

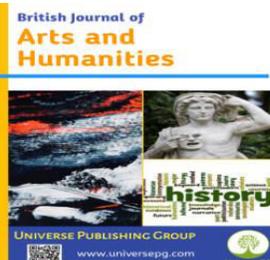


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Carbon Footprint Reduction through Sustainable Renovation of Buildings

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ABSTRACT

The escalating threat of climate change necessitates urgent global action to reduce carbon emissions and adopt sustainable practices. Buildings, as significant contributors to greenhouse gas emissions, require immediate attention and transformative solutions. This article delves into the concept of carbon footprint reduction through sustainable renovation of buildings, exploring essential strategies and initiatives in combating climate change and achieving environmental objectives. The paper begins with an introduction to the pressing issue of climate change, its correlation with carbon emissions from buildings, and the crucial importance of addressing the carbon footprint challenge in the construction sector. It introduces sustainable renovation as a viable solution to mitigate emissions. Through a comprehensive analysis, the article examines the impact of buildings on carbon footprints, highlighting statistics on global carbon emissions from the sector, scrutinizing energy consumption, and operational practices that contribute to heightened carbon footprints, and discussing the environmental consequences. The article then delves into key strategies for carbon footprint reduction, such as energy-efficient retrofitting, the integration of renewable energy sources, and water conservation methods. To highlight real-world success stories, the article presents case studies of sustainable renovation projects that have achieved substantial carbon emission reductions, shedding light on valuable lessons learned from these initiatives. Conclusively, the paper envisions the potential impact of sustainable renovation on global carbon emissions and offers recommendations to policymakers, stakeholders, and building owners to accelerate the transition towards sustainable building practices. In essence, this article provides a comprehensive overview of the significance of sustainable renovation in reducing the carbon footprint of buildings. By embracing collective efforts and committing to sustainable practices, a greener and more resilient future can be secured, ensuring a sustainable planet for generations to come.

Keywords: Carbon footprint, Sustainable renovation, Carbon emissions, Greenhouse gas, and Climate change.

INTRODUCTION:

The global challenge of climate change has brought to the forefront the urgent need for adopting sustainable practices to mitigate its adverse effects. Among the major contributors to greenhouse gas emissions, the building sector plays a significant role, emphasizing

the critical importance of addressing the carbon footprint challenge in this domain. Sustainable renovation emerges as a promising solution to reduce carbon emissions from buildings and pave the way towards a greener and more sustainable future. Climate Change and its Link to Carbon Emissions from Buildings:

Climate change, resulting from the accumulation of greenhouse gases in the Earth's atmosphere, poses severe threats to ecosystems, weather patterns, and human societies. Of these greenhouse gases, carbon dioxide (CO₂) is the most prevalent, primarily originating from the burning of fossil fuels for energy production, transportation, and industrial activities. Other contributing gases include methane (CH₄) and nitrous oxide (N₂O), which also arise from various human activities (Attia, 2013). Buildings, as vital components of human infrastructure, account for a significant proportion of global carbon emissions. The construction, operation, and demolition of buildings contribute to energy consumption, resource depletion, and waste generation, further intensifying their carbon footprint (Berardi *et al.*, 2021). The impacts of climate change, including rising sea levels, extreme weather events, and disruptions in ecosystems, underscore the urgency of mitigating carbon emissions (Christensen, 2019). The building sector's substantial contribution to global carbon emissions necessitates concerted efforts to confront this challenge. Failing to address the carbon footprint of buildings would hinder progress towards achieving climate goals, exacerbating environmental risks and vulnerabilities (Christensen, 2019).

Sustainable renovation offers a promising pathway to tackle the carbon footprint challenge in the building sector. This approach involves upgrading existing buildings using environmentally friendly and energy-efficient practices to minimize their environmental impact. Sustainable renovation encompasses optimizing energy efficiency, selecting eco-friendly materials, reducing waste, and the integrating renewable energy sources. By acknowledging the intricate relationship between climate change, carbon emissions from buildings, and the significance of sustainable renovation, this paper seeks to explore potential of adopting sustainable practices to reduce the carbon footprint of buildings (Davis Langdon, 2014). Through the integration of sustainable renovation methods, we can move towards a more resilient and environmentally conscious built environment, contributing to global efforts in combatting climate change (Dellottie, 2015).

The Impact of Buildings on Carbon Footprint

Buildings play a significant role in contributing to the carbon footprint, making them a crucial focus in global

efforts to combat climate change. The construction, operation, and maintenance of buildings consume vast amounts of energy, primarily derived from fossil fuels, which release carbon dioxide (CO₂) and other greenhouse gases into the atmosphere. Several factors contribute to the substantial carbon emissions associated with buildings: Energy Consumption: Buildings are responsible for a significant portion of the global energy consumption. The need for heating, cooling, lighting, & powering various systems within buildings leads to substantial carbon emissions, particularly in regions heavily reliant on fossil fuels for electricity generation.

Building Materials

The production and transportation of construction materials, such as cement, steel, and glass, result in the considerable carbon emissions. These "embodied carbon" the emissions occur even before a building becomes operational and add to its overall carbon footprint.

Inefficient Design

Poorly designed buildings, with inadequate insulation, inefficient heating and cooling systems, and energy-wasting appliances, consume more energy and contribute significantly to their carbon footprint (European Commission, 2019; Cruz JBD, 2023).

High-Rise Buildings

Tall buildings with large glass facades often demand extensive air conditioning to regulate indoor temperatures, which intensifies their energy consumption and carbon emissions.

Transportation

The location of buildings influences transportation patterns. Urban sprawl and extensive commuting lead to increased carbon emissions from transportation. Reducing the carbon footprint of buildings requires a multifaceted approach that encompasses energy-efficient design, sustainable materials, renewable energy integration, & efficient operational practices. Governments, architects, developers, and building owners play a vital role in implementing policies and practices that foster sustainable building construction and operation, ultimately contributing to global efforts to address climate change.

Global Percentage of the Carbon Emissions from Buildings

Buildings are responsible for a substantial proportion of global carbon emissions. According to data from the United Nations Environment Programme (UNEP), buildings contribute approximately 39% of the world's total energy-related carbon dioxide (CO₂) emissions. This percentage encompasses emissions resulting from energy use during the operational phase of buildings, as well as embodied carbon emissions from the construction and manufacturing of building materials.

Heating and Cooling

In regions with extreme climates, buildings require significant energy for heating during cold seasons and cooling during hot seasons. The use of fossil fuels or electricity-powered heating, ventilation, and air conditioning (HVAC) systems can intensify carbon emissions.

Lighting

Inefficient lighting systems, especially those using incandescent bulbs, consume more energy and contribute to higher carbon emissions.

Appliances and Equipment

Energy-intensive appliances and equipment used in buildings, such as refrigerators, computers, & washing machines, contribute to increased energy consumption and carbon footprint.

Inadequate Insulation

Poor insulation in buildings leads to higher heating and cooling demands, resulting in elevated energy consumption and carbon emissions.

Inefficient Building Systems

Inefficient operational practices, such as improper temperature control, excessive lighting, and lack of energy-efficient appliances, contribute to increased carbon emissions. The high carbon emissions from the buildings have several significant environmental consequences:

Climate Change

Greenhouse gases, including CO₂ contribute to global warming, leading to climate change and its associated impacts, such as rising sea levels, extreme weather events, and altered precipitation patterns.

Air Pollution

The burning of fossil fuels for energy in buildings releases not only CO₂ but also other pollutants, such as particulate matter and nitrogen oxides, which degrade air quality and have adverse effects on human health and ecosystems.

Resource Depletion

The production of energy and construction materials for buildings depletes natural resources, leading to habitat destruction and environmental degradation.

Biodiversity Loss

The environmental consequences of high carbon emissions from buildings also affect biodiversity, as changes in temperature and climate conditions can disrupt ecosystems and threaten various species. Addressing the carbon footprint of buildings through sustainable renovation and energy-efficient practices is essential to mitigate these environmental consequences and foster a more sustainable built environment.

Understanding Sustainable Renovation

Sustainable renovation refers to the process of upgrading existing buildings in an environmentally conscious and socially responsible manner to reduce their environmental impact and improve overall sustainability. Unlike conventional renovation practices that primarily focus on cosmetic changes and short-term improvements, sustainable renovation considers the long-term implications of building modifications on the environment, occupants, and society.

Principles of Sustainable Renovation

Energy Efficiency

Sustainable renovation aims to enhance the energy performance of buildings through the adoption of energy-efficient technologies and practices. This includes optimizing insulation, upgrading windows and doors, implementing efficient HVAC systems, and utilizing renewable energy sources.

Resource Conservation

Sustainable renovation emphasizes the responsible use of resources during the construction and operation of buildings. It involves selecting eco-friendly and recycled materials, reducing waste generation, and promoting circular economy principles.

Indoor Environmental Quality

Ensuring a healthy and comfortable indoor environment is another essential principle of sustainable renovation. This involves improving ventilation, minimizing indoor air pollutants, and incorporating natural lighting to enhance occupants' well-being and productivity.

Water Efficiency

Sustainable renovation strives to reduce water consumption by incorporating water-efficient fixtures, rain-water harvesting systems, & water recycling technologies.

Social and Community Considerations

Sustainable renovation takes into account the social impact of building upgrades. This includes creating inclusive and the accessible spaces, supporting local economies, and promoting community engagement.

Importance of Sustainable Building Materials and Techniques

Sustainable renovation places great emphasis on the selection of the appropriate building materials and techniques. Key aspects include -

Low Carbon Materials

Opting for low carbon footprint materials, such as recycled or reclaimed materials, minimizes the embodied carbon emissions associated with construction.

Renewable Resources

Choosing renewable materials like wood from sustainably managed forests reduces the reliance on non-renewable resources.

Energy-Efficient Techniques

Integrating energy-efficient construction techniques, such as passive solar design and thermal mass utilization, helps improve a building's overall energy performance.

Green Roofing and Wall Systems

Implementing green roofing and wall systems contributes to improved insulation, reduced stormwater runoff, and enhanced biodiversity. Introduction of Green Building Certifications and Their Role in Promoting Sustainable Renovation. Green building certifications are independent verification systems that assess a building's environmental performance and

sustainability. They play a crucial role in promoting sustainable renovation by providing recognized standards and incentives for environmentally responsible building upgrades. Prominent green building certifications include LEED (Leadership in Energy and Environmental Design), BREEAM (Building Research Establishment Environmental Assessment Method), and Green Star. These certifications encourage building owners and developers to prioritize sustainable practices during renovation projects and provide recognition for their efforts in reducing environmental impact. By adhering to sustainable renovation principles, incorporating eco-friendly materials, and obtaining green building certifications, the construction industry can make significant strides towards creating more sustainable and resilient built environments.

Advantages of Sustainable Renovation

Carbon Footprint Reduction and Positive Environmental Impact

One of the primary advantages of sustainable renovation is the significant reduction in the carbon footprint of buildings. By implementing energy-efficient technologies, utilizing renewable energy sources, & choosing eco-friendly materials, sustainable renovation helps decrease the greenhouse gas emissions. This reduction in carbon emissions contributes to global efforts in mitigating climate change and preserving the environment for future generations (Gacke, 2021).

Long-Term Savings and Economic Benefits for the Building Owners

Sustainable renovation offers long-term cost savings and economic advantages for building owners. Although initial investment costs may be higher than traditional renovation methods, the energy efficiency improvements and resource conservation lead to lower operating expenses over the building's lifespan. Reduced energy consumption translates into lower utility bills, providing financial relief for building owners in the long run. Additionally, enhanced building performance and higher market value associated with sustainable renovations can result increased resale value.

Improved Indoor Air Quality and Occupant Health in Sustainable Buildings

Sustainable renovation prioritizes the creation of healthy & comfortable indoor environments. By up-

grading ventilation systems, minimizing indoor air pollutants, & incorporating natural lighting, sustainable buildings offer better indoor air quality. Improved air quality promotes the well-being and productivity of building occupants, reducing health risks associated with poor indoor environments. Additionally, sustainable materials and finishes with low levels of volatile organic compounds (VOCs) contribute to a healthier living or working environment for occupants.

Enhanced Resilience and Adaptability

Sustainable renovation often includes climate-resilient design features and technologies. Such strategies can help buildings better withstand extreme weather events & changing climate conditions. By integrating adaptive measures, buildings can continue to function effectively and provide a safe environment for occupants, even in the face of environmental challenges.

Positive Social Impact and Community Engagement

Sustainable renovation projects can have a positive social impact on communities. By creating inclusive and accessible spaces, the promoting local economic development through sourcing sustainable materials locally, and engaging with stakeholders, these projects foster a sense of community and social responsibility.

Promotion of the Innovation and the Technological Advancements

The pursuit of sustainable renovation encourages innovation and the development of new technologies and practices in the construction industry. As more projects adopt sustainable strategies, it stimulates research & investment in sustainable building materials, renewable energy solutions, and the advanced building systems. In conclusion, sustainable renovation offers a wide array of advantages, ranging from reducing carbon emissions and benefiting the environment to providing economic savings for building owners and enhancing the well-being of occupants. Embracing sustainable practices in renovation projects is crucial for creating a more sustainable and resilient built environment.

Key Strategies for Carbon Footprint Reduction

Energy Optimization through Building Design and Construction

Revising construction practices to optimize energy efficiency is a fundamental strategy for reducing the carbon footprint. This involves adopting sustainable building design principles that prioritize passive solar design, effective insulation, and proper orientation to maximize natural lighting and ventilation. Energy-efficient materials and construction techniques, such as advanced insulation materials and high-performance windows, can significantly reduce energy consumption in building's (Ghani, 2013; Pimentel, 2023).

Integration of Renewable Energy Sources to Meet Building Needs

Incorporating renewable energy sources is crucial in transitioning to a low-carbon energy supply for buildings. Solar photovoltaic (PV) systems, wind turbines, and geothermal technologies are some examples of renewable energy solutions that can be integrated into buildings to generate clean electricity. By using the renewable energy on-site, buildings can reduce their reliance on fossil fuels and decrease greenhouse gas emissions.

Water Conservation Methods and their Impact on the Carbon Footprint

Water conservation is an essential aspect of carbon footprint reduction. Implementing water-saving fixtures, rainwater harvesting systems, and graywater reuse technologies helps minimize water consumption. This reduction indirectly lowers the energy required for water treatment and distribution; the consequently reducing associated carbon emissions (Ghani, 2013).

Sustainable Material Selection and the Construction Practices

Choosing eco-friendly and low-carbon materials for construction and renovation projects is crucial for reducing the carbon footprint of buildings. Utilizing recycled or reclaimed materials, responsibly sourced wood, and materials with the low embodied carbon content can significantly contribute to carbon reduction efforts.

Embracing Energy-Efficient Building Systems

Energy-efficient building systems, such as the smart lighting controls, energy management systems, and efficient heating, ventilation, and air conditioning (HVAC) systems, play a vital role in reducing energy consumption and related carbon emissions (Jea, 2019).

Building Retrofits and Upgrades

Retrofitting existing buildings with energy-efficient technologies and incorporating renewable energy systems can substantially lower their carbon footprint. This approach is particularly important, given that a significant portion of the building stock comprises older structures with less energy-efficient characteristics.

Lifecycle Assessment and Carbon Offsetting

Performing lifecycle assessments of buildings allows for a comprehensive understanding of their environmental impact. This assessment considers the entire lifecycle of a building, from construction and operation to demolition and the disposal. Additionally, carbon offsetting initiatives, such as supporting reforestation projects or renewable energy initiatives can help neutralize remaining carbon emissions that cannot be eliminated through other strategies. By implementing these key strategies, the building sector can make significant progress in reducing its carbon footprint, contributing to global efforts to combat climate change and create a more sustainable future.

Case Studies of Successful Sustainable Renovation Projects

One Angel Square, Manchester, UK

One Angel Square is an award-winning sustainable renovation project, transforming a dated 1970s building into a modern, energy-efficient office space. The retrofit incorporated a range of sustainable features, including the energy-efficient glazing, LED lighting, and a trigeneration system that generates electricity, heating, and cooling on-site. The building achieved a BREEAM "Outstanding" rating, one of the highest certifications for sustainable buildings, and recorded a remarkable 80% reduction in the carbon emissions compared to the original building.

The Edge, Amsterdam, Netherlands

The Edge, a state-of-the-art office building, is a prime example of sustainable renovation. It features innovative design elements, such as solar panels integrated into the building's facade and roof, intelligent LED lighting systems, and a sophisticated energy management system. The building's intelligent systems adapt to occupants' needs, optimizing energy usage and ensuring a comfortable indoor environment. The

Edge achieved a BREEAM "Outstanding" rating and achieved a significant reduction in energy consumption, resulting in a carbon-neutral status.

Empire State Building, New York City, USA

The iconic Empire State Building underwent a comprehensive sustainable renovation aiming to improve its energy efficiency and reduce its carbon footprint. The renovation included the installation of energy-efficient windows, a modernized HVAC system, and the implementation of green roofs. These improvements resulted in an impressive 38% reduction in energy consumption and saved millions of dollars in operating costs annually.

Lessons Learned and Achieved Carbon Reduction

These successful sustainable renovation projects have provided valuable lessons and achieved substantial carbon reductions.

Integrated Design Approach

The projects' success was due to adopting an integrated design approach, where architects, engineers, and sustainability experts collaborated from the initial stages to ensure cohesive, sustainable solutions.

Energy-Efficient Systems

The incorporation of the advanced energy-efficient systems, such as high-performance insulation, LED lighting, and energy management systems, significantly contributed to carbon reduction by minimizing energy consumption.

Renewable Energy Integration

Utilizing renewable energy sources, such as solar panels and trigeneration systems, allowed the buildings to generate clean energy on-site, leading to further carbon emission reductions.

Innovative Technologies

Employing innovative technologies, like adaptive lighting & occupancy sensors, ensured energy usage optimization & improved indoor environmental quality.

Sustainable Materials

The use of sustainable and low-carbon materials during the renovation contributed to lowering the buildings' embodied carbon and enhancing their overall sustainability.

Certifications and Standards

Seeking certifications, such as BREEAM, LEED, or Green Star, provided a framework for measuring and validating the projects' sustainable achievements. These case studies demonstrate that the sustainable renovation can achieve remarkable carbon reductions and deliver tangible environmental and economic benefits, inspiring the construction industry to embrace more sustainable practices and contribute to a greener and more resilient future.

Government Enthusiasm and Policies

Governments worldwide are increasingly showing enthusiasm for promoting sustainable renovation and embracing policies that support environmentally responsible practices in the construction sector. These policies aim to tackle climate change, reduce carbon emissions, conserve resources, and create more sustainable built environments. Some of the key initiatives and policies include.

Green Building Certifications and Standards

Governments encourage the adoption of green building certifications and standards, such as LEED (Leadership in the Energy and Environmental Design) & BREEAM (Building Research Establishment Environmental Assessment Method). These certifications provide clear benchmarks for sustainable building practices and offer incentives for developers and building owners to pursue sustainable renovation.

Financial Incentives and Subsidies

Governments often provide financial incentives, subsidies, and tax benefits to support sustainable renovation projects. These incentives may include grants, low-interest loans, or tax credits for energy-efficient retrofits and integration of renewable energy systems.

Building Codes and Regulations

Governments update building codes and regulations to incorporate energy efficiency & sustainability requirements. This ensures that new construction & renovation projects must meet specific environmental standards, encouraging the adoption of sustainable practices.

Public Procurement Policies

Governments use their purchasing power to drive sustainable practices by requiring environmentally

friendly materials and energy-efficient systems in public building projects. This practice sets an example for the private sector and stimulates demand for sustainable products and services.

Research and Development Funding

Governments invest in research and development to foster innovation in sustainable construction technologies and the materials. Funding research projects contributes to the advancement of sustainable renovation practices and the development of cutting-edge solutions.

Effectiveness of Incentives, Rewards, and Financial Benefits in Promoting Sustainable Actions

Financial incentives, rewards, and gifts have proven to be effective tools in promoting sustainable actions, including sustainable renovation. Several aspects contribute to their success. Cost Reduction and Return on Investment: Financial benefits, such as tax credits and subsidies, reduce the initial investment required for sustainable renovation, making it more financially attractive to building owners and developers. Additionally, energy-efficient upgrades often lead to long-term cost savings through reduced utility bills and lower operating expenses, providing a favorable return on investment.

Behavior Change and Awareness

Incentives and rewards can trigger behavior change among building owners and occupants. Financial benefits act as a motivator for the adopting sustainable practices, raising awareness of the importance of environmental responsibility.

Market Transformation

Financial incentives drive demand for sustainable products and services, encouraging the development and availability of eco-friendly materials and technologies. This, in turn, transforms the market, making sustainable options more accessible and the cost-competitive.

Public Engagement and Participation

Financial incentives and rewards engage the public and private sectors in sustainability initiatives. This collaboration fosters a shared responsibility for environmental conservation and encourages more widespread adoption of sustainable practices. However, the

effectiveness of financial benefits depends on various factors, such as the magnitude of incentives, the clarity of policy objectives, and the level of public awareness. Continuous evaluation and refinement of incentive programs are essential to ensure their optimal impact on promoting sustainable renovation and achieving environmental goals. In conclusion, governments' enthusiasm for sustainable renovation and the implementation of supportive policies, along with well-designed financial incentives, play a vital role in encouraging sustainable actions in the construction sector. These initiatives contribute to carbon reduction efforts, resource conservation, and the creation of more resilient and sustainable built environments.

Analysis of the Effectiveness of the Incentives, Rewards, and Financial Benefits in Promoting Sustainable Actions

Financial incentives, rewards, and gifts play a crucial role in promoting sustainable actions, including sustainable renovation. Their effectiveness lies in their ability to overcome initial barriers and motivate stakeholders to embrace environmentally responsible practices. Some key aspects of their effectiveness are (Mohajeri, 2020).

- **Overcoming Cost Barriers:** Sustainable renovation often involves higher upfront costs compared to conventional practices. Financial incentives, such as tax credits and subsidies, help offset these initial expenses, making sustainable options more financially viable for building owners and developers.
- **Behavior Change and Awareness:** Incentives and rewards act as catalysts for behavior change. They raise awareness about the importance of sustainability & motivate individuals and organizations to take positive actions towards greener practices.
- **Market Transformation:** By providing financial benefits, governments and organizations stimulate demand for sustainable products and services. This increased demand drives market transformation, making sustainable technologies and materials more widely available and affordable.
- **Encouraging Ongoing Commitment:** Incentives and rewards encourage ongoing commitment to sustainability. They reinforce the value of sustain-

able actions and help maintain stakeholders' interest in long-term environmental improvements.

Challenges and Obstacles to the Sustainable Renovation

While financial incentives and rewards are effective motivators, sustainable renovation projects still face several challenges and obstacles (Pachauri, 2014).

- **Initial Investment Hurdles:** Despite incentives, some building owners may still perceive sustainable renovation as financially burdensome. The high upfront costs and uncertainty about long-term returns can deter investment in sustainable practices.
- **Lack of Information and Expertise:** Many stakeholders may lack knowledge about sustainable renovation techniques and may struggle to identify the best solutions for their specific buildings. Access to reliable information and expertise is essential to overcome this challenge.
- **Regulatory and the Administrative Complexity:** Complex regulatory requirements and bureaucratic procedures can delay or hinder the implementation of sustainable renovation projects. Streamlining approval processes and providing clear guidelines can facilitate smoother project execution.
- **Market Fragmentation and Limited Supply Chain:** In some regions, the availability of sustainable materials and technologies may be limited, leading to market fragmentation. A well-developed supply chain is necessary to support the expansion of sustainable renovation.

Overcoming Financial, Technical, and Cultural Barriers to Scale Sustainable Renovation (Estern, 2000)

- **Financial Solutions:** Governments can enhance financial incentives and subsidies, making them more attractive to building owners. This can include providing grants or low-interest loans specifically for sustainable renovation projects.
- **Capacity Building and Training:** Training programs and capacity-building initiatives can improve stakeholders' understanding of sustain-

able renovation practices and equip them with the necessary skills to implement such projects.

- **Public Awareness and Education:** Raising public awareness about the benefits of sustainable renovation can foster a cultural shift towards embracing greener practices. Public education campaigns can help dispel misconceptions and promote positive attitudes towards sustainability.
- **Collaboration and Partnerships:** Encouraging collaboration between governments, private sector stakeholders, & non-governmental organizations can pool resources and expertise to overcome technical and financial challenges.
- **Streamlined Regulations:** Governments can simplify building codes and permit processes related to sustainable renovation. Clear and streamlined regulations will facilitate project execution and encourage wider adoption of the sustainable practices.
- **Addressing these challenges** requires a comprehensive and multi-faceted approach involving policy adjustments, financial support, capacity building, and public engagement. By overcoming these barriers, sustainable renovation can be scaled up and contribute significantly to global efforts to address climate change and create a more sustainable future.

Addressing Financial, Technical, and Cultural Barriers for Scaling Sustainable Renovation

Financial Solutions

- Increase funding and financial incentives for sustainable renovation projects, such as offering tax breaks, grants, and low-interest loans.
- Establish green building funds to support building owners and developers in implementing sustainable practices.
- Encourage public-private partnerships to share the financial burden and create innovative funding mechanisms (Unep, 2021).

Technical Support

- Develop capacity-building programs and training workshops for architects, engineers, and contractors to enhance their knowledge of sustainable renovation techniques.

- Facilitate access to the technical expertise and resources through online platforms and resource centers.
- Establish demonstration projects to showcase successful sustainable renovation examples and inspire others to follow suit.

Cultural Shift and Awareness

- Launch public awareness campaigns to promote the benefits of the sustainable renovation and highlight success stories.
- Foster collaboration between industry stakeholders, academics, and policymakers to create a shared vision for sustainable development.
- Integrate sustainability education into school curricula to cultivate a future generation with a strong environmental ethos.

Future Prospects and Recommendations

Incentivizing Net-Zero & Positive Energy Buildings

- Encourage the development of net-zero energy buildings that generate as much or more energy than they consume.
- Offer additional incentives for the projects that achieve the positive energy status, contributing surplus energy to the grid.

Circular Economy Approach

- Promote the use of recycled and reclaimed materials in renovation projects, aligning with circular economy principles.
- Encourage building design that allows for easy disassembly and reuse of materials during future renovations.

Impact of the Sustainable Renovation on Global Carbon Emissions

Carbon Reduction Potential

- Sustainable renovation has the potential to significantly reduce global carbon emissions by upgrading existing buildings to higher energy efficiency standards.
- Improved insulation, energy-efficient systems, and renewable energy integration can lead to substantial carbon savings.

Mitigating Climate Change

- Scaling up sustainable renovation efforts can contribute to achieving global climate targets,

such as the Paris Agreement's goal of limiting global warming to well below 2 degrees Celsius (UN-Habitat, 2020).

- Recommendations for Policymakers, Institutions, and Building Owners to Accelerate Sustainable

Renovation Strengthen Policies and Regulations

- Establish ambitious energy efficiency targets and standards for buildings, incentivizing sustainable renovation.
- Integrate sustainability requirements into building codes and planning regulations to drive adoption.

Financial Incentives and Support

- Enhance financial incentives, tax breaks, and subsidies for sustainable renovation projects.
- Establish green financing mechanisms and green bonds to support sustainable renovation initiatives.

Public-Private Partnerships

- Foster collaborations between the governments, private sector entities, and NGOs to leverage expertise and resources.
- Jointly fund research and development projects for innovative sustainable technologies.

Awareness and Education

Conduct awareness campaigns to educate the public and building owners about the benefits of sustainable renovation. Provide training programs and capacity-building initiatives to enhance technical knowledge and skills. By addressing financial, technical, and cultural barriers, and implementing effective policies and incentives, sustainable renovation can play a vital role in reducing global carbon emissions and creating more resilient and sustainable built environments. Collaboration among stakeholders and a shared commitment to sustainability are keys to accelerating progress towards a greener future (United Nations Environment Programme, 2018).

Future Prospects and Recommendations

Advancements in Green Technologies

Continued advancements in green technologies, such as energy-efficient materials, smart building systems, and renewable energy solutions, will further enhance the potential of sustainable renovation projects. Embracing emerging technologies like building-

integrated solar panels, energy storage systems, and AI-driven energy management will lead to even more efficient and sustainable buildings.

Integrated Digital Solutions

The integration of digital tools, Building Information Modeling (BIM), and Internet of Things (IoT) devices will streamline the design, construction, and operation of sustainable renovation projects. Data-driven insights and real-time monitoring will optimize building performance, identify energy-saving opportunities, and enhance occupant comfort.

Circular Economy Adoption

The adoption of circular economy principles will gain prominence, promoting resource efficiency and minimizing waste in renovation projects. Prefabrication and modular construction methods will be embraced, enabling easier disassembly and recycling of building components.

Incentive Innovation

Policymakers and governments should continuously evaluate and update financial incentives and rewards to align with changing market dynamics and emerging technologies. Innovative incentive structures, such as pay-for-performance models and green bonds, can further accelerate sustainable renovation adoption.

Global Collaboration

International collaboration and knowledge-sharing among countries will facilitate the exchange of best practices and lessons learned in sustainable renovation. Joint initiatives and partnerships can mobilize global resources to address common challenges and achieve shared sustainability goals.

Scaling Up Green Finance

Scaling up green finance mechanisms will attract private sector investments in sustainable renovation projects. Green banks and sustainable investment funds can play a crucial role in providing accessible financing options for building owners.

Community Engagement and Social Impact

Prioritizing community engagement and social impact in sustainable renovation projects can create a sense of ownership and support among the local residents. Inclusive and participatory approaches will ensure that

renovation efforts address the specific needs of the different communities.

Life Cycle Assessment and Reporting

Widespread adoption of life cycle assessment methodologies will become standard practice to evaluate the environmental impact of renovation projects comprehensively. Transparent reporting and disclosure of building performance metrics will drive accountability and encourage continuous improvement.

Building Resilience

Sustainable renovation projects should prioritize building resilience to climate change impacts, such as extreme weather events and rising sea levels. Incorporating adaptive design and the climate-responsive features will enhance buildings' long-term viability.

Green Building Certification Expansion

The expansion of green building certifications beyond new construction to include the existing buildings undergoing renovation will encourage sustainability across the building lifecycle. Governments and industry stakeholders should collaborate to develop tailored certification programs for renovation projects. In conclusion, the future of sustainable renovation holds great promise, driven by advancements in technology, policy innovation, and global collaboration. To accelerate progress, the stakeholders must embrace cutting-edge solutions, prioritize circular economy principles, and continuously adapt their approaches to align with evolving sustainability challenges. Through collective efforts and forward-thinking strategies, sustainable renovation can play a pivotal role in the achieving a greener, more resilient, and sustainable future for our built environment.

CONCLUSION:

Sustainable renovation presents a transformative pathway towards a greener and more sustainable future for our built environment. The urgency to combat climate change and reduce carbon emissions has underscored the significance of adopting environmentally responsible practices in the construction sector. Through financial incentives, technical advancements, and a cultural shift towards sustainability, we can overcome the barriers that hinder the widespread adoption of sustainable renovation. Financial incentives, such as tax breaks, grants, and subsidies, play a

pivotal role in encouraging building owners and developers to invest in sustainable renovation projects. By offsetting initial costs and offering attractive returns on the investment, these incentives create a compelling case for embracing greener practices.

Technical support and capacity-building initiatives are essential to equip industry professionals with the knowledge and skills necessary to implement sustainable renovation effectively. Integrating digital technologies and data-driven solutions enhances building performance, optimizes energy usage, and elevates occupant comfort. A cultural shift towards sustainability fosters a collective commitment to environmental stewardship. Public awareness campaigns, education, and collaboration among stakeholders generate momentum for sustainable practices, driving demand for eco-friendly materials and technologies. As we look to the future, continued advancements in green technologies, the adoption of circular economy principles and international collaboration will shape the trajectory of sustainable renovation. Policymakers, institutions, and building owners must seize the opportunity to accelerate progress through innovative incentive structures, green finance mechanisms, and comprehensive life cycle assessments. Sustainable renovation's impact on global carbon emissions cannot be understated. By retrofitting existing buildings to higher energy efficiency standards and integrating renewable energy solutions, we can significantly contribute to achieving climate targets and mitigating the effects of climate change.

The journey towards sustainable renovation is one that requires collective effort, continuous innovation, and a shared commitment to building a more sustainable world. Through joint initiatives and collaboration across borders, we can unlock the full potential of sustainable renovation, creating resilient, energy-efficient, and environment-tally responsible built environments for generations to come. In conclusion, sustainable renovation is not just a concept; it is a tangible and powerful tool to shape a sustainable future. By embracing this transformative approach, we can pave the way towards a healthier planet and leave a lasting legacy of environmental stewardship for future generations.

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Authors also state separately that they have all read the manuscript and have no conflict of interest.

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