SUSTAINABLE PRE-CONSTRUCTION PRACTICES: SETTING THE FOUNDATION FOR GREEN BUILDING CERTIFICATION

Highlight pre-construction strategies for achieving LEED or similar green certifications, such as material selection and site planning.

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Abstract

The pre-construction phase is a critical stage in sustainable construction, offering a unique opportunity to embed environmentally conscious strategies into a project's foundation. This article explores pre-construction practices to achieve green building certifications such as LEED, NGBS, and ENERGY STAR. Key strategies discussed include sustainable site selection, lifecycle-based material procurement, energy modeling, integrated design processes, and collaboration with certification authorities. A 3800 Acqua and Royal Sail Project case study demonstrates the tangible benefits of these practices, including significant energy savings, financial incentives, and enhanced marketability. Lessons learned and replicable practices are outlined to guide construction professionals in developing high-performance, sustainable projects that meet stringent certification standards and contribute to global sustainability goals.

Keywords—*Sustainable construction, pre-construction practices, green building certifications, LEED, NGBS, ENERGY STAR, lifecycle assessment, energy modeling, integrated design, mortgage insurance premium reduction*

I. INTRODUCTION TO GREEN BUILDING CERTIFICATION

Green building certifications act as signs for eco-friendliness, offering guidelines to check and honor buildings built, made, and run with care for nature. These certifications show that projects reach rigid rules for saving energy, protecting resources, and keeping people healthy. Some famous certifications include Leadership in Energy and Environmental Design (LEED), the National Green Building Standard (NGBS), ENERGY STAR, and Green Globes.

a. Overview of Green Building Certifications

i. Leadership in Energy and Environmental Design (LEED):

LEED – created by the U.S. Green Building Council (USGBC) – is a worldwide popular green building certification program. It judges projects using many criteria, e.g., eco-friendly site development, water use efficiency, energy performance, material choice, and indoor environmental quality. LEED awards different levels of certification: Certified Bronze, Silver, Gold, and Platinum, depending on points gained in these areas.

ii. National Green Building Standard (NGBS):

The NGBS – created by the International Code Council (ICC) and the National Association of Home Builders (NAHB), focuses on homes and buildings with mixed uses. It highlights energy-saving, water-saving, clean indoor air, and eco-friendly materials. Projects following NGBS rules need strict checks by outside experts during design and building steps to meet regulations.

iii. ENERGY STAR:

Run by the U.S. Environmental Protection Agency (EPA) – ENERGY STAR looks at energy use in buildings and gadgets. Buildings get certification when they work better than 75% of similar places nationwide and follow stringent energy-saving rules. ENERGY STAR certification also helps get credits under LEED and NGBS.

iv. Green Globes:

Green Globes certification – given by the Green Building Initiative (GBI) – offers another flexible choice. It checks projects regarding energy, water, resources, emissions, and indoor environment areas. This provides a practical option instead of LEED for some project types.

b. Importance of Pre-Construction Practices in Sustainability

Before construction starts – this stage plays a significant role in a building's life for adding eco-friendly goals. Choices made now directly affect the project's chance to reach green certification standards and how well it works over time. Significant advantages of focusing on sustainability before construction include:

i. Foundation for Sustainable Design:

Early thinking about sustainability in choosing sites, designing, and picking materials helps match certification needs. For example, selecting a site near public transport or designing for the best sun position gives many LEED points.

ii. Cost and Resource Efficiency:

Thinking about sustainability before building starts avoids expensive changes later. Talking early with sustainability experts and using energy tools finds cheap solutions that match green certification goals.

iii. Collaboration Across Stakeholders:

Before building begins, architects, engineers, builders, and certification experts can work together. This teamwork helps everyone know and reach sustainability targets, from buying materials to building methods.

iv. Compliance with Certification Standards:

Talking with certification groups and skilled advisors early helps meet document, energy model, and inspection needs. Doing this early reduces delays or extra costs during the certification steps.

As construction professionals, architects, engineers, and sustainability experts, you play a crucial role in applying these strategies in your projects. By focusing on sustainable actions before construction begins, you can aim for certifications like LEED or NGBS. This not only ensures the strength and success of your buildings over time but also contributes to the global sustainability movement.

II. SITE SELECTION AND SUSTAINABLE PLANNING

Choosing an environmentally friendly place to build is one of the significant choices before construction starts. A wisely picked spot lowers harm to nature and helps reach green building certification targets. This part examines what to consider when choosing a site, city renewal methods, and adding stormwater control systems.

a. Criteria for Selecting Environmentally Sustainable Sites

Choosing green sites focuses on areas that disturb nature very little. Skipping untouched lands and choosing used lands or old industrial spots saves wildlife and stops city spread. Being close to buses, walking paths, and bike routes cuts down car use, thus lowering vehicle pollution. This matches LEED's location credits, which promote links to current infrastructure [9]. Additionally, brownfield redevelopment cleaning and reusing contaminated urban land encourages urban regeneration and reduces pressure on undeveloped

greenfields [7]. Sites equipped with existing water, power, and sewage infrastructure require significantly less new construction, reducing resource consumption and lowering overall project costs.

b. Urban Regeneration and Minimizing Ecological Disruption

Renewing cities by reusing old industrial sites supports innovative land use. These projects clean up dirty areas for new growth while giving life back to city spaces. Adding trees, water spots, etc., to plans keeps nature alive and adds beauty and environmental value to projects [8].

c. **Integration of Stormwater Management Systems**

A key part of eco-friendly planning involves intelligent stormwater control. LID methods – e.g., bioswales, rain gardens, and permeable pavements handle water runoff while filling groundwater. These steps stop floods, cut pollution, and match sustainable stormwater management [9]. Green roofs and rainwater collection systems also help by cutting runoff and giving water to plants or other uses [10]. Active pollution control in stormwater, like stopping erosion and using sediment barriers, keeps up with eco rules and lowers impacts downstream [11].

By focusing on sustainable site selection and planning, the team actively reduces building impacts, protecting nature and quickly reaching vital eco-building points. This instills a sense of responsibility and a feeling of being part of a larger environmental mission in the audience.

III. MATERIAL SELECTION AND LIFECYCLE ANALYSIS

Picking the right materials significantly affects eco-friendly buildings, changing how much harm a project does to nature and whether it follows green building certification criteria. Sustainable material choices focus on low energy use and recyclable materials, reducing pollution from moving and throwing away stuff. A smart way is to pick materials that use less energy, the total power needed to make them and bring the material to where it's used. Things like recycled steel, bamboo, and engineered wood need much less energy than usual options like concrete or new steel. Using recycled materials also cuts down on taking new resources from nature and making trash, helping earn LEED credits for reusing materials [6].

Materials from nearby places are another big part of choosing sustainable items. Getting materials within 500 miles means fewer emissions from transport and helps local businesses grow. For instance, wood approved by the Forest Stewardship Council (FSC) shows good forest care while meeting demanding eco-friendly standards. These choices fit LEED’s focus on nearby materials and certified wood [5].

Lifecycle Assessment (LCA) is critical in picking sustainable items. It looks at all environmental effects throughout a material’s life, from getting it out of the ground to throwing it away. LCA tools give information on global warming potential, resource depletion, etc., helping people choose wisely. For example, comparing concrete and cross-laminated timber (CLT) might show that CLT has a more negligible environmental impact, making it better for building structures [8]. Also, choosing materials goes beyond just being suitable for nature; it also includes health. Picking low-VOC paints, glues, etc., makes indoor air cleaner better for living or working inside and gets extra points in green building certification systems [3].

By using ideas like low energy use, local sourcing, and lifecycle checks, teams can quickly reduce environmental harm while meeting eco goals. These actions follow green certification needs well and set an example for innovative material use in building projects.

IV. ENERGY MODELING AND BENCHMARKING

Energy modeling and benchmarking are essential for predicting how buildings will perform and ensuring they meet green certification standards. These practices help project teams guess energy use, make better design choices and match sustainability goals like LEED and ENERGY STAR.

Energy modeling uses special software to pretend how a building uses energy in different situations. By looking at where the building faces, insulation quality, HVAC efficiency, and lighting setup, energy models give helpful ideas for lowering energy use and improving efficiency [5]. These tools also help teams find spots for renewable energy – e.g., solar panels or geothermal systems.

A primary result of energy modeling is the Statement of Energy Design Intent (SEDI), which shows how much energy a building will probably use based on its design. The SEDI compares against ENERGY STAR standards, which need at least a score of 75 to show good energy efficiency. For example, the 3800 Acqua Lifestyle apartments project got an ENERGY STAR score of 87, much higher than needed, because it used optimized HVAC systems, top-notch insulation, and ENERGY STAR appliances, helping lower energy use and costs. Benchmarking helps monitor ongoing performance, too. Tools like the ENERGY STAR Portfolio Manager let property managers track energy use, compare it with similar buildings, and find ways to improve. Keeping an ENERGY STAR score of 75 or more meets certification needs and saves money while helping the environment [3].

Using energy modeling and benchmarking allows project teams to create buildings that meet strict sustainability standards while providing excellent performance. This is essential for obtaining green certifications and promoting efficient construction development.

V.INTEGRATED DESIGN PROCESSES

Integrated design steps are crucial for making high-quality, eco-friendly buildings that meet green building requirements. In these steps, architects, engineers, sustainability experts, builders, and future users work together from the first ideas to the final checks. This complete method inspires new ideas and cuts waste, keeping eco-friendly goals at the heart of the project [6][7].

Building Information Modeling (BIM) plays a significant role in integrated design. BIM combines structural, mechanical, electrical, and environmental information into detailed 3D pictures, giving instant feedback on design choices [12]. For example, it might show how natural light enters a space to improve lighting or test different HVAC setups to find the best energy-saving choice. By spotting design issues before a building starts, BIM reduces expensive fixes and waste, leading to more efficient and green buildings [5].

Talking early with green building consultants improves the integrated design. Since each certification, like LEED or NGBS, has unique needs and credit systems, eco-experts help teams with energy planning, material picking, and paperwork methods [1]. Group workshops and regular meetings keep everyone on track, inspiring a shared duty to hit the project’s eco-goals.

VI. COLLABORATION WITH CERTIFICATION AUTHORITIES

Building friendly ties with certification groups is essential for getting official approval for eco-friendly building projects. These groups, like the U.S. Green Building Council (USGBC) for LEED or Home Innovation Research Labs for NGBS, offer advice, checks, and outside validation of green claims [2].

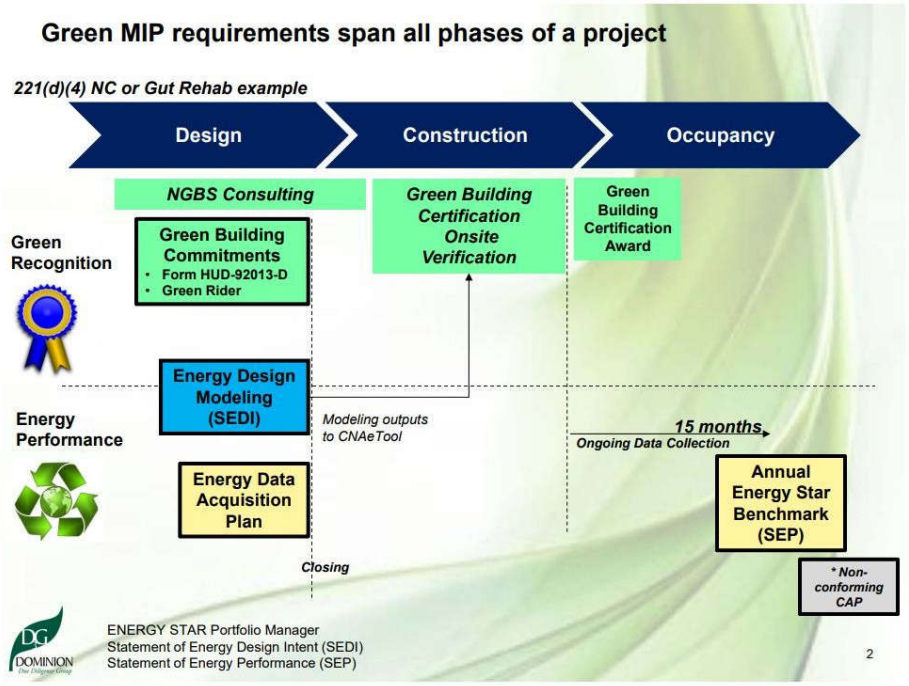

Figure 1: Green MIP reduction program.

Source: https://www.swaconline.net/assets/docs/Energy-and-Sustainability-SWAC-2018.pdf

a. Early Engagement

Talking to these groups before applying helps project teams understand specific needs for saving energy, conserving water, and using materials wisely [3]. Using this information early in design planning helps developers avoid last-minute changes and smooth the certification path.

b. Documentation and Verifications

Most eco-friendly certification programs require detailed paperwork, e.g., energy simulations, material lists, and on-site inspections [4]. Regular meetings with certifiers help ensure each document meets standards – reducing delays or extra costs.

c. Expert Navigation

Working with LEED-Accredited Professionals or NGBS Verifiers gives special knowledge. They spot possible problems early, suggest fixes, and speed up review steps [1]. Their know-how often proves very helpful in fine-tuning design parts that earn key points.

By communicating clearly and actively with certification bodies, project teams can speed up approvals, maintain high paperwork quality, and reach higher levels of green recognition.

VII. GREEN BUILDING COMPONENTS

Choosing the right parts is key to getting the best green results and hitting certification goals. Though LEED, NGBS, ENERGY STAR, and Green Globes have different needs, some essential features always make a building eco-friendly.

a. High-Efficiency HVAC Systems

HVAC systems use energy in buildings. Buying ENERGY STAR-rated units reduces energy use and

carbon output [3]. Advanced techs like VRF or geothermal pumps improve performance while keeping indoor spaces comfortable.

b. Strong Insulation
Good insulation stops heat transfer well. Materials like spray foam or cellulose stabilize indoor temperatures by reducing heating/cooling needs [8]. Sealing windows/doors tightly also stops air leaks, improving efficiency and comfort levels.

c. Efficient Lighting Controls
Switching old lights to LEDs lowers electricity bills a lot. Smart controls such as motion sensors ensure that lights are only on when needed, saving more power [5].

d. Water-Saving Technologies
Using low-flow taps/toilets plus rainwater systems earns water-saving credits across different programs [4]. These steps save water, a precious resource, and cut long-term costs.

e. Smart Building System
Automated systems manage HVAC, lighting, and security in real-time based on occupancy, weather, and time changes, keeping conditions optimal while using less power yet maintaining comfort inside buildings [6].

VIII. FINANCIAL AND OPERATIONAL BENEFITS

Investing money in eco-friendly actions before building starts brings many financial and operational benefits beyond the early project stage.

a. Lower Utility Bills
Energy-planning innovative HVAC systems and water-saving gadgets reduce utility costs over time. Even though green materials and technology might cost extra initially, these costs are usually covered by savings later [6].

b. Incentives and Tax Savings
Many places offer tax cuts, funds, or faster permits for energy-smart projects. National programs like the Green Mortgage Insurance Premium (MIP) reduction cut borrowing costs for approved projects [3].

c. Enhanced property value
Green certifications make buildings shine in competitive markets. Renters and buyers now often look for healthier indoor spaces, smaller carbon footprints, and lower utility bills – so green-certified buildings often fetch higher rents and prices [1].

d. Better Company Reputation
For business buildings, eco-friendly features boost a company's image with customers and investors. This market edge can lead to more tenants staying longer and greater loyalty from those who care about the environment [4].

IX. CHALLENGES AND BEST PRACTICES

Although green buildings offer significant benefits, getting green certification can be tricky and challenging. Knowing common problems and using innovative methods helps teams handle these issues well [8].

a. Common Problems
   i. High upfront Costs: Expensive materials and special services for certification stress budgets.

Incentives and future savings often balance these early costs.

ii. Complicated Rules: Different certifications need specific steps requiring careful planning and paperwork to follow the rules.

iii. Knowledge Lacks: Fast-changing technologies and design styles demand constant learning for project groups.

b. Best Practices

i. Bring in Experts Early: Including sustainability experts, energy planners, etc., from the beginning cuts down on redoing work and keeps projects on track with goals [1].

ii. Use Energy Modeling: Detailed tests show the real effects of design choices helping cheap improvements.

iii. Choose Integrated Design: Open talks among all involved build responsibility and make decisions easy [6].

iv. Regular Training: Updating project teams on new techs. Policy shifts, etc., guarantee steady progress [12].

By actively tackling these problems and following the best methods, project teams will probably gain high returns from green buildings, creating buildings that shine in both performance and care for nature [5].

X. CASE STUDY: 3800 ACQUA AND ROYAL SAIL PROJECT

In different ways, the 3800 Acqua Lifestyle Apartments and Royal Sail, located in Suffolk, VA, developed and built by BECO Asset Management, LLC and its subsidiaries, show how thoughtful planning before building brings significant energy savings, lower costs and easy-to-copy good ideas for green apartment buildings. Both projects started by looking closely at the land to make it as eco-friendly as possible. At 3800, Acqua developers picked a spot in a mixed-use area with ready utilities and simple access to public transport, cutting down on nature damage and supporting quick travel [13]. Meanwhile, the Royal Sail Project sat near important community spots and was close enough to walk to key services, decreasing the need for extra roads and easing traffic jams.

Before making final design choices, both teams did early energy modeling. At 3800 Acqua, they ran simulations to compare HVAC systems' insulation levels and building envelope setups. They eventually found a high-performance insulation package and ENERGY STAR-certified HVAC equipment that considerably cut predicted energy use. The Royal Sail Project had repeated modeling sessions with architects, engineers, and sustainability experts to match local climate data with HVAC design. This way, system sizing got optimized, and peak loads dropped while meeting NGBS rules. These technical checks fit well with integrated design workshops where architects, builders, and LEED-accredited experts work together to adjust material details, reduce conflicts, and simplify paperwork [13]. For the Royal Sail Project, starting with a whole building view made clear paths for certification and tracking milestones easy.

Material buying plans also played a big part. At 3800 Acqua, the team picked local and recycled items – using reclaimed steel and FSC-certified wood to cut down energy use. Lifecycle Assessments (LCAs) backed these picks, helping the project choose materials with minimal environmental harm. The Royal Sail Project used insulated concrete forms (ICFs) to improve building walls and picked low-VOC paints and glues for cleaner indoor air. All these actions helped meet credit needs in LEED, NGBS, etc.

DG DOMINION
Due Diligence Group

National Green Building Standard (NGBS): Rough Inspection Report

Project	Royal Sail
Address	3894 Bridge Road Suffolk, VA 23435
GC Point of Contact	David / Henry
Green Verifier	Stephen Evanko
Date	4/23/21
Building	Building B – 5th Floor (26 Units)

Scope of Pre-Drywall Inspection:

- Chapter 5: Review relevant Lot and Site management practices (e.g. stormwater mgmt., etc)
- Chapter 6
  - Inspect Weather Resistant Barriers and Flashing details
  - Review Material Selection and Waste Management Practices
- Chapter 7 Energy:
  - Confirm Window Performance Specifications
  - Grade Insulation Installation and confirm UA improvement
  - Inspect unit air-sealing, duct sealing, etc
  - Confirm return ducts/transfer grills to bedrooms
- Chapter 8: Not Applicable at Rough
- Chapter 9: Verify exhaust ducts for bathroom and dryers, Passive Radon System, HVAC duct work protection, etc

Units Cleared for Drywall: (Before Drywall in units – issues in red must be addressed)

Units		Notes
501 - 517	✓	Passed; Issues resolved; Pin R19 to top of roof truss
519	✓	Passed; Issues resolved; Pin R19 to top of roof truss
521	✓	Passed; Issues resolved; Pin R19 to top of roof truss
518		Walls passed, Need insulation in the ceiling
520		Walls passed, Need insulation in the ceiling
522		Walls passed, Need insulation in the ceiling
523		Walls passed, Need insulation in the ceiling
527		Walls passed, Need insulation in the ceiling

Figure 2: NGBS Rough inspection report for Royal Sail

Home Innovation RESEARCH LABS

2012 Revised May 15, 2018 **This project has met all the BRONZE requirements**

NGBS Scoring for New Construction
ICC 700-2012 National Green Building Standard™

Project Name: 3800 Acqua Lifestyle Apartements
Location: North side of US 17 near Bridge Road, Suffolk, VA 23435

Bronze

Chapter	Required Points	Claimed Points	Additional Claimed Points Above Bronze	Point Shortfall	Mandatory Status
Chapter 5: Lot Design, Preparation, & Development	50	78	28		N/A
Chapter 6: Resource Efficiency	43	59	16		Met
Chapter 7: Energy Efficiency	30	39	9		Met
Chapter 8: Water Efficiency	25	51	26		N/A
Chapter 9: Indoor Environmental Quality	25	36	11		Met
Chapter 10: Operation, Maintenance, & Building Owner Education	8	12	4		Met
Section Totals	181	275	94	0	
Additional Points Above Bronze	50		94	0	
Total Points	231	275		0	

To achieve Bronze:

* Reach required Bronze score for each chapter	*This requirement has been met.*
* Reach required Additional Points for this project	*This requirement has been met.*
* Meet all mandatory items	*This requirement has been met.*
* For Chapter 7: Energy Efficiency:	
~ Claim at least 30 points from Section 702 (Performance Path) or Section 703 (Prescriptive Path) and select a minimum of 2 items from Section 704, ***OR***	*You have met the Prescriptive Path minimum points requirement.*
~ Choose the Alternative Bronze Compliance Path	*You have met the minimum 2 required items from Section 704.*

Figure 3: NGBS Bronze requirements and claimed points for 3800 Acqua Project

Regarding energy ratings, 3800 Acqua got a Design ENERGY STAR score of 87, much higher than the usual score of 75. Using strong insulation and very efficient HVAC systems, the complex aimed to cut yearly energy use by 25%

more than local rules require. The Royal Sail Project showed a similar drop in total energy use compared to a basic design. These successes brought many monetary benefits, like lower monthly utility bills and chances for state-level incentives. For the 3800 Acqua and Royal Sail Project, it also meant less mortgage insurance costs through a federal green mortgage program. Both projects used their ENERGY STAR and LEED/NGBS scores to raise market value, drawing tenants concerned about spending less on energy and enjoying healthier living spaces.

When both the Projects qualified for a green mortgage program, they enjoyed a significant drop in mortgage insurance costs, making financing cheaper. The developer got their annual MIP rate cut by 0.35 percentage points from 0.60% to just 0.25%. Over a 30-year loan meant vast savings of money over the borrowed amount, helping developers cover higher upfront costs like energy planning, premium materials, etc. By using some of these savings in their budgets, the Developers could invest more boldly in new eco-friendly ideas not only improving the building's green features but also its long-term profits. This win-win situation encourages other multifamily builders to chase similar green mortgage deals.

Many essential lessons appeared that others could easily copy. Early thinking about long-term success, especially with energy planners and advisors, instead of spending much money later on fixes, helps pick the best designs. Regular teamwork among architects, engineers, builders, and green experts creates smooth results and keeps everyone on track with certification needs. Careful recording of materials, methods, and energy plans ensures that every step meets strict reporting rules. Being open to new ideas like using on-site renewable energy or trying new insulation types significantly improves performance and market project appeal. These ideas show the significant change possible with a data-based approach that looks ahead in planning for green building projects before they start.

Figure 4: NGBS Bronze Certificate for Royal Sail Building

XI. Conclusion and Future Directions

Sustainable pre-construction practices serve as the cornerstone of achieving green building certifications, ensuring that environmental goals are prioritized from the earliest stages of development. The strategic integration of site analysis, energy modeling, sustainable materials, and collaborative design processes enables project teams to meet

and exceed certification requirements. The 3800 Acqua and Royal Sail Project exemplify how these practices can yield substantial energy and financial savings, lower operational costs, and enhance property value. Furthermore, securing incentives like reduced mortgage insurance premiums underscores the economic feasibility of green building investments. As the construction industry evolves, incorporating advanced technologies such as Building Information Modeling (BIM) and lifecycle assessments will further drive innovation and sustainability. By adopting these proven strategies, developers can deliver projects that meet rigorous environmental standards and contribute to resilient and resource-efficient urban development.

REFERENCES

[1] U.S. Green Building Council, *LEED v4 for Building Design and Construction*, USGBC, 2020.
[2] ICC/NAHB, *National Green Building Standard (NGBS)*, Home Innovation Research Labs, 2021.
[3] U.S. Environmental Protection Agency, *ENERGY STAR Overview*, EPA, 2022.
[4] Green Building Initiative, *Green Globes Certification Program*, GBI, 2021.
[5] U. Berardi, "Sustainability assessment of urban communities through rating systems," *Environment Development and Sustainability*, vol. 15, 2013. doi: 10.1007/s10668-013-9462-0.
[6] R. Farr, *Sustainable Urbanism: Urban Design with Nature*, Wiley, 2008.
[7] S. Dasgupta and E. K. L. Tam, "ENVIRONMENTAL REVIEW: A Comprehensive Review of Existing Classification Systems of Brownfield Sites," *Environmental Practice*, vol. 11, no. 4, pp. 285–300, 2009. doi: 10.1017/S1466046609990287.
[8] J. R. Miller, M. Groom, G. R. Hess, T. Steelman, D. L. Stokes, J. Thompson, T. Bowman, L. Fricke, B. King, and R. Marquardt, "Biodiversity Conservation in Local Planning / Conservación de la Biodiversidad en la Planificación Local," *Conservation Biology*, vol. 23, no. 1, pp. 53–63, Jan. 2009. doi: 10.1111/j.1523-1739.2008.01110.x.
[9] G. Ercolani, E. A. Chiaradia, C. Gandolfi, F. Castelli, and D. Masseroni, "Evaluating performances of green roofs for stormwater runoff mitigation in a high flood risk urban catchment," *Journal of Hydrology*, vol. 566, pp. 830–845, 2018. doi: 10.1016/j.jhydrol.2018.09.050
[10] R. Pitt and M. Lalor, "The role of pollution prevention in stormwater management," in *Models and Applications to Urban Water Systems*, 2000, pp. 1–20.
[11] T. D. Fletcher, W. Shuster, W. F. Hunt, R. Ashley, D. Butler, S. Arthur, … M. Viklander, "SUDS, LID, BMPs, WSUD, and more – The evolution and application of terminology surrounding urban drainage," *Urban Water Journal*, vol. 12, no. 7, pp. 525–542, 2014. doi: 10.1080/1573062X.2014.916314.
[12] B. H. Mohammed, H. Sallehuddin, N. Safie, A. Husairi, N. A. Abu Bakar, F. Yahya, ... and S. AbdelGhany Mohamed, "Building information modeling and internet of things integration in the construction industry: a scoping study," *Advances in Civil Engineering*, vol. 2022, no. 1, pp. 7886497, 2022.
[13] P. Eriksson and T. Johansson, "Towards Differentiated Energy Renovation Strategies for Heritage-Designated Multifamily Building Stocks," *Heritage*, vol. 4, pp. 4318–4334, 2021. doi: 10.3390/heritage4040238.