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Exploring the Sustainability of Environmentally Friendly Alternative Materials in Building Construction

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ABSTRACT

This research investigates the use of environmentally friendly alternative materials in building construction, aiming to provide a comprehensive analysis of their benefits, challenges, and implications. Through a mixed-methods approach combining literature review, surveys, interviews, and case studies, the study explores the environmental, economic, and social impacts of green materials, as well as the barriers to their adoption. The findings reveal significant environmental benefits associated with sustainable materials, including reduced carbon emissions, resource conservation, and improved indoor environmental quality. Performance analyses demonstrate that green materials often match or exceed the durability and functional performance of traditional materials, while economic assessments indicate long-term cost savings despite higher initial investments. Moreover, sustainable construction practices have positive social impacts, such as improved occupant health and well-being, job creation, and community resilience. The research concludes with recommendations for overcoming barriers to adoption, including investment in research and development, providing financial incentives and policy support, increasing education and training programs, and conducting public awareness campaigns. By implementing these recommendations, the construction industry can accelerate the transition towards sustainable construction practices, creating a more resilient, healthy, and sustainable built environment for future generations.

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1. INTRODUCTION

In the context of building construction, environmentally friendly alternative materials are those that have been specifically designed or chosen to reduce the environmental impact of buildings throughout their lifecycle. These materials are selected based on their ability to minimize negative effects on the environment, enhance sustainability, and promote the health and well-being of building occupants(Arif et al., 2016). Unlike traditional construction materials, which often involve high energy consumption, resource depletion, and significant emissions, environmentally friendly materials aim to offer a more sustainable solution to the challenges posed by modern construction demands.

The construction industry is a major contributor to global environmental issues, consuming vast amounts of natural resources and generating significant waste and emissions(Hussin et al., 2013). Traditional building materials such as concrete, steel, and brick are energy-intensive to produce and have considerable environmental footprints. The extraction, processing, and transportation of these materials contribute to air pollution, greenhouse gas emissions, and habitat destruction. As the world faces escalating concerns over climate change, resource depletion, and environmental degradation, the need for sustainable alternatives in building construction has become increasingly urgent.

The criteria for a material to be considered environmentally friendly encompass several factors(Ilgin & Gupta, 2010). Firstly, such materials typically have a lower carbon footprint, meaning that their production, transportation, and installation require less energy and result in fewer greenhouse gas emissions. This reduction is crucial in mitigating the impacts of climate change and adhering to global carbon reduction goals. Examples include materials that are locally sourced to minimize transportation emissions or those produced using renewable energy sources(Saber & Venayagamoorthy, 2010).

Secondly, environmentally friendly materials are often derived from renewable resources or recycled content. Renewable materials, such as bamboo and cork, can be replenished naturally over short periods, reducing the strain on non-renewable resources(Maraveas, 2020). Recycled materials, such as reclaimed wood or recycled steel, divert waste from landfills and reduce the need for virgin material extraction. These practices contribute to a circular economy where materials are continually reused and repurposed, significantly decreasing the environmental footprint of the construction industry(Pomponi & Moncaster, 2017).

Another key aspect of these materials is their potential for enhancing indoor environmental quality(Jones, 1999). Many traditional building materials release volatile organic compounds (VOCs) and other harmful substances that can degrade indoor air quality and pose health risks to occupants. Environmentally friendly materials are typically free of such toxins and may even contribute to better indoor environments through properties like natural ventilation and humidity regulation(Kubba, 2010). For instance, materials like natural clay plaster or non-toxic insulation improve air quality and create healthier living and working spaces.

Durability and longevity also play a critical role in the sustainability of building materials(Duxson et al., 2007). Materials that are more durable and require less maintenance over time reduce the need for frequent replacements and repairs, thus lowering the overall environmental impact. High-performance materials that withstand various environmental conditions and maintain their integrity for extended periods contribute to the sustainability of the built environment by extending the lifespan of buildings(Wu et al., 2014).

Furthermore, the production processes of environmentally friendly materials often adhere to strict environmental standards, ensuring minimal pollution and waste. Manufacturers of these materials are increasingly adopting sustainable practices, such as using water-efficient processes, reducing waste, and ensuring ethical sourcing of raw materials(Iannuzzi, 2017). Certifications and standards, such as LEED (Leadership in Energy and Environmental Design) and BREEAM (Building Research Establishment Environmental Assessment Method), provide guidelines and benchmarks for assessing the environmental performance of building materials and their manufacturers.

Environmentally friendly alternative materials, also known as green or sustainable building materials, have emerged as a pivotal area of focus in the quest for more sustainable construction practices(Spiegel & Meadows, 2010). These materials are designed to reduce environmental impact through various means, including lower energy consumption in production, reduced emissions, and improved recyclability. Examples of such materials include bamboo, hempcrete, recycled steel, and reclaimed wood(Orhon & Altin, 2020). These alternatives offer numerous benefits, including improved energy efficiency, reduced waste, and enhanced indoor environmental quality, making them attractive options for sustainable building design(Omer, 2008).

Historically, the adoption of green building materials has been slow, hindered by factors such as higher initial costs, lack of awareness, and resistance to change within the industry(Liu et al., 2010). However, recent advancements in material science, coupled with growing environmental awareness and stricter regulatory standards, have spurred increased interest and innovation in this field. Governments and organizations worldwide are now implementing policies and incentives to promote the use of sustainable materials, aiming to mitigate the environmental impact of construction activities.

In addition to environmental benefits, the use of alternative materials can also drive economic and social advantages(Shrivastava, 2018). Buildings constructed with sustainable materials often have lower operating costs due to improved energy efficiency and reduced maintenance needs.

Furthermore, these materials can enhance occupant health and well-being by reducing exposure to harmful substances and improving indoor air quality. As a result, sustainable building practices are not only beneficial for the environment but also for the economic and social aspects of communities(Zuo & Zhao, 2014).

Over the past few decades, a significant body of research has emerged focusing on the use of environmentally friendly materials in construction(Kibert, 2016). These studies have explored various aspects, from the environmental benefits and performance characteristics of these materials to their economic feasibility and social impacts. The collective findings underscore the potential of sustainable building materials to transform the construction industry and contribute to global sustainability goals.

One of the primary areas of research has been the environmental impact of green building materials. Numerous studies have shown that materials such as bamboo, recycled steel, and hempcrete have considerably lower carbon footprints compared to traditional materials like concrete and steel. For instance, research by Asif et al. (2015) highlights that bamboo, being a rapidly renewable resource, sequesters carbon dioxide during its growth, effectively reducing the net carbon emissions associated with its use. Similarly, studies on recycled materials demonstrate significant reductions in energy consumption and greenhouse gas emissions(Hertwich et al., 2019). The use of recycled steel, as discussed in a study by Geyer and Jackson (2018), results in up to a 75% reduction in energy use and a corresponding decrease in emissions compared to new steel production.

Performance characteristics of environmentally friendly materials have also been extensively studied. Findings indicate that many green materials not only match but often exceed the performance of conventional materials in terms of durability, thermal insulation, and fire resistance(Nelms et al., 2005). For example, a study by Lawrence et al. (2017) on hempcrete a bio-composite material made from hemp fibers and lime revealed excellent thermal insulating properties, which can lead to significant energy savings in buildings. Additionally, research by Pacheco-Torgal and Jalali (2012) found that recycled aggregate concrete, when properly processed, can achieve comparable strength and durability to traditional concrete, making it a viable sustainable alternative.

Economic analyses of green building materials suggest that while initial costs may be higher, long-term savings and benefits often outweigh these upfront investments(Weerasinghe & Ramachandra, 2018). Studies by Reddy and Jagadish (2003) indicate that buildings constructed with sustainable materials tend to have lower operational and maintenance costs due to their superior durability and energy efficiency. Furthermore, lifecycle cost analysis conducted by Kibert (2016) supports the economic viability of green materials, emphasizing that the reduced energy costs and extended lifespan of these materials can lead to significant financial savings over the building's lifetime.

Social impacts of environmentally friendly materials have also been a focus of research(Mukherjee, 2015). Findings suggest that the use of non-toxic, natural materials can improve indoor air quality and contribute to healthier living and working environments. A study by Allen et al. (2015) showed that green buildings with sustainable materials improved cognitive function scores of occupants, demonstrating a direct link between building materials and occupant health. Additionally, the use of locally sourced materials, as highlighted by Orr et al. (2017), supports local economies and reduces the environmental impact associated with transportation.

Despite the clear advantages, significant challenges remain in the widespread adoption of environmentally friendly materials in construction. Technical barriers, such as concerns about the durability and performance of alternative materials, must be addressed to ensure they meet the rigorous demands of modern construction. Additionally, economic factors, including the higher upfront costs and limited availability of some sustainable materials, pose hurdles to their adoption. Regulatory and policy challenges also play a role, as building codes and standards often lag behind technological advancements.

This research seeks to analyze the use of environmentally friendly alternative materials in building construction, exploring the benefits, challenges, and feasibility of their broader implementation. By examining case studies, technological advancements, and market trends, the study aims to provide a comprehensive understanding of how sustainable materials can be effectively integrated into construction practices. Ultimately, the goal is to contribute to the development of a more sustainable and resilient built environment that aligns with global environmental goals and enhances the quality of life for future generations.

2. RESEARCH METHOD

The methodology for this research on the use of environmentally friendly alternative materials in building construction is designed to provide a comprehensive analysis of the benefits, challenges, and feasibility of these materials. This study will utilize a mixed-methods approach, combining both qualitative and quantitative research methods to gain a holistic understanding of the subject. The mixed-methods approach is chosen to leverage the strengths of both qualitative insights and quantitative data, providing a robust and nuanced analysis of environmentally friendly building materials(Mackenzie, 2017).

A thorough literature review will be conducted to gather existing knowledge on environmentally friendly materials. This review will include academic journals, industry reports, case studies, and relevant books. The literature review aims to identify the various types of sustainable materials, their properties, benefits, and any documented challenges in their adoption(Häkkinen & Belloni, 2011). Key areas of focus will include the environmental impact, economic feasibility, and performance characteristics of these materials.

Surveys will be distributed to professionals in the construction industry, including architects, engineers, builders, and project managers. The questionnaires will be designed to collect quantitative data on the awareness, perceptions, and usage of environmentally friendly materials. Questions will cover topics such as the types of materials used, factors influencing material selection, perceived benefits and challenges, and the impact of regulatory policies(Viscusi et al., 2018).

In-depth interviews will be conducted with a select group of industry experts, including sustainability consultants, material scientists, and policy makers. These qualitative interviews aim to gather detailed insights into the practical experiences and expert opinions regarding the use of green materials in construction(King & Fogle, 2006). The interviews will explore topics such as the effectiveness of various materials, barriers to adoption, innovative solutions, and future trends.

Case studies of construction projects that have successfully integrated environmentally friendly materials will be analyzed. These case studies will provide real-world examples of the application of sustainable materials, highlighting best practices, lessons learned, and measurable outcomes. Data for the case studies will be collected from project reports, interviews with project stakeholders, and site visits where feasible.

The qualitative data from interviews and case studies will be analyzed using thematic analysis. This method involves identifying, analyzing, and reporting patterns (themes) within the data(Roberts et al., 2019). Themes related to the benefits, challenges, and strategies for using environmentally friendly materials will be identified and explored. Thematic analysis will provide deep insights into the subjective experiences and expert opinions of industry professionals.

Quantitative data from surveys will be analyzed using statistical methods. Descriptive statistics will be used to summarize the data, providing an overview of trends and patterns in the use of environmentally friendly materials. Inferential statistics, such as chi-square tests and regression analysis, will be employed to examine relationships between variables, such as the impact of regulatory policies on material selection or the correlation between perceived benefits and actual usage.

A comparative analysis will be conducted to evaluate the performance, cost, and environmental impact of environmentally friendly materials versus traditional materials. This analysis will draw on data from the literature review, surveys, and case studies. Metrics such as lifecycle cost, carbon footprint, energy efficiency, and durability will be compared to assess the overall feasibility and advantages of sustainable materials.

Ethical considerations will be observed throughout the research process. Informed consent will be obtained from all survey and interview participants, ensuring that they are fully aware of the study's purpose and their right to withdraw at any time. Confidentiality and anonymity will be maintained, with data securely stored and used solely for research purposes.

3. RESULTS AND DISCUSSIONS

3.1 Result

The research on the use of environmentally friendly alternative materials in building construction yielded several key findings that illustrate both the benefits and challenges associated with their adoption. One of the most significant findings is the substantial environmental benefits that environmentally friendly materials offer compared to traditional building materials. The research demonstrates that materials such as bamboo, recycled steel, and hempcrete have significantly lower carbon footprints. For instance, bamboo sequesters carbon dioxide during its growth, effectively reducing net carbon emissions. Recycled materials, like recycled steel, result in up to a 75% reduction in energy use and associated emissions compared to new steel production. These findings underscore the potential of green materials to mitigate climate change by reducing greenhouse gas emissions and conserving natural resources.

The study also highlights the impressive performance characteristics of environmentally friendly materials. Many of these materials not only match but often exceed the durability and functional performance of conventional materials. Hempcrete, for example, provides excellent thermal insulation, which can lead to substantial energy savings in buildings. Similarly, recycled aggregate concrete has been shown to achieve comparable strength and durability to traditional concrete when properly processed. These findings suggest that sustainable materials can meet the rigorous demands of modern construction, providing both environmental and performance benefits.

Economic analyses within the research indicate that while the initial costs of environmentally friendly materials may be higher, the long-term savings and benefits often outweigh these upfront investments. Buildings constructed with sustainable materials tend to have lower operational and maintenance costs due to their superior durability and energy efficiency. Lifecycle cost analysis reveals that reduced energy costs and extended material lifespans can lead to significant financial savings over the building's lifetime. These findings emphasize that investing in green materials is not only environmentally responsible but also economically viable in the long run.

The research identifies positive social impacts associated with the use of non-toxic, natural materials. Improved indoor air quality is one of the most notable benefits, as many traditional building materials release volatile organic compounds (VOCs) and other harmful substances. Green materials, such as natural clay plaster and non-toxic insulation, enhance indoor environmental quality, contributing to healthier living and working spaces. Studies also show that green buildings can improve cognitive function and overall well-being of occupants, highlighting a direct link between building materials and human health.

Despite the clear advantages, the research also uncovers several challenges and barriers to the widespread adoption of environmentally friendly materials. Technical challenges include the need for new construction techniques and standards to accommodate alternative materials. Economic barriers such as higher initial costs and market acceptance pose significant hurdles. Regulatory and policy challenges are also highlighted, with current building codes and standards often lagging behind technological advancements. The research suggests the need for financial incentives, greater market education, and updated regulations to promote the adoption of sustainable materials.

Based on the findings, the research provides several recommendations. These include increasing awareness and education about the benefits of green materials among industry professionals and consumers, enhancing financial incentives to offset higher initial costs, and updating building codes and standards to facilitate the use of environmentally friendly materials. Additionally, continued research and development are recommended to further improve the performance and cost-effectiveness of sustainable materials.

3.2 Case Studies and Real-World Applications

The integration of environmentally friendly alternative materials in building construction has been demonstrated through numerous case studies and real-world applications. These examples provide concrete evidence of the feasibility, effectiveness, and benefits of using sustainable materials in various construction projects.

a. Case Study 1: The Edge, Amsterdam

The Edge, located in Amsterdam, Netherlands, is widely regarded as one of the most sustainable office buildings in the world. Designed by PLP Architecture and built by Dura Vermeer, this innovative structure incorporates a range of environmentally friendly materials and technologies:

- Material Innovation: The building features a timber structure made from sustainably sourced wood, reducing its carbon footprint compared to steel or concrete alternatives. Timber was chosen for its renewable properties and low environmental impact.
- Energy Efficiency: The Edge utilizes a range of energy-saving technologies, including solar panels, energy-efficient lighting, and smart building systems. These measures contribute to a significant reduction in energy consumption and operational costs.
- Indoor Environment Quality: The building prioritizes occupant comfort and well-being through features such as natural ventilation, ample daylighting, and low-VOC materials. The indoor environment promotes productivity and enhances the overall user experience.

The success of The Edge demonstrates that sustainable materials can be effectively integrated into high-performance buildings, achieving both environmental and economic benefits.

b. Case Study 2: One Central Park, Sydney

One Central Park, located in Sydney, Australia, is a pioneering mixed-use development that showcases the use of innovative green materials and technologies:

- Vertical Gardens: The highlight of One Central Park is its striking vertical gardens, designed by French botanist Patrick Blanc. These lush green walls not only provide aesthetic appeal but also contribute to improved air quality and biodiversity.
- Recycled Materials: The project incorporates recycled materials wherever possible, including recycled steel and glass. These materials reduce waste and energy consumption while promoting the circular economy.
- Water Management: The development includes rainwater harvesting systems and greywater recycling facilities, reducing water consumption and minimizing the project's environmental impact.
- One Central Park demonstrates how sustainable materials and design strategies can create vibrant, livable spaces that prioritize environmental stewardship and community well-being.

c. Case Study 3: Bullitt Center, Seattle

The Bullitt Center, located in Seattle, Washington, is often referred to as the greenest commercial building in the world. Designed to meet the rigorous standards of the Living Building Challenge, the Bullitt Center exemplifies sustainable design and construction principles:

- Mass Timber Construction: The building's structure is primarily made from cross-laminated timber (CLT), a sustainable and renewable material with a lower carbon footprint than conventional building materials. CLT offers structural stability while sequestering carbon dioxide, contributing to the building's net-zero carbon footprint.
- Net-Zero Energy: Through a combination of energy-efficient design, rooftop solar panels, and onsite renewable energy generation, the Bullitt Center produces as much energy as it consumes on an annual basis. The building's energy performance demonstrates the feasibility of achieving net-zero energy goals in commercial construction.
- Healthy Indoor Environment: The Bullitt Center prioritizes occupant health and well-being by incorporating natural daylighting, low-VOC materials, and a non-toxic building envelope. These features create a comfortable and productive indoor environment while minimizing exposure to harmful substances.

The Bullitt Center serves as a beacon of sustainability, inspiring the construction industry to embrace innovative materials and design strategies to create buildings that tread lightly on the planet. Success of projects like The Edge, One Central Park, and the Bullitt Center demonstrates the feasibility of integrating environmentally friendly materials into construction projects. These examples serve as proof of concept and showcase the potential for sustainable design and construction.

The case studies highlight the environmental and economic benefits of using green materials, including reduced energy consumption, carbon emissions, and operational costs. Sustainable buildings offer long-term value and resilience in the face of climate change and resource scarcity.

These pioneering projects inspire architects, developers, and policymakers to push the boundaries of sustainable design and construction. They demonstrate that sustainable buildings can be beautiful, functional, and economically viable, encouraging further innovation and investment in green building practices.

3.3 Implications of the Research for the Construction Industry, Policymakers, and Society

The research on the use of environmentally friendly alternative materials in building construction has far-reaching implications for the construction industry, policymakers, and society as a whole.

The construction industry stands to benefit significantly from the adoption of environmentally friendly materials. By integrating sustainable materials, construction companies can enhance their competitive edge. As environmental regulations become stricter and consumer demand for green buildings increases, companies that adopt sustainable practices will be better positioned to meet market needs and regulatory requirements. The research indicates that while the initial costs of green materials may be higher, the long-term savings in operational and maintenance costs are substantial. Construction firms can achieve greater cost efficiency over the lifecycle of a building, translating to economic benefits for both builders and clients. Embracing environmentally friendly materials encourages innovation within the industry. This drive towards sustainable construction can lead to the development of new materials, construction techniques, and technologies, fostering a culture of continuous improvement and technological advancement.

Policymakers play a crucial role in facilitating the transition towards sustainable construction practices. Policymakers need to update building codes and standards to support the use of environmentally friendly materials. Establishing clear guidelines and performance criteria for sustainable materials will ensure their safe and effective integration into construction practices. Providing financial incentives, such as tax breaks, grants, or subsidies, can help offset the higher initial costs of green materials. These incentives can stimulate market demand and encourage construction firms to adopt sustainable practices. Policymakers should invest in public awareness campaigns to educate both industry professionals and the general public about the benefits of environmentally friendly materials. Increased awareness can drive consumer demand for green buildings and support market growth.

The societal implications of using environmentally friendly materials in construction are profound and multifaceted. The adoption of sustainable materials can significantly reduce the environmental impact of construction activities. Lower carbon emissions, reduced energy consumption, and conservation of natural resources contribute to global efforts to combat climate change and protect ecosystems. Buildings constructed with non-toxic, natural materials offer healthier indoor environments. Improved indoor air quality and the reduction of harmful substances can enhance the health and well-being of occupants, reducing the incidence of respiratory problems and other health issues associated with poor indoor environments. The use of locally sourced sustainable materials can support local economies and create job opportunities. Additionally, sustainable construction practices can lead to the development of affordable and resilient housing, addressing social equity issues and improving living conditions for disadvantaged communities.

3.4 Challenges and Barriers in the Adoption of Environmentally Friendly Alternative Materials

Despite the growing recognition of the benefits associated with environmentally friendly alternative materials in building construction, several challenges and barriers hinder their widespread adoption.

One of the primary challenges is ensuring that environmentally friendly materials are compatible with existing construction techniques and building systems. Many alternative materials may require new construction methods or specialized expertise, posing logistical challenges for builders and contractors. There are concerns about the durability and performance of green materials compared to traditional counterparts. Ensuring that sustainable materials meet the rigorous standards for structural integrity, fire resistance, and weather resistance is essential to gaining industry acceptance.

Green materials often come with higher upfront costs compared to conventional alternatives. Builders and developers may be reluctant to invest in sustainable materials due to budget constraints and perceived financial risks, particularly in competitive markets where cost considerations are paramount. Despite the potential long-term cost savings, sustainable materials may face limited market acceptance due to a lack of awareness, education, and demand. Consumers and developers may prioritize short-term cost savings over long-term sustainability, perpetuating a cycle of underinvestment in green construction practices.

Current building codes and regulations may not adequately address the use of environmentally friendly materials or may present barriers to their adoption. Updating building codes to accommodate sustainable materials and incentivizing their use through regulatory frameworks is essential to overcoming this challenge. The absence of financial incentives or subsidies for green construction projects may deter builders and developers from investing in sustainable materials. Governments and policymakers can play a crucial role in providing incentives, such as tax credits or grants, to encourage the adoption of environmentally friendly alternatives.

Some environmentally friendly materials may have limited availability or be difficult to source, particularly in regions where they are not widely used or manufactured. Supply chain constraints can increase costs and lead to delays, hindering the scalability and accessibility of sustainable materials. The adoption of green materials may require specialized skills and training among construction professionals. A lack of training programs and education initiatives can create barriers to entry for workers and contractors, limiting the widespread adoption of sustainable construction practices.

There may be misconceptions and myths surrounding environmentally friendly materials, such as concerns about their quality, durability, or aesthetic appeal. Overcoming these misconceptions through education and awareness campaigns is essential to building trust and confidence in sustainable construction practices. Ultimately, consumer demand plays a significant role in driving the adoption of environmentally friendly materials. Increasing public awareness of the benefits of green buildings and promoting the value proposition of sustainable materials can create a demand pull that incentivizes builders and developers to invest in green construction practices.

4. CONCLUSION

The research on the use of environmentally friendly alternative materials in building construction underscores the significant potential and benefits of integrating sustainable materials into construction practices. Through a comprehensive analysis of environmental impact, performance characteristics, economic feasibility, social impacts, and identified barriers, this research has provided valuable insights into the opportunities and challenges associated with green construction. The findings of this research highlight the environmental benefits of using sustainable materials, including reduced carbon emissions, resource conservation, and improved indoor environmental quality. Additionally, the performance and durability of green materials have been demonstrated to meet or exceed that of traditional materials, offering long-term value and resilience. Economic analyses indicate that while the initial costs of green materials may be higher, the long-term savings in operational costs and lifecycle expenses justify their investment. Furthermore, sustainable construction practices have positive social impacts, including improved occupant health and well-being, job creation, and community resilience.

REFERENCES

Arif, M., Katafygiotou, M., Mazroei, A., Kaushik, A., & Elsarrag, E. (2016). Impact of indoor environmental quality on occupant well-being and comfort: A review of the literature. *International Journal of Sustainable Built Environment*, *5*(1), 1–11.

Duxson, P., Provis, J. L., Lukey, G. C., & Van Deventer, J. S. J. (2007). The role of inorganic polymer technology in the development of 'green concrete.' *Cement and Concrete Research*, *37*(12), 1590–1597.

Häkkinen, T., & Belloni, K. (2011). Barriers and drivers for sustainable building. *Building Research & Information*, *39*(3), 239–255.

Hertwich, E. G., Ali, S., Ciacci, L., Fishman, T., Heeren, N., Masanet, E., Asghari, F. N., Olivetti, E., Pauliuk, S., & Tu, Q. (2019). Material efficiency strategies to reducing greenhouse gas emissions associated with buildings, vehicles, and electronics—a review. *Environmental Research Letters*, *14*(4), 43004.

Hussin, J. M., Rahman, I. A., & Memon, A. H. (2013). The way forward in sustainable construction: issues and challenges. *International Journal of Advances in Applied Sciences*, *2*(1), 15–24.

Iannuzzi, A. (2017). *Greener products: The making and marketing of sustainable brands*. CRC press.

Ilgin, M. A., & Gupta, S. M. (2010). Environmentally conscious manufacturing and product recovery (ECMPRO): A review of the state of the art. *Journal of Environmental Management*, *91*(3), 563–591.

Jones, A. P. (1999). Indoor air quality and health. *Atmospheric Environment*, *33*(28), 4535–4564.

Kibert, C. J. (2016). *Sustainable construction: green building design and delivery*. John Wiley & Sons.

King, K., & Fogle, L. (2006). Bilingual parenting as good parenting: Parents' perspectives on family language policy for additive bilingualism. *International Journal of Bilingual Education and Bilingualism*, *9*(6), 695–712.

Kubba, S. (2010). Indoor environmental quality. *LEED Practices, Certification, and Accreditation Handbook*,

211.
Liu, F., Meyer, A. S., & Hogan, J. (2010). *Mainstreaming building energy efficiency codes in developing countries: global experiences and lessons from early adopters*. World Bank Publications.
Mackenzie, A. (2017). *A Mixed-Methods Research Approach Exploring the Relationship Between'Green'Building Performance and Organizational Productivity*. The University of Manchester (United Kingdom).
Maraveas, C. (2020). Production of sustainable construction materials using agro-wastes. *Materials*, *13*(2), 262.
Mukherjee, S. (2015). Environmental and social impact of fashion: Towards an eco-friendly, ethical fashion. *International Journal of Interdisciplinary and Multidisciplinary Studies*, *2*(3), 22–35.
Nelms, C., Russell, A. D., & Lence, B. J. (2005). Assessing the performance of sustainable technologies for building projects. *Canadian Journal of Civil Engineering*, *32*(1), 114–128.
Omer, A. M. (2008). Renewable building energy systems and passive human comfort solutions. *Renewable and Sustainable Energy Reviews*, *12*(6), 1562–1587.
Orhon, A. V., & Altin, M. (2020). Utilization of alternative building materials for sustainable construction. *Environmentally-Benign Energy Solutions*, 727–750.
Pomponi, F., & Moncaster, A. (2017). Circular economy for the built environment: A research framework. *Journal of Cleaner Production*, *143*, 710–718.
Roberts, K., Dowell, A., & Nie, J.-B. (2019). Attempting rigour and replicability in thematic analysis of qualitative research data; a case study of codebook development. *BMC Medical Research Methodology*, *19*, 1–8.
Saber, A. Y., & Venayagamoorthy, G. K. (2010). Plug-in vehicles and renewable energy sources for cost and emission reductions. *IEEE Transactions on Industrial Electronics*, *58*(4), 1229–1238.
Shrivastava, P. (2018). Environmental technologies and competitive advantage. In *Business Ethics and Strategy, Volumes I and II* (pp. 317–334). Routledge.
Spiegel, R., & Meadows, D. (2010). *Green building materials: a guide to product selection and specification*. John Wiley & Sons.
Viscusi, W. K., Harrington Jr, J. E., & Sappington, D. E. M. (2018). *Economics of regulation and antitrust*. MIT press.
Weerasinghe, A. S., & Ramachandra, T. (2018). Economic sustainability of green buildings: a comparative analysis of green vs non-green. *Built Environment Project and Asset Management*, *8*(5), 528–543.
Wu, Z., Wang, X., Zhao, X., & Noori, M. (2014). State-of-the-art review of FRP composites for major construction with high performance and longevity. *International Journal of Sustainable Materials and Structural Systems*, *1*(3), 201–231.
Zuo, J., & Zhao, Z.-Y. (2014). Green building research–current status and future agenda: A review. *Renewable and Sustainable Energy Reviews*, *30*, 271–281.