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Positive Carbon Building Methodology in Co-Design with Residents

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Abstract: The present article outlines the Positive Carbon Building certification's pioneering approach, aiming to establish a clear and rigorous methodology for buildings that are not only neutral in their environmental impact but are net positive. This certification challenges the industry by setting a higher bar — achieving net positivity. The approach does not just mitigate harm but actively contributes to environmental regeneration, thereby pushing the construction and real estate sectors towards innovative practices and collaborations. It calls for a reevaluation of how buildings are designed, constructed, and operated, encouraging the incorporation of renewable energy sources, energy-efficient designs, and materials with lower embodied carbon. This ambition signifies a move towards structures that produce more energy than they consume annually, thereby offering a surplus to the energy grid and reducing their carbon footprint comprehensively. This certification intends to work in conjunction with existing green building certifications, emphasizing net-positive energy production and ensuring alignment with both European and national legislations concerning nearly Zero Energy Buildings (nZEB) [1]. Traditionally, the focus has been on minimizing the negative environmental impacts of buildings, but the methodology for Positive Building Certification will mark a significant shift in the conceptualization of green building standards.

Keywords: E.U. climate goals; positive C. building; nZEB; life cycle

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1. Introduction

In response to the pressing imperative for sustainable development amidst the specter of climate change, the Positive Carbon Buildings initiative emerges as a beacon of transformation within the built environment. Acknowledging that buildings stand as significant contributors to energy consumption and carbon emissions on a global scale, this initiative sets out to redefine the benchmarks for energy performance and environmental impact. Its overarching goal? To reshape our constructed landscapes into agents of positive change. The paradigm shift extends far beyond technological innovations [2] and avant-garde architectural concepts; it requires a fundamental cultural reorientation in our relationship with the built environment. No longer mere structures for habitation or commerce, buildings are envisioned as dynamic participants in our ecological system, capable of not only sustaining but actively contributing to energy sustainability and carbon sequestration.

The Positive Carbon Buildings certification framework finds resonance with broader environmental ambitions, such as those underlined in the European Green Deal, which charts a course towards a climate-neutral continent by 2050. Embracing the principles of circular economy, wherein the value of resources is maximized and waste minimized, this initiative recognizes the imperative of considering a building's entire lifecycle — from initial material procurement to eventual decommissioning or repurposing.

In essence, the Introduction of the Positive Carbon Buildings [3] report heralds a bold vision for the future of green building certifications, advocating not merely for sustainability but for

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regenerative development. It offers a compelling invitation to stakeholders across the construction and real estate sectors, urging them to embark on a transformative journey towards buildings that are not only less harmful but unequivocally beneficial to the planet.

This is not just a call to action; it's an opportunity to reimagine our built environment's role in tackling environmental challenges, presenting a blueprint for a future where buildings not only exist within ecological limits but actively enrich them. Let us seize this moment, united in our commitment to creating a built environment that thrives in harmony with nature.

2. Materials and Methods

2.1. Goal and Purpose

This article aims to present the basics of RoGBC methodology, a comprehensive framework designed to promote sustainable building practices. This methodology aligns with the European Union's ambitious climate goals and offers practical guidelines for integrating sustainable materials and techniques in construction projects. The first results of an European H2020 project REN+HOMES lead by RINA Consulting and where Romania Green Building Council – RoGBC is part, are presented.

2.2. Inventory Analysis

In developing a universal positive methodology, it is essential to integrate various existing methodologies, each of which focuses on specific principles. These principles guide the development and implementation of sustainable and energy-efficient residential buildings.

The main principles of the five methodologies and how they can cooperate to form a comprehensive universal methodology, are presented in Table 1:

- PHI (Passive House Institute) methodology focuses on Primary Energy Renewable (PER) factors. PER factors measure the total renewable energy required to meet a building's energy demands, accounting for losses during conversion, distribution, and storage;
- RoGBC emphasizes reducing the carbon footprint, ongoing performance, energy optimization, and innovation. Using a detailed scorecard system, this methodology assesses various aspects of building performance to ensure they contribute positively to environmental sustainability;
- HPHI (Hellenic Passive House Institute) aims at achieving full building electrification and developing new business models for positive energy social housing;
- CERQUAL's (Confidence in the Evidence from Reviews of Qualitative Research) methodology is centered on the HQE (High Environmental Quality) standard, focusing on overall building performance in terms of environmental impact, comfort, health, and lifecycle analysis;
- TalTech (Tallinn University of Technology) emphasizes the integration of demand response systems and smart technologies to enhance energy efficiency.

Table 1. Methodologies' tools.

Method	Tool Name	Goal	Description
PHI	IES VE PRO	Energy Simulation	Models and predicts building performance, helps in making informed decisions about energy use and HVAC system sizing.
	Carbon Verify	Carbon Footprint Management	Measures and manages the carbon footprint during the building's operational phase, providing insights for improvement.
RoGBC	Scorecard System	Positive Carbon Assessment	Assesses building performance across categories like CO_2 emissions, energy optimization, and innovation

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HPHI	PHPP (Passive House Planning Package)	Energy Modeling	Calculates a comprehensive energy balance, estimates annual energy demands, and assists in the design and certification of Passive Houses.
	EnergyPlus	Dynamic Simulation	Models detailed interactions between climate, building materials, and systems operation, supporting dynamic simulations of building performance
	IES VE	Building Performance Simulation	Provides detailed analysis of daylight, energy, and thermal simulations, optimizing design choices for energy performance and occupant comfort.
CERQUAL	Lifecycle Assessment Tools	Environmental Impact	Evaluates environmental impacts associated with each stage of a building's lifecycle, ensuring sustainability from material sourcing to end-of-life.
TalTech	Control Algorithms	Demand Response	Automatically adjusts energy consumption based on parameters like geographical location and user profiles, optimizing energy efficiency.
	Collaborative Design Platforms	Co-design Process	Facilitates stakeholder involvement in developing demand response systems, ensuring technical feasibility and user satisfaction.

2.3. Framework for Developing Positive Carbon Certification

Positive buildings integrate innovative technologies, sustainable design principles, and rigorous regulatory compliance measures. This strategy aims not only to meet the stringent criteria set forth by the European Union but also to exceed the benchmarks for nZEB Buildings [4]. At its core, this comprehensive [5] approach requires a multifaceted consideration of various factors, including energy efficiency, carbon emissions reduction, and overall environmental impact [6]:

- leveraging state-of-the-art building materials and cutting-edge construction techniques is essential to achieving the ambitious goals of the Positive Carbon Building certification;
- fostering collaboration among architects, engineers, policymakers, and stakeholders is paramount. This collaborative effort ensures that all parties are aligned with the objectives and can contribute their expertise towards the development and implementation of innovative solutions;
- integrating renewable energy sources such as solar panels, wind turbines, and geothermal systems into building designs plays a crucial role in reducing reliance on fossil fuels and minimizing carbon footprints;
- implementing energy-efficient [7] HVAC systems, advanced insulation techniques, and smart building automation further enhances the building's performance while reducing energy consumption;
- adherence to strict regulatory standards and certification requirements is non-negotiable.

By aligning with the European Union's legislative framework [8], developers and builders can ensure compliance with the latest environmental regulations and demonstrate their commitment to sustainability. Ultimately, by adopting this holistic strategy, buildings seeking Positive Carbon Building certification can not only meet but exceed the stringent criteria set forth by the European Union. This approach not only contributes to combating climate change but also sets a new standard for environmentally conscious construction practices in the pursuit of a greener and more sustainable future.

The Positive Carbon Building certification aims to significantly exceed the renewable energy generation requirements stipulated by nZEB [9] standards. This ambition aligns with the EU's

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Renewable Energy Directive (RED), mandating the EU to source at least 32% of its energy from renewable sources by 2030. For Positive Carbon Buildings, this means not just meeting this threshold but also utilizing innovative technologies like photovoltaic solar panels, wind turbines, and geothermal energy systems to achieve net-positive energy status, contributing excess energy back to the grid.

Energy efficiency is central to the EU's approach to reducing carbon emissions from buildings. The Positive Carbon Building certification emphasizes adopting cutting-edge energy efficiency measures that surpass standards set by the Energy Efficiency Directive (EED) and the Energy Performance of Buildings Directive (EPBD). This includes using high-performance insulation, advanced window glazing, energy-efficient lighting [10] and HVAC systems, and smart building technologies to minimize energy demand. [11]

The EU's focus on a circular economy and sustainable material use in construction is reflected in its Circular Economy Action Plan and the Eco-design Directive. Positive Carbon Buildings prioritize low-embodied carbon materials, encourage reuse and recycling of construction materials, and support circular economy principles by designing for deconstruction and adaptability. This approach not only reduces buildings' embodied carbon but also aligns with the EU's ambition to transition to a more sustainable, low- carbon economy.

Aligning with EU directives opens opportunities for accessing legislative and financial incentives to encourage adoption of Positive Carbon Building standards. [12] This includes funding from the European Structural and Investment Funds (ESIF), low-interest loans for energy-efficient building projects and grants available through programs like Horizon Europe. Certification alignment with EU standards can facilitate compliance with national regulations, making it more attractive for developers and investors. [13]

The Positive Carbon Building certification integration will directly contribute to the EU's climate and energy goals, including the 2030 climate and energy framework and the European Green Deal's aim for a climate-neutral continent by 2050. Positive Carbon Buildings demonstrate the EU's commitment to environmental sustainability and climate resilience, showcasing innovative building design and operation approaches replicable across member states.[14]

Preparing Positive Carbon Building certification for integration with the EU's legislative landscape requires ongoing dialogue with regulatory bodies, industry stakeholders, and the scientific community. This collaborative approach ensures certification remains relevant, effective, and aligned with evolving environmental policies and technologies. By doing so, Positive Carbon Building certification achieves legislative alignment and sets a new sustainability benchmark for the construction industry, driving it towards a more sustainable and regenerative future.

2.4. Limitations in transitioning towards Positive Carbon Buildings

The journey toward Positive Carbon Buildings, designed to produce more energy than they consume and significantly reduce their carbon footprint, faces intrinsic limitations and challenges across the building lifecycle, from design and construction to operation and decommissioning. Addressing these limitations demands an integrated, innovative approach leveraging existing methodologies and pioneering new strategies for genuine sustainability. [15] This section delves into primary challenges encountered and potential strategies to overcome them, as presented in Table 2.

Table 2. Primary challenges and potential strategies in transitioning towards Positive Carbon Buildings.

Limitation	Challenge	Strategies
Embodied Emissions and Energy	Measuring embodied energy and emissions of building materials and equipment, especially for innovative products lacking established Environmental Product Declarations (EPDs).	Encourage EPD production, promote Life Cycle Assessment (LCA) tools, and support innovation in material development to mitigate embodied emissions.

Operational Limitations	Ensuring buildings operate in line with green user manuals to achieve projected energy efficiency and sustainability goals.	Develop user education programs, implement smart building technologies, and utilize performance monitoring for efficient operation. [16]
Focus on Energy Usage vs. Carbon Emissions	Overlooking energy source in energy efficiency efforts may indirectly contribute to carbon emissions.	Prioritize on-site renewable energy generation, enhance energy storage and demand response, and procure green energy to ensure carbon neutrality.
Emissions Offset as a Last Resort	Relying solely on emissions offsetting does not address direct emissions reduction.	Establish a hierarchy of carbon reduction strategies, verify offsets credibility, and prioritize direct emissions reduction.
Difficulty in Calculating Whole Range of Emissions	Accurately calculating building emissions, including indirect ones, is complex.	Develop comprehensive carbon accounting frameworks, advance simulation and modeling tools, and standardize emissions calculation methodologies.

Overcoming these limitations necessitates a collaborative effort from policymakers, developers, manufacturers, and occupants to move towards Positive Carbon Buildings. By addressing challenges related to embodied emissions, operational practices, energy usage, and emissions calculation, the construction industry can strive for buildings that minimize harm and actively contribute to environmental regeneration. This journey requires innovation, stakeholder engagement, and continuous refinement of methodologies to realize sustainable, positive carbon buildings.

2.5. Co-Design with Residents for Positive Buildings

Engaging residents in the co-design process is pivotal towards creating Positive Buildings—structures that contribute more to the environment than they take. [17] This chapter outlines the steps necessary to effectively collaborate with residents, ensuring that the outcome not only meets sustainability goals but also aligns with the needs, the preferences, and the values of those who inhabit these spaces. This participatory approach nurtures a feeling of ownership and responsibility among residents, leading to better adherence to sustainable practices and a more profound appreciation for the building's positive impact.[18]

The initial phase of co-design involves laying down the foundations for effective resident participation. This includes organizing informational sessions to introduce the concept of Positive Buildings, elucidating the environmental, economic, and health benefits that these buildings offer. Success in this phase is measured by the establishment of a common vision and understanding between designers, builders, and future residents, as detailed in Table 3. [19]

As the co-design process culminates, reaching a consensus on the final design becomes paramount. This stage involves synthesizing the collective input into a design that balances sustainability goals with resident preferences. Final review sessions are conducted to ensure that the design meets the agreed-upon criteria, with modifications made as necessary to align with the project's vision.

The implementation phase transitions the project from concept to reality. It is crucial at this stage to maintain the principles of sustainability and resident engagement, ensuring that the construction and operational phases reflect the co-design's outcomes [22]. Continuous feedback mechanisms are established to monitor the building's performance and resident satisfaction, allowing for adjustments that enhance sustainability and livability. [23]

An integral component of the co-design process is the ongoing education of residents about sustainable living practices. Through workshops, seminars, and resource-sharing, residents are

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equipped with the knowledge to actively participate in the building's sustainability efforts, from energy conservation to waste reduction.

This educational endeavor aims to cultivate a community of environmental stewards, where residents are not only informed about sustainability practices but are also motivated to advocate for and adopt these practices in their daily lives. The establishment of resident-led sustainability committees can further this aim, fostering a culture of continuous improvement and engagement.

Co-designing Positive Buildings with residents is a comprehensive process that requires time, commitment, and effective communication among all stakeholders. By actively involving residents in the design process, developers and architects can create buildings that not only achieve ambitious environmental goals but also provide living spaces that are genuinely valued and cared for by those who inhabit them. This participatory approach not only enhances the sustainability and functionality of buildings but also strengthens community ties, creating a shared sense of purpose and responsibility towards achieving a more sustainable future. The diversity of resident backgrounds and perspectives enriches the design process, introducing innovative solutions to sustainability challenges. Residents, equipped with their unique experiences and insights, contribute to the creation of spaces that are not only environmentally sustainable but also culturally and socially vibrant. [24]

The co-design process with residents represents a pivotal shift in the approach to creating Positive Buildings. By involving residents in the design process, buildings are transformed into spaces that truly reflect the needs, preferences, and values of their inhabitants.

Table 3. Steps towards Co-Design with Residents for Positive Buildings.

Step	Objective	Activity
Utilize digital platforms and physical models	Visualize the impact of their choices, fostering a more inclusive and informed decision-making process	Workshops and interactive sessions serve as platforms for idea exchange, ensuring that residents' voices are heard and integrated into the design.
Resident involvement	Establish the foundation for resident involvement by raising awareness about the project's goals, benefits, and the importance of their contribution.	Conduct informational sessions to introduce the concept of Positive Buildings and the co-design process. Share success stories and potential benefits (environmental, economic, and health-related) to motivate participation.
Education and Capacity Building.[20]	Equip residents with the necessary knowledge and skills to effectively engage in the co-design process.	Organize workshops on sustainable living, energy efficiency, and the principles of Positive Buildings. Provide resources and training on how to assess and articulate needs, preferences, and ideas for sustainable features. [21]
Needs Assessment and Visioning	Collect detailed information on the residents' needs, aspirations, and ideas for their living spaces.	Facilitate visioning workshops where residents can express their desires for the building's design and functionality. Use surveys or interviews to gather individual input and identify common themes and priorities.

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Co-Design Workshops	Collaboratively develop design concepts that integrate sustainability features with the residents' identified needs and preferences.	Organize interactive co-design sessions, involving architects, engineers, and residents, to brainstorm and refine ideas for the building. Utilize models, drawings, or digital design tools to visualize design options and facilitate decision-making.
Feedback and Iteration	Refine the co-designed solutions based on feedback, ensuring they align with both sustainability goals and residents' expectations.	Present preliminary design concepts to the resident community for feedback. Conduct iterative workshops to refine the designs based on the feedback received.
Implementation and Monitoring	Implement the co-designed solutions and monitor the building's performance and resident satisfaction.	Oversee the construction process to ensure the designs are executed as planned. After occupancy, monitor the building's environmental performance and residents' adherence to sustainable practices. Organize regular meetings with residents to discuss any issues, gather feedback, and propose adjustments if necessary.
Education and Continuous Engagement	Ensure long-term success by maintaining an ongoing relationship with residents, focusing on education and engagement.	Provide ongoing support and education to residents about how to make the most of the building's sustainable features. Establish a resident-led sustainability committee to foster a continuous culture of sustainability and innovation.

3. A Holistic Approach Towards the Assessment of a Positive Carbon Building

Assessing a Positive Carbon Building [25] requires a holistic approach that encompasses various aspects of the building's lifecycle and its interaction with the environment and energy systems. This assessment involves a detailed evaluation of operational carbon emissions, embodied carbon materials, energy efficiency, renewable energy production, and carbon sequestration methods, considering the entire lifecycle of the building. A framework for conducting such an assessment is described below:

3.1. Lifecycle Assessment (LCA) in Positive Carbon Building Development

Lifecycle Assessment (LCA) serves as a critical analytical tool in the sustainable development of Positive Carbon Buildings, providing a comprehensive evaluation of the environmental impacts associated with all stages of a building's life cycle. This section delves into the specific applications of LCA in material sourcing, embodied carbon assessment, and the construction phase, outlining objectives, methodologies, and strategies aimed at minimizing the carbon footprint of building projects.

The primary objective in this aspect of LCA is to assess and mitigate the carbon footprint resulting from the production, transportation, and implementation of building materials.

This phase focuses on identifying materials that offer environmental advantages in terms of lower embodied carbon, thus contributing significantly to the sustainability of the building project from its inception.

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Utilizing advanced LCA tools enables the precise quantification of embodied carbon across a wide array of materials, from the point of extraction through to manufacturing and delivery to the construction site. This meticulous approach ensures that decision-makers are equipped with accurate data to guide the selection of materials, favoring those with minimized carbon impacts. [26]

A key strategy involves the prioritization of materials that are not only low in embodied carbon but also boast high recycled content and originate from verified sustainable operations. The adoption of Environmental Product Declarations (EPDs) is encouraged, offering transparent documentation of a material's environmental impact, including its carbon emissions. This transparency supports informed decision-making in material selection, fostering a more sustainable construction ecosystem.

3.2. Construction Phase

The construction phase presents unique challenges and opportunities in the pursuit of sustainability. The objective is to implement construction practices that are not only efficient and minimize waste but also significantly reduce the carbon emissions associated with construction activities.

Adopting methodologies that emphasize waste reduction, optimal material usage, and minimal site disturbances form the cornerstone of sustainable construction practices. Special attention is given to the carbon emissions stemming from construction machinery and temporary works, with a focus on identifying and mitigating these sources of carbon output.

Strategies to achieve these objectives include the utilization of prefabrication and modular construction techniques. These methods offer numerous advantages, such as reducing the amount of on-site construction emission and waste, improving material efficiency, and shortening construction timelines. By pre-assembling components in a controlled factory setting, it's possible to achieve higher precision, reduce material overruns, and minimize the environmental impact typically associated with traditional construction methods.

The integration of Lifecycle Assessment (LCA) in the development of Positive Carbon Buildings underscores a commitment to environmental stewardship from the earliest stages of a project. By meticulously evaluating and optimizing material sourcing and construction practices, LCA facilitates a profound reduction in the carbon footprint of building projects. This holistic approach not only aligns with the sustainability goals of Positive Carbon Buildings but also sets a new standard in the construction industry, promoting practices that contribute to a more sustainable and environmentally responsible future.

Operational Lifecycle Assessment (LCA) [27], exemplified by tools like VERIFY, represents an advanced and dynamic approach to measuring and managing the environmental impact of buildings during their use phase. This section explores how operational LCA tools, particularly VERIFY, contribute to the overarching goals of Positive Carbon Buildings by ensuring ongoing sustainability and efficiency throughout the operational life of a building.

3.3. Operational Carbon Emissions

Performing energy modeling from the design phase to optimize the building's thermal performance, natural light utilization and HVAC system efficiency represents the key for the reduction of the energy demand of the building, as well as for the minimization of the operational carbon emissions. [28] The following strategies can be implemented: incorporation of the passive design strategies, high-performance building envelopes, efficient mechanical and electrical systems.

Assessing the potential for onsite renewable energy generation (solar, wind, geothermal) and integrate systems capable of exceeding the building's energy demand will enable the building to produce more renewable energy than it consumes, contributing to a cleaner energy grid. [29] The recommended strategies for achieving the goals include the design for maximum

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solar panel efficiency, the consideration of the wind turbines (if feasible), as well as the possibility of using geothermal systems for heating and cooling.

Including materials that have carbon sequestering capabilities and design landscapes that enhance carbon absorption allow the implementation of strategies within the building and its site that actively remove carbon dioxide from the atmosphere. The following are recommended: the use of bio-based materials and green roofs, while ensuring that the site includes vegetation that is native and conducive to high rates of carbon sequestration.

Designing for disassembly and reuse of building components and materials allows the decommissioning or repurposing of the building to minimize waste and emissions at the end of its useful life. The strategies are focused on incorporating materials that can be easily recycled or repurposed, documentation of materials and construction methods to facilitate future deconstruction.

Ensuring that the building's performance meets the Positive Carbon Building criteria throughout its lifecycle can be achieved by employing green building certifications that encompass energy efficiency, renewable energy, and carbon sequestration. Also, it is recommended to implement monitoring systems to track energy production, consumption, and overall carbon footprint. It is advisable to seek certifications that align with the principles of Positive Carbon Buildings, such as LEED, BREEAM, GREEN HOMES or the Living Building Challenge, with a focus on their most stringent sustainability and carbon reduction standards.

The assessment of a Positive Carbon Building is an intricate process that demands a comprehensive understanding of the building's environmental impact over its entire lifecycle. By focusing on reducing embodied and operational carbon, enhancing energy efficiency, maximizing renewable energy production, and incorporating carbon sequestration methods, buildings can move beyond mere sustainability towards being truly regenerative. This holistic approach not only mitigates the impact of climate change but also contributes positively to the environment, setting a new standard for the future of construction and real estate development.[30]

3.4. Relevant Tools

In the development and assessment of Positive Carbon Buildings, leveraging the right tools and adhering to recognized standards is crucial for accurate measurement, verification, and improvement of their environmental performance. The tools and standards are presented below, detailing how they can be effectively incorporated into the certification process [31]:

3.4.1. The Role of Operational LCA

Operational LCA focuses on the environmental impacts associated with the day-to-day use of a building, including energy consumption, water use, and waste generation. Unlike traditional LCA, which often focuses on the design and construction phases, operational LCA provides a continuous assessment framework for the operational phase, offering insights into the real-time environmental performance of buildings.

VERIFY stands as a prominent example of an operational LCA tool designed to monitor, analyze, and report on the environmental impact of buildings in operation. It enables building managers and occupants to understand the carbon footprint associated with their energy use, water consumption, and waste generation, providing a platform for informed decision-making and targeted interventions – Table 4.

Table 4. Features and Capabilities of VERIFY.

Feature	Capability
Real-Time Monitoring	VERIFY utilizes sensors and smart meters to collect real-time data on various environmental parameters, including energy and water usage, indoor air quality, and waste production.

Data Analysis and Reporting	The tool analyzes collected data to assess the building's environmental performance, generating reports that highlight areas of efficiency and pinpoint opportunities for improvement.
Benchmarking	VERIFY allows for the comparison of a building's performance against established sustainability benchmarks or similar buildings, fostering a competitive spirit aimed at reducing environmental impacts.
Customizable Dashboards	Users can access customizable dashboards that present complex environmental data in an accessible and understandable format, empowering them to make data-driven sustainability decisions.

Operational LCA tools like VERIFY are indispensable in the quest for Positive Carbon Buildings, offering a dynamic and continuous approach to measuring and improving the environmental impact of buildings in use. By providing detailed insights into a building's operational performance, VERIFY empowers stakeholders to make informed decisions that lead to significant environmental improvements.

This continuous feedback loop not only ensures that buildings meet their designed sustainability targets but also fosters an adaptive management approach that responds to changing conditions and evolving best practices. Through the integration of operational LCA, Positive Carbon Buildings can achieve their ambitious goals, contributing to a sustainable future and setting a new standard for environmental responsibility in the built environment.

Table 5. Strategies for Implementing VERIFY in Positive Carbon Buildings [32].

Strategy	Description
Integration with Building Management Systems (BMS)	Linking VERIFY with existing BMS ensures seamless data collection and enables automated control adjustments based on real-time environmental performance insights.
Occupant Engagement	Engaging occupants through the VERIFY platform by providing them with access to their own consumption data encourages responsible usage patterns and promotes a culture of sustainability within the building.
Continuous Improvement	Utilizing the insights gained from VERIFY, building managers can implement targeted sustainability initiatives, such as energy efficiency upgrades, water-saving measures, and waste reduction programs, ensuring continuous improvement in environmental performance.

Carbon Verify can be used as a tool for tracking, reporting, and verifying carbon emissions from building options. It helps in identifying key areas where emissions can be reduced and in verifying the effectiveness of implemented strategies. Integration with continuous monitoring systems ensures real-time data accuracy and facilitates immediate adjustments to operational practices to minimize carbon emissions.

3.4.2. Life Cycle Assessment (LCA) Based on Standard EN 15978:2011

In the pursuit of creating buildings that not only meet but significantly exceed current environmental performance standards, the application of Life Cycle Assessment (LCA) based on the EN 15978:2011 standard [33] emerges as a critical tool. This section delves into how these standard serves as a cornerstone in evaluating and enhancing the sustainability of buildings throughout their entire lifecycle.

The primary aim underpinning the use of EN 15978:2011 in LCA is to rigorously evaluate a building's environmental performance across all phases of its life, striving to achieve at least 50% better performance than established baselines. This ambitious goal underscores a commitment

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to not just incremental improvements but significant strides in reducing the environmental impact of the built environment.

The Holistic Scope of EN 15978:2011 provides a structured framework for conducting LCA on buildings, covering the spectrum from material sourcing to construction, operation, and eventual decommissioning. This standard emphasizes a holistic evaluation, ensuring that all aspects of a building's environmental impact are accounted for, including:

- Embodied Carbon: Assessing the carbon footprint associated with the production, transportation, and installation of building materials; evaluating the consumption of resources, such as water and energy, throughout the building's life; analyzing the waste produced during construction, operation, and decommissioning phases, aiming for reduction and responsible management. [34]
- Guiding Sustainable Decision-Making: by adhering to the EN 15978:2011 standard, project teams are equipped with a comprehensive methodology to make informed decisions that significantly lower the environmental footprint of buildings. This includes selecting low-impact materials, employing construction techniques that minimize waste, and designing for energy efficiency and reduced water usage.
- Integration with Design and Construction Processes: successfully implementing LCA based on EN 15978:2011 requires its integration into the design and construction processes from the outset. Architects, engineers, and developers must collaborate closely, using LCA findings to guide material selection, architectural design, and construction practices that align with sustainability objectives.
- Leveraging Technology for Enhanced Accuracy: the application of advanced software tools and databases that support EN 15978:2011 enables precise calculation and analysis of environmental impacts. These tools facilitate the detailed assessment of various design and construction alternatives, allowing project teams to optimize environmental performance.
- Continuous Performance Monitoring: adopting a lifecycle perspective means that the evaluation of environmental performance extends into the operation and maintenance phases of the building. Continuous monitoring of energy use, water consumption, and waste production ensures that the buildings performance remains aligned with the initial sustainability targets set forth by the LCA. [35]

The adoption of LCA based on the EN 15978:2011 standard represents a transformative approach to building design and construction, one that places environmental performance at the forefront of decision-making. By providing a structured, comprehensive framework for assessing and improving the sustainability of buildings, EN 15978:2011 not only facilitates compliance with ambitious environmental targets but also drives innovation in sustainable building practices. As the construction industry continues to evolve towards greater sustainability, standards like EN 15978:2011 will play a pivotal role in shaping the future of the built environment, ensuring that buildings contribute positively to both the planet and its inhabitants.

3.4.3. Energy Calculations: IES VE PRO/National nZEB Standards

In the endeavor to align building projects with the ambitious thresholds set by nZEB standards, the integration of advanced energy modeling and analysis tools becomes indispensable. This section delves into the strategic application of IES VE PRO, a premier modeling software, in conjunction with national nZEB standards, showcasing how this synergy fosters the creation of buildings that not only adhere to but also surpass these rigorous energy efficiency benchmarks.

The primary aim of employing detailed energy modeling and analysis through tools like IES VE PRO is to refine and optimize the energy performance of buildings, ensuring they meet and excel beyond the criteria established by national nZEB standards. This process involves a meticulous evaluation of various design and operational parameters to minimize energy consumption and maximize the use of renewable energy sources.

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IES VE PRO stands at the forefront of energy modeling technology, offering a comprehensive suite of features that enable detailed simulation of a building's energy dynamics. Its capabilities extend to analyzing energy consumption, thermal comfort, and daylighting, among other critical factors that influence a building's energy profile. By providing a virtual environment to test and refine design strategies, IES VE PRO empowers architects and engineers to make informed decisions that enhance the building's overall energy performance.

The fusion of IES VE PRO's analytical prowess with the guidelines provided by national nZEB standards forms a potent combination that drives the sustainable design process. This integration ensures that buildings are not only designed to meet the minimum energy performance requirements but are also optimized to reduce or negate net energy consumption [36] through strategic incorporation of on-site renewable energy production.

A Multi-Dimensional Approach needs to take into consideration the following strategies for implementation:

- Design Optimization: Utilizing IES VE PRO in the early stages of design allows for the exploration of various architectural and engineering solutions, such as optimal building orientation, envelope design, and material selection, that significantly impact energy efficiency.
- Renewable Energy Integration: The tool facilitates the precise calculation of renewable energy potential, enabling designers to seamlessly integrate solar panels, wind turbines, or other renewable energy systems into the building design, thereby enhancing the project's alignment with nZEB standards.
- Thermal Comfort and Daylighting [37]: By simulating thermal comfort levels and natural lighting, IES VE PRO aids in creating spaces that not only save energy but also improve occupant well-being, contributing to the broader goals of sustainability.

The application of IES VE PRO in conjunction with national nZEB standards represents a paradigm shift in the approach to sustainable building design. By enabling detailed energy modeling and analysis, this methodology paves the way for the development of buildings that excel in energy efficiency, embodying the principles of the nearly Zero Energy Building standards. [38,39] As the construction industry continues to advance towards sustainability, the role of sophisticated modeling tools like IES VE PRO will become increasingly central, driving innovation and excellence in the design of future-proof buildings that harmonize with the environment. [40]

3.4.4. Green Power and Carbon Offsets

As the construction and real estate sectors push towards the lofty goal of creating buildings that not only minimize their environmental impact but also contribute positively to the planet, the role of green power purchases and carbon offsets becomes increasingly pivotal. This section explores the strategic utilization of EKOenergy and Guarantees of Origin (GOs) with additional criteria as reputable frameworks for enhancing the renewable energy credentials of buildings and compensating for their unavoidable emissions.

The core objective of integrating green power and carbon offsets into the sustainability strategy of buildings is twofold: to directly support the transition towards renewable energy sources and to compensate for those emissions that are unavoidable, despite best efforts in design and operational efficiency. This dual approach ensures that buildings can achieve a net positive impact on the environment, aligning with the principles of Positive Carbon Buildings.

EKOenergy and Guarantees of Origin (GOs) with additional criteria provide reputable frameworks for purchasing renewable energy and carbon offsets. EKOenergy ensures that purchased green power meets strict sustainability and consumer protection criteria, while GOs with additional criteria ensure that the energy is sourced from renewable facilities that meet higher environmental standards.[41]

EKOenergy stands out as a label for electricity that not only confirms its renewable origin but also guarantees that its production meets stringent environmental and ethical standards. By choosing EKOenergy-certified power, buildings contribute to projects that have a demonstrable

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positive impact on conservation, support for local communities, and the advancement of renewable energy technologies. This label ensures that the green power purchased does not merely represent a token effort but is part of a broader, meaningful contribution to sustainability.

Guarantees of Origin (GOs) serve as a mechanism to certify the renewable source of electricity. However, GOs with additional criteria go a step further by ensuring that the energy is not only green but also sourced from facilities that adhere to higher environmental standards. These might include stricter controls on biodiversity impacts, enhanced community engagement, or additional measures to minimize any negative environmental effects.

By integrating these tools and standards into the assessment and certification process of Positive Carbon Buildings, stakeholders can ensure a rigorous, transparent, and effective approach to sustainability. These mechanisms not only facilitate the accurate measurement and reduction of environmental impacts but also guide improvements in design, construction, and operation that contribute to the building's overall positive impact on the planet [42]. Through this structured and standardized approach, the vision of truly sustainable, carbon-positive buildings can be realized, setting new benchmarks for the industry and contributing to global environmental goals.

An effective implementation of green power and carbon offsets into the sustainability strategy of buildings needs to take into consideration the following strategies:

- Integrating Green Power and Carbon Offsets into Building Design and Operation: Early planning and integration of these mechanisms can optimize the environmental performance of buildings from the outset. This involves not only the purchase of green power and offsets but also designing buildings to be operationally compatible with high levels of renewable energy use.
- Transparency and Stakeholder Engagement: Transparently communicating the use of EKOenergy and GOs with additional criteria builds trust among stakeholders, including occupants, investors, and the wider community. Engaging these groups in the decision-making process regarding green power purchases and offsets foster a shared commitment to sustainability goals.
- Continuous Evaluation and Adaptation: The effectiveness of green power purchases and carbon offset strategies should be regularly evaluated and adapted in response to changes in renewable energy markets, technological advances, and evolving environmental standards. This dynamic approach ensures that the sustainability strategy remains relevant and impactful.

By adopting reputable frameworks such as EKOenergy and Guarantees of Origin with additional criteria, stakeholders in the construction and real estate sectors can ensure their buildings not only reduce their environmental footprint but also actively contribute to global sustainability efforts. These mechanisms offer a transparent, effective way to support renewable energy adoption and compensate for unavoidable emissions, driving the transition towards truly sustainable, carbon-positive buildings. This strategic approach not only sets new benchmarks for environmental performance in the industry but also aligns with broader goals of habitat conservation, pollution reduction, and the promotion of renewable energy projects, marking a significant step forward in the journey towards sustainable development.

3.4.5. National Carbon Offset Projects

An exclusive option becomes available as a unique opportunity to contribute to carbon sequestration efforts actively at national level. Herein, we detail the options focusing on supporting approved carbon sequestration initiatives active within Romania:

- National Urban Composting Program - Zero Waste Romania: The National Urban Composting Program represents an innovative approach to reducing organic waste in urban areas while contributing to soil enrichment and carbon sequestration. This program aligns with the principles of the circular economy, transforming organic waste into valuable

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compost that aids in carbon fixation in the soil, thereby reducing the overall carbon footprint of urban environments. [43]

- Continuous Expansion and Rigorous Evaluation - The list of approved carbon sequestration projects is subject to continuous updates, with new initiatives being added weekly. These projects, proposed by partners and other stakeholders, under a rigorous evaluation process conducted by an independent committee of the Romania Green Building Council (RoGBC). This ensures that only the most impactful, sustainable, and credible projects are supported, aligning with the overarching goals of promoting environmental sustainability and carbon positivity.

Table 6. This Overview of RoGBC methodology scorecard.

Code	Description	Type	Example of Threshold
A1	Integrated Design	Requirement	At least 1 kick-off meeting
A2, A3	Life Cycle Assessment	Requirement	LCA report must cover at least 80%-95% of materials
A4	Education for Design and Execution Teams	Score	Attend a minimum of 3 courses
A5, A5.1	Construction Waste Management	Requirement	Diversion, sorting, reuse and recycling rates for waste
A6	Responsible Construction Practices	Requirement	Implement 80% of pollution prevention measures
A7, A8	Operational Waste Management	Requirement	Systems for sorting at least three waste categories
A9	Performance Period: Waste	Score	70% recycling earns 7 points
A10	Material Optimization and Ecodesign	Score	Demonstrates circularity and resource efficiency
B1	Education for FM/Ensuring Green Performance	Requirement	Manual for green operation of the home
B2	Transparency and Information Sharing	Requirement	Share energy and water usage data
B3	Heat Island Effect Reduction	Score	Use of high SRI materials, vegetative or cool roofs
B4	Reduced Light Pollution	Score	Lighting design adheres to specific standards
C1	Significant CO2 Emissions Reduction	Score	10% better than nZEB or specific energy performance
C2	White Goods	Score	Minimum A class energy performance for appliances
C5, C6	Commissioning for Mechanical Systems	Score	Fundamental and Enhanced Commissioning reports
C7	Commissioning for Insulation Installation	Score	Report by accredited thermography specialist
C8	Green Power and Carbon Offsets	Score	Support for approved carbon sequestration projects
H1	Various Ideas & Solutions	Score	Up to 10 points for innovative green performance improvements

4. Discussion and Further Directions

The emergence of the Positive Carbon Buildings initiative represents a pivotal response to the urgent need for sustainable development in the face of climate change. By recognizing the significant impact of buildings on global energy consumption and carbon emissions, this initiative aims to redefine the standards for energy performance and environmental impact within the built

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environment. It goes beyond technological advancements and architectural innovation, advocating for a cultural shift in our relationship with constructed spaces. Buildings are no longer structures but dynamic contributors to our ecological system, capable of not only sustaining but enriching our environment.

Aligned with broader environmental ambitions like the European Green Deal, the Positive Carbon Buildings initiative integrates principles of circular economies, emphasizing the importance of considering a building's entire lifecycle. By prioritizing renewable energy integration, energy efficiency measures, material sustainability, and legislative alignment, Positive Carbon Buildings not only meet but exceed stringent criteria while contributing to the EU's climate goals.

However, transitioning towards Positive Carbon Buildings faces inherent challenges across the building lifecycle, from design to decommissioning. These challenges include measuring embodied emissions, ensuring operational sustainability, balancing energy usage with carbon emissions, and navigating emissions offsetting. Overcoming these obstacles demands collaborative efforts from stakeholders, innovation in methodologies, and continuous refinement of strategies.

Furthermore, engaging residents in the co-design process is essential for creating buildings that align with their needs, preferences, and values. Initiatives such as informational sessions, capacity-building workshops, visioning exercises, and iterative design workshops foster inclusivity, ownership, and responsibility among residents, leading to better adherence to sustainable practices and a deeper appreciation for the building's positive impact.

In essence, the Positive Carbon Buildings initiative not only presents a vision for environmentally conscious construction practices but also offers a pathway towards a regenerative future. By seizing this opportunity and working collaboratively across sectors, we can create a built environment that not only exists within ecological limits but actively enriches them, setting a new standard for sustainability and resilience in the face of climate change.

Discussions on this topic hold significant relevance across various sectors. From the perspective of non-governmental organizations (NGOs), academia, and civic groups, the primary goal is to enhance the quality of the living environment. This involves creating sustainable, healthy, and efficient spaces that contribute positively to the well-being of communities and the environment. In contrast, the entrepreneurial sector views this methodology and the future accreditation of buildings through a financial lens. For businesses, the adoption of these practices can translate into substantial economic benefits, taxonomy. For instance, buildings that meet certain accreditation standards might qualify for tax reductions, which can significantly lower operational costs. Additionally, such accredited buildings may also be eligible for loans with more favorable interest rates, facilitating more affordable financing for future investments. This financial incentive encourages developers and property owners to invest in sustainable building practices, leading to a broader adoption of environmentally friendly and energy-efficient construction methods. Consequently, while the motivations may differ, the collaborative efforts across these various sectors ultimately contribute to the common goal of improving the living environment, demonstrating that economic and ecological interests can align harmoniously.

5. Conclusions

The RoGBC methodology, alongside other methodologies introduced in the article, forms part of the European REN+ HOMES project. Centered on the core concept of energy efficiency, each partner has contributed their unique approach. The overarching objective of the project is to forge a unified methodology that harmonizes diverse perspectives rather than promoting one over another.

The article specifically delves into the ROGBC methodology, highlighting its distinctive strength in its emphasis on innovation as a separate criterion.

Unlike traditional assessment frameworks, which often integrate innovation into broader categories, the RoGBC methodology elevates it as a pivotal element. This approach not only underscores the importance of pioneering solutions in the sustainable building sector but also incentivizes stakeholders to push the boundaries of current practices.

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By isolating innovation as a standalone metric, the RoGBC methodology encourages developers, architects, and engineers to prioritize creative problem-solving and the adoption of cutting-edge technologies. This can lead to more substantial advancements in green building practices, fostering a culture of continuous improvement and excellence. The emphasis on innovation also facilitates the identification and dissemination of best practices, contributing to the overall evolution of the industry.

Another aspect of the methodology is its classification system. This system is executed tabularly based on a points system, allowing beneficiaries to easily identify areas of deficiency. By presenting the evaluation results in a clear, tabular format, stakeholders can quickly grasp their performance across various criteria. This visual representation simplifies the complex process of assessment, making it more accessible and actionable.

The tabular classification method breaks down the overall evaluation into distinct categories, each assigned a specific number of points. This granularity provides detailed insights into specific strengths and weaknesses, enabling targeted improvements. For instance, if a project score lowers in energy efficiency but higher in water conservation, the beneficiary can focus efforts on enhancing energy-saving measures.

Furthermore, the points-based system fosters a transparent and objective assessment process. By assigning quantifiable values to different aspects of the project, it eliminates ambiguity and ensures that all evaluations are based on consistent standards. This transparency not only builds trust among stakeholders but also motivates continuous improvement, as progress can be clearly tracked over time.

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