.
4. To establish biophilic aesthetic strategies that optimise occupant health and daylighting, and secure surface cleanliness and maintenance harmonisation within the tight kitchen composites for industry adoption.
5. To create actionable instructions for guiding civil-interior teams, facilitating procurement, and regulation with project scale and delivery models.

3.1. Problem Statement

A more sustainable residential design focuses on the kitchen as a key space where environmental requirements,

material efficiency, and human well-being converge. The application of a combination of civil engineering concepts and interior design principles is a notion not yet explored. Biophilic aesthetics research is further pursued for its visual or psychological values, without consideration of practical applicability or performance in a kitchen environment (Neri, 2023). However, this also explains the obvious gap in research regarding eco-resilient kitchen frameworks: the combined interaction of recycled materials, biophilia, and transdisciplinary design concepts. The reason why this gap is important to bridge is that kitchens are sources of enormous material waste and consumption. The kitchen is therefore an important location for sustainable residential development. In addition, the above study, secondary evidence is synthesized in order to construct an eco-resilient kitchen model incorporating recycled materials, biophilic, and engineering principles.

3.2. Market Scopes

The present research targets mid to large-scale domestic and mixed-use kitchen design and construction projects, in which civil and interior specialists work hand in hand in the design and decoration stages. However, the sustainable interior design market is growing rapidly, driven by the demand for recycled composites such as wood-polymer hybrids, ethically sourced bamboo for construction, and Industrial byproduct materials (Ramesh et al. 2022).

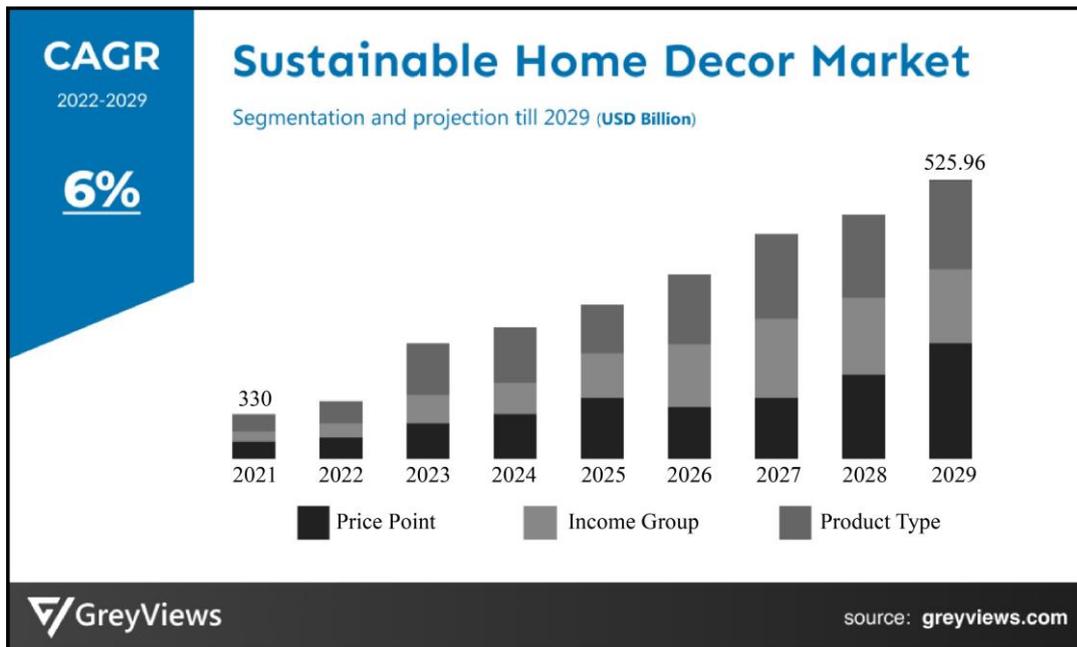


Fig. 1 The market size of the sustainable home décor

Source: GreyViews, 2021

The statistical report illustrated that the global sustainable home decor market increased from over 3400 billion USD in 2021 to 525.96 billion USD by 2029, with an expected CAGR of 6% in 2022-2029 (GreyViews, 2021). This indicates that demand for sustainability integration in household and interior applications is rapidly growing globally, creating an opportunity to expand the market for eco-resilient kitchen frameworks as well.

However, the kitchen segments of home interior decoration are likely to use most of the same materials with minimal environmental impact and to avoid the use of mineral resources in food processing. Instead, the market demand shifted toward smart kitchen appliances with advanced composites, recycled woods, and other materials, aligned with urban lifestyle standards (Jeyaguru and Thiagamani, 2025).

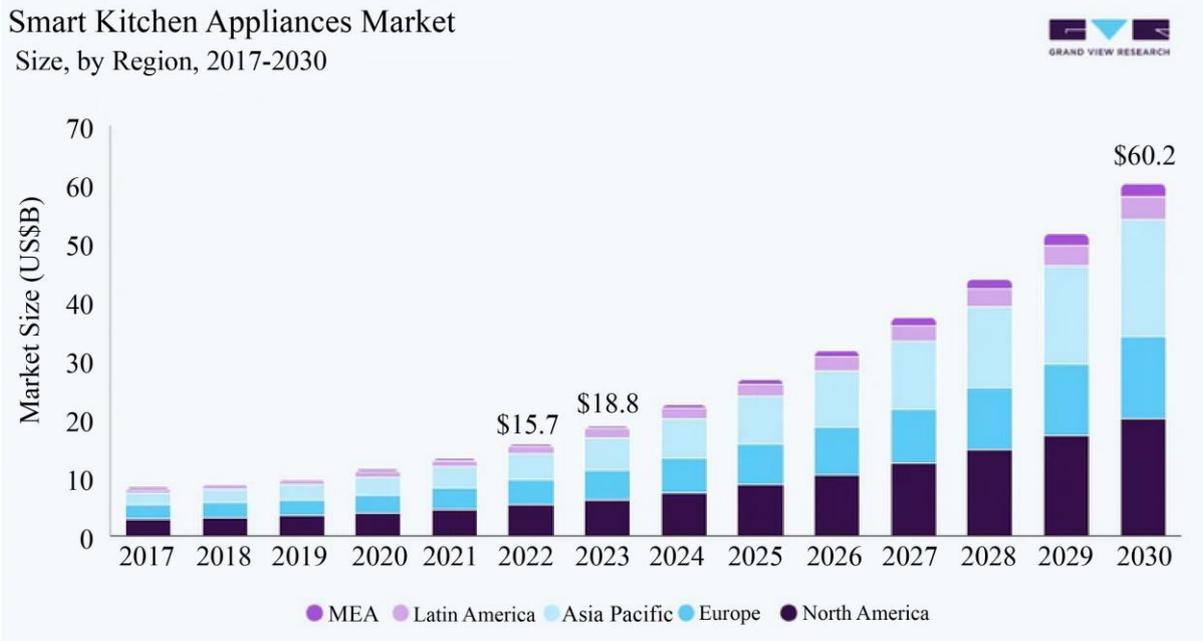


Fig. 2 The market size of the smart kitchen

Source: Grand View Research, 2023

The statistical figure indicates that the global smart kitchen appliances market is expected to increase from 18.5 billion USD in 2023 to 60.20 billion USD by 2030, with a CAGR of 17.9% from 2024 to 2030 (Grand View Research, 2023). In this manner, it reveals that the inclusion of electronics and digitalisation is increasing day by day, which enables civil-interior engineering professionals to ensure kitchen designs are advanced yet eco-friendly for modern kitchens.

From these analyses, it is evident that eco-resilient kitchen design offers significant market potential (Bressanelli et al. 2020). Alongside this, it would be accepted by the users and address all the requirements, including both digitalisation and sustainability in interior engineering. Thus, the research has the potential to analyse this topic for professional personnel, researchers, and business organisations, providing them with initial knowledge of eco-friendliness in kitchen frameworks and their environmental effectiveness.

3.3. Research Structure

The research covers all dimensions of the topic, including eco-resilient kitchen frameworks implemented by civil-interior teams in biophilic aesthetics. It introduces core insights about the topic and its significance in this research, while using different algorithms and statistical analyses. Also, the literature review by different authors from various perspectives related to the subject, and the secondary data collection from available online research, solidify the information.

Moreover, the research results and discussion thoroughly analyse the findings and key information and knowledge observed throughout the study, which can further help researchers and civil-interior teams construct an eco-resilient kitchen that meets the requirements. Lastly, the

research presents tangible recommendations for future researchers, business managers, and professional personnel to help them incorporate kitchen frameworks that incorporate accountable, ethical, and moral values.

4. Literature Review

4.1. Introduction

The literature review is a research approach that analyses and interprets existing scholarly articles on a particular topic. It demonstrates in-depth analysis of the issues and helps identify several systematic methods and theories aligned with the research purposes. In this topic on eco-friendly kitchen frameworks, the literature review can provide knowledge about the required infrastructure for implementing them, the core drivers, and their effectiveness for both humans and the environment. However, the review would provide a comprehensive coverage of the research, demonstrating the various dimensions of the research topics and their role in incorporating the required approach.

5. Theoretical Frameworks

5.1. Life Cycle Assessment (LCA) Theory



Fig. 3 Life cycle assessment framework

Source: Mi, 2024

The research by Aktas and Bilec (2012) underscored the fact that reliable estimation of building product service life has a significant impact on Life Cycle Assessment results, especially for kitchen interior finishes. A compound approach combining ASTM G166 statistical analysis and the ISO 15686 Factor Method enables reliable lifetime estimates by incorporating technical and social parameters that influence durability. However, this theory is integrated into the research purpose to provide pathways for sustainable alignment of smart kitchen construction in modern buildings.

6. Systems Integration Theory

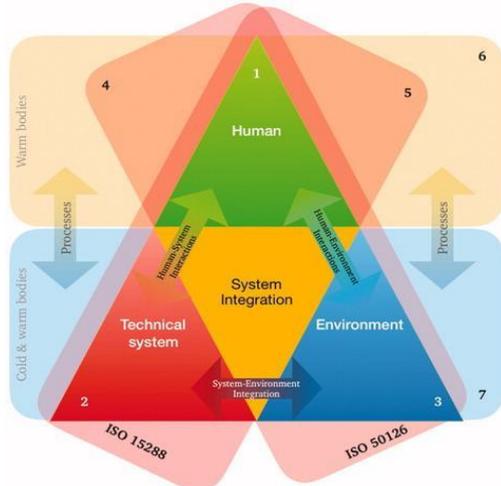


Fig. 4 Systems integration theory

Source: Rajabalinejad et al. 2020, January

Rajabalinejad et al. (2020, January) highlighted that the system integration approach involves integrating human, technical systems, and environmental interactions to achieve functional and resilient performance in complex projects. Also, the theory offers an organised framework for identifying and managing these interactions, shedding light on roles, responsibilities, and interdependencies among multidisciplinary engineering professionals and other professionals, such as interior specialists.

In a sustainable kitchen structure, civil and interior professionals can mitigate integration challenges, reduce failures, and improve sustainability, resilience, and the application of biophilic design in kitchen spaces by following this theoretical approach.

6.1. Sustainable Kitchen Design

The research by Lu & Ko (2023) demonstrates that moral sustainability, competence, and self-efficacy are very important determinants of waste reduction behaviors among kitchen workers, and the results are based on 415 Taiwanese samples. These behavioral correlations are integrated into eco-resilient kitchen designs because human behavior shapes how recycled composite materials, excess resources, or biophilic designs can mitigate resource or material waste. Nevertheless, the research can be said to have various limitations since it is based only on attitude measurements and does not cover the aspect of civil-interior integration with evidence regarding layouts or performance/biophilic factors concerning waste avoidance.



Fig. 5 Recycling of the wasted food from the food processing source or kitchen

Source: Kuligowski et al. 2023

The research by Kuligowski *et al.* (2023) confirms recycled kitchen waste fertilizers perform better in the cool seasons compared to mineral fertilizers, with increased yields of between 20-40% above 120 kg N/ha with high efficiency of N. This evidence informs eco-resilient kitchen infrastructure with its connections between indoor waste treatment systems and city-scale food loops, supporting recycled composites, closed-loop nutrient cycles, and biophilic stories of sustainability. However, the study

decouples the results of biological recycling in terms of space design in kitchen environments and interaction with waste creation and processing in professional kitchen environments. The future of work will incorporate anaerobic systems, composite materials recycled for interior use, and biophilic design concepts in the kitchen. This will help in the creation of kitchens that enhance circular eating, soil renewal, and climate adaptation.

6.2. Biophilic Design Framework

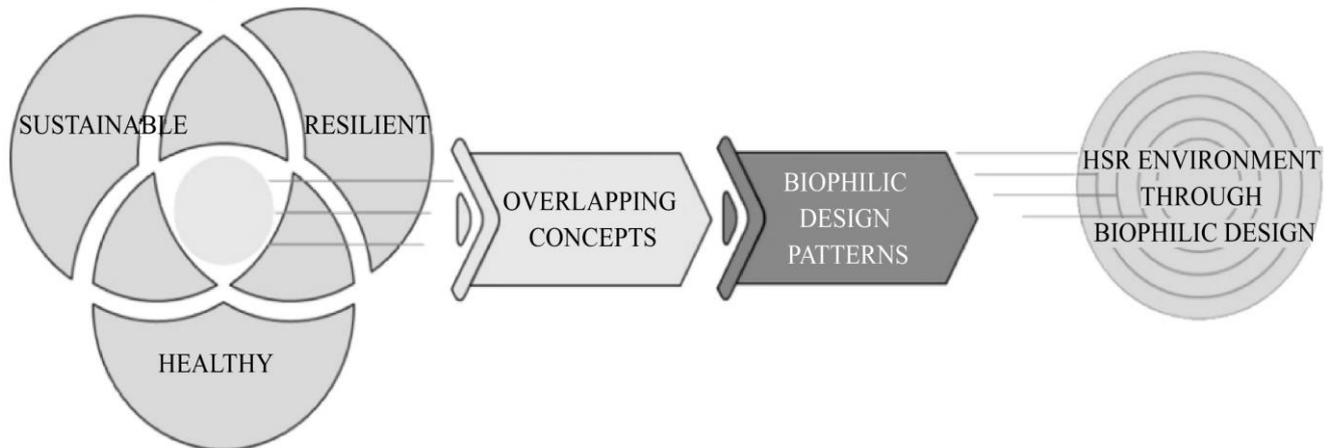


Fig. 6 Biophilic design framework

Source: Cacique and Ou, 2022

Biophilic design theory concerns the incorporation of nature's patterns, materials, and environmental connections into built structures. In this context, the research by Cacique and Ou (2022) identifies 19 common factors between Health, Sustainability, and Resilience (HSR), of which 16 are highly correlated with biophilic design. The incorporation of natural features such as vegetation, water, and daylight enhances occupant health, environmental performance, and flexibility, with quantifiable improvements to interior environments. Using this framework in eco-resilient kitchen frameworks facilitates material selection, spatial planning, and interface details, promoting human health without sacrificing structural performance and longevity.

Also, this study by Konsyna & Bondarenko (2023) showed a clear effect of moderate exposure to biophilic elements while attention restoration happens, and mindfulness practice contributed positively, irrespective of the level of exposure to nature. This is particularly significant for an eco-resilient kitchen framework, where a well-harmonized biophilic interior design can optimize worker concentration and performance in a high-risk food-preparation environment.

However, it is obtained that the study lacks quantifiable levels of exposure and does not apply the Attention Restoration Theory attributes to materials, lighting, and space. Biophilic design trials can be carried out in the future through recycled composite materials, multisensory stimuli, and attention data to identify the ideal restorative environment for sustainable kitchen environments.

6.2.1. Evaluation of Performance Structure and Material of Recycled Composites for Kitchen Uses

The research by Ricciardi *et al.* (2014) indicates that panels recycled from wastepaper and textile fibres exhibit good thermal performance with 0.034-0.039 W/m K k-values. Their acoustical absorption, with NRC values of 0.23-0.38, indicates potential for use in kitchen spaces where noise control and comfort are needed. Nevertheless, high density around 433 kg/m³ and susceptibility to humidity limit structural incorporation under operating conditions. Though they have good insulation, the panels have high energy use and a high global warming potential during manufacturing. The future design should aim for lighter, water-resistant composites with enhanced load-bearing capacity and detailing compatibility for civil-interior kitchen structures made from recyclable materials. According to the analysis by Veres and Tănase (2025), fibre-reinforced polymers recycled from their end-of-life products can achieve up to 93% of their initial tensile strength under pyrolytic conditions. This performance offers potential for application in load-bearing kitchen structures with high strength and endurance requirements for permanent service. Yet mechanical recycling decreases tensile strength by almost 29%, thereby reducing sustained structural performance in practice. Despite worldwide advancements, material heterogeneity and higher operational costs hamper the adoption of combined kitchen systems in civil interiors. Lack of standardised testing and lifecycle procedures limits accurate assessment, creating windows for the creation of efficient, cost-saving recycled composites explicitly designed for sustainable kitchen engineering and biophilic interior integration.

On the other hand, Van Stijn et al. (2020, November) identified four circular kitchen variants that combine bio-based, recycled, and modular materials, with long-lasting optimisation to enhance ecological performance. Based on Material Flow Analysis and Life Cycle Assessment, it formulated seven principles connecting component design to durability, reusability, and material capability. However, these principles are vital for the civil-interior systems that seek to harmonise structural integration and system functionality within the service conditions. Nevertheless, the study is lacking in quantifying load capacity, detailing joints, and assessing real-time durability under stresses encountered in kitchens.

6.2.2. Coordinating Structure for Harmonising Civil Engineering Services with Interior Design Systems

Zhou (2024) underscores the utmost need for integrated coordination among architectural design, civil engineering, and structural restoration to make cities more sustainable and system-efficient. Proper coordination ensures that mechanical, electrical, and plumbing services are available, robust, and harmonious with interior finishes, thereby ensuring long-term operational performance. The critique is that the study lacks precise policies and protocols to enhance coordination, resource management, and capability of the materials, which facilitates direct application to kitchen-scale frameworks. There is potential for future research to advance systematic integration policies that merge recycled composite designs, biophilic design strategies, and service routing codes to maximise civil-interior coordination. This line of action offers robust, sustainable, and human-oriented kitchen spaces with integrity to structures and the environment.

The article by Don et al. (2024, April) demonstrated that integrating landscape infrastructure with civil systems increases resistance to environmental hazards while accommodating social and cultural values in urban communities. Translating this to kitchen structures emphasises the need for synchronised planning between interior design and civil engineering services to ensure mechanical, electrical, and plumbing systems are easily accessible and durable under the stresses of use. Existing assessment is short on explicit details regarding spatial interface information, load management, and service sequencing for densely designed interiors and, therefore, is not directly applicable. Next-generation research would have to borrow regenerative and nature-based design approaches, merging water management concepts with recycled composite materials and biophilic design to create eco-resilient kitchens that harmonise structural performance, sustainability, and human-centred functionality.

6.2.3. Environmental and Lifecycle Assessment Guidelines for the Development of Recycled Kitchen Materials

In accordance with Shih et al. (2021), there are four kitchen waste management methods that can be applied, including “incineration, landfill, composting, and anaerobic digestion” by using a life cycle assessment with one metric

ton of waste as the basis. The results indicate anaerobic digestion delivers optimal environmental performance and allows flat electricity production, which is highly effective in central Taiwan’s farmland areas.

The results highlight the vital role of energy recovery in minimising embodied impacts and enhancing the lifecycle efficiency of all waste systems. Yet, the study does not provide a comprehensive assessment of material fixability and long-term recyclability potential in building use. Future research should modify these evaluation criteria for recycled composites in kitchen structures, establishing measurable environmental and durability standards for sustainable interior systems.

The research by Castorani et al. (2018) compared three kitchen air treatment systems —conventional, intelligent extractor, and intelligent filtering hoods with a supplementary aspiration unit — through a comprehensive comparative environmental analysis. However, the results show that intelligent systems reduce emissions and ecological footprints by maximising energy usage and minimising heat loss in operation. This shows how integrated intelligence in the kitchen components can maximise lifecycle efficiency and sustainability in building systems. However, the research leaves out consideration of recyclability, energy efficiency, and reparability for the resilient systems.

On the other hand, the article by Favi et al. (2018) highlighted that the comparison between induction and gas usage presents an attributional Life Cycle Assessment over a 20-year household use case in Italy. However, the research indicated that induction hobs are responsible for more than 60% of the impacts on climate change and ozone depletion, and more than 70% of the effects on metal depletion, primarily due to the consumption of rare metals. The production and use phases indicate high embodied energy and toxicity associated with non-renewable electricity use. Although applicable in sustainable kitchen design, the study does not emphasise material recyclability and reparability.

6.2.4. Developing Biophilic Aesthetic Strategies for Health, Sanitation, and Spatial Efficiency

As per the research by Khanzadeh, M. (2024), the research investigated the manner in which biophilic design principles enhance occupant health, productivity, and environmental engagement in 54 Turkish urban residential units. Natural features such as light, plants, water, and materials enhance comfort and psychological well-being and reinforce sustainable living. Biophilic aesthetics are found to be critical in incorporating wellness-oriented design in urban settings such as kitchens. Nevertheless, the research does not consider material hygiene or surface preparation, nor does it shed light on the functionalities of the areas. Future research needs to establish biophilic aesthetic approaches in eco-friendly kitchen interiors to improve the occupant well-being, cleanliness, and spatial balance, spurring industry uptake of eco-resilient interior paradigms.

Conversely, The author noted in the previous research that biophilic design reconnects people with the natural world through plants, water, sunlight, and natural finishes in architectural environments. The integration of sensory attributes enhances comfort, serenity, and efficiency, particularly in high-stress environments such as commercial kitchens. Moreover, the idea aligns with the design of health-oriented, ecoresilient kitchen interior systems that enhance user well-being and environmental harmony. However, it lacks emphasis on surface cleanliness, material strength, and proper demonstration of the dense kitchen appliance through biophilic design strategies.

6.2.5. Development of Operating Implementation Guidelines for Civil-Interior Teams and Project Management

The book by Davis and Fisher (2015) described how sustainable bath and kitchen design combines energy conservation, water saving, and material choice in line with industry standards. It focused on actionable approaches for civil and interior teams to collaborate on design coordination, procurement, and regulatory compliance to ensure effective project delivery. However, it does not include specific guidance on incorporating recycled composites or biophilic components in small, service-oriented rooms. Future research should develop integrated systems that align sustainability performance with accessible maintenance systems and robust, eco-focused kitchen design processes scalable across differing project sizes.

On the other hand, Hagejård et al. (2020) found that kitchen design significantly affects residential energy and water consumption, but typical plans often overlook sustainable resource management. Adequate storage, workspace design, and functional flexibility are critical to minimising waste and facilitating circular kitchen behaviour. The results show that effective implementation of circular approaches requires collaborative models that align civil and interior design professionals to provide flexible, eco-efficient solutions. Yet, the absence of formalised procurement models and regulatory support limits the widespread application of circular strategies. However, the research is helpful for further analysis of integrating sustainability measures into project delivery systems that incorporate recycled materials and biophilic design to achieve environmental well-being.

7. Methods

The research is based on insights suitable for collecting information resources through a secondary thematic synthesis that includes literature reviews from different authors' articles, websites, and online reports (Cheong et al. 2023). Alongside this, the research aims to interpret the data qualitatively through systematic thematic analysis. Thus, the research methodology focuses on the following sources, which primarily collect information from frontline personnel in civil engineering and interior design related to home decoration and sustainability. In this manner, the methodology is justified for demonstrating and evaluating

all segments and dimensions of the topic, thereby providing clearer insights.

7.1. Research Philosophy

The research philosophy aligns with paradigmatic realism, prioritising practical solutions, as evidenced by the secondary sources used in this research. Also, this position acknowledges that objective material performance is necessary, but accepts the need for an interpretivist philosophy and applies it in engineering practice (Walther et al. 2013). It also allows the integration of diverse types of evidence, combining quantitative lifecycle information with qualitative case findings to guide equitable practice recommendations. However, ethics demand open reporting, the citation of industry reports, and explicit delineation of limitations and applicability for civil interior projects.

7.2. Research Approach

For the objectives proposed in the study, a qualitative research method is used, aiming to explore the approach taken by eco-resilient kitchen frameworks with a civil engineering and interior design perspective (Taherdoost, 2022). A qualitative method is applicable in this study since it seeks to explain design approaches, applications of materials, and concept integration. Secondary data analysis helps in performing an analysis of known information in an effort to fill data gaps identified regarding recycled materials in biophilic kitchens. This is relevant in light of the research aims because it enables critical analysis of design frameworks in the context of practical sustainability conditions.

7.3. Data Collection

All data were gathered through peer-reviewed articles, speeches, and/or reports that concerned sustainable kitchens and built environments (Popowska & Sady, 2024). Criteria for inclusion focused on favouring recent literature, with clear methodologies and relevance to civilian interior integration. Literature with unclear methodologies was therefore not considered. The identified literature was coded to enable the analysis of themes within the qualitative studies to determine concepts, associations, and patterns. The thematic categories are developed iteratively to enhance consistency, analytical depth, and relevance to the concept of an eco-resilient kitchen proposed.

7.4. Ethical Considerations

- The paper relied only on secondary sources, making sure all information was public, thereby not involving any human subjects to address any ethical issues.
- All sources used have been cited for authenticity to avoid plagiarism or misrepresentation of original work by various authors.
- This approach to methodology design aimed to ensure a high degree of reproducibility, objectivity, and the fulfilment of ethics requirements, to enable a credible framework to be developed.
- No self-citation and no citations were manipulated, and the process assessed the relevancy and appropriateness of the cited sources.

8. Results And Discussion

8.1. Results

8.1.1. Theme 1: Structural Efficiency and Performance of Recycled Materials in Kitchen Applications

Recycling waste materials into new building products is a vital dynamic of sustainable construction. It plays a significant role in lower virgin resource consumption, minimising energy use, and reducing waste production. The recycled material used in kitchen appliances offers a notable environmental advantage, performing well and being used dynamically. The recycled material may also exceed the

structural efficiency of the virgin product in some applications, provided that factors such as intended use, binding agents, and processing are taken into account. An independent analysis emphasises that the use of recycled materials is essential for developing environmentally responsible building methods. The change demonstrates dedication to environmental leadership and marks a vital step toward creating an application that is more energy-efficient and ecologically friendly (Almusaed et al. 2024). It also drives broader adoption of the environmentally friendly process, putting it at the forefront of sustainable development.



Fig. 7 Categories of sustainable building materials

Source: Firoozi et al. 2024

Using recycled materials conserves natural resources and reduces the environmental impacts associated with disposal, extraction, and processing. It is used to calculate the percentage energy savings achieved by using recycled materials instead of virgin materials. From a performance and durability standpoint, recycled steel maintains the same structural integrity as virgin steel. It is used in demanding applications such as heavy infrastructure, where its ductility and strength are paramount. Use of recycled steel in the kitchen can also minimise environmental impact and lower material costs. However, recent technological developments have focused on improving the efficiency of the recycling process. For example, advanced sorting technology such as Near-Infrared (NIR) spectroscopy can enhance the accuracy of material separation and identification, thereby enabling the recovery of a “pure material stream” (Firoozi et al. 2024). These high-purity materials are critical for developing recycled products that meet stringent quality standards.

Disposal and treatment of kitchen waste involves resource recovery, landfilling, and incineration. The characteristics of kitchen waste vary with the season, requiring suitable disposal, adaptation, and treatment. Due to differences in the composition of kitchen waste, the application of conventional treatment processes makes it challenging to utilise organic components. The management of kitchen waste emphasises a few focuses on the influence of kitchen waste composting on “further use of the digestate” and “anaerobic digestion performances”. Recycled products like steel, glass, and plastics are widely used; however, kitchen hazardous waste remains a problem.

“Process optimisation”, “pre-treatments”, “dosing of additives”, and “co-digestion” are some of the effective measures that can alleviate inhibition of hazardous waste components in kitchen waste during anaerobic digestion (Meng et al. 2022). However, the efficiency of resource utilisation from kitchen waste is enhanced by optimising parameters and selecting a reliable configuration tailored to the regional characteristics of kitchen waste components.

8.1.2. Theme 2: Integration of Civil-Interior Engineering for System Accessibility and Resilience

The dynamic of engineering and art integration is constantly evolving. IQ of the architectural is not just a theory; it is a form of digitisation and modelling that becomes a common dynamic in everyday activities, in engineering, architecture, and art (Kapliński, 2022). The importance of a knowledge-based design is also growing systematically. Once restrained and modest, research in various areas of life is now interwoven with reality, grounded in the efficiency, creativity, and resourcefulness of human existence. It is also favoured and mandated by requirements for new design or by sustainable development paradigms. Integration of civil engineering can enhance collaboration among extended networks of other fields and sub-disciplines, such as environmental science, urban planning, and architecture. It includes the use of data-driven architectures and advanced technologies that further enhance performance and foster decision-making in an infrastructure system. The main and tacit knowledge of design needs to be more easily understood by interior architects and architects.

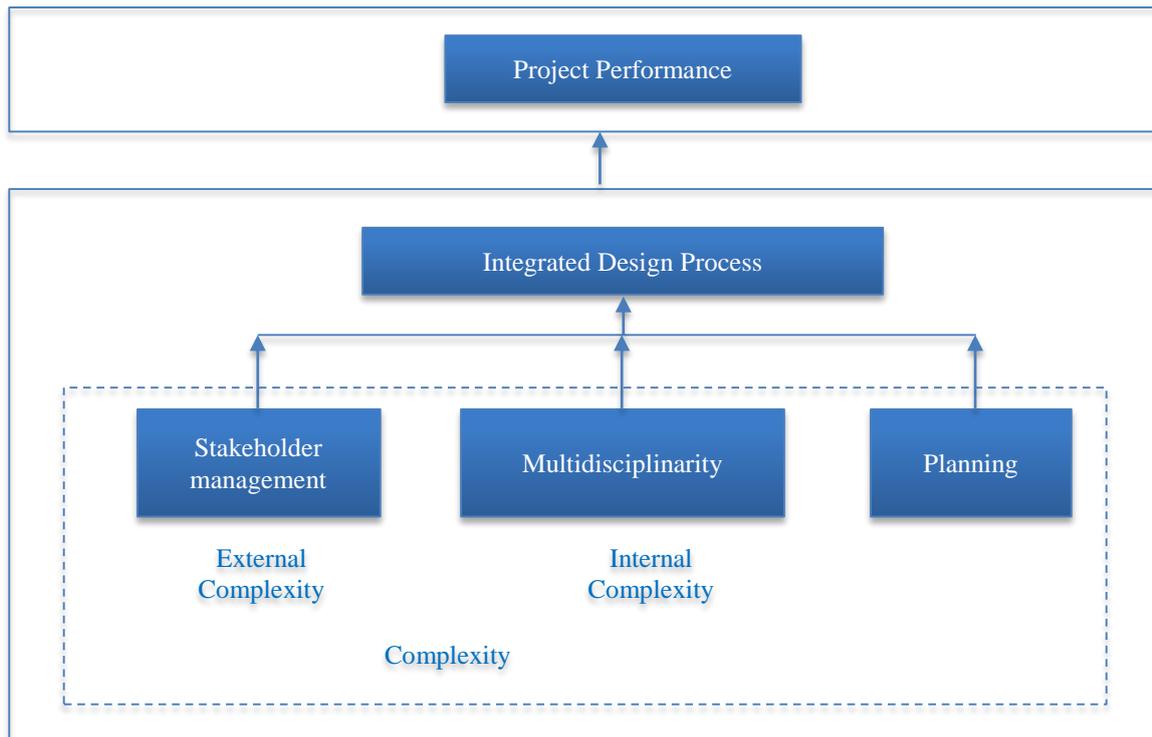


Fig. 8 Integrated design process with project performance

Source: Keusters et al. 2024

The integrated approach of the project performance is a design approach that integrates all disciplines and all parties' interests in a design solution in a beneficial and balanced dynamic for all. As mentioned by Keusters et al. (2024) and shown in Figure 7, complexity emerges as a main theme that can help decompose project performance into three components: "Stakeholder Management", "Multidisciplinary", and "Planning" —representing available time for integrated design. The civil-interior field is foundational infrastructure development that also supports modern society. However, recent urbanisation has accelerated the demand for civil engineering to deliver complex, resilient, and sustainable infrastructure. One of the main forces driving the need for civil engineering intervention is accelerated technological advancement. Adoption of innovative tools such as smart materials, "Building Information Modelling" (BIM), and "Geographic Information Systems" (GIS) transforms the way civil engineering is executed, designed, or planned for projects. These technologies can improve project management, enable more accurate simulation, and enhance visualisation, thereby increasing cost-effectiveness and efficiency. Additionally, amid rising concerns about sustainability and climate change, civil engineering integration has focused on promoting renewable energy, enhancing resilience to climate change, and reducing the environmental impacts of infrastructure projects. However, "Artificial Intelligence" (AI) is integrated in architectural design by adopting generative algorithms for designing through AI-powered "machine learning algorithms" and "virtual reality tools" (Almaz et al. 2024). These tools allow architects to optimise projects for structural integrity and energy efficiency, explore design options, and evaluate extensive data to make

informed design decisions. For example, tools like "AI-powered BIM" help designers visualise scenarios and receive feedback on energy efficiency, feasibility, and cost, saving time and resources while ensuring the final product meets high standards of sustainability and quality. The interior design, architectural education, and industry are undergoing radical change due to AI tools. Basic implicit architecture knowledge is projected to be deciphered by architects with the aid of AI, fostering a complete reconstruction of design.

8.1.3. Theme 3: Environmental and Lifecycle Evaluation of Recycled Materials

For analysing the Environmental and Lifecycle Evaluation of Recycled Materials, this theme selects some commonly used materials or substances within the kitchen context. As per Imtiaz et al. (2021), concrete is a widely used construction material. "Ordinary Portland Cement" (OPC) used in the production of concrete has a detrimental influence on the environment because of the release of a large amount of "greenhouse gas-like CO₂". As these studies confirm that "One ton of CO₂ is released by the production of one ton of OPC", and the other existing environmental issues are the dumping of construction and demolition wastes from kitchens or any other construction site. Imtiaz et al. (2021) collected data on concrete production through a questionnaire for the evaluation of the life cycle inventory flow of concrete and "Recycled Aggregate Geopolymer Concrete" (RAGC). A cut-off classification process is used; this approach is mainly based on the assumption that the primary producer of materials is allocated to the main customer and has no credit or influence on their recycled materials.

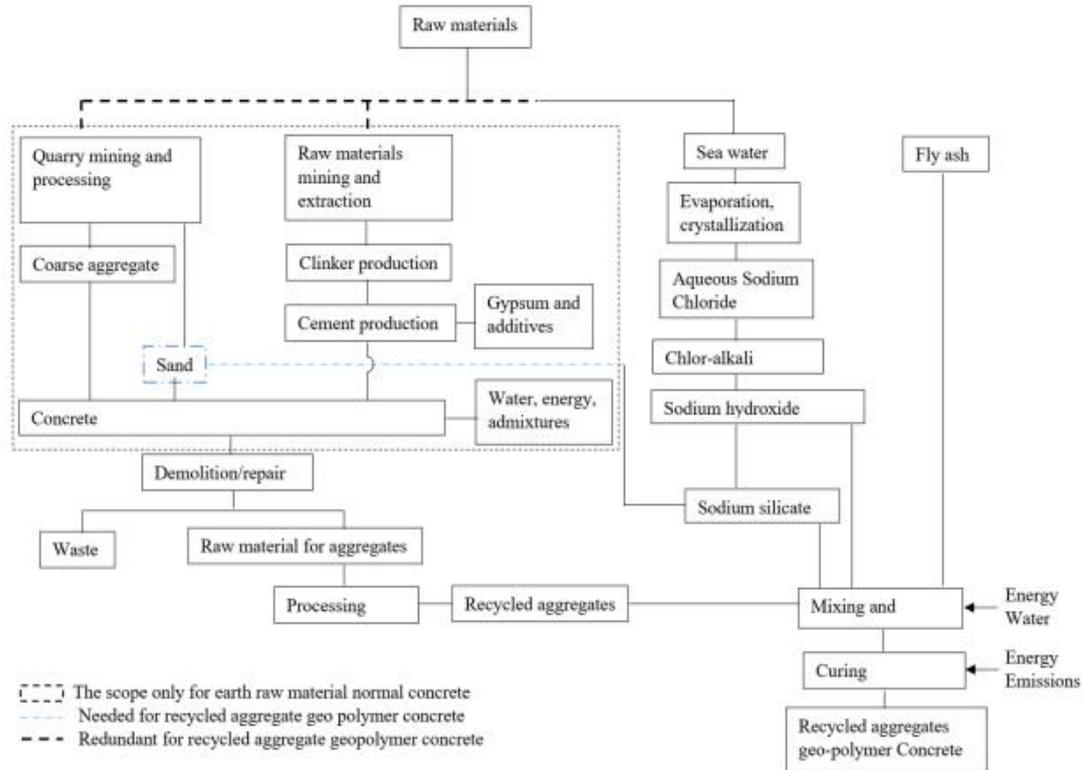


Fig. 9 Life cycle inventory flow of OPC concrete and RAGC

Source: Imtiaz et al. 2021

Plastic is also widely used in various kitchen settings. However, as mentioned by Saleem et al. (2023), the use of “recycled Polypropylene (PP) fibre” in the concrete-based application can reduce 99% of water utilisation and 93% of carbon emissions as compared to the steel wire mesh. A mixture of fly ash and recycled plastics can be used in concrete, reducing carbon emissions by 13%. Therefore, the “Life cycle assessment” of the end-of-life plastic waste emissions through different scenarios by Saleem et al. (2023), like incineration, use of construction, and virgin material replacement. The analysis of the environmental effects of plastic packaging recycling showed that recycling of “Polyethylene (PE)” and “Polyethylene Terephthalate (PET)” can save 30% and 40% of energy, respectively, and reduce carbon emissions. Recycling lightweight packaging using both chemical and mechanical methods is environmentally and economically preferable to mechanical recycling alone.

8.1.4. Theme 4: Biophilic and Hygienic Design Strategies for Kitchen Well-being

Transformation of residential spaces in therapeutic interior environments is accomplished through a combination of biophilic design and design that fosters self-care. Biophilic design can apply to any residential indoor spaces, such as the kitchen, dining room, etc. (Huntsman and Bulaj, 2022). The principles of biophilic design are mainly organised around three categories: “natural analogues”, “nature in the space”, and “nature of the space”. “Nature in the space” establishes a visual connection with nature, such as the use of vegetation (trees, plants, and flowers) inside and outside a residential space. “Nature of

the space” imitates natural processes, such as “circadian rhythms”, by analysing the spatial compositions and lighting patterns of nature, as in the development of a reading nook that offers a sense of safety and refuge. “Natural analogues”, textures, patterns, geometries, colours, materials, and shapes found in the natural world, as they offer an indirect sense of the outdoors (Huntsman and Bulaj, 2022). The principles used for biophilic design are “sustained and repeated engagement with nature” and focus “on human adaptations to the natural world that over evolutionary time have advanced people’s health, fitness and well-being.”

Biomimetic design serves as the foundation of regenerative building by blending with its natural surroundings, and biophilic design creates an environment that supports human growth, both physically and psychologically. Figure 9 illustrates different forms of sustainable architecture. Regenerative architecture and bio-inspired design are interdependent, so they are implemented together across three significant fields of design: “development engineering”, “additive manufacturing”, and “climate change adaptation and mitigation”. By using this four-part human-centred design thinking model, development engineers synthesise natural elements into designs for biophilic or biomimetic structures. Ensuring poor socioemotional well-being and environmental biological health. The Bio-inspired architecture also allows for adapting buildings to mitigate the ongoing climate crisis, which is directly driven by excessive greenhouse gas emissions, by assimilating and transferring knowledge from biology to ecology.

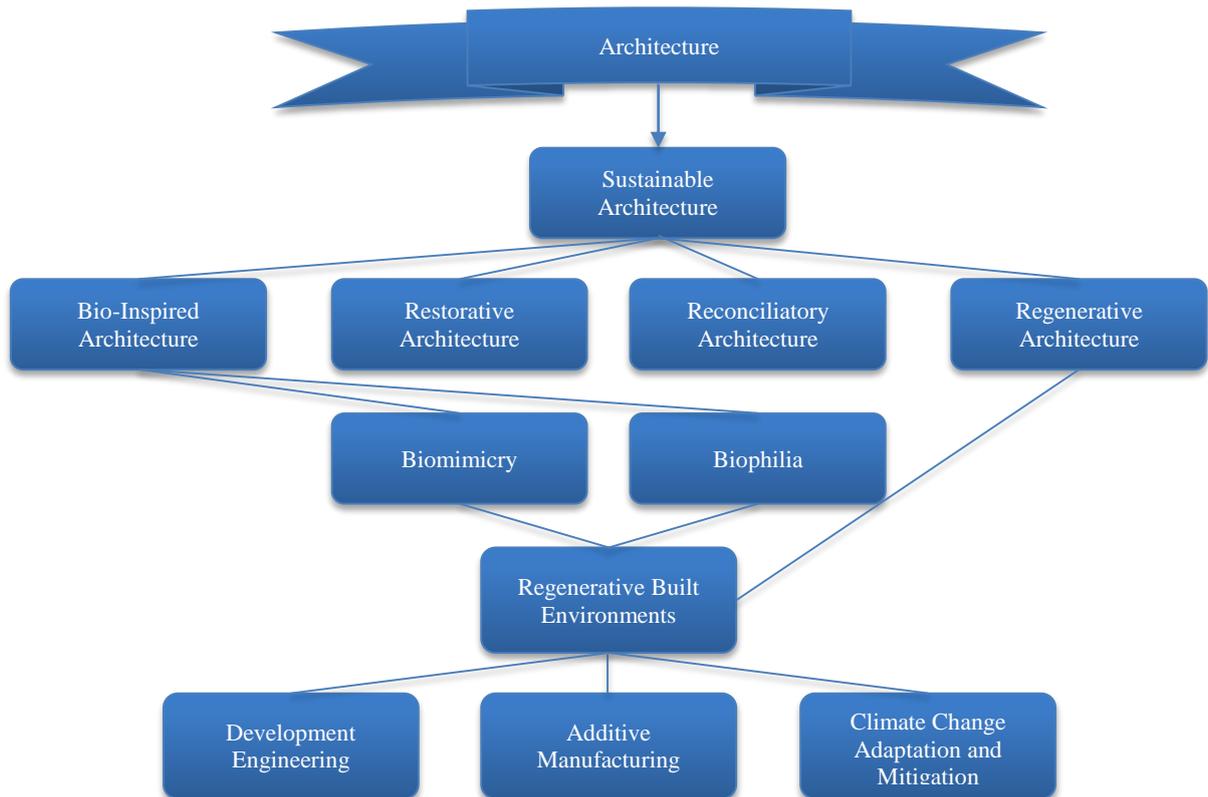


Fig. 10 Hierarchical organisation of the domains of sustainable architecture

Source: Arora and McIntyre, 2021

8.1.5. Theme 5: Guidelines for Sustainable Kitchen Design Collaboration

Design has inherent potential to affect consumer behaviour related to systems, products, and services. However, wider environmental influences on decisions during cooking extend beyond the kitchen, as they affect the performance of all downstream and upstream activities (Scherer et al. 2023). Choices made in the initial stages of the design process can influence 70 % of the environmental consequences associated with the final solution. The development of sustainable, innovative product solutions is

a crucial competence for creative professionals working in the field. This dynamic analysis examines the influence of user behaviour and how design inspires more sustainable behaviour in kitchen design collaboration. “Design for Sustainable Behaviour” (DfSB) seeks to reduce economic and socio-environmental impacts by shaping users’ interactions with products. This multidisciplinary field lies at the intersection of three domains: “Design”, “Sustainability”, and “Behavioural Psychology”, as shown in Figure 10.



Fig. 11 Design for sustainable behaviour

Source: Scherer et al. 2023

However, behind all this behaviour and kitchen design factors, it is also clear that the kitchen plays a primary role in everybody’s homes, with daily interactions. It is generally a place where traditions meet new technologies and where well-being and family health are nurtured. Kitchen design is multifunctional and serves a social purpose as well. It needs to be functional and comfortable, and to provide a better experience for the user by allowing individuals to share their lives and express their emotions. Research on the design of design focuses on the well-being and mental health of users (Xu et al. 2023). However, ergonomics, human physical

health, and the enhancement and optimisation of the user experience are driven by advances in technology.

9. Discussion

9.1. The Evaluation of Material Structure and Performance Metrics of the Recycled Composites in the Eco-Resilient Kitchen

Several materials can be used in eco-resilient kitchen appliances to manage waste reduction and cause less harm to the environment.

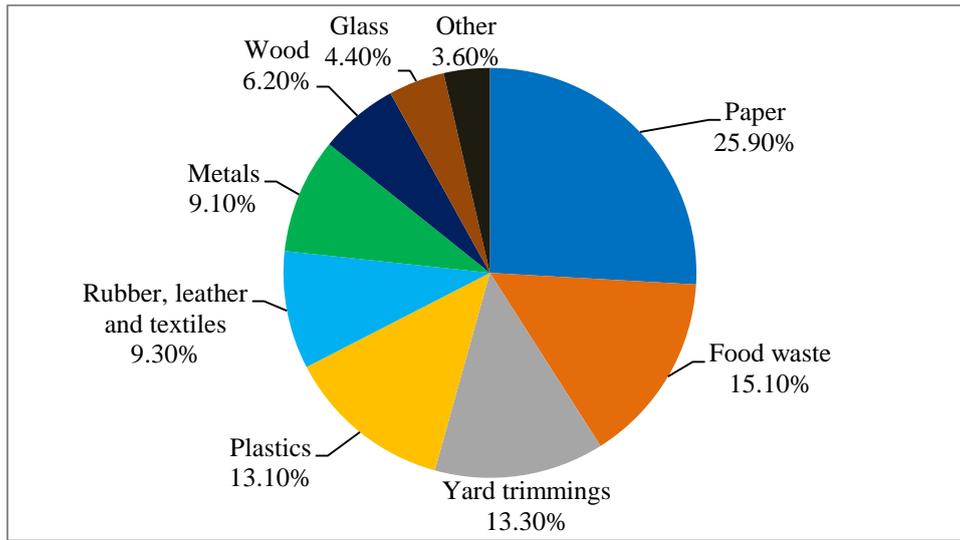


Fig. 12 The potential recycled materials per mass basis

Source: Ibrahim et al. 2023

Table 1. The potential recycled products and their usage in the eco-resilient kitchen

Material Type	Percentage (%)	Potential Use in Eco-Resilient Kitchen Frameworks
Paper	25.9%	Recycled paper-based composites for cabinets, packaging, and insulation materials.
Food waste	15.1%	Converted into bio-compost or biogas for kitchen energy systems or garden integration.
Yard trimmings	13.3%	Used for composting, biogas production, or as natural mulch for kitchen gardens.
Plastics	13.1%	Recycled into countertop materials, cabinet panels, or sustainable flooring tiles.
Rubber, leather, and textiles	9.3%	Repurposed into shock-absorbing mats, upholstery, or acoustic panels.
Metals	9.1%	Recycled into kitchen fixtures, cabinet handles, and structural supports.
Wood	6.2%	Reclaimed wood is used for countertops, cabinetry, or shelving.
Glass	4.4%	Recycled glass surfaces, backsplash tiles, or composite countertops.
Other	3.6%	Includes ceramics, electronics, or miscellaneous materials; potential for reuse in decorative or structural elements.

The table underscores the significant recycled, reusable, and restructured materials based on waste management, which can be used in making eco-resilient kitchen frameworks. The table also indicates that paper is the main waste at 25.9%, which can be used for kitchen

cabinets, insulation materials, and green food packaging (Ibrahim et al. 2023). On the other hand, food, plastics, wood, glass, metals, and yard trimmings are other potential recyclables that are wasted in the kitchen.

9.2. Coordination of the Professionals of Civil Engineering and Interior Designers in Meeting the Ultimate Outcomes

Table 2. The coordination of civil engineering and interior designing professionals in the eco-resilient kitchen frameworks

Stage	Civil Engineer's Role	Interior Designer's Role	Joint Approach	Example Data/Result
Planning and Structure	Make sure the structure can support recycled panels and modular kitchen units.	Choose lightweight recycled materials that fit the structure.	Safe and stable use of recycled materials.	Panels: 20–25 kg/m ² ; strong yet lightweight.
Choosing Materials	Approve eco-friendly materials like recycled concrete or bamboo.	Select attractive surfaces like reclaimed wood or recycled glass.	Balance strength with beauty and sustainability.	40% lower carbon footprint using recycled steel and glass.
Energy & Comfort Design	Plan for good insulation, daylight use, and energy-saving systems.	Add natural colours, plants, and textures to create a sense of comfort.	Combine energy efficiency with natural, relaxing design.	Natural light cuts electric use by about 30%.
Water & Waste Systems	Design composting and greywater reuse systems.	Fit these systems into kitchen cabinets or plant walls.	Manage waste and water sustainably.	Compost: 5 kg/day; reused water: 25–30 L/day.
Building & Installation	Oversee safe assembly and reduce construction waste.	Arrange layout for easy movement and aesthetic flow.	Easy-to-maintain and adaptable kitchen setup.	15–20% less waste than traditional builds.
Final Checks	Test structure, energy use, and recycled content.	Check indoor air quality, lighting, and comfort.	Verify the kitchen's environmental performance.	VOC levels <0.3 mg/m ³ ; recycled content ≥60%.

The table illustrates the collaborative process between civil and interior professionals in creating eco-resilient kitchen presentations. Also, the result of each combined approach is presented here. The combined contributions of

civil engineers and interior professionals can provide appropriate finishing, beauty polish, and strength to the construction, which will be sustainable and meet the urban lifestyle standard at the same time (Emmons et al. 2025).

9.2.1. Environmental and Recycled Assessment Guidelines for the Eco-Resilient Kitchen Usage

Impact comparison: landfill, incineration and recycling

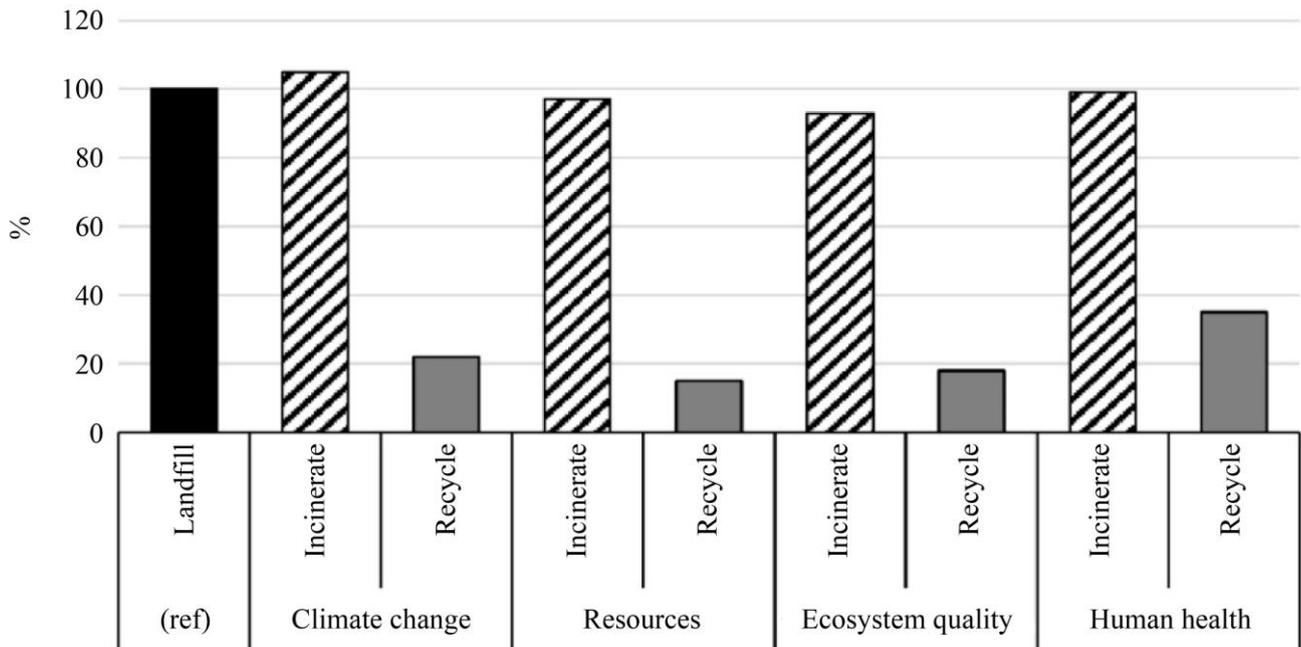


Fig. 13 The impact comparison of landfill disposal, incineration, and recycling, reproduced Source: Krauklis et al. 2021

The statistical data showed that landfill, recycling, incineration, and replacement approaches are significant steps toward preventing waste and promoting sustainability across all areas, including kitchen areas (Krauklis et al. 2021).

9.2.2. Easily Repairable and Recycled Materials

The eco-resilient kitchen should include materials that are easy to access after the recycling process and that protect food processing and preparation. Thermocomposites, thermoplastics, and biocomposites are functional, sustainable, yet modular kitchen materials.

9.2.3. Sustaining Energy and Environmental Costs

Mechanical cutting machines and grinding tools consume less energy than thermal methods (Wang et al. 2025). Therefore, the eco-resilient kitchen should include these tools to reduce energy consumption.

9.2.4. Maintaining Material Reuse and Recycling

Materials should be used in ways that remind users of their reusability while maintaining quality and performance. The reclaimed wood, recycled paper, glass, and ethically sourced bamboo are suitable materials that meet the purposes of the eco-resilient kitchen.

9.2.5. Biophilic Aesthetics for Helping in Maintaining Health, Hygiene, and Spatial Efficiency

Quantity of keyword occurrences in publications

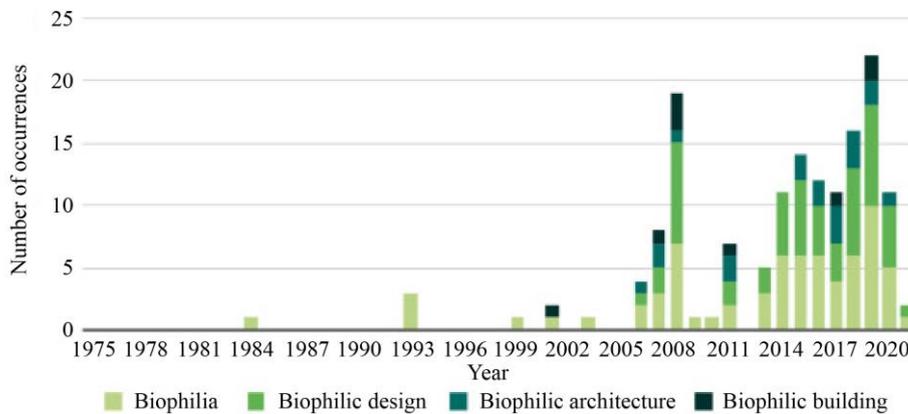


Fig. 14 The impact comparison of landfill disposal, incineration, and recycling, reproduced

Source: Zhong et al. 2022

The biophilia is the name of the process that connects the human being to nature after moving on to the artificial environment and leaves for survival. The statistical data demonstrated that the implementation of ‘biophilia’, ‘biophilic design’, ‘biophilic architecture’, and ‘biophilic building’ is increasing day by day as per the report till the

year 2020 (Zhong et al. 2022). It also mentioned that the research obtained its findings from three authentic databases, including Scopus, Web of Science, and Google Scholar, to get the appropriate algorithmic data for this dashboard.



Fig. 15 Sustainable green building factors

Source: Xiang et al. 2022

The figure reminds us of the operating factors to consider for both civil and interior professionals when proceeding with the eco-resilient kitchen.

9.2.6. Energy and Resource Efficiency in the Kitchen

The professionals should remind the effectiveness of the energy resources, such as solar, water, and wind-generated energy in the kitchen, which will be more efficient than the thermal and traditional methods.

9.2.7. The Environment of the Interior and Comfort

The civil and interior designers have to verify the comfort and the ambience of the interior, while integrating sustainable and recycled materials for designing the kitchen.

9.2.8. Integration of Artificial Intelligence and Automation

Professionals might have access to advanced tools for eco-resilient kitchen operations, such as automation systems, AI speakers, and other helpful tools, which could be more attractive to young people.

9.2.9. Managing Efficient Sustainable Operation

The professionals can use the efficient advanced tools for measuring the effectiveness, energy data, lifecycle of the recycled materials, forecasting data by “Building Information Modelling (BIM)” tools, which will ensure the longevity of the materials and performance quality (Abuhussain et al. 2024, February).

9.2.10. Justification of the Research-169

This study addressed all the problems obtained from this study, through a comprehensive and in-depth analysis of the peer-reviewed studies and combined strategies of recycled material approaches and biophilic design concepts in a kitchen design context, which are maintained separately in current studies. In the past studies, the performance of civil engineering or interior aesthetics was usually done in isolation, compared to the current study, which shows how they work together towards eco-resilient kitchen designs. Also, this framework offers enhanced results by combining the concepts of civil engineering and interior design instead of considering these fields as distinct entities. A qualitative synthesis has helped investigate overlapping design areas and inefficiencies in existing state-of-the-art methods, thereby improving conceptual understanding and interdisciplinary suitability. Advances are achieved through rigorous thematic comparison across studies, facilitating practical integration that balances material longevity, efficiency, and occupant well-being. The result can be of use to designers and planners as an instrument for making sustainable decisions when designing and planning a residential kitchen.

10. Conclusion

10.1. Conclusion of the Study

Sustainability concerns are increasing everywhere, including in buildings and their interiors. The study selected segments of interior design for eco-resilient kitchens that require core sustainability, maintenance of performance,

adherence to urban life standards, and consideration of the material lifecycles of reused composite materials. However, the research holistically analyses, interprets, and evaluates all dimensions of the topic, enabling the researcher to derive core knowledge. Alongside this, it is one of the sectors being focused on by authorities such as global health organisations, governments from various countries, building contractors, and users to integrate a green approach in buildings, kitchens, and, especially, food processing areas. However, the researchers incorporated a well-defined, well-designed structure to illustrate the factors required to achieve the research objectives. From the beginning, the study provided detailed demonstrations of the topic, set the research purpose and objectives, discussed its importance and impacts on the environment, and supported these claims with statistical data. After that, it included a substantial section with several literature analyses by different researchers on particular topics that address the research objectives. Also, the methodology highlighted the data collection process to analyse the structure and patterns that were essential and appropriate for this chosen topic. Moreover, the result and discussion sections outlined the research’s ultimate findings and analyses, with real-time and algorithmic presentations.

10.2. Recommendations

10.2.1. Encouraging in Life Cycle Assessment Approach

Professionals might adopt lifecycle evaluation tools to reduce environmental harm and maintain the performance quality of kitchen composite materials (Ead et al. 2021). This measure would help professionals choose materials by investigating their durability, lifecycles, performance, quality, and effectiveness in the green kitchen.

10.2.2. Increasing Urban Standards

Civil and interior professionals should focus on developing innovative yet smart, eco-resilient kitchen measures that meet the urban standards of the current era. Alongside this, it is necessary to outline proper procedures for recycling, repairing, and renewing energy use to prepare an ideal eco-resilient kitchen appliance.

10.2.3. Developing Collaboration and Performance Discipline

The collaborative environment among the civil engineers, interior designers, and supplier management teams can facilitate a comprehensive final outcome (McGee and Park, 2022). Also, joint training and workshop programs for the output can help them integrate and understand the integrity of the different segments, including electronics, plumbing, mechanical, and technical factors, to achieve an ideal eco-resilient kitchen.

10.2.4. Reminding the Biophilic Principles

In the kitchen interior, designers can use biophilic elements such as greenery, sustainable lighting, organic textures, and colours (Elforgani et al., 2024). This will allow users to have pure air, comfort, and mental freshness and well-being, in addition to health and hygiene.

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