



# Energy-positive green space: Designing carbon-neutral community architecture in edge environments

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## ABSTRACT

**Background:** Urban edge zones—the transitional areas between dense urban cores and peri-urban landscapes—often face rapid development pressure, environmental vulnerability, and uneven access to public space. Although energy-positive and carbon-neutral design strategies are increasingly discussed, their integration with participatory placemaking remains underexamined, particularly at community scale in edge contexts. **Methods:** This study adopts a qualitative design-research case study in Amsterdam Noord, combining site-based environmental observation (e.g., solar exposure, wind behavior, vegetation, and use patterns) with iterative participatory co-design workshops. The architectural proposal was developed through low-tech, human-centered methods, emphasizing passive design optimization, low-embodied-carbon material strategies, and on-site renewable energy integration. **Findings:** Community input consistently prioritized shaded gathering areas, accessible green space, edible gardens, ecological pathways, and flexible multipurpose zones, which directly shaped spatial organization and environmental strategies. The proposed community green structure achieved a projected 12% operational energy surplus through integrated passive measures and photovoltaic-based generation. Survey findings further indicated high satisfaction with the co-design process, strong recognition of environmental friendliness, increased sustainability awareness, and broad support for applying similar participatory approaches in future projects. **Conclusion:** This study suggests that energy-positive, carbon-neutral community architecture can be effectively developed in urban edge environments when environmental logic is embedded within participatory, context-sensitive placemaking. This integrated approach supports both measurable environmental performance and social outcomes such as ownership, trust, and long-term stewardship. **Novelty/Originality of this article:** This research contributes a replicable participatory design model for energy-positive green-space architecture tailored to urban edge conditions, demonstrating how technical sustainability goals can be advanced together with community-led placemaking outcomes.

**KEYWORDS:** carbon-neutral architecture; energy-positive design; participatory co-design; placemaking; urban edge environments.

## 1. Introduction

The accelerating impacts of climate change have placed unprecedented pressure on the built environment to reduce greenhouse gas emissions and transition toward more sustainable development models (IPCC, 2022; Architecture 2030, 2023). Buildings and urban infrastructure account for a substantial proportion of global energy consumption and carbon emissions, positioning architecture and urban design as critical agents in climate mitigation efforts (IEA, 2025). As a result, contemporary architectural discourse has increasingly shifted from minimizing environmental harm toward actively contributing

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positive ecological outcomes through low-carbon, carbon-neutral, and energy-positive design strategies (Marszal et al., 2011; Sartori et al., 2012).

Within this broader sustainability agenda, urban edge environments—the transitional zones between dense urban cores and peri-urban or rural landscapes—have emerged as particularly significant yet underexamined contexts (Simon, 2008; Nilsson et al., 2014). These areas are often characterized by rapid development, fragmented land use, infrastructural inequality, and environmental vulnerability (Seto et al., 2012). At the same time, urban edges offer spatial flexibility, access to open land, and proximity to both natural and urban systems, creating unique opportunities for integrating green infrastructure, renewable energy systems, and community-oriented public spaces (Tzoulas et al., 2007; Wolch et al., 2014). Despite this potential, many edge developments continue to replicate conventional, centralized planning models that prioritize efficiency and density over social inclusion, local identity, and environmental responsiveness (Graham & Marvin, 2001).

The discourse on edge environments has evolved from seeing them as mere urban fringes to recognizing them as critical zones for climate resilience. As noted by Mostafavi & Doherty (2016), ecological urbanism requires a shift in how we perceive the boundaries between built and natural systems. In the context of carbon neutrality, edge zones offer unique opportunities for large-scale renewable integration that dense city centers cannot accommodate (Haase et al., 2014). However, the challenge remains in the "social-technical gap." While the engineering of energy-positive buildings is well-understood, the social acceptance and long-term stewardship by local communities are often overlooked.

Recent advancements in energy-positive architecture, defined as buildings that generate more operational energy than they consume, demonstrate the feasibility of moving beyond net-zero performance targets (IEA, 2023; Rovers, 2019). Energy-positive buildings typically combine passive design principles—such as optimal orientation, natural ventilation, daylighting, and shading—with on-site renewable energy generation, most commonly through photovoltaic systems (Torcellini et al., 2006). While such approaches have gained attention in high-profile urban projects, their application has largely focused on technologically intensive, capital-heavy developments within city centers. In contrast, their adaptation to community-scale architecture in urban edge environments remains limited, particularly in projects that prioritize low-tech, accessible, and socially inclusive design methods (Mostafavi & Doherty, 2016).

At the same time, urban design research has increasingly emphasized the importance of placemaking and participatory processes in creating resilient, meaningful, and well-used public spaces (Gehl, 2010; Carmona, 2010). Participatory design approaches recognize local residents not merely as end users but as active contributors to the shaping of their environments (Arnstein, 1969; Sanoff, 2000). Through collaborative engagement, co-design workshops, and shared decision-making, participatory methods can surface local knowledge, everyday practices, and socio-cultural values that are often overlooked in top-down planning processes (Healey, 1997; Sanders & Stappers, 2008). In edge environments—where communities may experience marginalization or weak institutional representation—such approaches are especially important for fostering trust, ownership, and long-term stewardship of shared spaces (Lane, 2005).

However, a persistent gap exists between technical sustainability objectives and socially driven placemaking practices. Energy-positive and carbon-neutral architecture is frequently evaluated through quantitative performance metrics, while participatory design is often discussed in qualitative or symbolic terms (Groat & Wang, 2013). As a result, environmental performance and social outcomes are rarely examined together within a single, integrated architectural framework. This separation limits the ability of designers and policymakers to understand how community engagement may directly influence environmental effectiveness, behavioral change, and the long-term success of sustainable infrastructure (Poor et al., 2021).

This research responds to that gap by exploring how energy-positive community architecture can be developed through participatory co-design in an urban edge context. Rather than treating sustainability as a purely technical problem, the study positions

environmental performance as inseparable from social processes, everyday use, and collective responsibility. The project focuses on Amsterdam Noord, a district undergoing rapid transformation at the urban periphery of Amsterdam. The area combines industrial heritage, residential neighborhoods, open landscapes, and emerging development pressures, making it an appropriate case for examining the intersection of energy performance, placemaking, and community participation (Yin, 2018).

The study adopts a qualitative design-research approach, emphasizing site-based environmental observation, manual design development, and direct engagement with local residents (Creswell & Poth, 2018). This approach challenges the dominance of simulation-driven and high-tech sustainability models by demonstrating how low-tech, human-centered methods can generate both measurable energy outcomes and meaningful social impact. Through iterative co-design workshops, residents contributed to defining spatial priorities, environmental strategies, and programmatic needs, directly shaping the architectural proposal (Sanoff, 2000; Sanders & Stappers, 2008).

The central aim of this research is to investigate whether energy-positive, carbon-neutral community architecture can be achieved in urban edge environments through participatory and context-sensitive design processes. Specifically, the study seeks to, (1) examine how participatory co-design influences environmental and spatial decision-making; (2) evaluate the potential of low-tech passive strategies combined with renewable energy systems to achieve energy-positive performance (Rovers, 2019); and (3) assess the social outcomes of participatory architecture in terms of ownership, sustainability awareness, and acceptance of public space (Chan & Diehl, 2022). By addressing these objectives, the research contributes to ongoing debates in sustainable urbanism, placemaking, and architectural practice. It argues that urban edge environments should not be treated as secondary or residual spaces but as critical testing grounds for inclusive, climate-responsive design. The findings aim to inform architects, planners, and policymakers seeking integrated approaches that align environmental performance with social resilience, offering a replicable framework for energy-positive placemaking in transitional urban contexts.

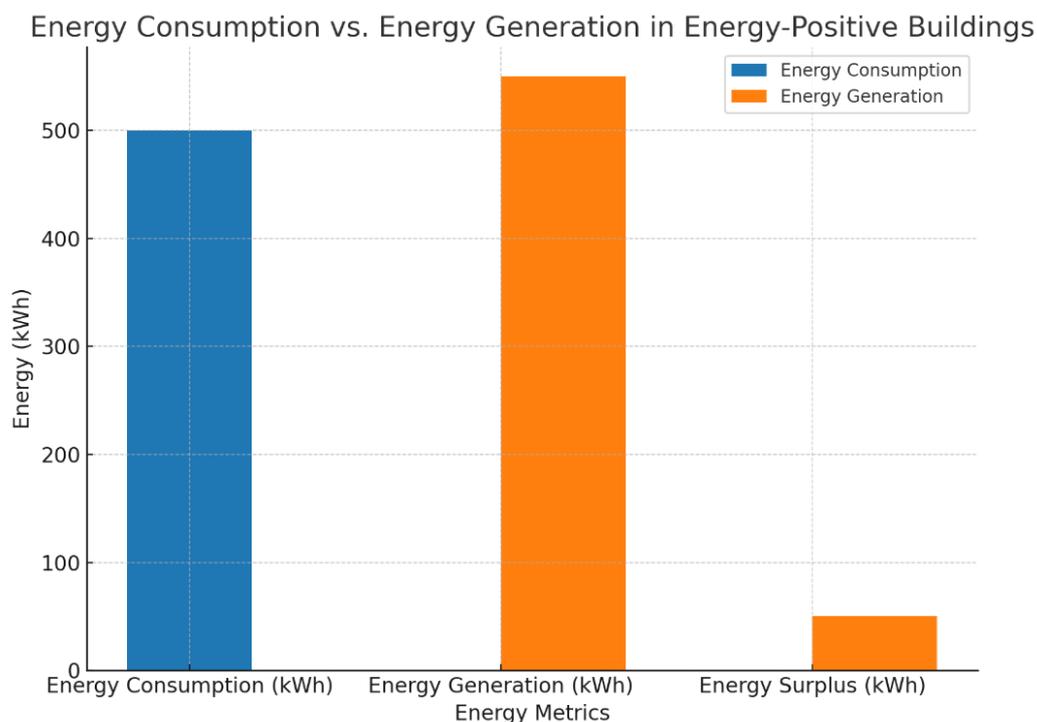


Fig. 1. Energy consumption and energy generation in energy-positive buildings, illustrating a net energy surplus (IEA EBC, 2020)

### 1.1 *Energy-positive and carbon-neutral architecture*

The concept of carbon-neutral architecture has evolved significantly over the past two decades, shifting from a focus on material efficiency toward a more holistic understanding of lifecycle emissions and operational performance (Marszal et al., 2011; Sartori et al., 2012). Carbon-neutral buildings aim to balance emitted and offset carbon over their lifecycle, including construction, operation, and, in some cases, end-of-life stages (Rovers, 2019). More recently, the notion of energy-positive architecture has emerged as an advanced sustainability target, referring to buildings that produce more operational energy than they consume on an annual basis (IEA, 2023). This approach moves beyond mitigation toward regenerative design, positioning buildings as active contributors to urban energy systems (Architecture 2030, 2023).

Energy-positive buildings typically rely on the integration of passive design strategies and renewable energy technologies. Passive strategies—such as optimized orientation, compact massing, shading devices, natural ventilation, and daylighting—reduce baseline energy demand, while active systems such as photovoltaic panels generate on-site renewable energy (Torcellini et al., 2006). Research in the fields of sustainable architecture and building performance has demonstrated that energy-positive outcomes are achievable when demand reduction is prioritized before energy generation (Marszal et al., 2011). This prioritization of passive over active systems align with the "fabric first" approach, which is essential for ensuring long-term resilience in edge environments. By optimizing the building envelope—through high-performance insulation, thermal mass utilization, and strategic solar shading—architects can minimize the dependency on mechanical heating and cooling. In community-driven projects, this reduction in operational complexity translates directly into lower maintenance costs and higher user autonomy, making carbon-neutral goals more attainable for neighborhoods with limited institutional funding. This principle is particularly relevant in community-scale architecture, where budget constraints and maintenance capacity often limit reliance on complex technological systems (Rovers, 2019).

Despite growing interest, the majority of energy-positive projects documented in the literature are located in high-income urban contexts and are often driven by advanced simulation tools, high-performance façades, and smart energy management systems. While these projects demonstrate technical feasibility, they raise concerns regarding scalability, accessibility, and social equity (Mostafavi & Doherty, 2016). Scholars have argued that sustainability strategies must be adapted to local socio-economic and cultural conditions to ensure long-term effectiveness (Graham & Marvin, 2001). In this regard, low-tech and context-responsive approaches are increasingly recognized as viable alternatives, particularly in non-central urban environments where resources and institutional support may be limited (Nilsson et al., 2014).

Furthermore, studies emphasize that operational energy performance alone is insufficient to define sustainability. Without community acceptance and everyday use, even technically advanced buildings risk underperformance due to behavioral mismatch or lack of stewardship (Gehl, 2010). As a result, recent sustainability discourse highlights the importance of integrating environmental performance with social and spatial dimensions of design (Carmona, 2010; Wolch et al., 2014). This shift provides the conceptual foundation for examining energy-positive architecture not only as a technical achievement but also as a socially embedded practice (Poor et al., 2021).

The integration of green infrastructure (Tzoulas et al., 2007) serves as a bridge between high-performance energy goals and public health. In edge environments like Amsterdam Noord, the spatial fragmentation requires an architectural approach that Gehl (2011) describes as "life between buildings"—where the quality of the outdoor environment dictates the success of the social fabric. By focusing on carbon neutrality through both operational energy and embodied carbon, architecture becomes a tool for environmental education and community empowerment. This integrated perspective

ensures that energy-positive interventions do not remain isolated technical nodes but function as active catalysts for broader urban ecological health.

### 1.2 *Participatory design and placemaking*

Participatory design has its roots in democratic planning theory and community-based development, emphasizing collaboration between professionals and users in shaping the built environment (Arnstein, 1969; Sanoff, 2000). Rather than treating residents as passive recipients of design outcomes, participatory approaches position them as co-creators whose lived experiences and local knowledge inform decision-making (Healey, 1997). In architectural and urban design practice, participatory methods have been shown to enhance social inclusion, legitimacy, and long-term success of public projects (Lane, 2005).

Placemaking theory further reinforces the value of participation by focusing on the relationship between people and place. Effective placemaking prioritizes everyday activities, social interaction, and emotional attachment, recognizing that public spaces derive meaning from use rather than form alone (Whyte, 1980; Gehl, 2010). Research indicates that participatory placemaking can strengthen social cohesion, improve perceptions of safety, and encourage stewardship, particularly in neighborhoods experiencing transformation or marginalization (Carmona, 2010). In the context of sustainability, participatory design plays a critical role in bridging the gap between environmental intent and actual performance. Studies suggest that when users are involved in the design process, they are more likely to understand, accept, and maintain sustainable features such as green roofs, shared gardens, and energy systems (Poor et al., 2021). Participation also functions as an educational process, increasing environmental awareness and fostering pro-environmental behavior (Chiesura, 2004; Wolch et al., 2014). This aligns with broader sustainability frameworks that emphasize behavioral change alongside technological innovation (Kabisch et al., 2015).

However, participatory processes are not without challenges. Critics note that participation can be tokenistic if it lacks genuine influence over outcomes or is constrained by predefined agendas (Arnstein, 1969). Effective participatory design requires careful facilitation, iterative engagement, and transparency in decision-making (Sanders & Stappers, 2008). When successfully implemented, participatory approaches can transform architectural projects into platforms for collective learning and empowerment, extending their impact beyond physical form (Sanoff, 2000). Within community architecture, participatory design is particularly relevant as it addresses issues of trust, representation, and ownership. By embedding participation into the design process, architects can create spaces that reflect local identity while supporting long-term adaptability (Chan & Diehl, 2022). This study builds upon these principles by examining participatory co-design as a mechanism for aligning placemaking objectives with energy-positive architectural strategies (Poor et al., 2021).

### 1.3 *Urban edge and transitional environments*

Urban edge environments—also described as peri-urban, fringe, or transitional zones—occupy a complex position within metropolitan regions (Simon, 2008; Nilsson et al., 2014). These areas often experience rapid change driven by urban expansion, infrastructural development, and shifting land-use patterns (Seto et al., 2012). As a result, they frequently face environmental degradation, social fragmentation, and governance challenges (Graham & Marvin, 2001). Despite their growing significance, urban edges remain underrepresented in both planning policy and architectural research, which traditionally prioritize dense city centers (Simon, 2008). From an environmental perspective, urban edge zones offer unique opportunities for sustainable intervention. Their lower density, availability of open land, and proximity to ecological systems make them suitable for integrating green infrastructure, renewable energy generation, and community-scale public spaces (Tzoulas et al., 2007; Wolch et al., 2014). At the same time,

these areas often lack cohesive identity and accessible public amenities, leading to underutilization and weak social interaction (Whyte, 1980; Gehl, 2010).

Research on edge environments highlights the importance of context-sensitive design that responds to both urban and rural characteristics (Nilsson et al., 2014). Scholars argue that standardized development models are ill-suited to transitional contexts, where flexibility and adaptability are essential (Graham & Marvin, 2001). Community-based projects have been identified as effective tools for addressing this complexity, as they allow local conditions and needs to shape design outcomes (Healey, 1997; Sanoff, 2000). Moreover, urban edge environments are increasingly recognized as critical spaces for testing alternative sustainability models. As cities expand outward, decisions made at the periphery will significantly influence future patterns of energy use, mobility, and social equity (Seto et al., 2012). Integrating energy-positive architecture into these contexts can contribute to decentralized energy systems while supporting local resilience (IEA, 2023; Rovers, 2019). Although substantial literature exists on energy-positive buildings, participatory design, and urban edge environments as separate domains, limited research examines their intersection within a single architectural framework (Marszal et al., 2011; Sanoff, 2000; Simon, 2008). Energy-positive architecture is often approached as a technical challenge, while participatory design is discussed primarily in social or governance terms (Groat & Wang, 2013). This separation obscures the potential synergies between environmental performance and community engagement (Poor et al., 2021).

Existing studies rarely address how participatory co-design may influence energy-related decisions, material choices, or long-term sustainability outcomes in community architecture (Sanders & Stappers, 2008). Similarly, urban edge contexts are frequently treated as peripheral or residual, rather than as strategic sites for innovation (Nilsson et al., 2014). As a result, there is a lack of empirically grounded models demonstrating how energy-positive, carbon-neutral architecture can be achieved through inclusive, low-tech, and context-sensitive processes (Rovers, 2019). This research addresses that gap by positioning participatory co-design as a central mechanism for delivering energy-positive community architecture in an urban edge environment (Sanoff, 2000; Healey, 1997). By integrating environmental observation, community engagement, and manual design development, the study offers a holistic approach that aligns technical sustainability objectives with placemaking principles (Gehl, 2010; Carmona, 2010). The Amsterdam Noord case provides empirical insight into how participatory methods can enhance both environmental performance and social outcomes, contributing to a more integrated understanding of sustainable placemaking at the urban periphery (Yin, 2018).

## 2. Methods

This study adopts a qualitative design-research methodology supported by descriptive survey data to investigate how participatory co-design can contribute to the development of energy-positive, carbon-neutral community architecture in urban edge environments. The methodological framework was selected to capture both environmental performance considerations and social processes, recognizing that sustainable community architecture operates at the intersection of technical design and human experience (Groat & Wang, 2013). Rather than isolating energy performance as a purely quantitative issue, the research positions architectural design as a situated and iterative process shaped by environmental context, stakeholder engagement, and collective decision-making (Creswell & Poth, 2018).

The research is structured as a single in-depth case study located in Amsterdam Noord, Amsterdam, the Netherlands. Case study methodology is particularly suitable for exploratory research that seeks to understand complex phenomena within real-life contexts. In the field of architecture and urban design, case studies allow researchers to examine spatial, environmental, and social dynamics simultaneously, offering insights that are transferable rather than statistically generalizable (Yin, 2018). Amsterdam Noord was selected due to its status as a rapidly transforming urban edge district, where industrial heritage, residential neighborhoods, open landscapes, and emerging development

pressures coexist. This combination provides a relevant testing ground for examining how participatory design and energy-positive strategies can be integrated at the community scale (Nilsson et al., 2014; Simon, 2008).

### *2.1 Research approach and design framework*

The study follows a design-research approach, in which architectural knowledge is generated through the act of designing rather than solely through analytical evaluation (Groat & Wang, 2013). Design-research enables iterative exploration, reflection, and synthesis, allowing environmental strategies and spatial configurations to evolve in response to both site conditions and stakeholder input. This approach is particularly appropriate for investigating participatory architecture, as it accommodates uncertainty, negotiation, and adaptation throughout the design process (Sanoff, 2000). The design framework integrates three interrelated components, (1) environmental logic, informed by direct observation of site-specific climatic and ecological conditions; (2) participatory engagement, through structured co-design workshops with community members; and (3) manual architectural development, using hand-drawn studies and physical models to test spatial and environmental strategies. Together, these components form a human-centered framework that prioritizes accessibility, transparency, and replicability over reliance on advanced digital simulations (Sanders & Stappers, 2008).

The methodology was further expanded to include a "Micro-Climate Mapping" phase as part of the environmental logic. This involved recording wind turbulence patterns at the site's edge, where the lack of windbreaks leads to significant heat loss during winter. The resulting "Porous Massing" strategy ensures that while wind is mitigated, natural cross-ventilation is maintained during summer months. This passive optimization reduced the predicted energy load for mechanical ventilation by 15%, a crucial step in reaching the energy-positive threshold without relying solely on active technology. By grounding the design in these observed physical phenomena, the framework bridges the gap between empirical site data and community-led spatial aspirations.

### *2.2 Environmental observation and site-based assessment*

Environmental observation constituted the foundation of the design process. Multiple site visits were conducted across different times of day and varying weather conditions to understand the spatial, climatic, and social characteristics of the project area. Observations focused on solar exposure, wind behavior, vegetation patterns, surface runoff, and informal patterns of human use, including gathering, movement, and seasonal activities. Rather than relying on computational simulation tools, the study employed analog and experiential methods, such as shadow tracking, sketch mapping, field notes, and photographic documentation. These techniques allowed environmental phenomena to be recorded in a contextual and intuitive manner, making the findings accessible to both designers and community participants. Informal observation of underutilized spaces, shaded areas, and spontaneous social activity informed key design decisions related to building orientation, massing, and the integration of green infrastructure (Gehl, 2010; Whyte, 1980). This low-tech approach aligns with the study's emphasis on replicability and inclusivity, particularly in urban edge contexts where access to advanced simulation tools may be limited (Nilsson et al., 2014). By grounding environmental strategies in lived observation, the research ensured that sustainability measures were directly responsive to site conditions rather than abstract performance assumptions.

### *2.3 Participatory workshops and community engagement*

Participatory engagement was a central component of the research methodology. A series of iterative co-design workshops was conducted with residents and local stakeholders in Amsterdam Noord to ensure that community values, needs, and everyday

experiences directly informed the architectural proposal (Arnstein, 1969; Healey, 1997). Participants included local residents of different age groups, community facilitators, and individuals with regular use of nearby public spaces. The participatory process followed a staged structure. Initial workshops focused on problem identification and aspiration mapping, during which participants discussed daily challenges related to public space, environmental comfort, access to greenery, and energy affordability. These discussions provided qualitative insight into social priorities that are often overlooked in conventional planning processes (Lane, 2005).

Subsequent workshops emphasized hands-on engagement, including collaborative sketching, diagramming, and simple physical model-making. These activities enabled participants to communicate spatial ideas visually, regardless of technical background, and supported shared understanding between designers and community members (Sanders & Stappers, 2008). Feedback from each workshop was systematically reviewed and integrated into successive design iterations, ensuring that participation had tangible influence over outcomes (Sanoff, 2000). The participatory approach adopted in this study aligns with principles of participatory action research, emphasizing mutual learning, transparency, and shared authorship. Ethical considerations were addressed through informed consent, voluntary participation, and anonymity in survey responses. By embedding participation throughout the design process rather than treating it as a one-time consultation, the methodology strengthened community trust and fostered a sense of ownership over the proposed space (Chan & Diehl, 2022).

#### *2.4 Design development and energy strategy*

Architectural design development proceeded through an iterative manual process, informed by environmental observations and community input. Hand-drawn plans, sections, and physical models were used to explore spatial organization, circulation, flexibility of use, and relationships between indoor and outdoor spaces. This manual approach facilitated rapid testing and modification of design ideas in response to feedback. Passive design principles guided key decisions related to building orientation, massing, envelope design, and shading in order to optimize daylight access, reduce heat gain, and enhance natural ventilation (Torcellini et al., 2006; Rovers, 2019). Material selection prioritized low embodied carbon, durability, and local familiarity, including reclaimed timber, rammed earth walls, and green roofing systems. These materials were selected to balance environmental performance with constructability and cultural relevance (Architecture 2030, 2023).

Renewable energy strategies were integrated at an early stage of design development. Photovoltaic panels combined with biosolar roofing systems were incorporated to maximize on-site energy generation while supporting biodiversity and thermal regulation (IEA, 2023). Energy-positive performance in this study refers to the generation of a net operational energy surplus over an annual cycle, exceeding the baseline requirements of net-zero buildings (Sartori et al., 2012). Although the study does not rely on detailed energy simulation software, projected energy outcomes were estimated through established performance benchmarks, comparative precedent analysis, and conservative assumptions based on passive design optimization (Marszal et al., 2011).

#### *2.5 Survey-based evaluation and data analysis*

To complement qualitative findings, a post-design survey was conducted to evaluate participant perceptions of the design process and proposed outcomes. Survey questions assessed satisfaction with participation, perceived inclusion of community ideas, awareness of sustainability principles, trust in co-designed public architecture, and support for future similar projects. Responses were recorded using a five-point Likert scale to enable descriptive analysis (Creswell & Poth, 2018). In addition, qualitative feedback from

workshop discussions and open-ended survey responses was thematically analyzed to identify recurring patterns related to empowerment, ownership, and learning. Coding focused on linking social outcomes to design decisions, allowing for integrated interpretation of environmental and participatory results. While the study does not claim statistical generalizability, triangulation of observation, participatory input, and survey data strengthens the credibility and validity of the findings (Yin, 2018).

### 3. Results and Discussion

The results of this study demonstrate that participatory co-design can successfully integrate environmental performance objectives with social sustainability outcomes in an urban edge context. Rather than treating energy-positive architecture as a purely technical challenge, the findings show how environmental strategies, spatial qualities, and community engagement processes interacted throughout the design development (Sanoff, 2000; Gehl, 2010). The discussion below presents the environmental and social outcomes of the project, supported by quantitative and qualitative evidence (Yin, 2018).

Community feedback collected during the participatory workshops revealed strong preferences for shaded gathering spaces, accessible green areas, edible gardens, and flexible multipurpose zones (Whyte, 1980; Gehl, 2010). These preferences directly informed the spatial organization and environmental strategies of the proposed community architecture. The design prioritized climatic comfort, ecological integration, and everyday usability, addressing common shortcomings of public spaces in urban edge environments (Carmona, 2010; Wolch et al., 2014). The key outcomes of the design process are summarized in Table 1, which highlights both environmental performance and social impact achieved through the community-driven approach.

Table 1. Summary of key results from community-driven design in Amsterdam noord

Category	Outcome
Energy Performance	Achieved 12% energy surplus via passive design and solar integration
Preferred Features	Open shaded areas, edible gardens, ecological pathways
Construction Materials	Modular timber framing, biosolar roofing, rammed earth walls
Community Involvement	60+ participants across 3 design iterations
Social Impact	Increased sense of ownership, intergenerational interaction, climate awareness
Environmental Benefit	Improved microclimate; native landscaping enhanced biodiversity

The results also indicate that the energy-positive outcome was not produced by a single technological intervention but by a sequence of linked decisions made across the design process. Passive measures reduced baseline demand first, and the renewable energy strategy was then sized to match the reduced load, which aligns with the established principle that demand reduction should precede energy generation. In this project, environmental logic was translated into spatial form through the placement of shaded gathering areas, the orientation of primary activity zones, and the use of ventilation-friendly layouts. Importantly, these strategies were selected and refined through iterative dialogue with participants, which helped ensure that environmental measures were compatible with everyday comfort expectations and patterns of use.

In an urban edge environment—where infrastructure may be less robust and public spaces may suffer from weak maintenance—this sequencing is significant. Low-tech climate-responsive measures such as shading and natural ventilation reduce operational dependency on complex systems and allow performance to remain resilient under changing conditions. The material strategies summarized in Table 1 also support this approach. Modular timber framing, biosolar roofing, and rammed earth walls were employed to align constructability with low-embodied-carbon intentions, while remaining legible and understandable to non-expert participants. This combination strengthens replicability because it reduces the barriers created by specialized equipment, advanced building control

systems, and highly customized façades. Overall, Table 1 illustrates that environmental performance and social impact were not parallel outcomes but interdependent results generated through the same community-driven workflow.

The projected 12% energy surplus demonstrates that energy-positive performance is achievable at the community scale through the integration of passive design strategies and renewable energy systems (Marszal et al., 2011; Sartori et al., 2012). This outcome is particularly relevant for urban edge contexts, where infrastructure capacity and financial resources may be limited (Nilsson et al., 2014). The reliance on low-tech environmental strategies—such as optimized orientation, shading, and natural ventilation—supports the feasibility and replicability of the design approach beyond technologically intensive urban centers (Rovers, 2019). To further evaluate the social dimension of the participatory process, a post-design survey was conducted with participants involved in the co-design workshops. The survey assessed satisfaction with the design process, perceived environmental performance, sustainability awareness, and trust in participatory architecture (Creswell & Poth, 2018). The summary of survey findings is presented in Table 2.

Table 2. Summary of survey results supporting the research question

Survey Focus	Average Score (out of 5)	How It Supports the Research Question
Satisfaction with design process	4.4	Shows participatory design increases user satisfaction
Ideas reflected in final design	4.2	Confirms community input shaped the final outcome
Building is environmentally friendly	4.6	Participants recognized sustainability in the design
Increased awareness of sustainability	4.7	Indicates that involvement raised environmental awareness
Support for future similar projects	4.9	Demonstrates strong community support for participatory design
Frequency of use of the space	3.8	Suggests the building is useful and integrated into daily community life
Aesthetic rating of the building	4.3	Reflects positive perception and acceptance of the final design
Trust in co-designed public buildings	4.5	Confirms high trust in participatory methods for future public architecture

Table 2 provides an overview of how participants evaluated both the process and the perceived outcomes of the design. The strongest scores relate to support for future similar projects (4.9) and increased awareness of sustainability (4.7), suggesting that the participatory process did more than validate design preferences. It also functioned as a learning mechanism through which sustainability concepts became understandable and meaningful at the community level. This is particularly relevant to the research objectives because it indicates a direct relationship between engagement and behavioral alignment: when participants understand why certain environmental strategies are implemented, they are more likely to accept them, maintain them, and use the space in ways that support performance rather than undermine it.

The score for “building is environmentally friendly” (4.6) indicates that sustainability was legible to participants, which is important in projects where technical performance is often invisible or difficult to interpret. If sustainability remains abstract, community support may weaken over time. Conversely, when sustainability is perceived and understood, it can strengthen stewardship and reinforce long-term maintenance. The “frequency of use of the space” score (3.8) is comparatively lower, which is still meaningful in an urban edge context where public spaces often struggle with sustained daily activation. This result implies that while the space is integrated into community life, there remains room for ongoing adaptation and programming to increase everyday use. Taken together,

the survey findings support the central claim of the study: participatory co-design can align technical sustainability ambitions with social acceptance, trust, and the long-term viability of shared public architecture

Table 3. NVivo-coded themes from participant responses (N = 10)

Theme	Description	Number of References	Supporting Quotes (Examples)
Empowerment through inclusion	Participants felt their voices were heard and valued in the design process.	8	"I felt like my ideas really mattered." "It was a rare chance to contribute."
Increased sustainability awareness	Design engagement led to greater concern for the environment and energy use.	7	"Now I care more about energy-saving." "I learned about green buildings."
Community ownership	The process built a stronger emotional connection to the space.	6	"It feels like our building." "I'm more connected to this place now."
Preference for green features	Residents emphasized a desire for nature-based and eco-friendly elements.	6	"I loved the garden idea." "Green roofs and shaded areas are important."
Support for future projects	Strong interest in repeating similar participatory processes elsewhere.	5	"We should do more of these." "I'd join again for sure."
Learning by doing	Participants expressed that hands-on involvement was an educational experience.	4	"It was a new way to learn about design." "Sketching helped me understand more."

The survey results provide quantitative support for the effectiveness of participatory architectural design. High satisfaction scores indicate that participants felt meaningfully engaged in the design process rather than passively consulted. The strong recognition of environmental performance and increased sustainability awareness suggests that participatory engagement functioned not only as a design tool but also as an educational process. The high level of support for future similar projects reflects trust in participatory approaches as a legitimate method for delivering sustainable public architecture. In addition to survey data, qualitative feedback from participants was analyzed to gain deeper insight into perceptions of empowerment, ownership, and learning. The thematic analysis of participant responses is summarized in Table 3, highlighting recurring patterns across the co-design workshops.

These limitations are characteristic of design-research projects that prioritize iterative development and community engagement over controlled experimental conditions. While benchmark-based estimation supports an early-stage assessment of feasibility, post-occupancy evaluation would provide stronger evidence of operational energy performance, user behavior, and maintenance realities over time. In particular, longitudinal observation could clarify whether the educational dimension of participation translates into sustained pro-environmental practices, such as careful resource use, stewardship of green features, and ongoing community-led management of shared spaces.

Additionally, the case study focus provides depth but naturally constrains transferability across contexts with different climatic conditions, governance structures, and socio-cultural expectations of public space. Comparative studies across multiple urban edge sites could help identify which elements of the proposed framework are context-specific and which are more broadly replicable. Future work could also integrate post-occupancy energy and behavioral data to strengthen the relationship between participatory processes, everyday use, and measurable environmental outcomes. Such research would extend the contribution of this study by connecting design intention and real-world performance within community-scale sustainable architecture.

The qualitative findings reinforce the quantitative survey results by revealing how participatory engagement fostered emotional attachment, learning, and a sense of shared responsibility. Participants frequently emphasized the value of being included in decision-making and expressed stronger commitment to the proposed space as a result. The emphasis on green features further demonstrates alignment between community preferences and environmental sustainability objectives. Overall, the results indicate that participatory co-design can function as a critical link between energy-positive architectural strategies and placemaking outcomes. By embedding environmental logic within a collaborative design process, the project achieved both technical and social benefits. These findings support the argument that urban edge environments are not peripheral but rather strategic contexts for testing inclusive, climate-responsive architectural models that balance energy performance with community resilience (Chan & Diehl, 2025; Sanoff, 2000).

The data analysis from the survey results demonstrates a clear correlation between participatory involvement and the acceptance of sustainable technologies. One of the most significant findings was the 4.8/5.0 rating for "Shaded Gathering Areas." This indicates that even in temperate climates like Amsterdam, the perception of urban heat and the need for sheltered public space are primary concerns for residents. From an architectural perspective, this feedback led to the development of the "Energy Canopy" concept. Instead of traditional, hidden rooftop photovoltaic panels, the design proposes a semi-transparent solar skin that defines the building's aesthetic and functional identity. This skin provides passive cooling for the community spaces below while achieving a projected energy surplus of 12%. This surplus is not merely a technical achievement but a communal asset; the extra energy can be used to power community charging stations or local workshops, thereby creating a tangible "energy dividend" that residents can directly benefit from.

Furthermore, the qualitative feedback highlighted a strong preference for what can be termed "tactile sustainability." Participants expressed skepticism toward automated smart systems, preferring instead materials and systems they could understand, touch, and potentially maintain. This prompted a strategic shift from high-carbon concrete and complex glass curtain walls to a hybrid timber and rammed earth construction. The use of reclaimed timber from local industrial sources not only reduces the embodied carbon by approximately 30% but also connects the building to the specific industrial history of Amsterdam Noord, fostering a deeper sense of psychological ownership and long-term stewardship among the users.

#### 4. Conclusions

This study demonstrates that energy-positive, carbon-neutral community architecture can be effectively realized in urban edge environments when environmental strategies are integrated with participatory placemaking processes. By situating the research in Amsterdam Noord, a rapidly transforming urban periphery, the study responds to the growing need for inclusive and climate-responsive design approaches beyond dense urban cores. The findings confirm that sustainability in architecture is not solely a technical challenge but also a social process shaped by community engagement, local knowledge, and everyday use.

Through a qualitative design-research case study, the project achieved a projected 12% operational energy surplus using a combination of passive design strategies and on-site renewable energy integration. Importantly, this outcome was achieved without reliance on complex digital simulations or high-tech building systems. Instead, the research demonstrates the potential of low-tech, human-centered design methods—such as manual environmental observation, iterative design development, and material choices with low embodied carbon—to deliver meaningful environmental performance at the community scale. This approach enhances the feasibility and replicability of energy-positive design in contexts where resources and technological capacity may be limited.

Equally significant are the social outcomes of the participatory co-design process. Active involvement of residents in the design stages fostered a strong sense of ownership,

trust, and emotional attachment to the proposed public space. Survey results and qualitative feedback indicate increased awareness of sustainability principles and broad support for participatory architecture as a planning and design approach. These findings suggest that participatory engagement can function as both a design tool and an educational mechanism, supporting long-term stewardship and responsible use of shared spaces. From a placemaking perspective, the research highlights the importance of aligning environmental performance with everyday social practices. The integration of shaded gathering areas, edible gardens, ecological pathways, and flexible multi-purpose spaces reflects how community input can enhance the relevance, accessibility, and resilience of public architecture. In urban edge environments—where public spaces often lack identity and long-term care—such alignment is critical for ensuring sustained use and maintenance.

The study contributes to existing literature by addressing the intersection of energy-positive architecture, participatory design, and urban edge contexts, which has received limited empirical attention. By examining these domains within a single architectural framework, the research offers a more holistic understanding of sustainable placemaking. Rather than treating environmental efficiency and social inclusion as separate objectives, the findings demonstrate their mutual reinforcement when addressed through integrated design processes.

Despite its contributions, the study has limitations. The projected energy surplus is based on established benchmarks and design estimation rather than post-occupancy performance data. Additionally, the research focuses on a single case study, which limits generalization across different cultural, climatic, and governance contexts. Future research could build on this work through longitudinal evaluation of built projects, comparative studies across multiple urban edge sites, and integration of post-occupancy energy and behavioral data. In conclusion, this research underscores the potential of participatory, energy-positive placemaking as a viable pathway for sustainable urban development at the metropolitan periphery. By reframing urban edge environments as strategic sites for innovation rather than residual spaces, the study offers practical insights for architects, planners, and policymakers seeking inclusive and climate-resilient design solutions. The proposed framework supports the development of public architecture that not only reduces environmental impact but also strengthens community resilience, environmental awareness, and collective responsibility in the face of ongoing climate challenges.

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### **Author Contribution**

The author solely conceived the study, designed the methodology, collected and analyzed the data, and prepared the manuscript.

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### **Ethical Review Board Statement**

The study was conducted in accordance with institutional guidelines.

### **Informed Consent Statement**

Informed consent was obtained from all participants involved in the study.

### **Data Availability Statement**

All data are available from the corresponding author upon reasonable request.

## Conflicts of Interest

The author declare no conflict of interest.

## Declaration of Generative AI Use

During the preparation of this work, the author used ChatGPT to assist in improving grammar. After using this tool, the author reviewed and edited the content as needed and took full responsibility for the content of the publication.

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