Research Centre on
ZERO EMISSION
NEIGHBOURHOODS
IN SMART CITIES

NTNU SINTEF

# ZEB CERTIFICATES

## Conceptual framework and guiding principles

ZEN MEMO No. 54 – 2024

Raymond Andreas Stokke | NTNU/SINTEF Digital

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# Preface

## Acknowledgements

This memo has been written within the Research Centre on Zero Emission Neighbourhoods in Smart Cities (FME ZEN). The authors gratefully acknowledge the support from the Research Council of Norway, the Norwegian University of Science and Technology (NTNU), SINTEF, the municipalities of Oslo, Bergen, Trondheim, Bodø, Bærum, Elverum and Steinkjer, Trøndelag county, Norwegian Directorate for Public Construction and Property Management, Norwegian Water Resources and Energy Directorate, Norwegian Building Authority, ByBo, Elverum Tomteselskap, TOBB, Snøhetta, AFRY, Asplan Viak, Multiconsult, Civitas, FutureBuilt, Heidelberg Materials, Skanska, GK, NTE, Smart Grid Services Cluster, Statkraft Varme, Renewables Norway and Norsk Fjernvarme.

## The Research Centre on Zero Emission Neighbourhoods (ZEN) in Smart Cities

The ZEN Research Centre develops solutions for future buildings and neighbourhoods with no greenhouse gas emissions and thereby contributes to a low carbon society.

Researchers, municipalities, industry and governmental organizations work together in the ZEN Research Centre in order to plan, develop and run neighbourhoods with zero greenhouse gas emissions. The ZEN Centre has nine pilot projects spread over all of Norway that encompass an area of more than 1 million m2 and more than 30 000 inhabitants in total.

In order to achieve its high ambitions, the Centre will, together with its partners:

- Develop neighbourhood design and planning instruments while integrating science-based knowledge on greenhouse gas emissions;
- Create new business models, roles, and services that address the lack of flexibility towards markets and catalyze the development of innovations for a broader public use; This includes studies of political instruments and market design;
- Create cost effective and resource and energy efficient buildings by developing low carbon technologies and construction systems based on lifecycle design strategies;
- Develop technologies and solutions for the design and operation of energy flexible neighbourhoods;
- Develop a decision-support tool for optimizing local energy systems and their interaction with the larger system;
- Create and manage a series of neighbourhood-scale living labs, which will act as innovation hubs and a testing ground for the solutions developed in the ZEN Research Centre. The pilot projects are Furuset in Oslo, Fornebu in Bærum, Sluppen and Campus NTNU in Trondheim, Mære Campus, Ydalir in Elverum, Campus Evenstad, Ny by-ny flyplass Bodø, and Zero Village Bergen.

The ZEN Research Centre will last eight years (2017-2024), and the budget is approximately NOK 380 million, funded by the Research Council of Norway, the research partners NTNU and SINTEF, and the user partners from the private and public sector. The Norwegian University of Science and Technology (NTNU) is the host and leads the Centre together with SINTEF.

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## Abstract

This memo introduces Zero Emission Building (ZEB) certificates as a specialized form of carbon certificates designed specifically for the building industry, aimed at fostering sustainable development and reducing greenhouse gas emissions. These certificates act as market-based instruments within cap-and-trade systems, incentivizing emission reduction through renewable energy, afforestation, and energy efficiency projects. By assigning a financial value to carbon savings, ZEB-certificates incentivises the building sector to adopt greener practices, contributing to climate change mitigation efforts and aligning with both Norwegian and international GHG reduction targets.

ZEB-certificates are proposed as a structured process including quantification, verification, certification, trading, and retirement of emissions reductions, all under the oversight of regulatory bodies and standard-setting organizations. This framework is designed to ensure the integrity and effectiveness of emission reduction claims, facilitating the transition to low-carbon building materials and practices. The system encourages the use of innovative technologies such as low-carbon concrete, which, despite higher initial costs, can become financially viable through the market mechanisms provided by ZEB-certificates.

The market dynamics of ZEB certificates are influenced by a complex interplay of supply and demand factors, which in turn affect pricing and trading within the carbon market. Challenges such as ensuring the additionality and permanence of emission reductions, as well as addressing potential issues like double counting and market transparency, are critical for maintaining the credibility and effectiveness of ZEB-certificates. Addressing these challenges is essential for the future growth and impact of such a certificate market in promoting sustainable building practices.

ZEB certificates hold significant promise for incentivising sustainable practices within the building industry, providing a crucial mechanism for financing and incentivizing emission reductions. Through a well-regulated market system, ZEB-certificates can support the transition to zero-emission buildings and neighbourhoods. Future prospects for ZEB certificates are promising, contingent upon improvements in standardization, transparency, and verification processes to ensure their long-term viability and effectiveness.

# Contents

## 1. Introduction

Zero Emission Building (ZEB) certificates represent a specialized category of carbon certificates tailored for the building industry to encourage sustainable practices and reduce greenhouse gas (GHG) emissions. As a component of market-based mechanisms, ZEB certificates are designed to quantify GHG reduction efforts, with each certificate representing the avoidance or absorption of one metric ton of carbon dioxide (CO2) or its GHG equivalent. These certificates are generated through a variety of environmentally positive projects, including but not limited to, renewable energy initiatives, afforestation efforts, and enhancements in energy efficiency, all contributing to the mitigation of CO2 emissions or the absorption of CO2 from the atmosphere (Eichholtz, Kok, & Quigley, 2010).

## 2. General Purpose and Functioning

The original and general objective of the creation of carbon certificates was to economically incentivize the reduction of GHG emissions. They are integral to cap-and-trade systems implemented by governments or regulatory bodies that set emissions caps and allocate a finite number of certificates. However, these types of certificates have not been very focused in terms of scope and industry. ZEB-certificates are therefore introduced as a specialized measure for the building industry. In this new system, entities in the building industry exceeding their emission allowances can purchase ZEB-certificates for compliance, while those with emissions below their allowances can monetize their surplus certificates. This mechanism effectively rewards and encourages efficient emission reduction strategies within the building sector (Aldy & Stavins, 2012).

Carbon certificates, often referred to as carbon credits or offsets, play a crucial role in global climate change mitigation efforts. They aim to reduce atmospheric levels of CO2 and other GHGs, which are significant contributors to global warming and climate change. By assigning a financial value to carbon emissions, carbon certificates motivate both corporations and individuals to adopt greener and more sustainable practices (Stavins, 2008). These certificates support the achievement of international GHG reduction targets, as outlined in agreements like the Paris Agreement.

The financial incentives provided by carbon certificates encourage investments in sustainable practices, such as the utilization of low-carbon building materials, the integration of renewable energy sources, and the application of energy efficiency measures within the building industry. Such investments not only contribute to environmental protection but also offer financial gains for companies through the sale of generated carbon credits (Ellerman & Buchner, 2007). The operation of carbon certificates within carbon markets exemplifies the application of market efficiency to environmental conservation. Carbon markets facilitate the trade of carbon credits, ensuring that emission reductions are realized in the most cost-effective manner. This market-driven approach enables the identification and adoption of the most economically viable solutions for carbon reduction (Ellerman, Convery, & De Perthuis, 2010).

Revenue from the sale of carbon credits is often directed towards projects that yield dual benefits: they reduce emissions and foster sustainable development. Such projects extend their impact beyond GHG reduction, contributing to improved air and water quality, biodiversity conservation, and community support, thus aligning with broader sustainable development objectives (Goulder & Parry, 2008).

ZEB certificates, as an integral part of the broader carbon certificate framework, can provide a compelling incentive for the adoption of sustainable practices within the building industry. Through the mechanism of cap-and-trade systems and the operational dynamics of carbon markets, these certificates facilitate the cost-effective reduction of GHG emissions, thereby contributing to global climate change mitigation efforts. The dual benefits of emission reduction and sustainable development underscore the value of ZEB-certificates in promoting environmental stewardship and economic sustainability within the building sector.

## 2.1 Functioning

The functioning of ZEB-certificates would involve several key steps and components:

1. Quantification and Verification: Emission reductions or removals must be quantified and verified by independent third parties to ensure their integrity. This involves measuring the emissions reduced or avoided by a project and comparing them to a baseline scenario of what emissions would have been without the project.
2. Certification and Issuance: Once verified, these emission reductions are certified by recognized standards (such as the Verified Carbon Standard, Gold Standard, or the Clean Development Mechanism) and issued as ZEB-certificates, where each certificate typically represents one tonne of CO2 equivalent reduced or removed from the atmosphere.
3. Trading: These certificates can then be traded in carbon markets. There are two main types of carbon markets: compliance markets, where entities are legally required to offset their emissions, and voluntary markets, where entities voluntarily choose to offset their emissions for corporate social responsibility reasons or to meet sustainability goals. ZEB-certificates will adhere to the latter.
4. Retirement: When a ZEB-certificate is used to offset an emission, it is "retired" to ensure that each tonne of CO2 equivalent is only counted once. This prevents double counting and ensures the integrity of the emission reduction claim.
5. Regulation and Oversight: Regulatory bodies and standard-setting organizations oversee the functioning of carbon markets, ensuring transparency, integrity, and environmental effectiveness.

Simply put, the ZEB-certificate market is a method that will make it profitable for actors to introduce environmentally friendly technology into the market, even if it is initially unprofitable, in that the costs are distributed among several actors. For certificates in zero-emission buildings, it means transferring part or all of the responsibility for carbon costs and regulatory flexibility to the market. Figure 1 illustrates the overarching system in practice:

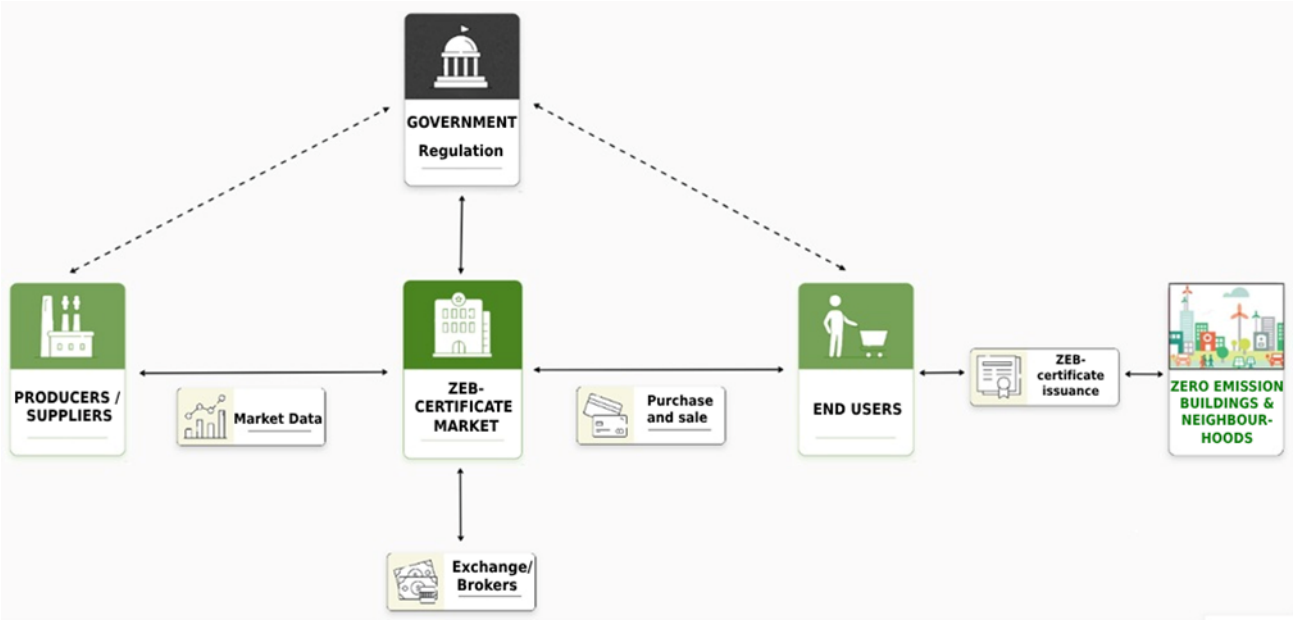


Figure 1. Schematic overview of the proposed ZEB-certificate market (source: author).

The aim of ZEB-certificates in this context is to introduce more emission-free materials such as low-carbon concrete in the building and construction market at the expense of traditional concrete, which has high carbon emissions. This type of low-carbon concrete is as an example too expensive (mainly due to high CCS investment costs among other cement production) to enter the market on traditional commercial terms (Stokke & Kvellheim, 2020). But it can be achieved if a business, struggling to meet its environmental obligations due to lack of investment or high operating costs, finds another party willing to ensure compliance at a lower cost.

Producers, and especially early upstream suppliers in the construction industry, need more instruments to influence the 'greening' of their innovation ecosystem (Stokke et al., 2022). ZEB certificates will be a tool for these. For the producers of, for example concrete, this certificate means an incentive, and for the end users it represents a fee. Both will in theory reduce the concrete price for the suppliers.

Subsidies and fees are restructured among suppliers and end users via traditional market effects.

ZEB certificates are a technology-neutral and industry-specific certification scheme, as is the case with green energy certificates. This will create a level playing field between technological alternatives, with markets and innovation systems determining how best to reduce emissions. As such, technology neutrality can help the process of driving down the prices of clean technology, creating competition as well as innovation in the market. The introduction of ZEB-certificates is expected to transfer obligations in the value chain, increase demand for low-carbon concrete (and other low-carbon building materials), lower producer prices for these types of sustainable materials over time, and reduce the production of traditional concrete.

ZEB-certificates, once scaled, can also play a vital role in the global effort to combat climate change by providing a market-based mechanism to incentivize and finance emission reductions. Their

effectiveness depends on robust standards for measurement, verification, and market regulation to ensure that they deliver real, additional, and long-term benefits for the climate.

### 2.2 Differences and similarities between ZEB-certificates and green certificates

ZEB-certificates and green certificates are both instrumental in supporting sustainable practices and lowering greenhouse gas emissions, yet they operate differently and serve distinct purposes within the environmental regulatory and market frameworks. ZEB-certificates are primarily focused on the reduction of carbon dioxide emissions or other greenhouse gases to combat climate change. They represent a quantifiable reduction in emissions, with one certificate typically equating to one ton of CO2 reduced or sequestered from the atmosphere. These certificates are integral to cap-and-trade systems where entities are mandated to meet certain emission standards and can trade these credits to maintain compliance, thereby incentivizing reductions in greenhouse gas emissions (Stavins, 2008).

On the other hand, green certificates, often referred to as renewable energy certificates (RECs), are designed to promote the generation and consumption of renewable energy. Each green certificate represents a certain amount of renewable energy generated and supplied into the grid, typically measured in megawatt-hours. The primary aim of green certificates is to support the renewable energy sector by providing a financial incentive for energy producers and allowing consumers to contribute indirectly to renewable energy production, even if they cannot generate renewable energy themselves (Gillenwater, 2008).

Despite these differences, carbon and green certificates share the common goal of environmental sustainability and the reduction of carbon footprints. Both serve as market-based mechanisms that translate environmental benefits into tangible financial assets, facilitating a shift towards more sustainable practices in energy production, consumption, and overall corporate operations. By creating a marketplace for these certificates, both firms and individuals can contribute to climate change mitigation efforts and the transition to renewable energy, aligning economic incentives with environmental objectives (Bird, Holt, & Carroll, 2007). A recent study (Chang et al., 2023) show there is broadly some coupling effect between carbon emission trading and tradable green certificates. However, real market processes are highly intricate, and their proposed model is broad depend on various assumptions. Figure 2 illustrates similarities and differences in relation to the energy market:

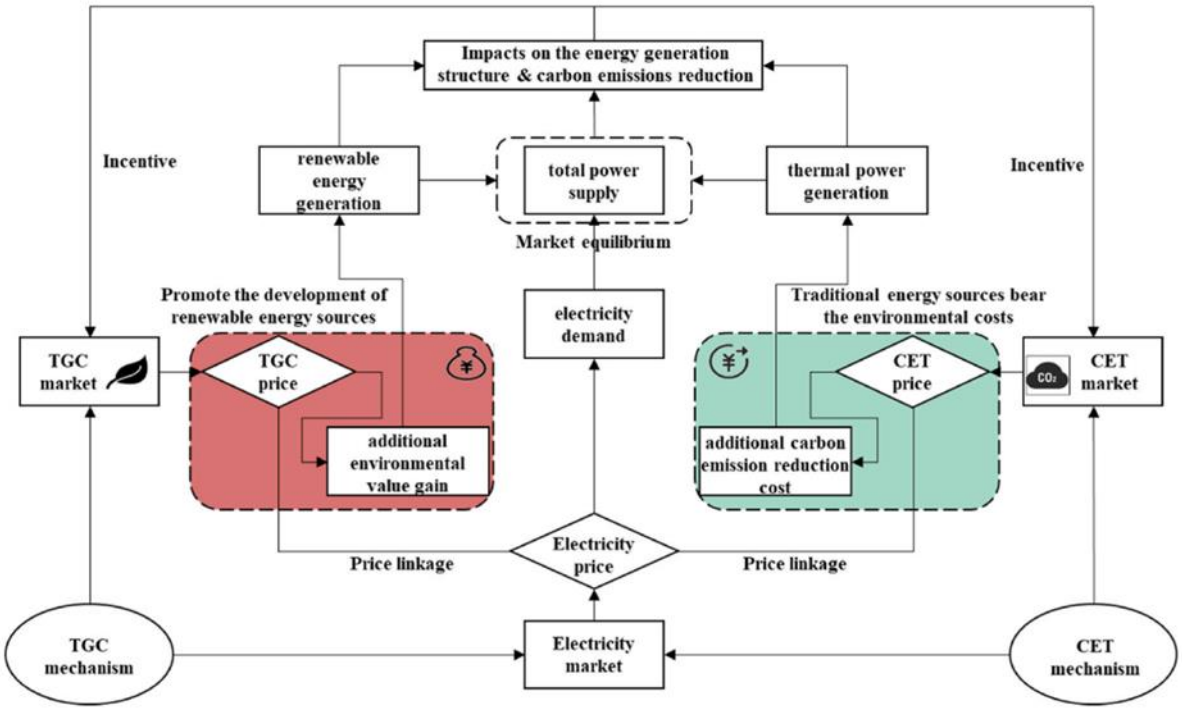


Figure 2. The schematic coupling effect of emission trading and tradable green certificates as well as the electricity market (Chang et al., 2023).

Furthermore, both carbon and green certificates offer flexibility in meeting environmental goals. Entities that find it challenging to directly reduce emissions or generate renewable energy can purchase these certificates to offset their carbon footprint or meet renewable energy targets. This flexibility is crucial for entities with operational constraints or those in regions where direct emission reductions or renewable energy generation is not feasible. This market-driven approach allows for the cost-effective achievement of environmental targets across different sectors and geographies.

While ZEB-certificates and green certificates would operate under different frameworks and serve distinct purposes, they both play crucial roles in the systemic effort to mitigate climate change and promote renewable energy. By providing financial incentives and market-based mechanisms, these certificates help bridge the gap between economic activities and environmental sustainability, encouraging a widespread transition towards a more sustainable and low-carbon future.

## 3. Market Dynamics

The carbon certificate market is divided into two main segments: compliance and voluntary markets. The compliance market is regulated by mandatory national, regional, or international carbon reduction regimes, such as the European Union Emissions Trading System (EU ETS). The voluntary market, on the other hand, caters to entities that voluntarily offset their emissions for corporate social responsibility, branding, or other non-regulatory reasons. ZEB-certificates will in the first phase be underpinned by the voluntary market.

### 3.1 Supply and demand factors

The market dynamics of ZEB-certificates involve a complex interplay of supply and demand factors, regulatory frameworks, and economic incentives, all of which influence the pricing, trading, and effectiveness of carbon markets. The operationalization and technical components of the market is beyond the scope of this memo-report. However, understanding the overarching dynamics is crucial for stakeholders, including governments, businesses, and investors, as they navigate the carbon market to achieve emission reduction targets and sustainability goals.

**Supply Factors**

- Project Development: The supply of ZEB-certificates is primarily driven by the development of projects and technologies that reduce or remove greenhouse gas emissions, such as low-carbon building materials with carbon, capture and storage (CCS), renewable energy installations, reforestation or afforestation projects, and energy efficiency improvements. The ease of project development and the availability of technology significantly impact the supply.
- Certification Standards: The rigor and requirements of various certification standards (e.g., Verified Carbon Standard, Gold Standard) affect the supply of carbon certificates. More stringent standards may result in higher quality but lower quantity of available certificates.
- Geographical Distribution: The geographical distribution of projects also affects supply. Developing countries often host a large number of projects due to lower costs and the potential for sustainable development benefits, which can lead to regional variations in certificate availability.

**Demand Factors**

- Regulatory Requirements: Compliance markets, where entities are legally mandated to offset a portion of their emissions, generate a significant and predictable demand for ZEB-certificates. The stringency of these regulations directly impacts demand.
- Corporate Sustainability Goals: Increasingly, companies voluntarily commit to carbon neutrality or net-zero targets, driving demand in the voluntary carbon market. Corporate social responsibility and consumer pressure can significantly influence this demand.
- Market Speculation: Investors and traders speculating on future price movements of carbon certificates can also influence demand. Expectations about future tightening of emission regulations or an increase in voluntary commitments can lead to increased demand.

**Pricing**

The price of ZEB-certificates is determined by market forces within the context of supply and demand. However, prices can be highly volatile due to:

- Changes in regulatory policies or international agreements.
- Economic fluctuations affecting industries that are significant buyers or sellers of certificates.
- Technological advancements that alter the cost-effectiveness of emission reduction projects.
- Variations in the perceived quality or integrity of different certification standards.

**Market Mechanisms**

In compliance markets, a cap is set on the total amount of emissions allowed, and entities are allocated or must purchase emission allowances (MacKenzie, 2009; Narassimhan et al., 2018). Entities that reduce their emissions below their allowance can sell excess allowances or ZEB-certificates to those who

exceed their limits. Both in compliance and voluntary markets, entities can purchase ZEB-certificates to offset their emissions. This allows for flexibility in meeting emission reduction targets and supports emission reduction projects. Some carbon markets are linked, allowing for the trading of ZEB-certificates across different jurisdictions. This can lead to more efficient global carbon pricing and emission reductions but also requires harmonization of standards and regulations.

As such, understanding the market dynamics of ZEB-certificates is essential for effectively leveraging carbon markets to drive emission reductions and achieve climate goals. Continuous improvement of market mechanisms, standards, and regulatory frameworks is needed to enhance the efficiency, transparency, and integrity of carbon markets.

### 3.2 Benefits

ZEB-certificates offer multiple benefits. They provide a flexible and economically efficient means for entities to meet their carbon reduction targets. By placing a monetary value on carbon, they make environmental protection a tangible part of financial decision-making. Moreover, many carbon offset projects deliver additional social, economic, and environmental benefits, such as biodiversity conservation, job creation in rural areas, and improved air and water quality (McAfee, 2016; Orlando, 2002).

ZEB-certificates offer a range of benefits that extend beyond their immediate purpose of reducing greenhouse gas emissions. These benefits encompass environmental, economic, and social dimensions, contributing to sustainable development and climate change mitigation efforts worldwide (Bustamante et al., 2014; Singh, 2009).

Environmental Benefits**:**

- Climate Change Mitigation: The primary benefit of ZEB-certificates is their contribution to the reduction of greenhouse gases in the atmosphere, directly addressing the global challenge of climate change. By providing a quantifiable mechanism to offset emissions, ZEB-certificates encourage the adoption of cleaner, low-carbon technologies and practices.
- Promotion of Renewable Energy: Carbon markets incentivize investment in green energy initiatives such as wind, solar, and hydroelectric power, by making them more financially viable. This not only decreases dependence on fossil fuels but also supports the advancement of clean energy technologies.
- Biodiversity Conservation: Many carbon offset projects, particularly those related to reforestation and avoided deforestation, contribute to the conservation of ecosystems and biodiversity. These projects can protect endangered species, preserve natural habitats, and maintain ecological balance.
- Air and Water Quality Improvement: Projects that reduce emissions from industries and vehicles, or involve the restoration of natural landscapes, often result in improved air and water quality. This has positive implications for both the environment and public health.

Economic Benefits:

- Market Efficiency: Carbon markets harness the efficiency of market mechanisms to find the most cost-effective solutions for reducing emissions. This can lead to innovation and the discovery of new methods for cutting carbon footprints in various sectors.
- Revenue Generation for Sustainable Projects: By monetizing the reduction of emissions, ZEB-certificates provide a source of revenue for projects that might otherwise be financially unviable. This can stimulate local economies and support the growth of green industries.
- Job Creation: The development, implementation, and maintenance of projects eligible for carbon certificates can create jobs, particularly in rural and underdeveloped regions. This can include roles in project management, monitoring, and the renewable energy sector.
- Corporate Social Responsibility (CSR): Companies purchasing ZEB-certificates to offset their emissions or to achieve net-zero targets can enhance their brand value and reputation. This demonstrates a commitment to sustainability, potentially attracting customers, investors, and employees who prioritize environmental responsibility.

Social Benefits:

- Community Development: Many carbon offset projects, especially those in developing countries, are designed with community benefits in mind. These can include improved local infrastructure, access to clean energy, education, and healthcare services.
- Empowerment of Indigenous Peoples: Projects such as forest conservation and sustainable land management can empower indigenous communities by recognizing their land rights and involving them in project planning and benefits.
- Health Improvements: Reductions in air pollution and access to clean energy can lead to significant health benefits, particularly in areas affected by high levels of emissions from fossil fuels. This can reduce the incidence of respiratory and cardiovascular diseases associated with pollution.
- Global Cooperation: Carbon markets encourage collaboration between countries, corporations, and peoples towards a common goal of reducing global emissions.

The benefits of ZEB-certificates extend well beyond the direct reduction of greenhouse gas emissions. They can potentially play a vital role in aiding sustainable development, advancing clean technologies, and supporting economic and social progress worldwide. However, maximizing these benefits requires robust standards, transparency, and integrity in the development and implementation of carbon offset technology and projects.

### 3.3 Challenges

Despite their potential, ZEB-certificates would face several challenges. These include concerns about the actual environmental integrity and additionality of some projects (i.e., ensuring projects lead to real, measurable, and additional emissions reductions). There's also the risk of double counting, where the same emission reduction is counted more than once. The complexity and lack of transparency in some carbon markets can also hinder their effectiveness (Michaelowa et al., 2019; Michaelowa, et al., 2021; Schneider, 2019).

Key Challenges:

- Additionality: One of the fundamental challenges is ensuring that the emission reductions represented by ZEB-certificates are truly additional—that is, they would not have occurred without the financial incentive provided by the carbon market. Some projects might have been economically viable even without the sale of carbon certificates, thus inflating the actual impact of carbon markets on reducing emissions.
- Permanence: Projects that involve carbon sequestration, such as reforestation, face the issue of permanence. There is a risk that the stored carbon could be released back into the atmosphere due to future events like forest fires, illegal logging, or changes in land use, undermining the long-term benefits of these carbon certificates.
- Measurement and Verification: Precisely measuring the amount of carbon reduced or sequestered by a project and verifying these reductions can be complex and costly. There is a risk of overestimation or underestimation of the impact of projects, which can affect the integrity of ZEB-certificates.
- Double Counting: Ensuring that a single emission reduction is not counted more than once, especially in the context of international transactions of certificates, is a significant challenge. Double counting can occur if both the buying and selling countries claim the same emission reduction towards their national climate targets, undermining global emission reduction efforts.
- Leakage: Projects that reduce emissions in one area might inadvertently cause an increase in emissions elsewhere, a phenomenon known as leakage. For example, protecting a forest in one area might shift deforestation activities to another area, negating the benefits of the original project.

### 3.4 Criticisms

The volatile nature of carbon prices, influenced by economic cycles and policy changes, can lead to instability and uncertainty in the market, potentially deterring investment in long-term emission reduction projects. Some projects generating ZEB-certificates can theoretically proceed without the financial incentives provided by the carbon markets, thus not leading to any real or additional reduction in emissions (Warnecke, Spalding-Fecher, & Van Horen, 2014).

The availability of carbon offsets may also encourage companies to rely on purchasing certificates rather than implementing direct emission reduction measures within their own operations or jurisdictions. This could potentially delay the structural changes needed to transition to a low-carbon economy. The complexity of some carbon markets, along with the lack of uniform standards, can lead to issues with transparency and accountability. This could raise concerns about the potential for fraud and the overall integrity of the carbon market.

The use of certificates by companies to claim carbon neutrality or other environmental credentials has led to accusations of greenwashing, where companies may exaggerate their environmental commitments without making significant operational changes to reduce their carbon footprint (Spillette, Do, & Di Domenico, 2022).

Addressing these challenges and criticisms is crucial for the effectiveness and credibility of carbon certificate markets. This involves improving standards for additionality, permanence, and verification,

strengthening regulatory frameworks, enhancing transparency and public trust, and ensuring that carbon markets complement rather than replace direct emission reduction efforts.

# 4. Future Prospects

The future of ZEB-certificates looks promising but warrants significant improvements in terms of standardization, transparency, and verification to ensure their long-term viability and effectiveness. Innovations such as blockchain technology and artificial intelligence could enhance transparency, expedition, and tracking (Woo et al., 2021). Additionally, as awareness and commitments to combat climate change intensify, the demand for ZEB-certificates is likely to grow, potentially leading to more robust markets and more innovative solutions for reducing GHG emissions.

The future prospects of ZEB-certificates are closely tied to evolving national and global climate policies, technological advancements, and shifts in societal attitudes towards sustainability. As governments intensifies its efforts to combat climate change there needs to be market incentives if they are to reach their goals. As a result, carbon certificate markets and the role of industry related measures, such as ZEB-certificates, are likely to expand and evolve in several key areas.

There is a growing momentum towards linking regional carbon markets to create a more unified global carbon market (Ewing, 2022). This integration can lead to more efficient markets, providing stronger economic incentives for reducing greenhouse gas emissions at scale. Carbon certificate markets may expand to cover more sectors and greenhouse gases. Sectors like agriculture, forestry, and waste management have significant potential for emission reductions and carbon sequestration, and their inclusion could enhance the scope and impact of carbon certificate markets.

## 4.1 ZEB certificates and investment cost

ZEB-certificates have the potential to significantly reduce the investment costs associated with low-carbon building materials, such as low-carbon cement equipped with Carbon Capture and Storage (CCS) technology. Several mechanisms can facilitate the adoption of such sustainable materials in the construction industry (Carvalho et al., 2022; Haya et al., 2020; Pan & Dong, 2023):

- Offsetting Higher Production Costs: Low-carbon cement, particularly those varieties that incorporate CCS technology, often comes with higher production costs due to the advanced processes and technologies involved. By generating ZEB-certificates through the quantification of emissions saved compared to traditional cement, manufacturers can offset these higher costs. The sale of these carbon certificates provides an additional revenue stream, making the production of low-carbon cement more financially viable.
- Encouraging R&D Investment: The financial incentives from ZEB-certificates can be reinvested into research and development, driving further innovations in low-carbon cement formulations and CCS technologies. This continuous improvement can lead to more efficient production methods and even greater emission reductions, further enhancing the environmental value and marketability of these materials.
- Leveraging Regulatory Support: In regions where regulations mandate the decrease of carbon emissions in the construction industry, ZEB-certificates provide a tangible way to demonstrate

compliance. This regulatory advantage can make low-carbon cement the preferred choice for projects, as it directly contributes to meeting or exceeding these mandates, potentially avoiding fines or benefiting from government incentives.

- Attracting Green Financing: Projects that incorporate low-carbon building materials are increasingly attractive to green investors and financing programs. The ability to generate ZEB-certificates adds to the environmental credentials of such projects, making them more likely to receive funding from sources dedicated to sustainability, which can further offset the costs associated with these materials.
- Building Market Demand: As the construction industry becomes more aware of the availability and benefits of low-carbon cement, demand is likely to increase. This growing market demand, spurred in part by the financial mechanisms of ZEB-certificates, can lead to economies of scale, lowering the cost of production and, consequently, the market price of these materials.
- Facilitating Long-term Contracts: Manufacturers of low-carbon cement can enter into long-term contracts with developers and construction companies, guaranteeing a steady demand for their product. The promise of ZEB-certificates and the financial benefits they bring can be a key negotiating point in these contracts, ensuring a stable market for low-carbon materials.
- Enhancing Brand Reputation: Companies that produce and utilize low-carbon materials with CCS and generate ZEB-certificates enhance their brand reputation as leaders in sustainability. This positive brand image can lead to expanded market share and potentially command a premium in the market, further offsetting the initial investment costs.
- Innovation Ecosystem Collaboration: The carbon certificate mechanism can foster increased innovation ecosystem collaborations between cement suppliers, construction companies, project developers, public builders and municipalities. Joint initiatives can pool resources for the development and deployment of low-carbon materials, sharing the benefits of carbon certificates and reducing individual investment costs.

ZEB-certificates offer a powerful tool to make low-carbon building materials like cement, and in turn concrete, with CCS technology more financially accessible. Through a combination of offsetting production costs, leveraging regulatory support, attracting green financing, and fostering market demand, ZEB-certificates can play a pivotal role in reducing the investment costs associated with these sustainable building materials, thereby accelerating their adoption in the building and construction industry.

### 4.2 ZEB certificates and zero emission neighbourhoods

ZEB-certificates can play a significant role in the development of zero-emission buildings and neighborhoods, serving as both a financial mechanism and an incentive for integrating sustainable practices and technologies. The development of zero-emission buildings often requires upfront investment in sustainable materials, energy-efficient designs, and renewable energy systems (Maduta et al., 2022; Wilberforce et al., 2023; Wu & Sky, 2021). ZEB-certificates can provide a source of revenue for developers who implement these practices, as the emission reductions achieved can be quantified and sold as carbon credits in the market. This financial incentive can help offset the initial costs and make green building practices more economically viable.

Zero-emission buildings and neighborhoods rely heavily on green energy sources (solar, wind, and geothermal) to meet their energy needs without contributing to greenhouse gas emissions. By generating ZEB-certificates through the installation and use of renewable energy systems, developers and property owners can gain additional financial benefits, encouraging the adoption of these technologies. ZEB-certificates can also incentivize the implementation of energy-efficient technologies and practices in buildings, such as high-efficiency HVAC systems, LED lighting, and smart building management systems. These technologies reduce the overall energy consumption of a building, leading to lower emissions and the generation of certificates.

In developing zero-emission neighborhoods, the integration of sustainable transportation is also crucial (Brozovsky, Gustavsen, & Gaitani, 2021). Investments in infrastructure for electric vehicles, bike-sharing programs, and pedestrian-friendly pathways can be supported by the sale of ZEB-certificates, as these initiatives contribute to the reduction of transportation-related emissions. The inclusion of green spaces, urban forests, and green roofs in building and neighbourhoods designs not only enhances biodiversity and residents' well-being but also contributes to carbon sequestration. These natural carbon sinks can generate ZEB-certificates, providing an additional incentive for their incorporation into urban planning.

The prospect of generating ZEB-certificates can drive innovation in sustainable construction materials and techniques, such as the use of low-carbon cement, recycled materials, and modular construction methods. These innovations can reduce the carbon footprint of the construction process itself, further contributing to the development of zero-emission buildings. As governments and international bodies implement stricter regulations and standards for building emissions, ZEB-certificates can help developers and property owners comply with these requirements. By demonstrating emission reductions through certificates, stakeholders can meet or exceed regulatory benchmarks and possibly avoid penalties.

ZEB-certificates offer a multifaceted approach to supporting the development of zero-emission buildings and neighborhoods. Through financial incentives, regulatory compliance, market competitiveness, and community engagement, these types of certificates can significantly contribute to the adoption of sustainable practices and technologies in the built environment, aligning local efforts with global sustainability goals.

## 5. Wider Uptake

According to Gouldson et al. (2015) can carbon finance be leveraged to support energy efficiency and renewable energy projects in urban areas, reducing emissions and contributing to the development of zero-emission neighbourhoods. ZEB-certificates can incentivize the integration of renewable energy sources, such as solar panels and wind turbines, into neighbourhood designs. As emphasized by Kennedy et al. (2009), the transition to low-carbon energy systems is essential for achieving urban sustainability goals, with carbon trading schemes providing a financial mechanism to support this shift.

The construction of energy-efficient buildings is crucial for zero-emission neighbourhoods. Pérez-Lombard et al. (2008) claims buildings account for a significant portion of global energy use and GHG emissions. ZEB-certificates generated from energy savings in buildings can drive the adoption of green

building standards, such as LEED or BREEAM, making energy efficiency both a sustainable and economically viable goal.

Zero-emission neighbourhoods require sustainable transportation systems. Studies like those by Banister (2008) suggest that reducing urban transport emissions is key to achieving broader sustainability targets. ZEB-certificates can fund the development of public transport infrastructure, cycling paths, and electric vehicle charging stations, encouraging a shift away from fossil fuel-dependent vehicles. Urban green spaces play a significant role in carbon sequestration and provide numerous environmental benefits. As Tzoulas et al. (2007) highlights, integrating green infrastructure into urban planning can enhance biodiversity and contribute to climate change mitigation. ZEB-certificates generated from urban forestry and green roofs can provide additional funding for these green initiatives.

The creation of zero-emission neighbourhoods involves not just technological solutions but also community engagement. Ehrhardt-Martinez et al. (2010) emphasize the importance of engaging residents in energy-saving behaviours. Carbon certificate programs can include community-based projects, fostering a sense of ownership and participation in sustainability efforts. Moreover, smart cities utilize data and technology to improve urban services and sustainability. Kramers et al. (2014) note that smart technologies can optimize energy use, manage waste, and improve transportation efficiency. ZEB-certificates can finance the integration of these technologies into neighbourhood planning, enhancing the overall sustainability of urban environments.

Furthermore, the development of zero-emission neighbourhoods is often supported by urban policy and regulations. According to Bulkeley et al. (2014) do local governments play a crucial role in climate governance. Carbon certificate schemes can align with municipal policies, providing a market-based tool to support regulatory objectives and encourage private sector investment in low-carbon urban development. Zero-emission neighbourhoods can serve as scalable and replicable models for urban development. The experience and knowledge gained from utilizing ZEB-certificates to finance and incentivize sustainable projects should be shared across cities and regions. This knowledge transfer can accelerate the transition to sustainable urban environments on a larger scale.

## 6. Conclusion

ZEB-certificates can play a pivotal role in facilitating the creation of zero-emission neighbourhoods within smart cities by providing a mechanism to finance and incentivize carbon reduction initiatives in the building industry. The sale of ZEB-certificates can, if implemented correctly, provide crucial funding for sustainable urban development projects. ZEB-certificates offer a flexible and effective tool to support the creation of zero-emission buildings and neighbourhoods within smart cities. By providing a financial mechanism to incentivize and fund sustainable urban development projects, ZEB-certificates can contribute significantly to the global efforts towards sustainability and climate change mitigation.

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## VISION:

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