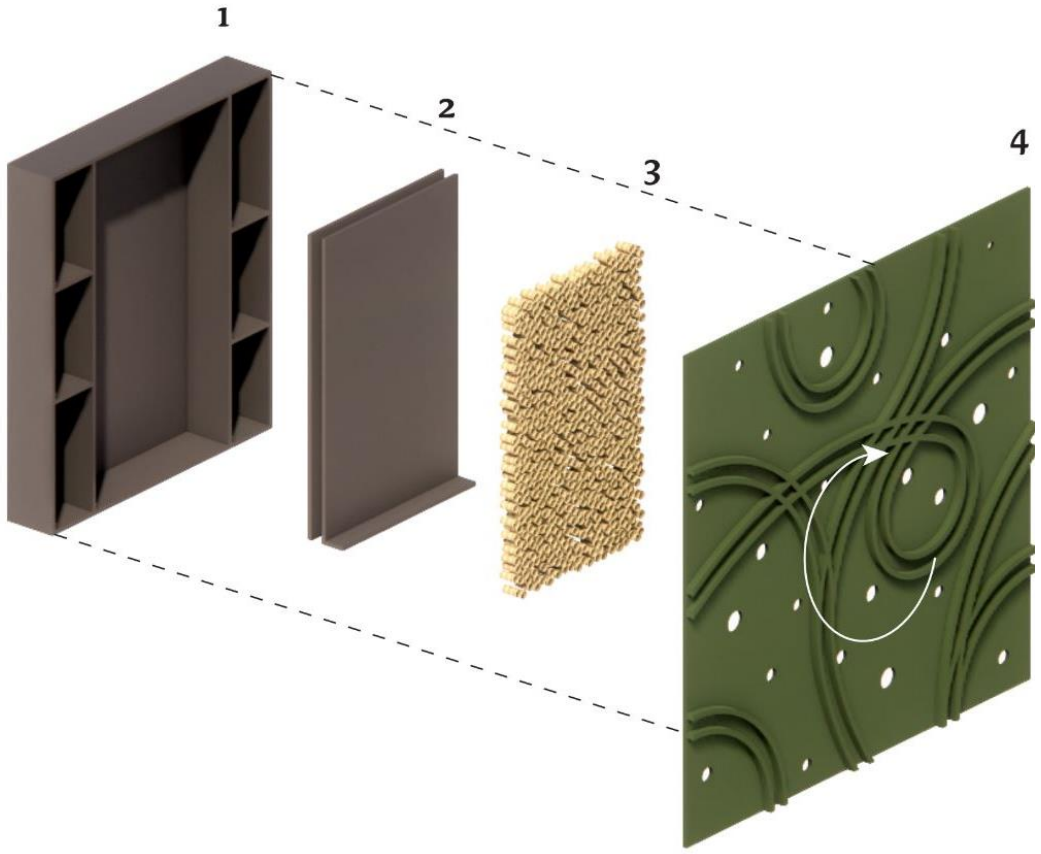
Natuurinclusieve Gebiedsontwikkeling



Nature-inclusive biobased facades

A comprehensive guide to design, evaluate and redesign

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This document is a deliverable within Work Package 1 of project Natuurinclusieve Gebiedsontwikkeling
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Natuurinclusieve Gebiedsontwikkeling

Abstract

Nature-inclusive facades have emerged as a sustainable and aesthetically pleasing approach to architectural design, integrating elements of nature into building exteriors to enhance biodiversity, environmental quality, and human well-being. This guideline presents a comprehensive framework for architects, designers, and urban planners to create, assess, and refine nature-inclusive facades.

The guideline outlines key steps for designing nature-inclusive facades, including research and analysis of local conditions, integration of vegetation and sustainable materials, enhancement of biodiversity, community engagement, and maintenance considerations. Drawing on principles of biophilic design, sustainable architecture, and green building standards, the guideline emphasizes the importance of incorporating native plant species, and providing habitat for wildlife.

Furthermore, the guideline provides recommendations for evaluating the performance of nature-inclusive facades, such as monitoring biodiversity, and soliciting feedback from occupants and stakeholders. By collecting data and feedback, designers can identify areas for improvement and refine their designs to optimize environmental and social benefits.

Finally, the guideline emphasizes the iterative nature of designing nature-inclusive facades, encouraging continuous evaluation and redesign based on evolving needs, technological advancements, and feedback from stakeholders. By following this guideline, designers can create innovative and sustainable architectural solutions that enhance the built environment while fostering connections with nature.

1. Introduction

The accelerating pace of urbanization has led to a decrease in biodiversity due to habitat loss, pollution and fragmentation (1). Furthermore, in the Netherlands it is estimated that the native species have decreased from 44% in 1900 to only 14% in 2010 (2). In urban environments it is estimated that the decrease of breeding birds and butterflies decreased by 50% from 1990 to 2017 (3) (4). However, research suggests that integrating nature into urban environments through innovative design approaches, such as nature-inclusive facades, can help mitigate the adverse impacts of urbanization. This introduction aims to define nature-inclusive facades, underscore the significance of incorporating nature within urban settings, and outline the purpose of this report in providing comprehensive guidelines for designing, evaluating, and redesigning nature-inclusive facades.

Definition of nature-inclusive facades

Nature-inclusive facades, also known as green facades or living walls, incorporate vegetation, such as climbing plants, vertical gardens, and hydroponic systems, into the exterior surfaces of buildings, transforming them into living, breathing structures. Another, emerging type of nature inclusive facades, are specifically designed to accommodate fauna and insects by implementing nesting space within the façade.

Importance of integrating nature into urban environments

As cities expand and become increasingly dense, residents are becoming more disconnected from nature, leading to a host of detrimental effects on health, well-being, and the environment. Nature-inclusive facades offer a solution by reintroducing greenery into urban landscapes, thereby fostering biophilic connections and restoring ecological balance (5) (6). Scientific research has demonstrated that exposure to nature in urban settings has numerous positive effects, including stress reduction, improved air quality, enhanced biodiversity, and increased social cohesion. Moreover, nature-inclusive facades contribute to energy efficiency by providing natural shading, reducing the urban heat island effect, and improving insulation.

Every organism in an ecosystem has a function. A reduction in biodiversity results in fewer organisms. This has a negative impact on ecosystem functions (7). Consequently, the area's ability to perform that specific function is diminished. Thus, biodiversity influences ecological resilience ,the ecosystem's ability to recover after a disturbance (8).

Natuurinclusieve Gebiedsontwikkeling

Purpose of the report

The objective of this report is to provide a guideline for the design, evaluation, and redesign of nature-inclusive facades. By synthesizing existing research, that integrates principles of biophilic design, environmental science, and architectural engineering, this report will offer insights into site analysis, material and vegetation selection, and performance evaluation. Ultimately, the guideline seeks to facilitate the widespread adoption of nature-inclusive facades as a transformative solution for enhancing biodiversity in cities.

2. Case studies; nature-inclusive facades

Nature-inclusive facades have gained prominence in recent years as innovative solutions for integrating nature into urban environments. A review of existing projects reveals several key notes and lessons learned, shedding light on the effectiveness, challenges, and best practices associated with these architectural features.

Key notes

- Diverse design approaches: Existing nature-inclusive facades encompass a wide range of design approaches, including green walls, vertical gardens, and living façade systems as well as fauna hotels in the more recent years. Projects such as One Central Park in Sydney, Australia, and Bosco Verticale in Milan, Italy, showcase the versatility of these designs, incorporating lush vegetation into high-rise buildings to create visually stunning and ecologically vibrant spaces.
- Environmental benefits: Scientific research has demonstrated the environmental benefits of nature-inclusive facades, including improved air quality, energy efficiency, and biodiversity support. Studies by Wong et al. (2011) and Oberndorfer et al. (2007) have shown that greenery on building exteriors can reduce the urban heat island effect, enhance thermal insulation, and provide habitat opportunities for urban wildlife, thereby contributing to sustainable urban development.
- Biodiversity enhancement: Nature-inclusive facades play a crucial role in enhancing biodiversity by providing habitat opportunities for a variety of plant and animal species within urban environments. Green walls, vertical gardens, and living façade systems serve as refuges for pollinators, birds, and insects, contributing to urban ecological networks and promoting species diversity (Dunnett & Kingsbury, 2004; Haase et al., 2014).
- Ecosystem Services: Projects such as the High Line in New York City demonstrate the multifunctional benefits of nature-inclusive facades in providing ecosystem services that enhance urban livability. Greenery on building exteriors contributes to improved air quality, stormwater management, and temperature regulation, creating healthier and more resilient urban ecosystems (Scholz-Barth, 2015; Breuste et al., 2016).
- Human Well-being: Scientific research has shown that proximity to nature and access to green spaces have positive effects on human health and well-being. Nature-inclusive facades create biophilic environments that promote relaxation, stress reduction, and

social interaction, thereby enhancing the quality of life for urban residents (Bratman et al., 2012; Kabisch et al., 2017).

- Challenges and maintenance: Despite their numerous advantages, nature-inclusive facades pose challenges related to maintenance, structural integrity, and long-term viability. Issues such as irrigation management, plant selection, and structural load-bearing capacity must be carefully considered to ensure the success of these projects. Additionally, ongoing maintenance requirements, including pruning, watering, and pest control, can pose logistical and financial challenges for building owners and managers.

Lessons learned

- Native Plant Selection: The choice of plant species is critical for maximizing biodiversity and ecological functionality in nature-inclusive facades. Native plants are preferred for their ability to support local wildlife, require less maintenance, and are better adapted to local climate conditions. Projects such as the California Academy of Sciences Living Roof demonstrate the importance of using regionally appropriate vegetation to enhance biodiversity and ecosystem resilience (Sustainable Sites Initiative, 2009).
- Community Engagement: Engaging local communities in the planning, design, and maintenance of nature-inclusive facades fosters a sense of ownership and stewardship, ensuring the long-term success and sustainability of these projects. Community gardens, participatory design workshops, and educational programs can empower residents to connect with nature, support biodiversity, and cultivate a sense of place within their neighborhoods (Francis & Lorenzo, 2018; Tzoulas et al., 2007).
- Site-Specific Considerations: Successful implementation of nature-inclusive facades requires careful consideration of site-specific factors, including climate, building orientation, and local ecology. Projects such as the PNC Tower in Pittsburgh, USA, exemplify the importance of tailoring design strategies to suit the unique characteristics of the site, maximizing environmental performance and occupant satisfaction.
- Integrated Design Approach: A holistic and integrated design approach is essential for the successful implementation of nature-inclusive facades. Collaboration between architects, landscape designers, engineers, and biologists is crucial to address technical, aesthetic, and ecological considerations effectively. Projects such as The Spheres in Seattle, USA, demonstrate the benefits of interdisciplinary collaboration in creating immersive and biophilic environments that promote well-being and productivity (9).
- Post-Occupancy Evaluation: Continuous monitoring and post-occupancy evaluation are essential for assessing the performance and effectiveness of nature-inclusive facades

over time. Longitudinal studies, such as those conducted by MacIvor and Lundholm (2011) on insect species composition in green roofs, provide valuable insights into the ecological dynamics and functionality of these systems, informing future design iterations and improvements.

3. Biophilic design principles

Biophilic design integrates natural elements and processes into the built environment to enhance human well-being and connection with nature (10). This approach acknowledges the innate human affinity for nature and seeks to create spaces that foster a sense of harmony and belonging within the urban landscape (11).

Incorporating vegetation

One of the central principles of biophilic design involves incorporating plants into indoor spaces. Plants not only enhance aesthetic appeal but also contribute to improving air quality by filtering out pollutants and increasing oxygen levels. Research studies such as those conducted by NASA and the University of Technology Sydney have demonstrated the positive effects of indoor plants on air quality and human health (12) (13).

Creating habitat

Designing spaces that mimic natural habitats can promote biodiversity and support various forms of wildlife. Incorporating features such as green roofs, bird feeders, and ponds can attract birds, insects, and other wildlife, creating a dynamic and diverse ecosystem within urban environments. Studies published in journals like "Urban Ecosystems" and "Frontiers in Ecology and the Environment" have explored the benefits of creating habitat-rich environments in urban areas (14) (15).

Effects on livability

By incorporating elements such as natural light, vegetation, water features, and biomorphic forms, biophilic design aims to reduce stress, improve cognitive function, and promote overall health and happiness among occupants (10) (11).

Scientific research has demonstrated the positive effects of biophilic design on various aspects of human physiology and psychology, including lowered blood pressure, increased productivity, and enhanced mood and creativity (16). Furthermore, biophilic design principles align with sustainability goals by promoting resource efficiency, biodiversity conservation, and ecological resilience in urban environments (10) (11). As cities continue to grow and urbanization intensifies, integrating biophilic design strategies becomes increasingly important for creating healthy, resilient, and livable spaces that benefit both people and the planet.

4. Material selection

The choice of materials in constructing inclusive facades plays a significant role in influencing biodiversity in nature. Various factors, including material composition, texture, and sustainability, contribute to either enhancing or diminishing biodiversity. Biobased materials, derived from renewable natural resources, offer several advantages over conventional materials in promoting biodiversity and nature inclusivity.

Material composition: The composition of materials used in facades can directly impact biodiversity. Research by Chiang suggests that materials containing toxic substances or non-renewable resources can have adverse effects on the surrounding ecosystem by leaching harmful chemicals or depleting natural resources (17).

Texture influence: Texture plays a crucial role in enhancing biodiversity on facades. Studies by Kadas indicate that materials with varied textures provide microhabitats for diverse flora and fauna, such as mosses, lichens, and insects. Rough textures create niches for colonization, fostering biodiversity (18).

Biobased materials: Biobased materials, derived from renewable biological sources, offer inherent advantages for biodiversity. According to research by European Bioplastics (2020), biobased materials such as wood, bamboo, and natural fibers provide habitat and food sources for various organisms, thereby promoting biodiversity.

Advantages of biobased materials for nature inclusivity

Renewability: Biobased materials are derived from renewable resources, reducing dependency on finite fossil fuels and mitigating environmental degradation associated with extraction and processing (Nikolaou et al., 2020).

Carbon sequestration: Biobased materials have the potential to sequester carbon dioxide during growth and can continue to store carbon throughout their lifespan (European Commission, 2019). This contributes to mitigating climate change impacts and enhances environmental sustainability.

Biodiversity promotion: Biobased materials support biodiversity by providing habitats, food sources, and promoting ecological balance (Hodgkinson et al., 2020). Their natural composition and textures create conducive environments for various species to thrive.

Material choice significantly influences biodiversity in nature-inclusive facades. Texture, composition, and sustainability are critical factors affecting biodiversity outcomes. Biobased materials offer distinct advantages in promoting biodiversity and nature inclusivity due to their

renewable nature, carbon sequestration potential, and ability to provide habitats for diverse organisms.

5. Urban planning

Urban environments, characterized by dense infrastructure and limited green spaces, often lack the vital connection to nature essential for human health and well-being. Biophilic design principles offer a solution by integrating natural elements into the built environment, fostering a symbiotic relationship between humans and nature. Nature-inclusive facades represent a tangible manifestation of biophilic design, enriching urban landscapes with greenery while enhancing the quality of life for inhabitants.

Ecosystem services

Ecosystem services refer to the benefits that humans derive from natural ecosystems, including provisioning, regulating, cultural, and supporting services (19). These services are essential for supporting human well-being, economic prosperity, and societal development (20). Provisioning services, such as food, water, and timber, directly fulfil human needs and are vital for sustaining livelihoods and economies (20). Regulating services, including climate regulation, water purification, and pest control, help maintain environmental balance and mitigate natural disasters (19). Cultural services encompass aesthetic, spiritual, and recreational values provided by ecosystems, contributing to cultural identity and social cohesion (19).Finally, supporting services, such as soil formation, nutrient cycling, and pollination, underpin the functioning of ecosystems and enable the delivery of other services (20). Understanding and valuing ecosystem services are critical for informing land use planning, natural resource management, and conservation efforts to ensure the continued provision of these benefits for future generations (19).Nature-inclusive facades contribute to the provision of ecosystem services, including air purification, temperature regulation, noise reduction, and habitat creation. By mimicking natural ecosystems, these facades support biodiversity and ecological resilience while mitigating the environmental impacts of urbanization (21).

Urban heat island effect

The urban heat island (UHI) effect refers to the phenomenon where urban areas experience significantly higher temperatures than their surrounding rural areas due to human activities and modifications to the landscape (22). Urbanization leads to the replacement of natural vegetation with impervious surfaces such as asphalt and concrete, which absorb and retain heat, resulting in elevated temperatures (22). Additionally, the concentration of buildings, vehicles, and industrial activities in urban areas generates heat through energy consumption and waste heat production (22). The UHI effect exacerbates heat-related health risks, such as heat stress and heat-related illnesses, particularly during heatwaves (23). Furthermore, higher

temperatures in urban areas can disrupt ecosystems, alter precipitation patterns, and exacerbate air pollution, further impacting human health and environmental quality (23). Addressing the UHI effect requires strategic urban planning and design interventions, such as increasing green spaces, implementing cool roof and pavement technologies, and enhancing natural ventilation to mitigate heat buildup and promote urban resilience (24). Vertical gardens or green nature-inclusive facades can help mitigate this effect by providing shade, evaporative cooling, and thermal insulation, reducing energy consumption for cooling (24) (25) (26).

6. Monitoring

Performance metrics

Assess the performance of vegetative nature-inclusive facades based on quantitative metrics, such as energy savings, carbon sequestration, stormwater retention, and air quality improvement to inform future design iterations. Use modelling tools, sensor data, and monitoring systems to measure key indicators over time (27).

Surveys

Conduct surveys and interviews to gather feedback from building occupants and neighbours regarding their perception of the nature-inclusive facade. Evaluate factors such as visual aesthetics, thermal comfort, air quality, and psychological well-being to understand the human experience and identify areas for improvement (28).

Numerous studies have demonstrated the positive impact of nature exposure on mental health and cognitive function. For instance, Ulrich's seminal study on the "restorative effects of nature" found that views of nature from hospital windows significantly reduced patients' stress levels and facilitated faster recovery from surgery. Similarly, research by Kaplan and Kaplan revealed that natural environments promote attention restoration and emotional resilience, thereby enhancing overall psychological well-being (29). Nature-inclusive facades provide occupants with access to greenery and natural light, creating biophilic environments that promote relaxation, concentration, and stress reduction.

Ecological monitoring

It is important to monitor fauna and insect biodiversity and bio density throughout the different seasons of the year. For more accurate and complete data, the monitoring should take place at least one year before the implementation of the nature inclusive façade. Similarly, the same method for monitoring should be applied after the measures have been implemented for at least one or two years in order to be able to collect enough data for a comparison of the biodiversity and bio density before and after the nature inclusive measure was implemented.

Monitor biodiversity indicators, such as species diversity, abundance, and habitat quality, to evaluate the ecological performance of the facade. Use ecological surveys, camera traps, and citizen science initiatives to assess the presence and behaviour of wildlife in the vicinity of the building (30).

7. Guideline

Guidelines for implementation and redesign of nature-inclusive facades

1. Site analysis: Conduct a thorough site analysis to understand the local climate, microclimate, soil conditions, and ecological context. Identify opportunities and constraints for implementing nature-inclusive facades, considering factors such as sunlight exposure, wind patterns, and spatial limitations (31). Furthermore, a flora and fauna quick scan should be performed to determine the original state of biodiversity and bio density. The quick scan should result in a species list which includes the frequency of the species in the monitored area. Moreover, a clear map must be included which illustrates the area and route. It is recommended to monitor the site for at least four seasons to get a good indication of the fauna in the area. Finally, the species list should highlight the native species so they are easily identified during the design process.

2. Collaborative design process: Engage multidisciplinary teams of architects, landscape architects, engineers, ecologists, and stakeholders in the design process to integrate diverse perspectives and expertise. Foster collaboration between professionals to develop holistic and innovative solutions that address environmental, social, and economic objectives (32). Native flora will attract native fauna and therefore it is recommended to use the identified native species in the area for the nature inclusive façade and surrounding the building (36). In order to design a façade which is really nature inclusive one has to provide at least two of the four most important aspects for fauna; food, safety, space to reproduce and nest and water. Shelter and nest space can be provided within the façade and green walls as well, however water and food can be hard to implement within the structure and thus the surrounding should also be part of the design. When designing for nature inclusivity it is important to consider the safety and protocols of the buildings in order to determine whether adding flora to the façade can be considered a risk. In that case the vegetation should be added in the surroundings of the building.

3. Adaptive management; Adopt an adaptive management approach to facilitate continuous learning, experimentation, and adaptation throughout the lifecycle of the nature-inclusive facade. Monitor performance metrics, gather feedback from stakeholders, and iterate on design strategies to optimize functionality and resilience over time (33). The site analysis (see step 1) should be repeated after the implementation of the nature inclusive façade and neighboring measures in order to be able to properly evaluate the

4. Community engagement: Involve local communities, residents, and organizations in the planning, implementation, and maintenance of nature-inclusive facades to foster a sense of

ownership, stewardship, and pride. Educate and empower stakeholders to participate in green building initiatives and sustainable urban development efforts (34).

Educate building occupants and visitors about the benefits of nature-inclusive facades and how they can contribute to biodiversity conservation.

8. Conclusions

Nature-inclusive facades represent a promising approach to sustainable architecture, harnessing the inherent benefits of nature to enhance the environmental and social performance of buildings. By integrating vegetation, biodiversity, and ecological systems into building exteriors and their surroundings, these facades offer a range of benefits, from energy efficiency to biodiversity conservation and human well-being. Through careful design and evaluation nature-inclusive facades can contribute to the creation of healthier, more resilient, and vibrant urban environments.

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Appendix

Appendix 1: Guideline for redesigning ProRail façade

Redesigning nature-inclusive facades involves a multifaceted approach that considers ecological, aesthetic, and functional aspects. This guideline aims to provide a systematic framework for re-designing existing facades to enhance their ecological performance, visual appeal, and overall functionality. By integrating principles of biophilic design, green infrastructure, and adaptive management, re-designed nature-inclusive facades can contribute to sustainable urban development and an increase in biodiversity.

Assessment and analysis:

1. Site evaluation: Conduct a comprehensive assessment of the existing building site, considering factors such as microclimate, soil conditions, sunlight exposure, and surrounding vegetation. Identify opportunities and constraints for re-designing the facade to maximize ecological benefits and minimize environmental impacts.

2. Ecological audit: Evaluate the ecological performance of the current facade, including biodiversity indicators, habitat quality, and ecosystem services provision. Use ecological surveys, monitoring data, and expert assessments to identify strengths and weaknesses and prioritize areas for improvement. Additionally an ecological quickscan can be performed of the surroundings.

3. Stakeholder engagement: Engage building occupants, local communities, and relevant stakeholders in the re-design process to gather input, feedback, and support. Foster collaboration and communication to ensure that diverse perspectives and priorities are considered in the decision-making process.

Design principles and strategies:

1. Integration of vegetation: Incorporate diverse vegetation elements into the facade design, including green walls, vertical gardens, and planter boxes. Select plant species that are well-suited to the local climate and microclimate conditions, considering factors such as water availability, sunlight exposure, and maintenance requirements. Use native species as much as possible. By increasing biodiversity in flora, insects and fauna will be more drawn to the façade as they not only have safety and a nesting space but also a food source.

2. Biodiversity enhancement: Enhance habitat quality and biodiversity by including the surroundings of the substations in the design. Select plant species that attract pollinators, birds, and other wildlife. Incorporate diverse vegetation layers and habitat features, such as wood

logs and leaves. Adjust the nesting façade by increasing the variety in entrance diameter. Adding vertical and horizontal slots for butterflies and other insects to be able to use the façade.

3. Water implementation and management: Implement open water sources for fauna. Additionally efficient irrigation systems, rainwater harvesting, and greywater recycling techniques to sustain plant growth and minimize external water consumption. Design the facade to capture, retain and redirect rainwater, reducing runoff and supporting ecosystem services such as stormwater management and groundwater recharge.

4. Material selection: Choose sustainable and eco-friendly materials for the facade construction, such as recycled materials, low-impact finishes, and FSC-certified wood. Prioritize materials that have minimal environmental footprint and contribute to the overall sustainability of the building. Chose moldable or rough materials as increasing the texture of the façade enhances biodiversity.

Implementation and monitoring:

1. Phased implementation: Develop a phased re-design plan to minimize disruption to building occupants and maximize resource efficiency. Prioritize high-impact interventions and implement changes incrementally, monitoring performance and feedback at each stage of the process.

2. Adaptive management: Adopt an adaptive management approach to facilitate continuous learning and improvement throughout the re-design process. Monitor ecological indicators, occupant satisfaction, and performance metrics to evaluate the effectiveness of design interventions and make adjustments as needed.

3. Maintenance and care: Establish a maintenance plan to ensure the long-term viability and success of the re-designed nature-inclusive facade. Train building staff or engage professional maintenance services to provide regular care, including pruning, watering, fertilization, and pest management.

Community engagement and education:

1. Educational outreach: Raise awareness and build community support for the re-designed nature-inclusive facade through educational outreach and public engagement activities. Host workshops, guided tours, and educational events to showcase the ecological and social benefits of the project and empower stakeholders to participate in sustainability initiatives.

2. Interactive features: Incorporate interactive elements into the re-designed facade, such as interpretive signage, educational displays, and interactive artworks, to engage and educate building occupants and visitors about the natural environment and sustainable living practices.

3. Demonstration site: Establish the re-designed nature-inclusive facade as a demonstration site for best practices in sustainable architecture and urban greening. Share lessons learned, case studies, and monitoring data with the broader community and inspire other projects to emulate similar approaches.

Conclusion: Redesigning nature-inclusive facades offers a transformative opportunity to enhance the ecological, social, and aesthetic value of existing buildings. By integrating principles of biophilic design, green infrastructure, and adaptive management, re-designed facades can contribute to urban biodiversity conservation, climate resilience, and community well-being. Through careful assessment, collaborative design, and ongoing monitoring, re-designed nature-inclusive facades can serve as exemplars of sustainable architecture and inspire positive change in the built environment.